APPENDIX D

CALCULATION OF HVAC TOTAL SYSTEM PERFORMANCE RATIO

D101 Scope. This appendix establishes criteria for demonstrating compliance using the HVAC total system performance ratio (HVAC TSPR) for systems serving office (including medical offices), retail, library, and education occupancies and buildings, which are subject to the requirements of Section C403.3.5 without exception, and dwelling units and common areas within multifamily buildings. Those HVAC systems shall comply with Section C403 and this appendix as required by Section C403.1.1.

D101.1 Core and Shell/Initial Build-Out, and Future System Construction Analysis. Where the building permit applies to only a portion of the HVAC system in a building and the remaining components will be designed under a future building permit or were previously installed, the future or previously installed components shall be modeled as follows:

1. Where the HVAC zones that do not include HVAC systems in the current permit will be or are served by independent systems, then the block including those zones shall not be included in the model.
2. Where the HVAC zones that do not include complete HVAC systems in the permit are intended to receive HVAC services from systems in the permit, their proposed zonal systems shall be modeled with equipment that meets, but does not exceed, the requirements of Section C403.
3. Where the zone equipment in the permit receives HVAC services from previously installed systems that are not in the permit, the previously installed systems shall be modeled with equipment matching the certified value of what is installed or equipment that meets the requirements of Section C403.
4. Where the central plant heating and cooling equipment is completely replaced and HVAC zones with existing systems receive HVAC services from systems in the permit, their proposed zonal systems shall be modeled with equipment that meets, but does not exceed, the requirements of Section C403.

Informative Notes:

1. Examples of HVAC systems that are intended to receive HVAC services from systems in the permit include future zonal water source heat pumps that will receive loop water that is heated by a boiler or cooled by a cooling tower included in the permit, any system that will receive outdoor ventilation air from a dedicated outdoor air system included in the permit, and future zone terminal units that will be connected to a central VAV system included in the permit.
2. An initial build-out with heating coils served from a previously installed system with a high-efficiency condensing boiler would use the installed efficiency if it exceeded the current requirements. If the installed boiler had a lower efficiency than the current requirements, the current requirement would be used.
3. A partial central plant upgrade (e.g., chiller, but not boiler replacement) cannot use this method.

D201 Compliance. Compliance based on *HVAC total system performance ratio* requires that the provisions of Section C403.3 are met and the *HVAC total system performance ratio* of the *proposed design* is more than or equal to the *HVAC total system performance ratio* of the *standard reference design*. The *HVAC TSPR* is calculated according to the following formula:

HVAC TSPR = annual heating and cooling load/annual carbon emissions from energy consumption of the building HVAC systems

Where:

Annual carbon emissions from energy consumption of the building HVAC systems	=	sum of the annual carbon emissions in pounds for heating, cooling, fans, energy recovery, pumps, and heat rejection calculated by multiplying site energy consumption by the carbon emission factors from Table D201
Annual heating and cooling load	=	sum of the annual heating and cooling loads met by the building HVAC system in thousands of Btus.

TABLE D201
CARBON EMISSIONS FACTORS

Type	CO2e (lb/unit)	Unit
Electricity	0.44	kWh
Natural gas	11.70	Therm
Oil	19.2	Gallon
Propane	10.5	Gallon
Other[a]	195.00	mmBtu
On-site renewable energy[b]	0.00	

a. District energy systems may use alternative emissions factors supported by calculations approved by the code official.
b. Not applicable to TSPR calculation in Appendix D

D300 Simulation Program

D301 General.

D302 Calculation of the HVAC TSPR for the Standard Reference Design. The simulation program shall calculate the HVAC TSPR based only on the input for the proposed design and the requirements of this appendix. The calculation procedure shall not allow the user to directly modify the building component characteristics of the standard reference design.

D303 Specific approval. Performance analysis tools meeting the applicable subsections of Appendix D and tested according to ASHRAE Standard 140 shall be permitted to be approved. Tools are permitted to be approved based on meeting a specified threshold for a jurisdiction. The code official shall be permitted to approve tools for a specified application or limited scope.

D400 Climatic data. The simulation program shall perform the simulation using hourly values of climatic data, such as temperature and humidity, using TMY3 data for the site as specified here:

https://buildingenergyscore.energy.gov/resources

D500 Documentation. Documentation conforming to the provisions of this section shall be provided to the code official.

D501 Compliance report. Building permit submittals shall include:

1. A report produced by the simulation software that includes the following:
   - 1.1. Address of the building.
   - 1.2. Name of individual completing the compliance report.
   - 1.3. Name and version of the compliance software tool.
   - 1.4. The dimensions, floor heights and number of floors for each block.
   - 1.5. By block, the U-factor, C-factor, or F-factor for each simulated opaque envelope component and the U-factor and SHGC for each fenestration component.
   - 1.6. By block or by surface for each block, the fenestration area.
   - 1.7. By block, a list of the HVAC equipment simulated in the proposed design including the equipment type, fuel type, equipment efficiencies and system controls.
   - 1.8. Annual site HVAC energy use by end use for the proposed and baseline building.
   - 1.9. Annual sum of heating and cooling loads for the baseline building.
   - 1.10. The HVAC total system performance ratio for both the standard reference design and the proposed design.
2. A mapping of the actual building HVAC component characteristics and those simulated in the proposed design showing how individual pieces of HVAC equipment identified above have been combined into average inputs as required by Section D601.10 including:
   - 2.1. Fans
   - 2.2. Hydronic pumps
   - 2.3. Air handlers
   - 2.4. Packaged cooling equipment
   - 2.5. Furnaces
   - 2.6. Heat pumps
   - 2.7. Boilers
   - 2.8. Chillers
   - 2.9. Cooling towers

2.10. Electric resistance coils

2.11. Condensing units

2.12. Motors for fans and pumps

2.13. Energy recovery devices

For each piece of equipment identified above include the following as applicable:

2.14. Equipment name or tag consistent with that found on the design documents.

2.15. Rated efficiency level.

2.16. Rated capacity.

2.17. Electrical input power for fans and pumps (before any speed or frequency control devices) at design conditions and calculation of input value (W/cfm or W/gpm).

3. Floor plan of the building identifying how portions of the buildings are assigned to the simulated blocks and areas of the building that are not covered under the requirements of Section C403.1.1.

D600 Calculation procedure. Except as specified by this appendix, the standard reference design and proposed design shall be configured and analyzed using identical methods and techniques.

D601 Simulation of the proposed building design. The proposed design shall be configured and analyzed as specified in this section.

D601.1 Block geometry. The geometry of buildings shall be configured using one or more blocks. Each block shall define attributes including block dimensions, number of floors, floor to floor height and floor to ceiling height. Simulation software may allow the use of simplified shapes (such as rectangle, L shape, H Shape, U shape or T shape) to represent blocks. Where actual building shape does not match these pre-defined shapes, simplifications are permitted providing the following requirements are met:

1. The conditioned floor area and volume of each block shall match the proposed design within 10 percent.
2. The area of each exterior envelope component from Table C402.1.4 is accounted for within 10 percent of the actual design.
3. The area of vertical fenestration and skylights is accounted for within 10 percent of the actual design.
4. The orientation of each component in 2 and 3 above is accounted for within 45 degrees of the actual design.

The creation of additional blocks may be necessary to meet these requirements.

Exception: Portions of the building that are unconditioned or served by systems not covered by the requirements of Section C403.1.1 shall be omitted.

D601.1.1 Number of blocks. One or more blocks may be required per building based on the following restrictions:

1. Each block can have only one occupancy type (multifamily dwelling unit, multifamily common area, office, library, education, or retail). Therefore, at least one single block shall be created for each unique use type.
2. Each block can be served by only one type of HVAC system. Therefore, a single block shall be created for each unique HVAC system and use type combination. Multiple HVAC units of the same type may be represented in one block. Section D601.10.2 provides directions for combining multiple HVAC units or components of the same type into a single block.
3. Each block can have a single definition of floor to floor or floor to ceiling heights. Where floor heights differ by more than two feet, unique blocks should be created for the floors with varying heights.
4. Each block can include either above grade or below grade floors. For buildings with both above grade and below grade floors, separate blocks should be created for each. For buildings with floors partially above grade and partially below grade, if the total wall area of the floor(s) in consideration is greater than or equal to 50 percent above grade, then it should be simulated as a completely above grade block, otherwise it should be simulated as a below grade block.
5. Each wall on a façade of a block shall have similar vertical fenestration. The product of the proposed design U-factor times the area of windows (UA) on each façade of a given floor cannot differ by more than 15 percent of the average UA for that façade in each block. The product of the proposed design SHGC times the area of windows (SHGCA) on each façade of a given floor cannot differ by more than 15 percent of the average SHGCA for that façade in each block. If either of these conditions are not met, additional blocks shall be created consisting of floors with similar fenestration.
6. For a building model with multiple blocks, the blocks should be configured together to have the same adjacencies as the actual building design.

D601.2 Thermal zoning. Each floor in a block shall be modeled as a single thermal zone or as five thermal zones consisting of four perimeter zones and a core zone. Below grade floors shall be modeled as a single thermal block. If any fa?de in the block is less than 45 feet in length, there shall only be a single thermal zone per floor. Otherwise each floor shall be modeled with five thermal zones. A perimeter zone shall be created extending from each fa?de to a depth of 15 feet. Where facades intersect, the zone boundary shall be formed by a 45 degree angle with the two facades. The remaining area or each floor shall be modeled as a core zone with no exterior walls.

D601.3 Occupancy.

D601.3.1 Occupancy type. The occupancy type for each block shall be consistent with the building area type as determined in accordance with C405.4.2.1. Portions of the building that are building area types other than multifamily dwelling unit, multifamily common area, office, school (education), library, or retail shall not be included in the simulation. Surfaces adjacent to such building portions shall be modeled as adiabatic in the simulation program

D601.3.2 Occupancy schedule, density, and heat gain. The occupant density, heat gain, and schedule shall be for multifamily, office, retail, library, or school as specified by ASHRAE Standard 90.1 Normative Appendix C.

D601.4 Envelope components.

D601.4.1 Roofs. Roofs will be modeled with insulation above a steel roof deck. The roof U-factor and area shall be modeled as in the proposed design. If different roof thermal properties are present in a single block, an area weighted U-factor shall be used. Roof solar absorptance shall be modeled at 0.70 and emittance at 0.90.

D601.4.2 Above grade walls. Walls will be modeled as steel frame construction. The U-factor and area of above grade walls shall be modeled as in the proposed design. If different wall constructions exist on the fa?de of a block an area-weighted U-factor shall be used.

D601.4.3 Below grade walls. The C-factor and area of below grade walls shall be modeled as in the proposed design. If different slab on grade floor constructions exist in a block, an area-weighted C-factor shall be used.

D601.4.4 Above grade exterior floors. Exterior floors shall be modeled as steel frame. The U-factor and area of floors shall be modeled as in the proposed design. If different wall constructions exist in the block an area-weighted U-factor shall be used.

D601.4.5 Slab on grade floors. The F-factor and area of slab on grade floors shall be modeled as in the proposed design. If different below grade wall constructions exist in a block, an area-weighted F-factor shall be used.

D601.4.6 Vertical fenestration. The window area and area weighted U-factor and SHGC shall be modeled for each fa?de based the proposed design. Each exterior surface in a block must comply with Section D601.1.1 item 5. Windows will be combined in to a single window centered on each façade based on the area and sill height input by the user. When different U-factors, SHCG or sill heights exist on a single façade, area weighted average for each shall be input by the user.

D601.4.7 Skylights. The skylight area and area weighted U-factor and SHGC shall be modeled for each floor based the proposed design. Skylights will be combined in to a single skylight centered on the roof of each zone based on the area input by the user.

D601.4.8 Exterior shading. Permanent window overhangs shall be modeled. When windows with and without overhangs or windows with different overhang projection factors exist on a fa?de, window width weighted projection factors shall be input by the user as follows:

$$P_{avg} = \frac{A_1 \text{ x } L_{o1} + A_2 \text{ x } L_{o2} \ldots A_n \text{ x } L_{on}}{L_{w1} + L_{w2} \ldots L_{wn}}$$

Where:

P_{avg} = Average overhang projection modeled in the simulation tool.

A = Distance measured horizontally from the furthest continuous extremity of any overhang, eave or permanently attached shading device to the vertical surface of the glazing.

L_o = Length off the overhang.

L_w = Length of the window.

D601.5 Lighting. Interior lighting power density shall be equal to the allowance in Table C405.4.2(1) for multifamily, office, retail, library, or school. The lighting schedule shall be for multifamily, office, retail, library, or school as specified by ASHRAE Standard 90.1 Normative Appendix C. The impact of lighting controls is assumed to be captured by the lighting schedule and no explicit controls shall be modeled. Exterior lighting shall not be modeled.

D601.6 Miscellaneous equipment. The miscellaneous equipment schedule and power shall be for multifamily, office, retail, library, or school as specified by ASHRAE Standard 90.1 Normative Appendix C. The impact of miscellaneous equipment controls is assumed to be captured by the equipment schedule and no explicit controls shall be modeled.

Exceptions:

1. Multifamily dwelling units shall have a miscellaneous load density of 0.42 W/ft2.
2. Multifamily common areas shall have a miscellaneous load density of 0 W/ft2.

D601.7 Elevators. Elevators shall not be modeled.

D601.8 Service water heating equipment. Service water heating shall not be modeled.

D601.9 On-site renewable energy systems. On-site Renewable Energy Systems shall not be modeled.

D601.10 HVAC equipment. HVAC systems shall meet the requirements of Section C403 Mechanical Systems.

D601.10.1 Supported HVAC systems. At a minimum, the HVAC systems shown in Table D601.10.1 shall be supported by the simulation program.

Table D601.10.1
PROPOSED BUILDING HVAC SYSTEMS SUPPORTED BY HVAC TSPR SIMULATION SOFTWARE

System No.	System Name	System Abbreviation
1	Packaged Terminal Air Conditioner	PTAC
2	Packaged Terminal Air Heat Pump	PTHP
3	Packaged Single Zone Gas Furnace (includes split system)	PSZGF
4	Packaged Single Zone Heat Pump (air to air only) (includes split system)	PSZHP
5	Variable Refrigerant Flow (air cooled only)	VRF
6	Four Pipe Fan Coil	FPFC
7	Water Source Heat Pump	WSHP
8	Ground Source Heat Pump	GSHP
9	Packaged Variable Air Volume (DX cooling)	PVAV
10	Variable Air Volume (hydronic cooling)	VAV
11	Variable Air Volume with Fan Powered Terminal Units	VAVFPTU
12	Dedicated Outdoor Air System (in conjunction with systems 1-8)	DOAS

D601.10.2 Proposed building HVAC system simulation. The HVAC systems shall be modeled as in the proposed design with clarifications and simplifications as described in Table D601.10.2. System parameters not described in the following sections shall be simulated to meet the minimum requirements of Section C403. All zones within a block shall be served by the same HVAC system type as described in Section D601.1.1 item 2. Where multiple system components serve a block, average values weighed by the appropriate metric as described in this section shall be used. Heat loss from ducts and pipes shall not be modeled.

1. Where multiple fan systems serve a single block, fan power shall be based on weighted average using the design supply air cfm.
2. Where multiple cooling systems serve a single block, COP shall be based on a weighted average using cooling capacity. DX coils shall be entered as multi-stage if more than 50% of coil capacity serving the block is multi-stage with staged controls.
3. Where multiple heating systems serve a single block, thermal efficiency or heating COP shall be based on a weighted average using heating capacity.
4. Where multiple boilers or chillers serve a heating water or chilled water loop, efficiency shall be based on a weighted average for using heating or cooling capacity.
5. When multiple cooling towers serving a condenser water loop are combined, the cooling tower efficiency, cooling tower design approach and design range are based on a weighted average of the design water flow rate through each cooling tower.
6. Where multiple pumps serve a heating water, chilled water or condenser water loop, pump power shall be based on a weighted average for using design water flow rate.
7. When multiple system types with and without economizers are combined, the economizer maximum outside air fraction of the combined system shall be based on weighted average of 100% supply air for systems with economizers and design outdoor air for systems without economizers.
8. Multiple systems with and without ERVs cannot be combined.

9. Systems with and without supply air temperature reset cannot be combined.
10. Systems with different fan control (constant volume, multi-speed or VAV) for supply fans cannot be combined.
11. Demand Controlled Ventilation (DCV) shall be modeled using a simplified approach that adjusts the design outdoor supply air flow rate based on the area of the building that is covered by DCV.

TABLE D601.10.2
PROPOSED BUILDING SYSTEM PARAMETERS

Category	Parameter	Fixed or User Defined	Required	Applicable Systems
HVAC System Type	System Type	User Defined	Selected from Table D601.10.1	All
System Sizing	Design Day Information	Fixed	99.6% heating design and 1% dry-bulb and 1% wet-bulb cooling design	All
	Zone Coil Capacity	Fixed	Sizing factors used are 1.25 for heating equipment and 1.15 for cooling equipment	All
	Supply Airflow	Fixed	Based on a supply-air-to-room-air temperature *set-point* difference of 20°F	1-11
		Fixed	Equal to required outdoor air ventilation	12
Outdoor Ventilation Air	Portion of Supply Air with Proposed Filter ≥ MERV 13	User Defined	Percentage of supply air flow subject to higher filtration (adjusts baseline fan power higher. Prorated)	All
	Outdoor Ventilation Air Flow Rate	Fixed	As specified in ASHRAE Standard 90.1 Normative Appendix C, adjusted for proposed DCV control	All
	Outdoor Ventilation Supply Air Flow Rate Adjustments	Fixed	Based on ASHRAE Standard 62.1 Section 6.2.4.3 system ventilation efficiency (E_VS) is 0.75	9-11
		Fixed	System ventilation efficiency (E_VS) is 1.0	1-8, 12
		Fixed	Base is 1.0 zone air distribution effectiveness	All
System Operation	Space temperature Set points	Fixed	As specified in ASHRAE Standard 90.1 Normative Appendix C, except multifamily which shall use 68°F heating and 76°F cooling setpoints	1-11
	Fan Operation – Occupied	User Defined	Runs continuously during occupied hours or cycled to meet load. Multispeed fans reduce airflow related to thermal loads	1-11
	Fan Operation – Occupied	Fixed	Fan runs continuously during occupied hours	12
	Fan Operation – Night Cycle	Fixed	Fan cycles on to meet setback temperatures	1-11
Packaged Equipment Efficiency	DX Cooling Efficiency	User Defined	Cooling COP without fan energy calculated in accordance with ASHRAE Standard 90.1 Section 11.5.2c.[b]	1, 2, 3, 4, 5, 7, 8, 9, 11, 12
	DX Coil Number of Stages	User Defined	Single state or multistage	3, 4, 9, 10, 11, 12
	Heat Pump Efficiency	User Defined	Heating COP without fan energy calculated in accordance with ASHRAE Standard 90.1 Section 11.5.2c.[c]	2, 4, 5, 7, 8
	Furnace Efficiency	User Defined	Furnace thermal efficiency[c]	3, 9, 11, 12
Heat Pump Supplemental Heat	Control	Fixed	Supplemental electric heat locked out above 40°F. Runs In conjunction with compressor between 40°F and 0°F.	2, 4
System Fan Power and Controls	Part-Load Fan Controls	User Defined	Constant volume or two speed	1-8
	Part-Load Fan Controls[a]	User Defined	Constant volume or variable air volume	12
	Part-Load Fan Controls[a]	Fixed	Variable air volume. VFD with static pressure reset.	9-11
	Design Fan Power (W/cfm)	User Defined	Input electric power for all fans in required to operate at *fan system design conditions* divided by the supply airflow rate	All
	Low-Speed Fan Power	User Defined	Low speed input electric power for all fans required to operate at low speed conditions divided by the low speed supply airflow rate. This is a “wire to air” value including all drive, motor efficiency and other losses.	1-8

TABLE D601.10.2—continued
PROPOSED BUILDING SYSTEM PARAMETERS

Category	Parameter	Fixed or User Defined	Required	Applicable Systems
Variable Air Volume Systems	Supply Air Temperature (SAT) Controls	User defined	If not SAT reset constant at 55°F. Options for reset based on outdoor air temperature (OAT) or warmest zone. If warmest zone, then the user can specify the minimum and maximum temperatures. If OAT reset, SAT is reset higher to 60°F at outdoor low of 50°F. SAT is 55°F at outdoor high of 70°F.	9, 10, 11
	Minimum Terminal Unit airflow percentage	User Defined	Average minimum terminal unit airflow percentage for *block* weighted by cfm	9, 10, 11
	Terminal Unit Heating Source	User Defined	Electric or hydronic	9, 10, 11
	Dual Set Point Minimum VAV Damper Position	User Defined	Heating maximum airflow fractions	9, 10
	Fan Powered Terminal Unit (FPTU) Type	User Defined	Series or parallel FPTU	11
	Parallel FPTU Fan	Fixed	Sized for 50% peak primary air at 0.35 W/cfm	11
	Series FPTU Fan	Fixed	Sized for 50% peak primary air at 0.35 W/cfm	11
Economizer	Economizer Presence	User Defined	Yes or No	3, 4, 9, 10, 11
	Economizer Control Type	Fixed	Differential dry-bulb	3, 4, 9, 10, 11
Energy Recovery	Sensible Effectiveness	User Defined	Heat exchanger sensible effectiveness at design heating and cooling conditions	3, 4, 9, 10, 11, 12
	Latent Effectiveness	User Defined	Heat exchanger latent effectiveness at design heating and cooling conditions	3, 4, 9, 10, 11, 12
	Economizer Bypass	User Defined	If ERV is bypassed during economizer conditions	3, 4, 9, 10, 11, 12
	Bypass SAT Setpoint	User Defined	If bypass, target supply air temperature	3, 4, 9, 10, 11, 12
	Fan Power Reduction during Bypass (W/cfm)	User Defined	If ERV system include bypass, static pressure set point and variable speed fan, fan power can be reduced during economizer conditions	3, 4, 9, 10, 11, 12
Demand Controlled Ventilation	DCV Application	User Defined	Percent of block floor area under DCV control	3, 4, 9, 10, 11, 12
DOAS	DOAS Fan Power W/cfm	User Defined	Fan electrical input power in W/cfm of supply airflow	12
	DOAS Supplemental Heating and Cooling	User Defined	Heating source, cooling source	12
	Minimum SAT Setpoint (Cooling)	User Defined	SAT setpoint if DOAS includes supplemental cooling	12
	Minimum SAT Setpoint (Heating)	User Defined	SAT setpoint if DOAS includes supplemental heating	12

TABLE D601.10.2—continued
PROPOSED BUILDING SYSTEM PARAMETERS

Category	Parameter	Fixed or User Defined	Required	Applicable Systems
Heating Plant	Boiler Efficiency	User Defined	Boiler thermal efficiency	1, 6, 7, 9, 10, 11, 12
	Heating Water Loop Configuration[a]	User Defined	Constant flow primary only; variable flow primary only; constant flow primary-variable flow secondary; variable flow primary and secondary	1, 6, 7, 9, 10, 11, 12
	Heating Water Primary Pump Power (W/gpm)	User Defined	Heating water primary pump input W/gpm heating water flow	1, 6, 7, 9, 10, 11, 12
	Heating Water Secondary Pump Power (W/gpm)	User Defined	Heating water secondary pump input W/gpm heating water flow (if primary/ secondary)	1, 6, 7, 9, 10, 11, 12
	Heating Water Loop Temperature	User Defined	Heating water supply and return temperatures	1, 6, 9, 10, 11, 12
	Heating Water Loop Supply Temperature Reset Included	User Defined	Yes/No	1, 6, 9, 10, 11, 12
	Heating Water Loop Supply Reset Temperature	Fixed	Reset HWS by 27.3 percent of design delta-T (HWS - 70°F (21.1°C) space heating temperature set point) between 20°F (-6.7°C) and 50°F (10°C) OAT	1, 6, 9, 10, 11, 12
	Boiler Type	Fixed	Noncondensing boiler where input thermal efficiency is less than 86 percent; condensing boiler otherwise	1, 6, 7, 9, 10, 11, 12
Chilled Water Plant	Chiller Compressor Type	User Defined	Screw/Scroll, Centrifugal or Reciprocating	6,1 0, 11, 12
	Chiller Condenser Type	User Defined	Air cooled or water cooled	6, 10, 11, 12
	Chiller Full Load Efficiency	User Defined	Chiller COP	6, 10, 11, 12
	Chilled Water Loop Configuration[a]	User Defined	Variable flow primary only, constant flow primary – variable flow secondary, variable flow primary and secondary	6, 10, 11, 12
	Chilled Water Primary Pump Power (W/gpm)	User Defined	Primary pump input W/gpm chilled water flow (if primary/secondary)	6, 10, 11, 12
	Chilled Water Secondary Pump Power (W/gpm)	User Defined	Secondary pump input W/gpm chilled water flow	6, 10, 11, 12
	Chilled Water Temperature Reset Included	User Defined	Yes/No	6, 10, 11, 12
	Chilled Water Temperature Reset Schedule (if included)	Fixed	Outdoor air reset: CHW supply temperature of 44°F at 80°F outdoor air dry bulb and above, CHW supply temperature of 54°F at 60°F outdoor air dry bulb temperature and below, ramped linearly between	6, 10, 11, 12
	Condenser Water Pump Power (W/gpm)	User Defined	Pump input W/gpm condenser water flow	6, 7, 8, 10, 11, 12
	Condenser Water Pump Control	User Defined	Constant speed or variable speed	6, 7, 8, 10, 11, 12
	Cooling Tower Efficiency	User Defined	gpm/hp tower fan	6, 7, 10, 11, 12
	Cooling Tower Fan Control	User Defined	Constant or variable speed	6, 7, 10, 11, 12
	Cooling Tower Approach and Range	User Defined	Design cooling tower approach and range temperature	6, 7, 10, 11, 12
Heat Pump Loop Flow Control	Loop flow and Heat Pump Control Valve	Fixed	Two position Valve with VFD on Pump. Loop flow at 3 gpm/ton	7, 8

TABLE D601.10.2—continued
PROPOSED BUILDING SYSTEM PARAMETERS

Category	Parameter	Fixed or User Defined	Required	Applicable Systems
Heat Pump Loop Temperature Control		User Defined	Restrict to minimum 20°F and maximum 40°F temperature difference	7
GLHP Well Field		Fixed	Bore depth = 250' Bore length 200'/ton for greater of cooling or heating load Bore spacing = 15'; Bore diameter = 5" 3/4" Polyethylene pipe Ground and grout conductivity = 4.8 Btu-in/h-ft^2-°F	8

a. Part load fan power and pump power modified in accordance with Table D601.10.3.

TABLE D601.10.3
FAN AND PUMP POWER CURVE COEFFICIENTS

Equation Term	Fan Power Coefficients	Pump Power Coefficients	
	VSD + SP Reset	Ride Pump Curve	VSD + DP/Valve Reset
b	0.0408	0	0
x	0.088	3.2485	0.0205
x^2	-0.0729	-4.7443	0.4101
x^3	0.9437	2.5295	0.5753

D602 Simulation of the standard reference design. The standard reference design shall be configured and analyzed as specified in this section.

D602.1 Utility rates. Same as proposed.

D602.2 Blocks. Same as proposed.

D602.3 Thermal zoning. Same as proposed.

D602.4 Occupancy type, schedule, density, and heat gain. Same as proposed.

D602.5 Envelope components. Same as proposed.

D602.6 Lighting. Same as proposed.

D602.7 Miscellaneous equipment. Same as proposed.

D602.8 Elevators. Not modeled. Same as proposed.

D602.9 Service water heating equipment. Not modeled. Same as proposed.

D602.10 On-site renewable energy systems. Not modeled. Same as proposed.

D602.11 HVAC equipment. The standard reference design HVAC equipment consists of separate space conditioning systems and dedicated outside air systems as described in Table D602.11 for the appropriate building occupancies.

TABLE D602.11
STANDARD REFERENCE DESIGN HVAC SYSTEMS

Parameter	Building Type				
	Large Office[a]	Small Office and Libraries[a]	Retail	School	Multifamily
System Type	Water-source Heat Pump	Packaged air-source Heat Pump	Packaged air-source Heat Pump	Packaged air-source Heat Pump	Packaged air-source Heat Pump
Fan control[b]	Cycle on load	Cycle on load	Cycle on load	Cycle on load	Cycles on load
Space condition fan power (W/cfm) Proposed < MERV 13	0.528	0.528	0.522	0.528	0.528
Space Condition Fan Power (W/cfm) Proposed ≥ MERV 13	0.634	0.634	0.634	0.634	0.634
Heating/Cooling sizing factor[c]	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15	1.25/1.15
Supplemental heating availability	NA	<40°F	<40°F	<40°F	<40°F
Modeled cooling COP (Net of fan) [d]	4.46	3.83	4.25	3.83	3.83
Modeled heating COP (Net of fan) [d]	4.61	3.81	3.57	3.81	3.86

TABLE D602.11—continued
STANDARD REFERENCE DESIGN HVAC SYSTEMS

Parameter	Building Type				
	Large Office[a]	Small Office and Libraries[a]	Retail	School	Multifamily
System Type	Water-source Heat Pump	Packaged air-source Heat Pump	Packaged air-source Heat Pump	Packaged air-source Heat Pump	Packaged air-source Heat Pump
Cooling Source	DX (heat pump)	DX (heat pump)	DX (heat pump)	DX (heat pump)	DX (Heat Pump)
Heat source	Heat Pump	Heat Pump	Heat Pump	Heat Pump	Heat Pump
Number of Stages of Cooling	Single	Single	Two	Single	Single
OSA Economizer[e]	No	No	Yes	Yes	Yes
Occupied ventilation source[f]	DOAS	DOAS	DOAS	DOAS	DOAS
DOAS Fan Power (W/cfm of outside air)	0.819	0.819	0.730	0.742	0.780
DOAS Fan Power (W/cfm) Proposed ≥ MERV 13	1.042	1.042	0.928	0.944	0.944
DOAS temperature control[g, h]	Bypass	Wild	Bypass	Bypass	Wild
ERV efficiency (sensible only)	70%	70%	70%	70%	70 percent
WSHP Loop Heat Rejection	Cooling Tower[i]	NA	NA	NA	NA
WSHP Loop Heat Source	Gas Boiler[j]	NA	NA	NA	NA
WSHP Loop Temperature Control[k]	50°F to 70°F	NA	NA	NA	NA
WSHP circulation Pump W/gpm[l]	16	NA	NA	NA	NA
WSHP Loop Pumping Control[m]	HP Valves & pump VSD	NA	NA	NA	NA

a. Offices <50,000 ft^2 use "Small Office" parameters; otherwise use "Large Office" parameters.
b. Space conditioning system shall cycle on to meet heating and cooling set point schedules as specified in ASHRAE Standard 90.1 Normative Appendix C. One space conditioning system is modeled in each zone. Conditioning system fan operation is not necessary for ventilation delivery.
c. The equipment capacities (i.e. system coil capacities) for the standard reference design building design shall be based on design day sizing runs and shall be oversized by 15% for cooling and 25% for heating.
d. COPs shown are direct heating or cooling performance and do not include fan energy use. See 90.1 appendix G (G3.1.2.1) for separation of fan from COP in packaged equipment for units where the efficiency rating includes fan energy (e.g., SEER, EER, HSPF, COP).
e. Economizer on space conditioning systems shall be simulated when outdoor air conditions allow free cooling. Economizer high limit shall be based on differential dry-bulb control. DOAS system continues to operate during economizer mode.
f. Airflow equal to the outside air ventilation requirements is supplied and exhausted through a separate DOAS system including a supply fan, exhaust fan, and sensible only heat exchanger. No additional heating or cooling shall be provided by the DOAS. A single DOAS system will be provided for each block. The DOAS supply and return fans shall run whenever the HVAC system is scheduled to operate in accordance with ASHRAE Standard 90.1 Normative Appendix C.
g. "Wild" DOAS control indicates no active control of the supply air temperature leaving the DOAS system. Temperature will fluctuate based only on entering and leaving conditions and the effectiveness of ERV.
h. "Bypass" DOAS control includes modulating dampers to bypass ERV with the intent to maintain supply air temperature at a maximum of 60°F when outside air is below 75°F. Once outside air is above 75°F bypass dampers will be fully closed.
i. Includes a single axial fan cooling tower with variable-speed fans at 40.2 gpm/hp, sized for an approach of 10°F and a range of 10°F.
j. Includes a single natural draft boiler with 80% Et.
k. Loop boiler and heat rejection shall be controlled to maintain loop temperature entering heat pumps between 50°F and 70°F.
l. Pump motor input power shall be 16 W/gpm.
m. Loop flow shall be variable with variable speed drive pump and unit fluid flow shutoff at each heat pump when its compressor cycles off.