Example 6: NR Classroom Laboratory, VAV-DOAS with Four-Pipe Fan Coils and Air-to-Water Heat Pump

SYSTEM TAG: T24STD-DOAS-FPFC-AWHP-HRV

PROJECT VISION

California Title 24 compliance modeling requires translating mechanical system designs into CBECC 2025 software objects, a process for which little practical guidance exists. Developed as part of the *Addressing Complex HVAC Systems in Code Compliance* project, funded by Southern California Edison through the CalBEM working group, each example walks through how a recognizable HVAC system type translates into CBECC objects, what Title 24 2025 Part 6 requires, and what assumptions were made.

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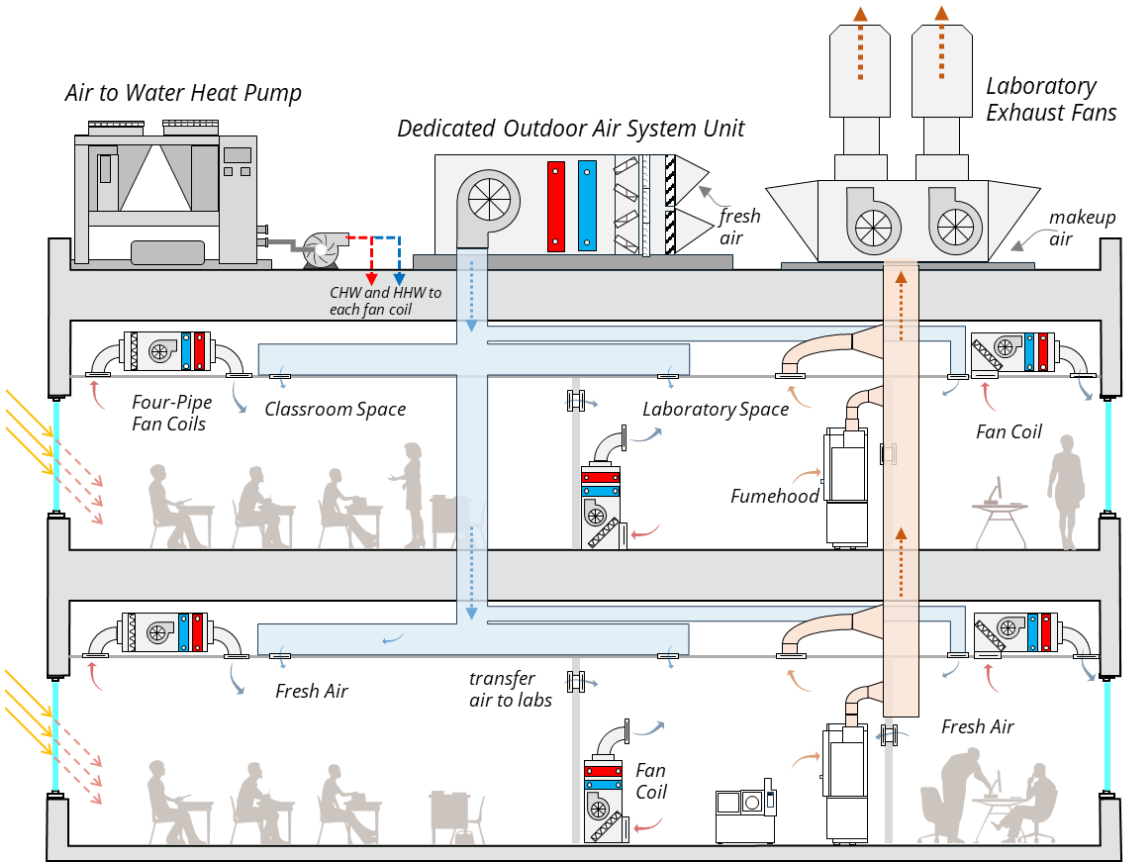
System Tag: T24STD-DOAS-FPFC-AWHP-HRV
Title 24 2025 STD:140.4-Aii

Mechanical Description

The building is conditioned by a dedicated outdoor air system (DOAS) with distributed four-pipe-fan coil units (FPFC), providing heating and cooling. A central plant, consisting of an air-to-water heat pump, produces hot and cold water conditioning the ventilation air and each thermal space.

Chilled water as well as hot water for heating and cooling are generated by an air-to-water heat pump. Fresh air is provided by a central DOAS unit, transferred from classrooms and offices to laboratory spaces, and exhausted through a central laboratory exhaust system. The laboratory spaces include fumehoods to demonstrate how exhaust driven ventilation systems are balanced.

Laboratory exhaust is handled by a dedicated variable speed exhaust fan system capable of wide turndown to track actual exhaust demand across varying fume hood and general exhaust loads.



The diagram shows a central DOAS unit supplying tempered ventilation air to each zone. A separate fan coil is provided in each thermal zone, with ventilation air supplied to each zone and transferred to the laboratories for cascaded airflow.

Mechanical Details

The system was applied to the custom lab classroom prototype, with 25 thermal zones.

Ventilation: 100% outdoor air delivered to each zone via DOAS. Air is cascaded through the classrooms to the laboratories and exhausted wit additional exhaust at the DOAS.

Ventilation control: Variable volume DOAS with zone-level VAV terminals in rooms where DCV is required and CV terminals in others.

Cooling: Four-pipe fan coil units for space cooling with chilled water from air-cooled screw chiller; DOAS chilled water coil for ventilation air pre-cooling.

Heating: Four-pipe fan coil units for space heating with hot water from air-to-water heat pump; DOAS hot water coil for ventilation air tempering.

Capacity control: Variable chilled and hot water flow at fan coil units with variable-speed fans; DOAS operates at variable ventilation airflow tracking zone demand

Economizing: No economizing

Heat Recovery: Sensible and latent heat recovery through energy recovery ventilator serving the DOAS.

Mechanical Capacities and Sizing

The following tables show the capacities for major components in this example model for the DOAS ventilation unit and central plant heating and cooling devices.

The ventilation system was sized based to meet total outdoor air requirements across all zones, with heating and cooling coil capacities matched to peak ventilation loads.

A exhaust fan was included in the lab exhaust air system only. To enable the DOAS air system to function only a supply segment and fan were configured without any exhaust or return air segment.

Air Systems	Sys Type	Fan Ctrl	Supply CFM	Min CFM (VSD)	Supply Density (CFM/sf)
DOAS-AHU Supply	DOAS	VSD	15,879	10,177	0.59
DOAS-AHU Exhaust	DOAS	VSD	5,294	5,294	0.30
Lab Exhaust Fan	Exhaust	VSD	10,585	4,883	0.39

Equipment	Plant Type	Rated Capacity (Btu/h)	Capacity / Building Area (Btu/sf)	EER	IPLV	COP
Air Cooled Chiller	ChilledWater	989,261	36.6	15	21	n/a
Air-to-Water HP	HotWater	308,705	11.4	n/a	n/a	2.5

Four-pipe fan coil units were sized with each zone's heating and cooling loads, with independent chilled water and hot water coil capacities assigned separately to reflect the decoupled nature of the four-pipe configuration.

Central plant equipment: the air-cooled screw chiller and air-to-water heat pump were sized to the peak loads of the FCUs and DOAS coils. Chiller and heat pump efficiencies were specified based on capacity and minimum allowed efficiency requirements per Title 24 2025. DOAS heating and cooling coil components were assigned efficiencies consistent with code minimums, and heat recovery effectiveness was assumed to reflect typical energy recovery ventilator performance.

Code Compliance Software Configuration

DOAS System

The DOASVAV type delivers 100% outside air and includes:

- A chilled water cooling coil and hot water heating coil served by the central hydronic plant.
- A variable-speed drive centrifugal supply fan to modulate flow.
- An exhaust fan to balance flow.
- An outside air control for demand-based ventilation.
- A HeatRecovery object to recover energy from exhaust.

VAV Terminal Units

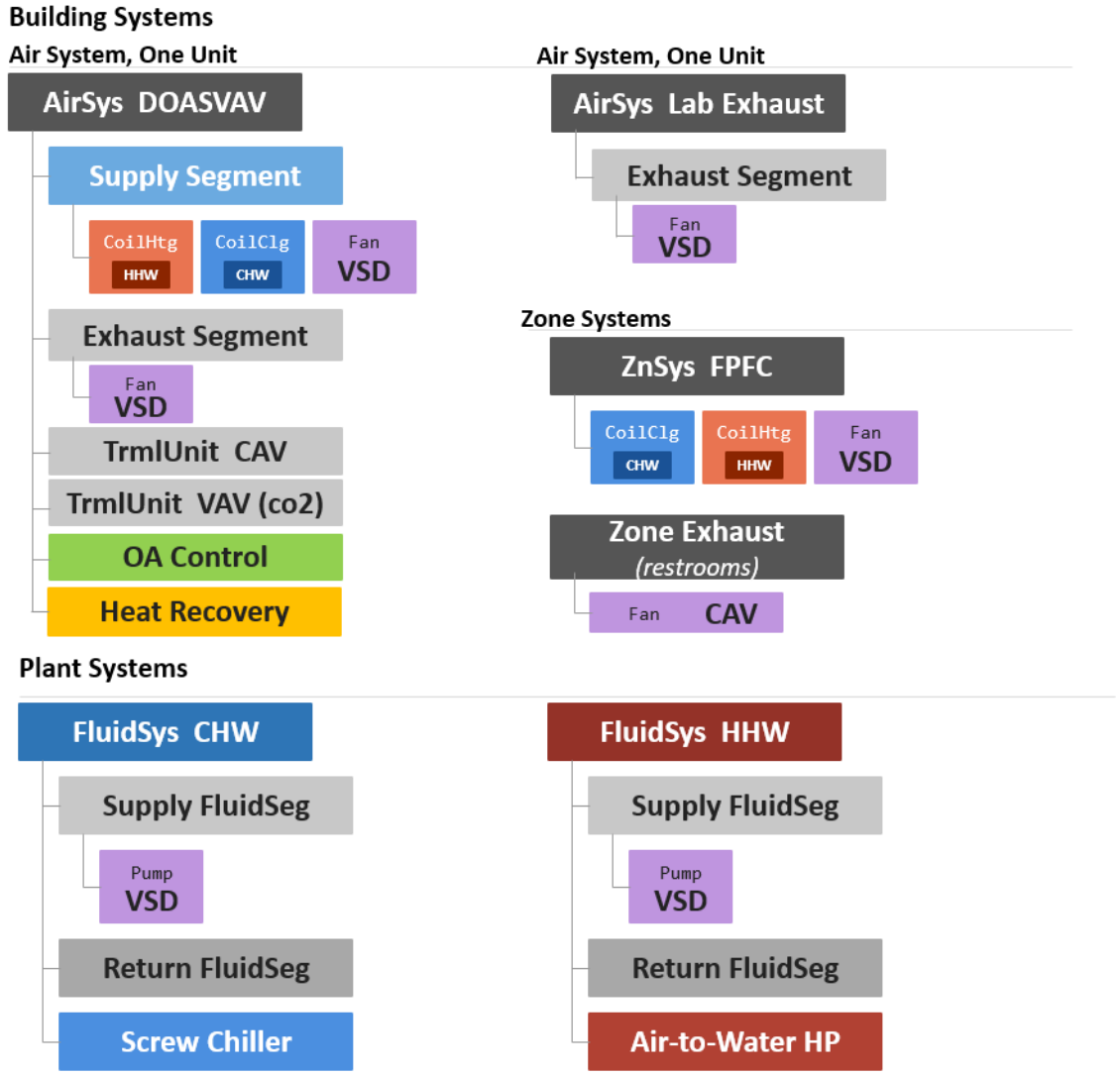
VAVNoReheatBox terminal units distribute ventilation air to zones. Zones with CO2-based control requirements have the lower limit configured to enable modular flow.

Central Hydronic Plant

The chilled water plant is modeled as an air-cooled screw chiller on a primary variable-flow loop. The hot water plant uses an air-to-water heat pump. Both loops serve DOAS coils and fan coil units.

Lab Exhaust System

The laboratory exhaust system uses a variable-speed exhaust fan sized to peak exhaust demand. Supplemental zone fans serve exhaust zones such as restrooms.



The system configuration is shown from CBECC 2025.2 for the DOAS -VAV-FPFC (CHW/HHW) system components.

The plant systems are depicted for the chilled water and hot water systems.

The DOAS air system is shown with each coil, fan, and terminal units, and finally the heat recovery device and outdoor air controller

The laboratory exhaust system, an air system, is shown with the single exhaust fan type. The zone system exhaust fans and a sample zone fan coil system are also shown with their individual coils and fans.

Plant Systems

- CHW Plant 1 (ChilledWater)
  - Air Cooled Chiller (Screw)
  - CHW Supply (PrimarySupply)
    - CHW Primary Pump (VariableSpeed)
  - CHW Return (PrimaryReturn)
- HHW Plant 1 (HotWater)
  - HHW Supply (PrimarySupply)
    - HHW Primary Pump (VariableSpeed)
  - HHW Return (PrimaryReturn)
  - Air to Water HP Heat Only

Building Systems

- DOAS-AHU (DOASVAV (Qty 1), New)
  - DOAS-AHU Supply (Supply, Path = Ducted)
    - DOAS-AHU CHW Coil (ChilledWater, Gross = 480 MBH)
    - DOAS-AHU HHW Coil (HotWater, Gross = 154 MBH)
    - DOAS-AHU Supply Fan (VariableSpeedDrive,
  - DOAS-AHU Exhaust (Exhaust, Path = NotApplicable)
    - DOAS-AHU Exhaust Fan (VariableSpeedDrive,
  - AT-L2_ZN02_Core Classroom (VAVNoReheatBox (Qty 1),
  - AT-L2_ZN07_Huddle Area (VAVNoReheatBox (Qty 1),
  - AT-L2_ZN04_Huddle Offices (VAVNoReheatBox (Qty 1),
  - AT-L2_ZN07 North Conf (VAVNoReheatBox (Qty 1),
  - AT-L2_ZN01_Core Conf Room (VAVNoReheatBox (Qty 1)
  - AT-L2_ZN06 Corner Conf (VAVNoReheatBox (Qty 1),

  hidden terminal units

  - DOAS-AHU HRV
  - OutsideAirControl 1 (NoEconomizer, 15,879 cfm)

Continued

- Exhaust Lab 1 (Exhaust (Qty 1), New)
  - Lab Exhaust Air System 1 Exhaust (Exhaust, Path = NotApplicable)
    - Lab Exhaust Air System 1 Exhaust Fan (VariableSpeedDrive
- Exhaust_RR1 (Exhaust (Qty 1), New)
  - Exh_Fan_1 (ConstantVolume, Centrifugal, FlowCap = 350 cfm)
- Exhaust_RR2 (Exhaust (Qty 1), New)
- FC-L2_ZN02_Core Classroom (FPFC, (Qty 1),
  - FC-L2_ZN02_Core Classroom CoolingCoil (ChilledWater, Gross = 20 MBH)
  - FC-L2_ZN02_Core Classroom HeatingCoil (HotWater, Gross = 6 MBH)
  - FC-L2_ZN02_Core Classroom Fan (VariableSpeedDrive, Centrifugal

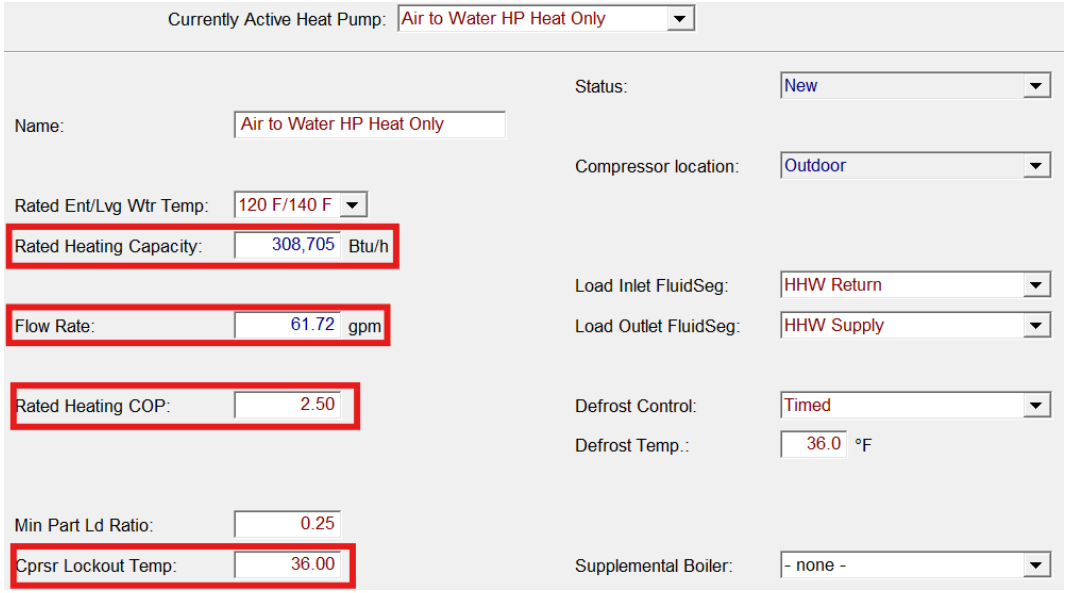
CBECC Object Locations

Key screenshots of the system for the ventilation unit, central plant components, and the laboratory exhaust are shown below.

Plant System

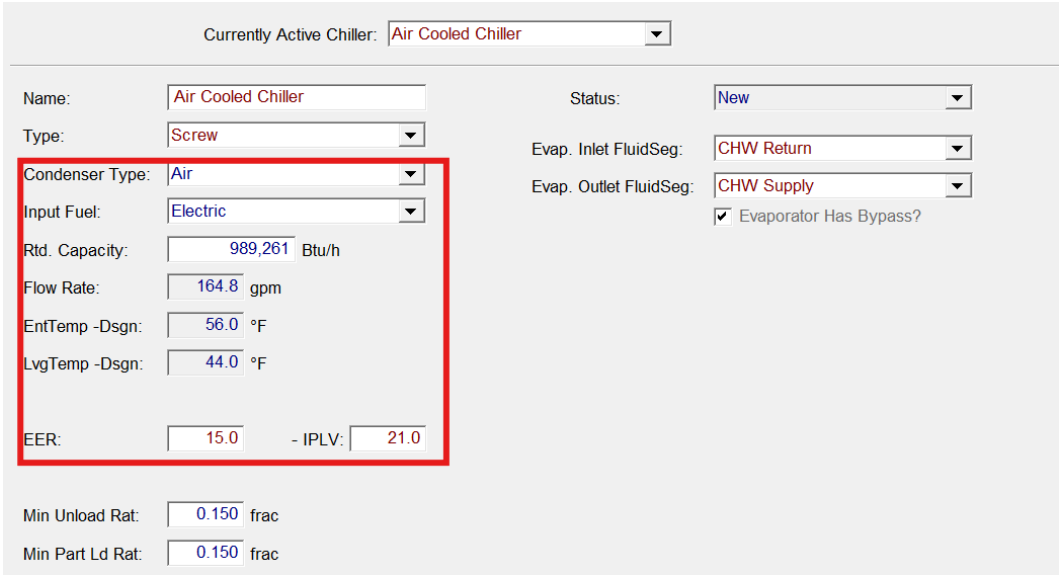
The heating plant consists of an air-to-water heat pump, supplying hot water at the fan coils and DOAS unit HW coil.

Coil Type	HeatPump (air-to-water)
Capacity	308,705 Btu/hr (25.7 tons)
Capacity / Area	11.42 Btu/sf
COP	2.5 (heating)
Flow Rate	61.72 gpm
HP Lockout	36°F



The cooling plant consists of an air cooled chiller serving the same fan coils and a DOAS CHW coil.

Coil Type	Air Cooled Chiller (Screw)
Net Capacity	989,261Btu/hr (82.5 tons)
Capacity / Area	36.56 Btu/sf
EER	15
IPLV	21
Flow Rate	164.8 gpm
Entering and Leaving Temp	56°F/44°F

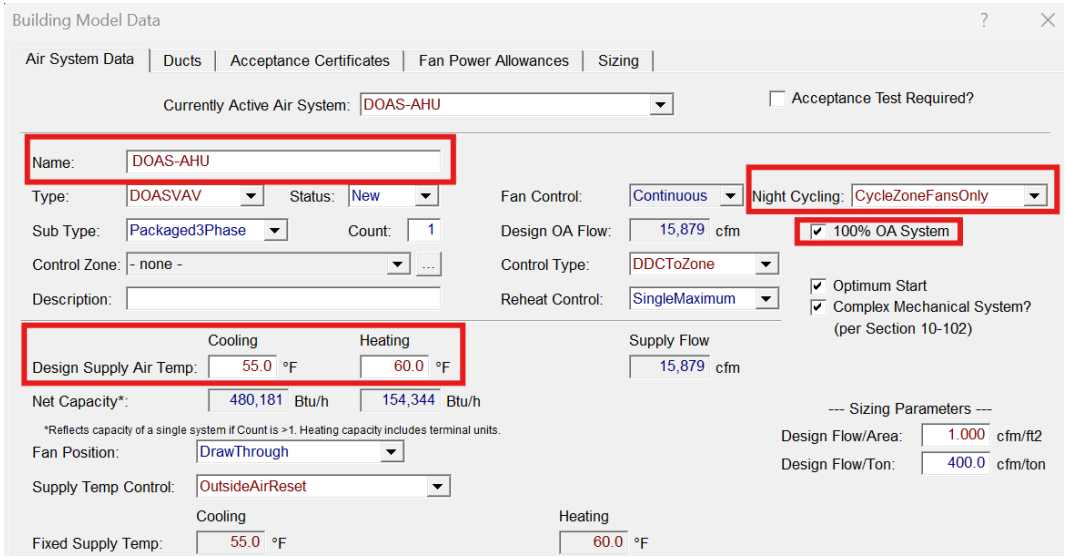


DOAS Air System

The DOAS is a 100% outdoor air system configured as a DOASVAV type, enabling ventilation airflow to modulate at the zone depending on the terminal unit types.

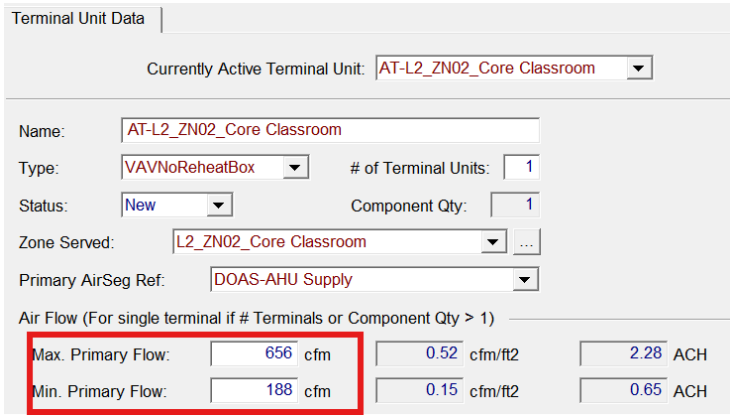
The air temperature is maintained at neutral conditions, which has design supply temperatures of 55 F and 60 F for cooling and heating.

To maintain temperature at night, the local zone fan coils are used, keeping the ventilation system off.



Air System Terminal Units

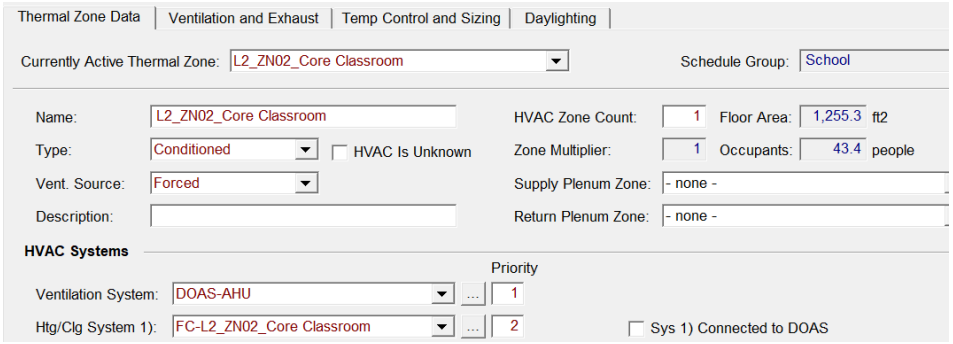
Air terminal units are created under the DOAS Air System for each thermal zone ventilation delivery. The terminal units are configured for ventilation only, providing peak flow for fully occupied and a lower level for minimum ventilation allowed based on CO2 sensors.

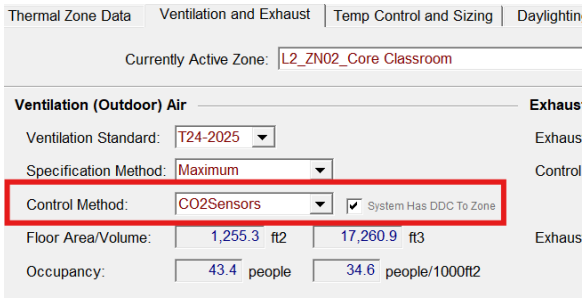


Thermal Zones

At each thermal zone, ventilation is configured from the DOAS unit and heating and cooling from the zones designated four pipe fan coil.

Nine zones have CO2 sensors based on occupant density and therefore also have minimum and maximum ventilation rates. All zones utilized a Variable Air Volume Terminal Unit for simplicity though only nine were configured with a lower airflow limit.





Thermal Zone Exhaust Ventilation Control

Air Terminal Units

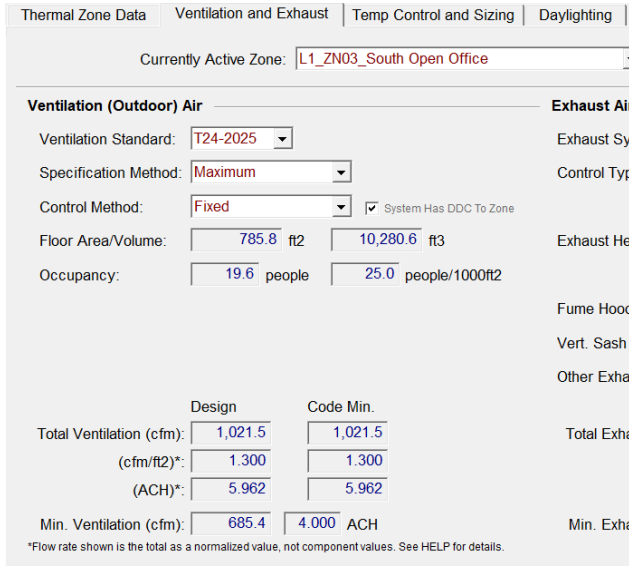
For classrooms with laboratory exhaust, the second tab of inputs in the Thermal Zone Data object is a key source for definition. This tab defines the exhaust system serving this building as well as links the exhaust system to an exhaust heat recovery device, located in the supply side air system.

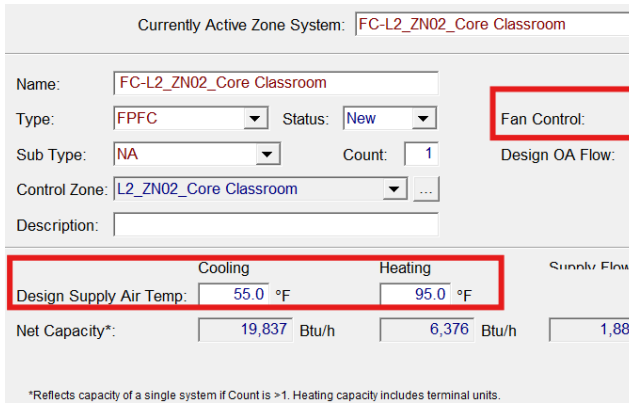
Zone System Four Pipe Fan Coils

The zone systems consist of four pipe fan coils, serving each thermal zone. Additional air terminal units supply the fresh air from DOAS. Even with systems where fresh air is routed to a fan coil, the proper configuration is to enable two elements serving each zone in CBECC, a terminal unit and a zone system.

Units were configured with cycling fans, which is the only modulating fan control allowed for these zone systems. Supply air temperature was left at default, supplying 55°F air in cooling, 95°F heating.

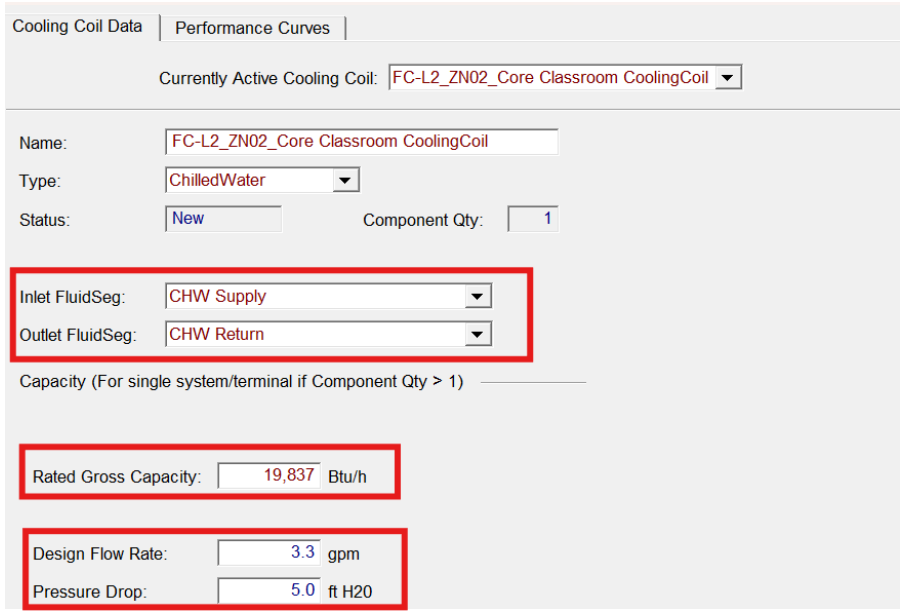
Fans are set to variable speed drive. Regardless of their assignment, in CBECC 2025 they are set to on off fans upon simulation and will cycle on and off as needed.

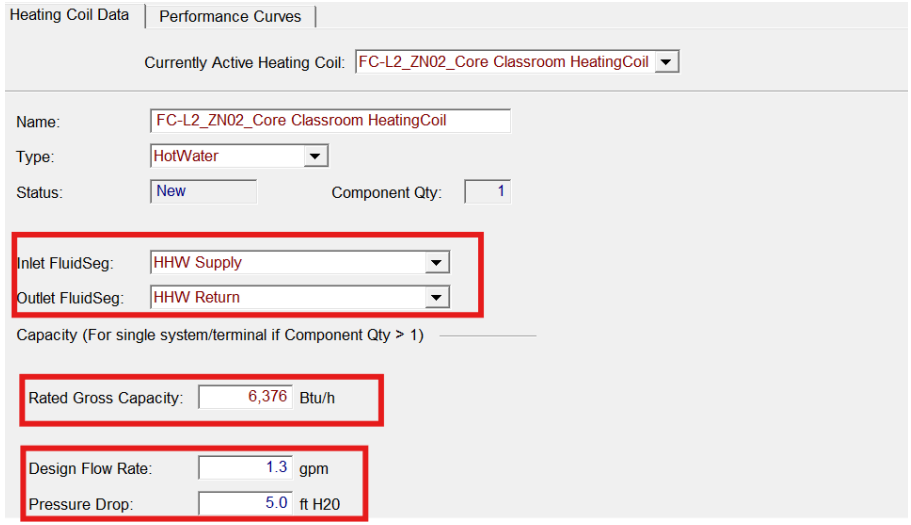




Four Pipe Fan Coil Heating and Cooling Coils

Each zone is served by a four-pipe fan coil unit with both a chilled water cooling coil and a hot water heating coil connected to their respective supply and return fluid segments. The unit operates with a variable speed drive centrifugal fan with a defined maximum and minimum flow capacity


Cooling Coil Data
Performance Curves
Currently Active Cooling Coil: FC-L2_ZN02_Core Classroom CoolingCoil
Name: FC-L2_ZN02_Core Classroom CoolingCoil
Type: ChilledWater
Status: New
Component Qty: 1
Inlet FluidSeg: CHW Supply
Outlet FluidSeg: CHW Return
Capacity (For single system/terminal if Component Qty > 1)
Rated Gross Capacity: 19,837 Btu/h
Design Flow Rate: 3.3 gpm
Pressure Drop: 5.0 ft H20


Heating Coil Data
Performance Curves
Currently Active Heating Coil: FC-L2_ZN02_Core Classroom HeatingCoil
Name: FC-L2_ZN02_Core Classroom HeatingCoil
Type: HotWater
Status: New
Component Qty: 1
Inlet FluidSeg: HHW Supply
Outlet FluidSeg: HHW Return
Capacity (For single system/terminal if Component Qty > 1)
Rated Gross Capacity: 6,376 Btu/h
Design Flow Rate: 1.3 gpm
Pressure Drop: 5.0 ft H20

System Efficiency Tables

Category	Proposed (FPFC/DOAS+CHW/HHW)	Standard (SZHP / PVAV / SZAC)
System Type	FPFC/DOAS central plant all zones (IT: SZAC)	SZHP: small zones | PVAV: large open-office zones | SZAC: IT
Cooling Efficiency	Central air-cooled chiller EER=15.0 / COP=4.40	SZHP: EER=11.4 / SEER=14 | PVAV: EER=9.8
Heating Primary	Air-to-Water HP COP = 2.5 | HHW to FPFC coils and DOAS	SZHP: air-source HP COP=3.2 / PVAV: gas HHW boilers 82% AFUE
Heating Supp.	None	SZHP: electric resistance at 35°F OAT | PVAV: gas HHW reheat
Fan Type	VSD on ALL FPFC zones + VSD DOAS (0.35–2.29 W/cfm zone fans)	SZHP zones: CV (0.58–0.69 W/cfm) | PVAV: VSD (1.10–1.11 W/cfm)
Economizer	No Economizer at zone level (DOAS pre-conditions OA; no free-cool cycle)	SZHP: FixedDryBulb 71°F on 11 zones | PVAV: NoEconomizer
DCV	CO2Sensors on 11 zones | Fixed on 16 zones	CO2Sensors on fewer zones | Fixed on most
Supp Lockout	N/A, no supplemental heat, Defrost enabled at 36°F	SZHP: electric resistance adds at 35°F OAT | HP lockout at 17°F

Relevant Energy Code Citations

Required Demand Control Ventilation

401.2.1.2.3 [Section 120.1(d)3]

Nine zones exceeded the occupancy density limit, requiring CO2-based modulating ventilation airflow. Zone-level VAV terminals on the DOAS serve those zones.

Fan Power Budget - DOAS Unit

401.3.3.4 [Section 140.4(a)3E] and 401.3.17.1 [Section 140.4(p)]

The DOAS unit is required to comply with the prescriptive system requirements for a four-pipe fan coil system with DOAS. That section sets a maximum DOAS fan power of 0.77 W/cfm at design airflow. The modeled DOAS fan power is consistent with this prescriptive limit.

Fan Power Budget - Indoor Fan Coil Units

401.3.3.3 [Section 140.4(a)3D]

Indoor fan coil units were aligned with prescriptive code for the multi-zone heat pump system to a fan power of 0.35 W/cfm.

Air-Side Economizer Exemption - DOAS Unit

401.3.7 [Section 140.4(e)]

The DOAS unit operates at 100% outdoor air and therefore has no return air damper to modulate. An air-side economizer is not applicable to this system configuration.

Exhaust Air Heat Recovery

401.3.18 [Section 140.4(q)]

Outdoor air systems delivering 3,000 CFM or more at 70% or greater outdoor air fraction are required to include exhaust air heat recovery. The DOAS delivers 100% outdoor air above this airflow threshold, requiring the modeled heat recovery ventilator.

Minimum DOAS Cooling and Heating Efficiency

Section 140.4(a)3Aii, 140.4(a)3Aiii, or 140.4(a)3B

The DOAS cooling coil and heat pump heating coil are each required to meet minimum EER and COP thresholds for their capacity ranges. Both modeled coils exceed the applicable mandatory minimums.

Lab Hoods

The lab exhaust fans are required to meet thresholds per Table 120.1-C, Table 140.4-B, Section 140.9(c), Table 170.2-C. Lab exhaust fans are modelled according to the mandatory minimums.

Same Criteria as Example 1

- Duct Sealing and Leakage Testing
- Direct Digital Controls to Zone
- Optimum Start/Stop Controls

This example is one of eight developed as part of the *Addressing Complex HVAC Systems in Code Compliance* project. The full guide includes additional HVAC system types, alternative configurations, and working CBECC model files. All resources are available through the CalBEM working group and EnergyCodeAce platform.