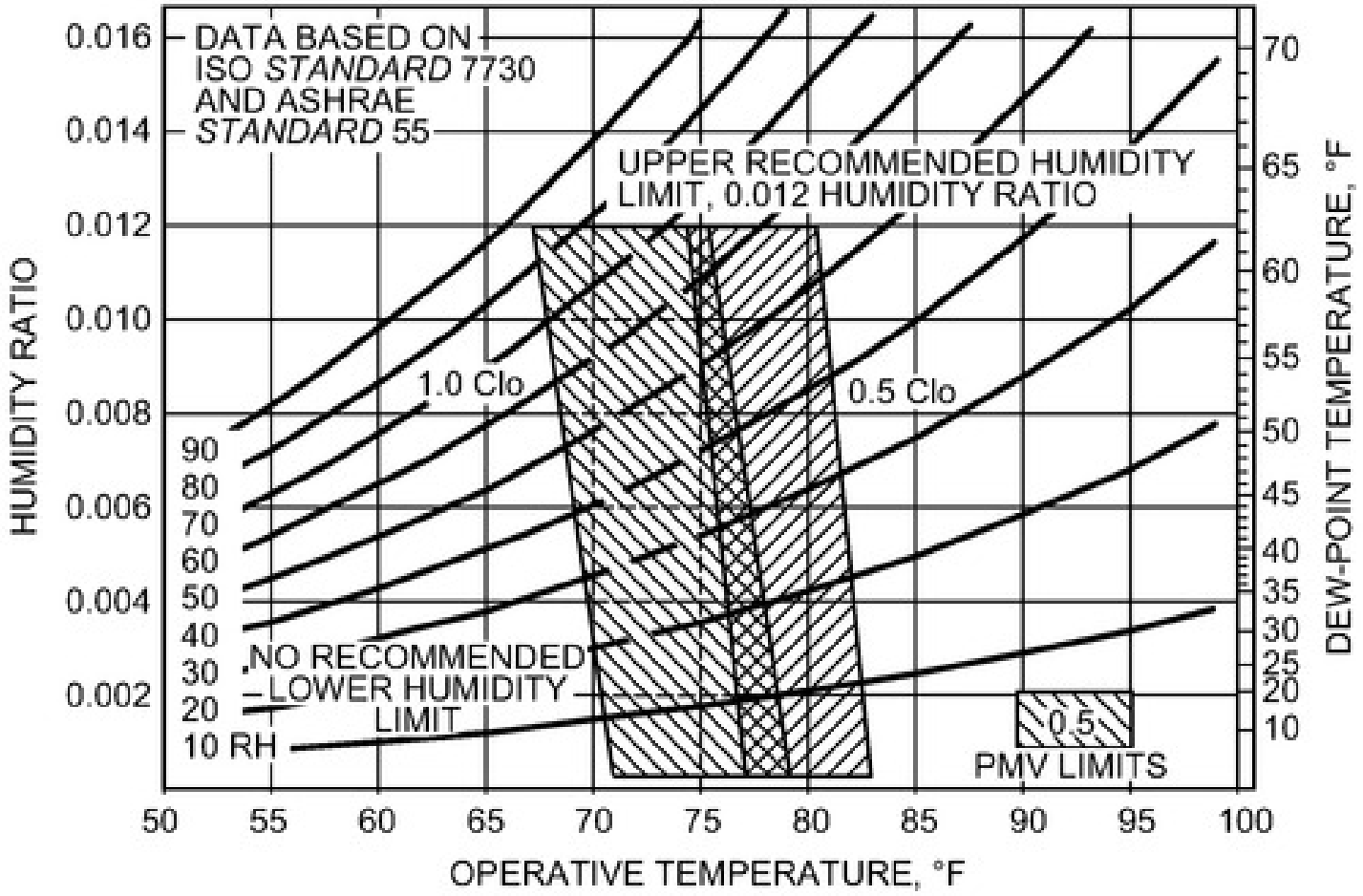
HVAC System Basics

Basic Purpose of HVAC

- Air-Conditioning for thermal and humidity comfort



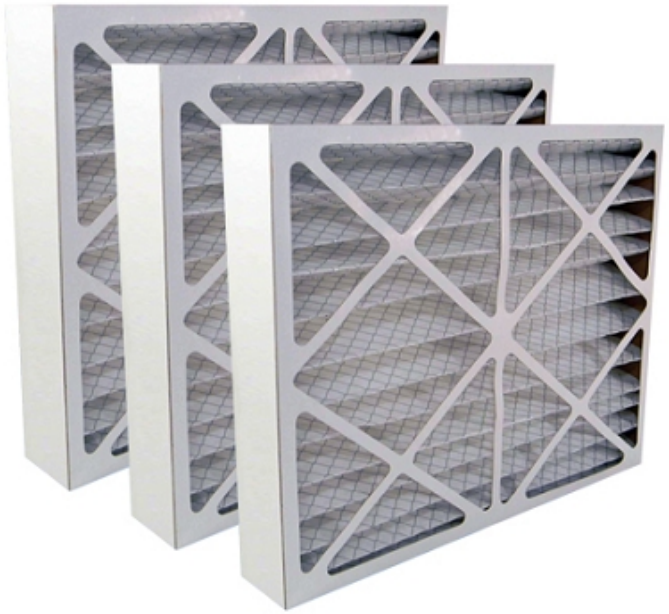
Basic Purpose of HVAC

- Ventilation
  - Introduction of required outside air

Basic Purpose of HVAC

- Ventilation
  - Filtration
    - ASHRAE 52.2

MERV 8



503.3 Filters. [BSC-CG] *In mechanically ventilated buildings, provide regularly occupied areas of the building with air filtration media for outside and return air that provides at least a Minimum Efficiency Reporting Value (MERV) of 8. MERV 8 filters shall be installed prior to occupancy, and recommendations for maintenance with filters of the same value shall be included in the operation and maintenance manual in compliance with Chapter 5, Division 5.5. of the California Green Building Standards Code (CALGreen).*

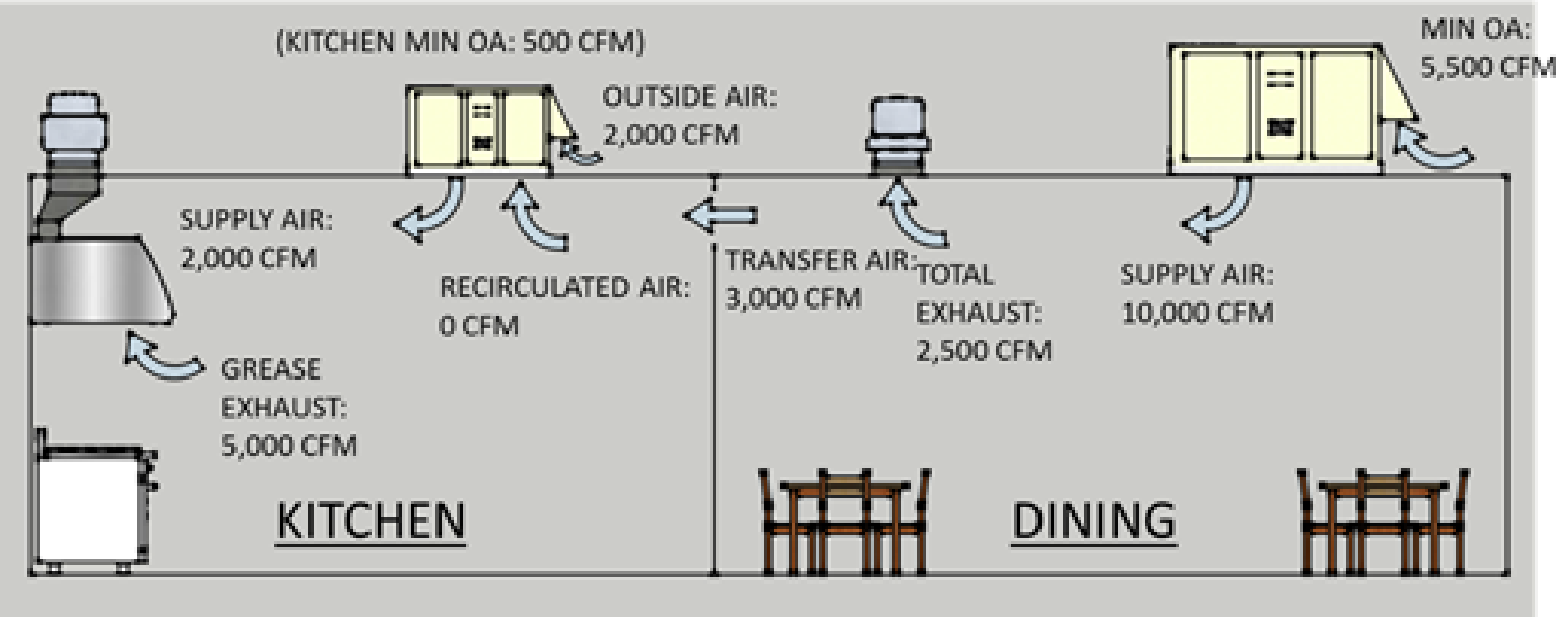
Exceptions:

1. *An ASHRAE 10-percent to 15-percent efficiency filter shall be permitted for an HVAC unit meeting the 2013 California Energy Code having 60,000 Btu/h (17.6 kW) or less capacity per fan coil, if the energy use of the air delivery system is 0.4 W/cfm [848 W/(m^3/s)] or less at design air flow.*
2. *Existing mechanical equipment.*

503.3.1 Labeling. *Installed filters shall be clearly labeled by the manufacturer indicating the MERV rating.*

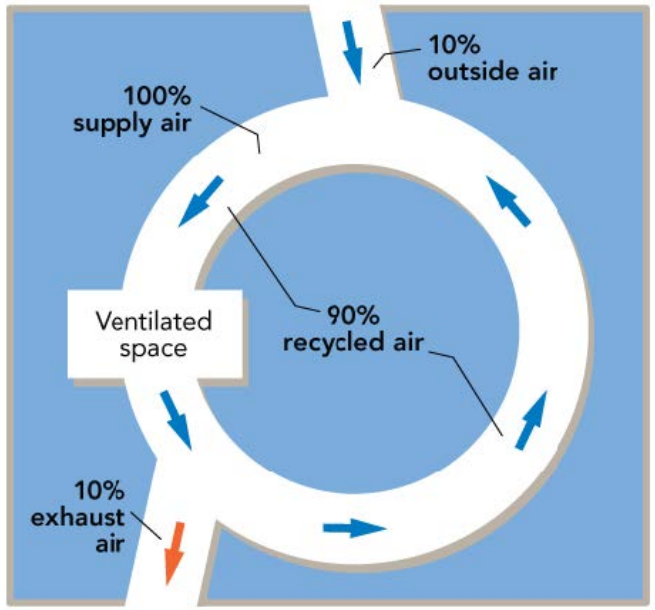
Basic Purpose of HVAC

- Ventilation
  - Exhaust of undesirable air (toilet, kitchen, lab exhaust)



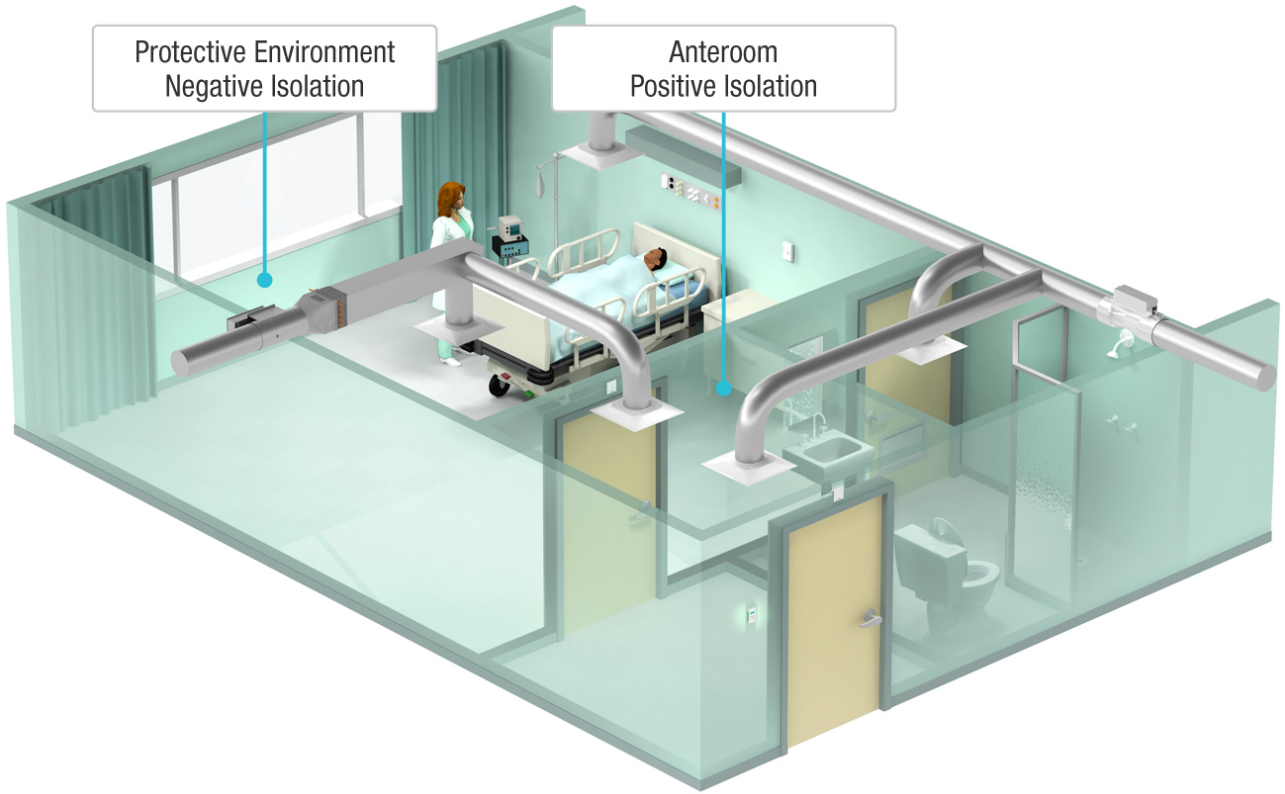
Basic Purpose of HVAC

- Ventilation
  - Air movement in space



Basic Purpose of HVAC

- Space pressurization
  - Control infiltration
  - Makeup of exhausted air



Heat Gain vs Heat Loss

Heat Gains

- Solar thru windows / walls
- Summer transfer / infiltration
- Internal
  - Electric use, Lighting & Equipment
  - Body Heat

Heat Loss

- Air Leaks (infiltration)
- Transfer
  - Walls
  - Roofs
  - Floor
  - Windows

Heat Gain vs Heat Loss

Air Conditioning

- Two general types of air conditioning (cooling)
  - Refrigeration-based: refrigerant cycle moves heat from space (indoors) to another (outdoors)
    - Refrigerant has a low boiling point, making it ideal for HVAC systems
    - Like a car AC
  - Non-refrigerant: evaporative cooling

Air Conditioning

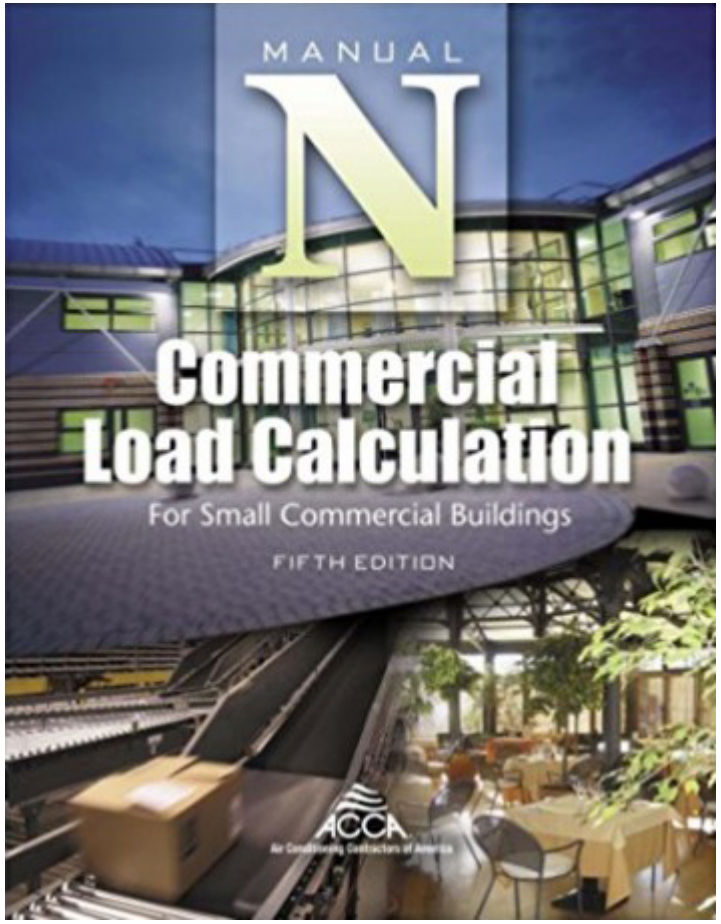
- Simple vs. Complex

DX COOLING SYSTEM

CHILLED WATER SYSTEM

System Capacity Sizing

- Verify that cooling and heating capacity sizing (load calculations) have been completed (C403.2.1)



» **1105.0 General Requirements.**

» **1105.1 Human Comfort.** Cooling systems used for human comfort shall be in accordance with the return-air and outside-air provisions for furnaces in Section 904.7 and Section 904.8. Cooling equipment used for human comfort in dwelling units shall be selected to satisfy the calculated loads determined in accordance with the reference standards in Chapter 17 or other approved methods. Refrigerants used for human comfort shall be in accordance with Section 1104.6.

System Capacity Sizing

- Verify that equipment is not unreasonable over-sized (C403.2.2)
- Why?

SECTION C403
BUILDING MECHANICAL SYSTEMS

C403.1 General.

Mechanical systems and equipment serving the building heating, cooling or ventilating needs shall comply with Section C403.2 and shall comply with Sections C403.3 and C403.4 based on the equipment and systems provided.

Walk-in coolers, walk-in freezers, refrigerated warehouse coolers and refrigerated warehouse freezers shall comply with Section C403.2.15 or C403.2.16.

C403.2 Provisions applicable to all mechanical systems (Mandatory).

Mechanical systems and equipment serving the building heating, cooling or ventilating needs shall comply with Sections C403.2.1 through C403.2.16.

C403.2.1 Calculation of heating and cooling loads.

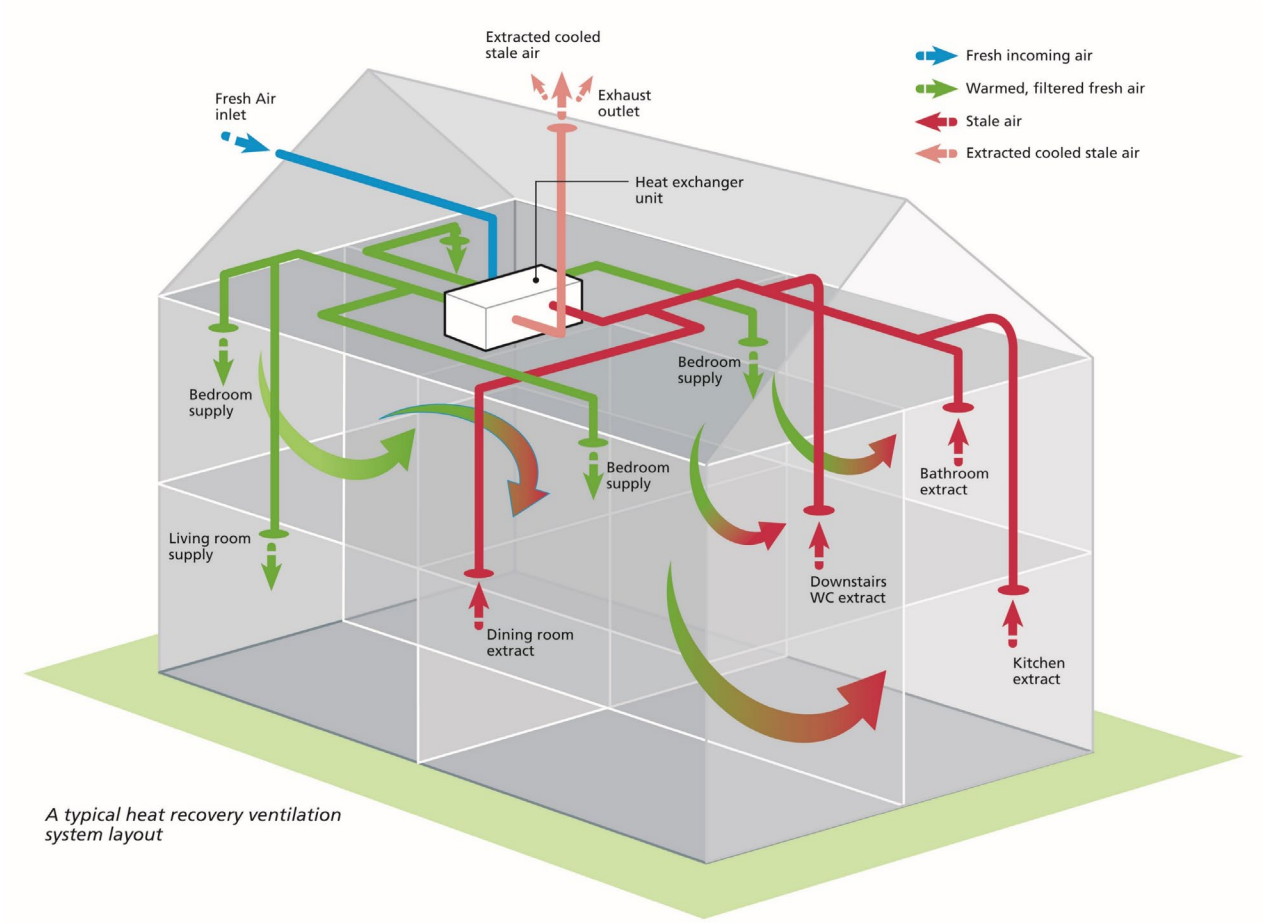
Design loads associated with heating, ventilating and air conditioning of the building shall be determined in accordance with ANSI/ASHRAE/ACCA Standard 183 or by an *approved* equivalent computational procedure using the design parameters specified in Chapter 3. Heating and cooling loads shall be adjusted to account for load reductions that are achieved where energy recovery systems are utilized in the HVAC system in accordance with the ASHRAE *HVAC Systems and Equipment Handbook* by an approved equivalent computational procedure.

C403.2.2 Equipment sizing.

The output capacity of heating and cooling equipment shall be not greater than the loads calculated in accordance with Section C403.2.1. A single piece of equipment providing both heating and cooling shall satisfy this provision for one function with the capacity for the other function as small as possible, within available equipment options.

Ventilation

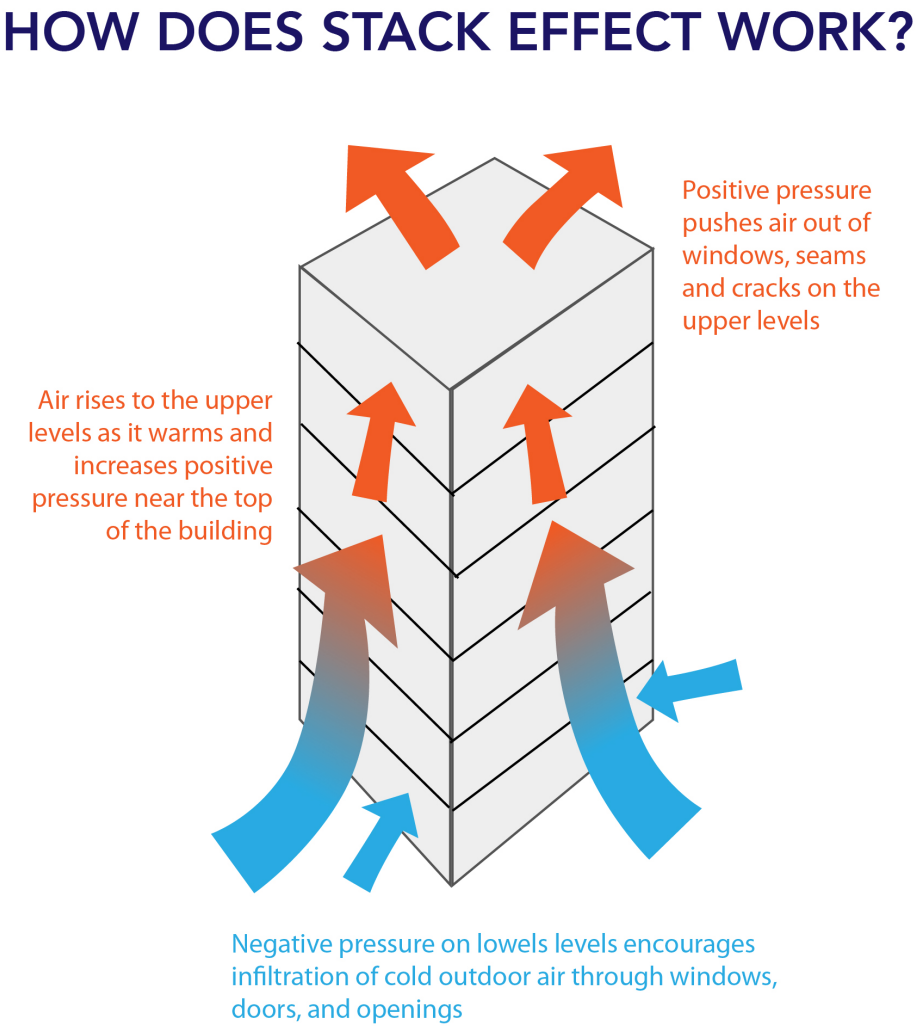
- Two types
  - Mechanical ventilation (Active)



A typical heat recovery ventilation system layout

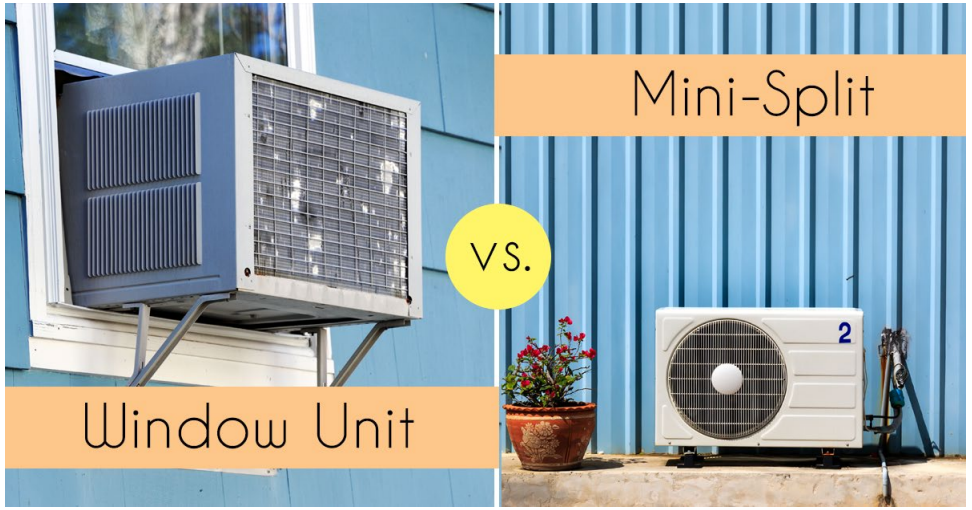
Ventilation

- Two types
  - Natural ventilation (Passive)



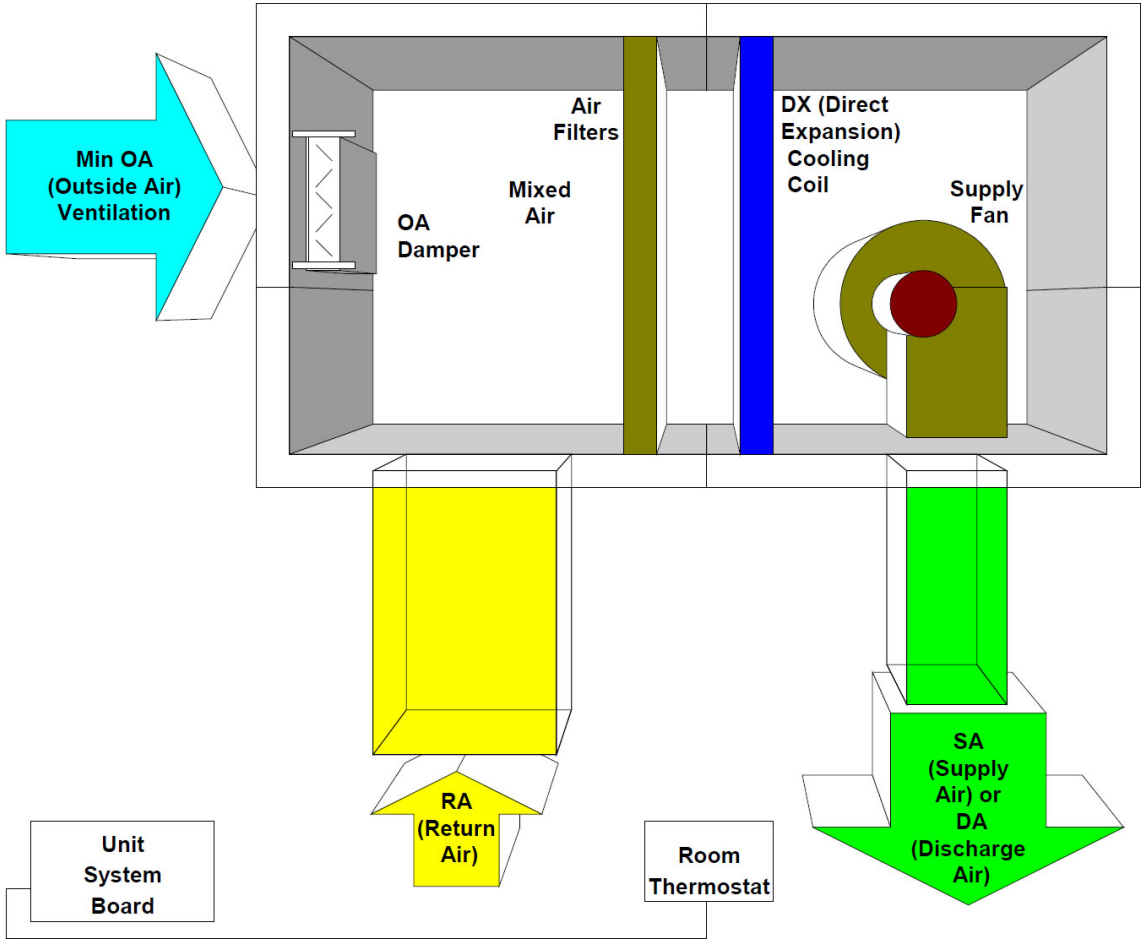
Simple HVAC Systems

- Package Units
  - Thru-wall air conditioner
  - Package Terminal Air Conditioner (PTAC)
  - Package Terminal Heat Pump (PTHP)
- Unitary
  - Air conditioner
  - Furnace
  - Heat Pumps
  - Packaged, split, mini-split
  - Variable refrigerant Flow (VRF)

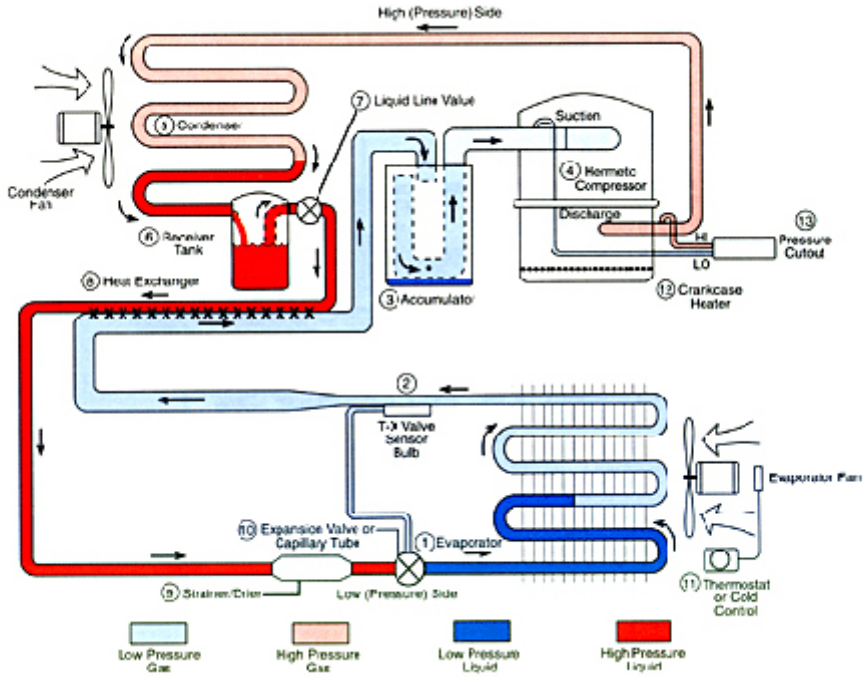


Packaged Rooftop Cooling Unit (RTU)

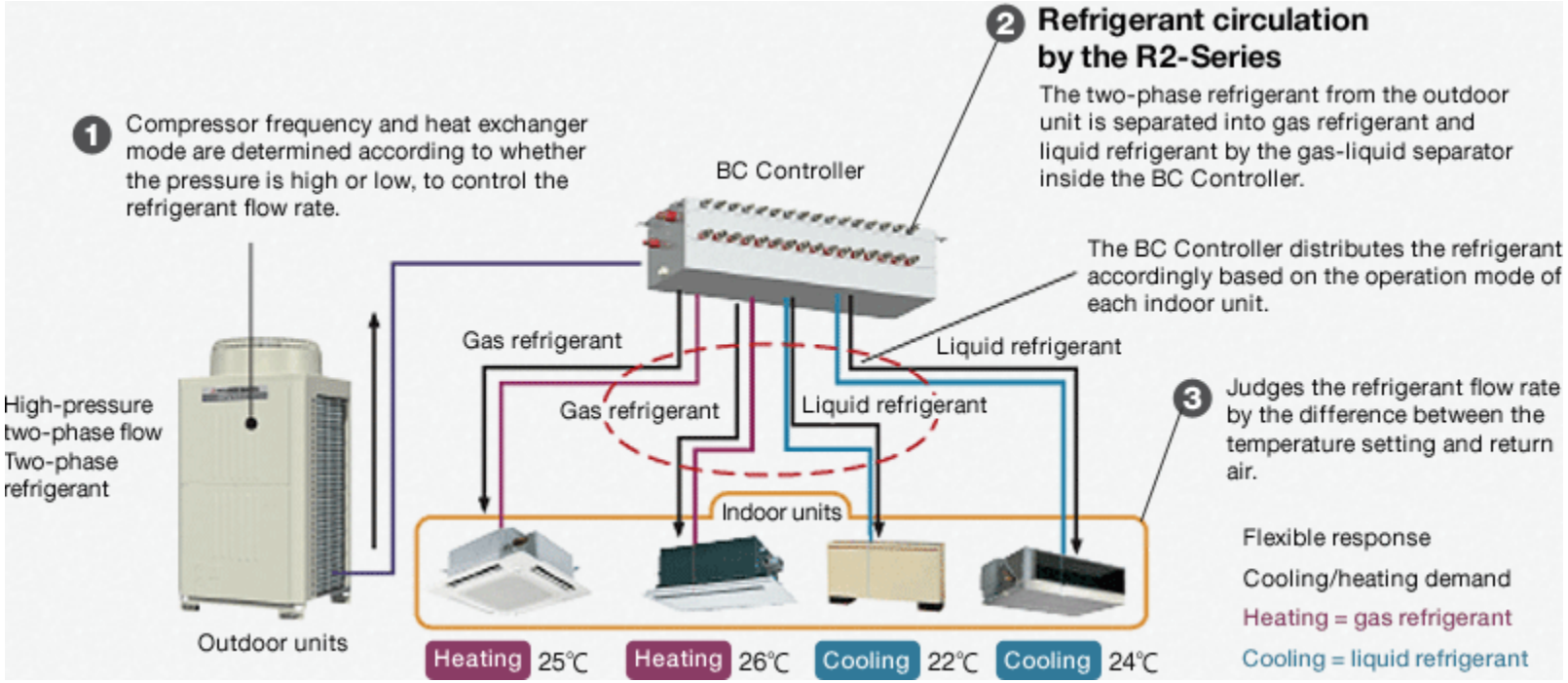
DX COOLING SYSTEM



Refrigeration Cycle



Variable Refrigerant Flow (VRF)



Energy Code

APPENDIX E

TABLE E 503.7.1(1)
ELECTRICALLY OPERATED UNITARY AIR CONDITIONERS AND CONDENSING UNITS
MINIMUM EFFICIENCY REQUIREMENTS
[ASHRAE 90.1: TABLE 6.8.1-1]

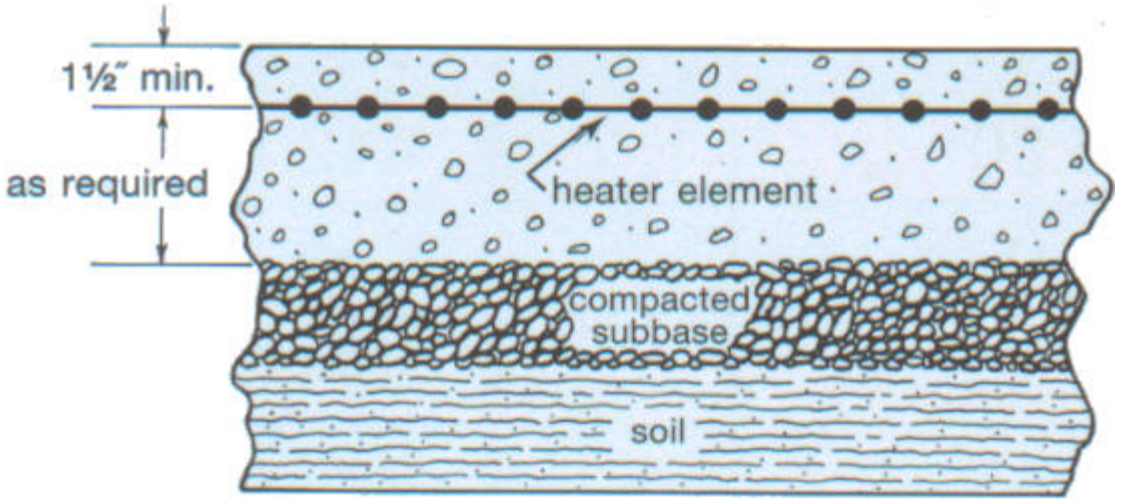
EQUIPMENT TYPE	SIZE CATEGORY	HEATING SECTION TYPE	SUBCATEGORY FOR RATING CONDITION	MINIMUM EFFICIENCY	TEST PROCEDURE[1]
Air conditioners, air cooled	<65 000 Btu/h[2]	All	Split System	13.0 SEER	AHRI 210/240
			Single Package	13.0 SEER (before 1/20/15) 14 SEER (as of 1/1/2015)	
Through-the-wall, air cooled	≤30 000 Btu/h[2]	All	Split System	12.0 SEER	
			Single Package	12.0 SEER	
Small duct high velocity, air cooled	<65 000 Btu/h[2]	All	Split System	11.0 SEER	
Air conditioners, air cooled	≥65 000 Btu/h and <135 000 Btu/h	Electric resistance (or none)	Split system and single package	11.2 EER 11.4 IEER (before 1/1/2016) 12.9 IEER (as of 1/1/2016)	
		All other	Split system and single package	11.0 EER 11.2 IEER (before 1/1/2016) 12.7 IEER (as of 1/1/2016)	
	≥135 000 Btu/h and	Electric resistance (or none)	Split system and single package	11.0 EER 11.2 IEER (before 1/1/2016) 12.4 IEER (as of 1/1/2016)	

Top of the Charts

- Most Impactful Basic HVAC Control Measures
  - Snow and ice melt heater control
  - Temperature setback scheduling
  - Full 5-degree thermostat deadband
  - Economizer controls
  - Limits on simultaneous heating and cooling (VAV reheat)
  - VAV ventilation optimization
  - Supply air temperature & fan static reset controls
  - Exterior ductwork insulation (C403.2.9)
  - Fan power limits
  - Proper equipment sizing
  - Commissioning

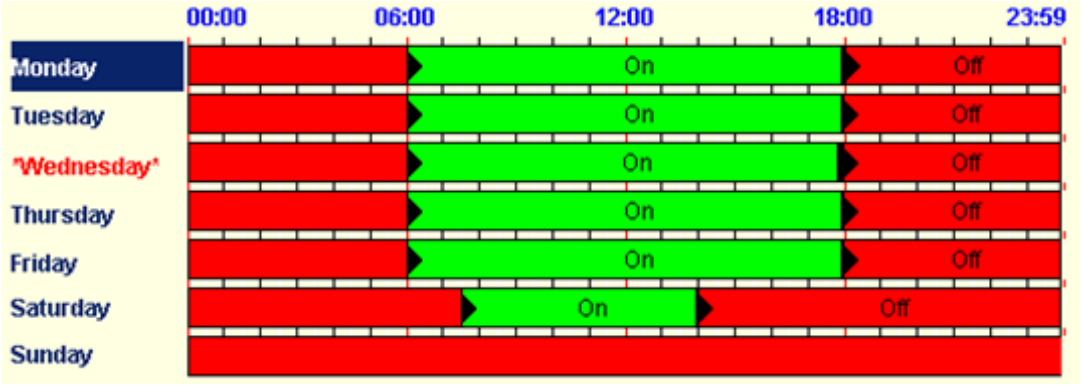
Snow and Ice Melt Heater Control

- Snow and ice melt heaters will use a large amount of energy if not properly and automatically controlled



Temperature Setback Scheduling

- Simple control systems
  - Programmable thermostats
    - Seven different daily schedules/week
    - Manual override
  - Occupant sensor is an alternative
- DDC (Direct Digital Control) systems
  - Central scheduling of all units
  - Optimum start activated

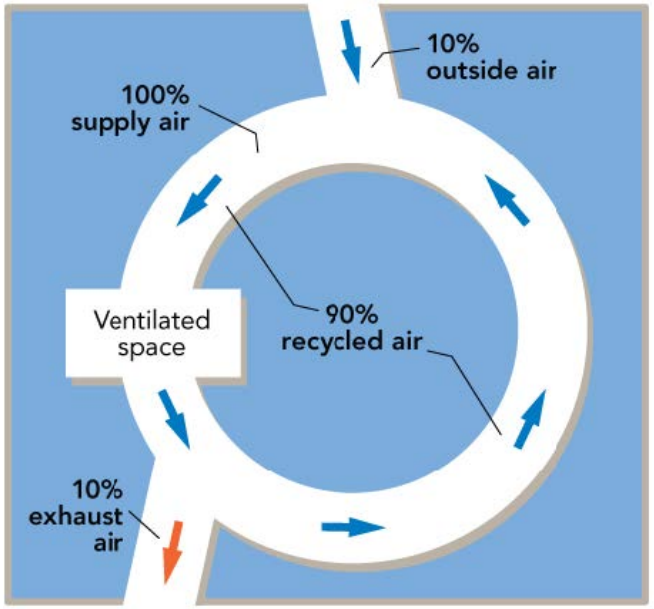


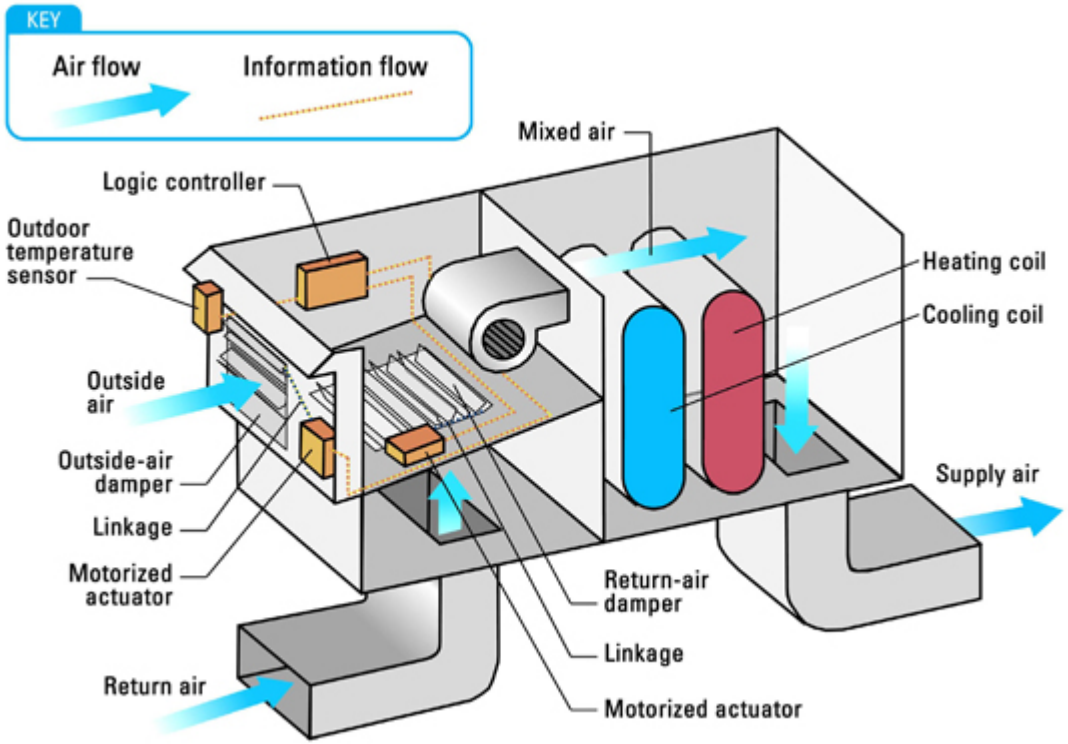
Full 5-degree Thermostat Deadband Economizer Controls

- A most significant control feature is temperature deadband
- If heating is set at 70°F, then cooling should be ≥ 75°F
- Should be the found condition during an inspection
- Why?
  - Simple systems can fight each other in open office areas
  - VAV systems have excessive reheat if settings are too tight
- Energy Star recommended factory default setpoints of:
  - Heating 70°F
  - Cooling 78°F

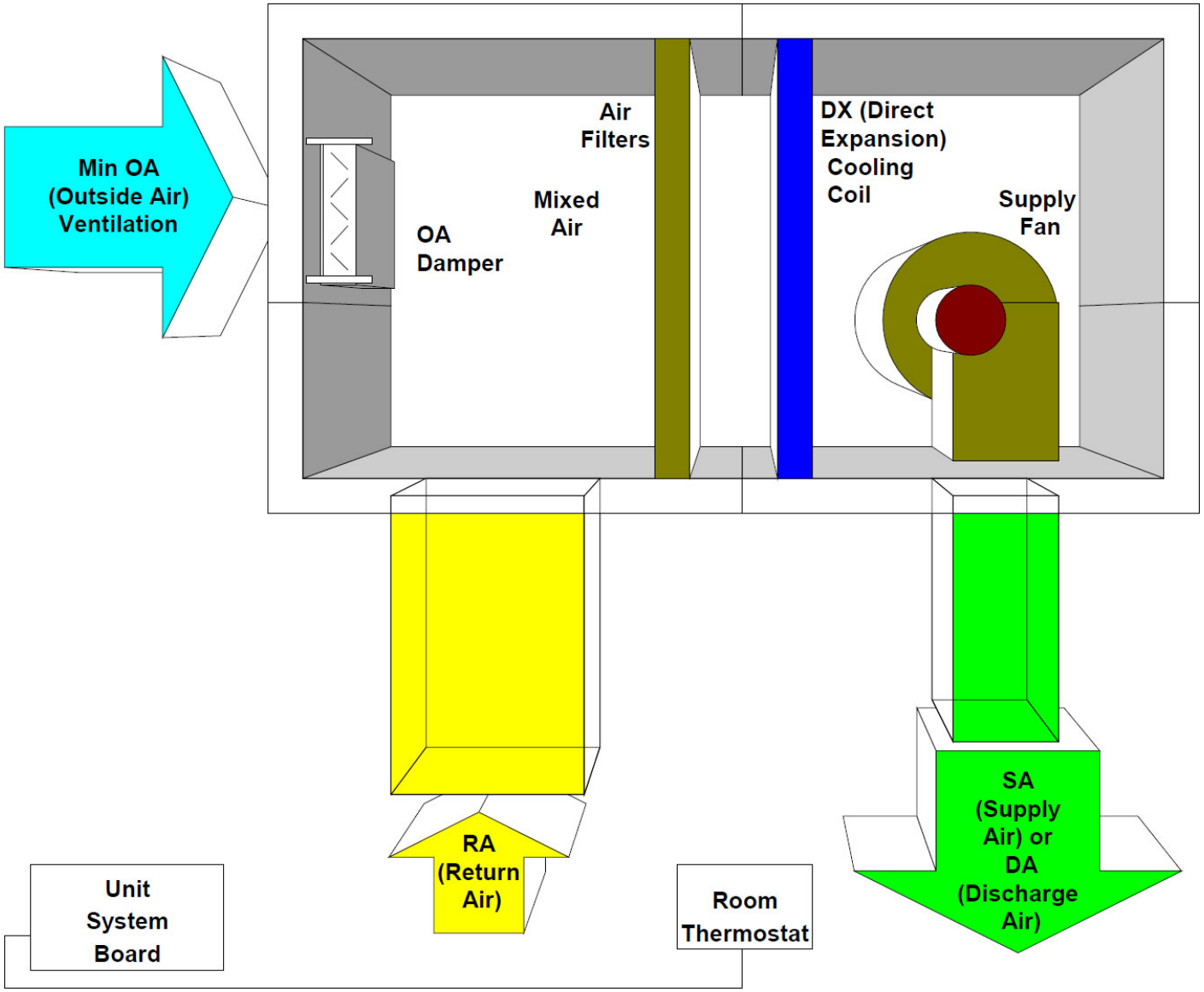
HVAC – Economizers “Free Cooling”

- Quantity of Outside Air (OA): Meet Minimum Ventilation Requirement
- Economizer Function: Flush out building heat with cool outside air

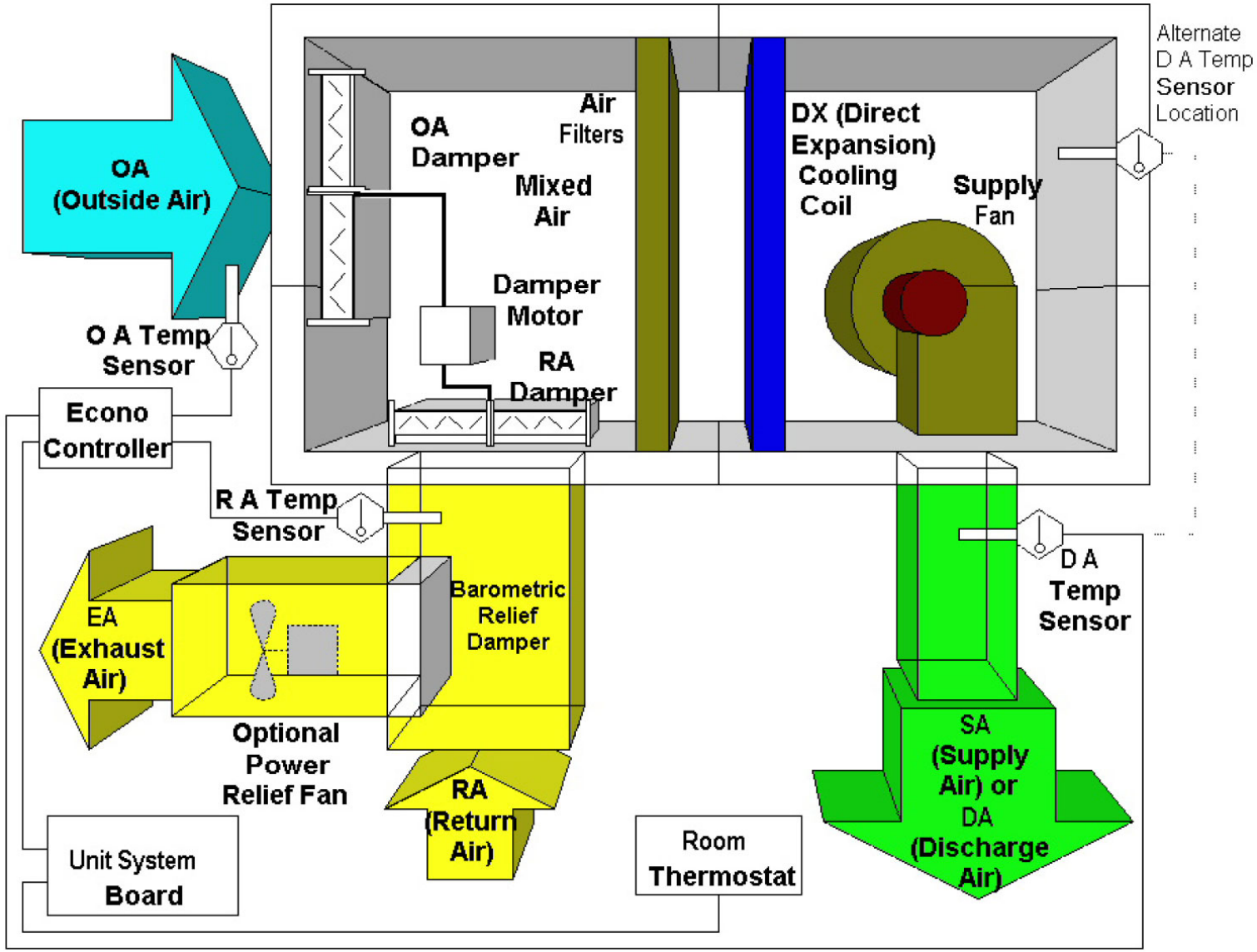




Packaged Rooftop Cooling Unit



Basic OA Economizer Idea



Top of the Charts

- Most Impactful Basic HVAC Control Measures
  - Snow and ice melt heater control
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  - Supply air temperature & fan static reset controls
  - Exterior ductwork insulation (C403.2.9)
  - Fan power limits
  - Proper equipment sizing
  - Commissioning

Ductwork in Attics or Outside the Building

TABLE E 503.7.2(1)
MINIMUM DUCT INSULATION R-VALUE[1] FOR COOLING AND HEATING ONLY SUPPLY DUCTS AND RETURN DUCTS
[ASHRAE 90.1: TABLE 6.8.2-1]

CLIMATE ZONE	DUCT LOCATION						
	EXTERIOR	VENTILATED ATTIC	UNVENTED ATTIC ABOVE INSULATED CEILING	UNVENTED ATTIC WITH ROOF INSULATION[1]	UNCONDITIONED SPACE[2]	INDIRECTLY CONDITIONED SPACE[3]	BURIED
HEATING ONLY DUCTS							
1, 2	none	none	none	none	none	none	none
3	R-3.5	none	none	none	none	none	none
4	R-3.5	none	none	none	none	none	none
5	R-6	R-3.5	none	none	none	none	R-3.5
6	R-6	R-6	R-3.5	none	none	none	R-3.5
7	R-8	R-6	R-6	none	R-3.5	none	R-3.5
8	R-8	R-8	R-6	none	R-6	none	R-6
COOLING ONLY DUCTS							
1	R-6	R-6	R-8	R-3.5	R-3.5	none	R-3.5
2	R-6	R-6	R-6	R-3.5	R-3.5	none	R-3.5
3	R-6	R-6	R-6	R-3.5	R-1.9	none	none
4	R-3.5	R-3.5	R-6	R-1.9	R-1.9	none	none
5, 6	R-3.5	R-1.9	R-3.5	R-1.9	R-1.9	none	none
7, 8	R-1.9	R-1.9	R-1.9	R-1.9	R-1.9	none	none
RETURN DUCTS							
1 to 8	R-3.5	R-3.5	R-3.5	none	none	none	none

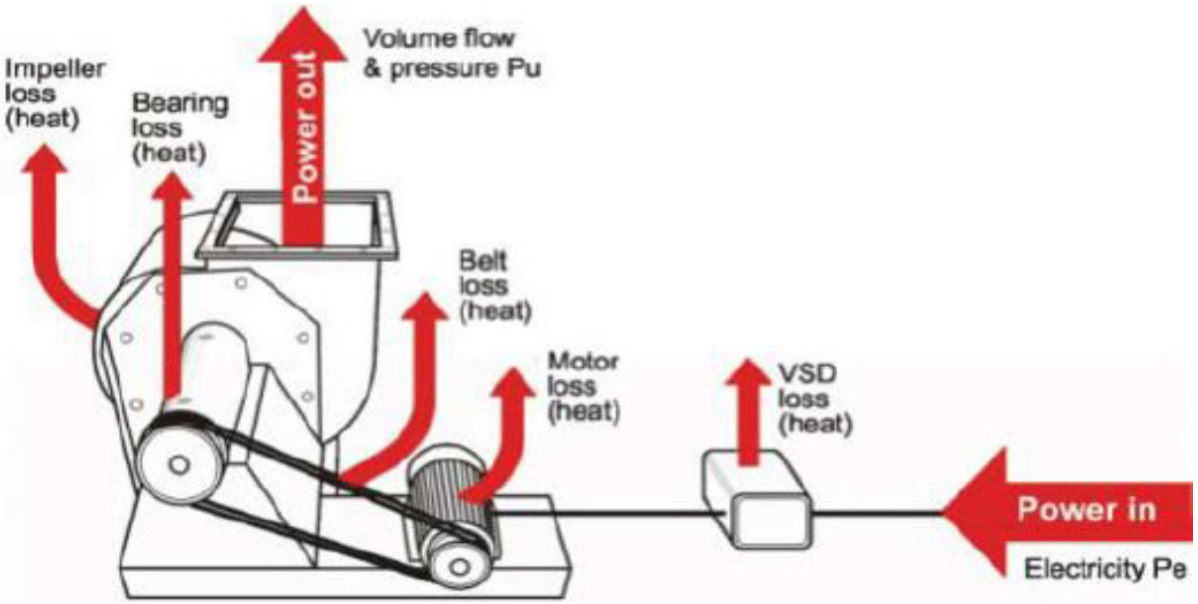
Notes:

1 Insulation R-values, measured in [°F•h•ft²/(Btu•in)] [(m•K)/W], 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 in accordance with the most restrictive condition of Section E 503.4.7.2 or ASHRAE 90.1. Insulation resistance measured on a horizontal plane in accordance with ASTM C518 at a mean temperature of 75°F (24°C) at the installed thickness.

2 Includes crawlspaces, both ventilated and nonventilated.

3 Includes return air plenum, with or without exposed roofs above.

Overall Fan System Efficiency



Complex Building Energy Use - HVAC

CHILLED WATER SYSTEM

EXTRACT AND VENTILATION SYSTEMS

Heating and Cooling

Central Plant: Boilers

Central Plant: Chillers

Air Cooled

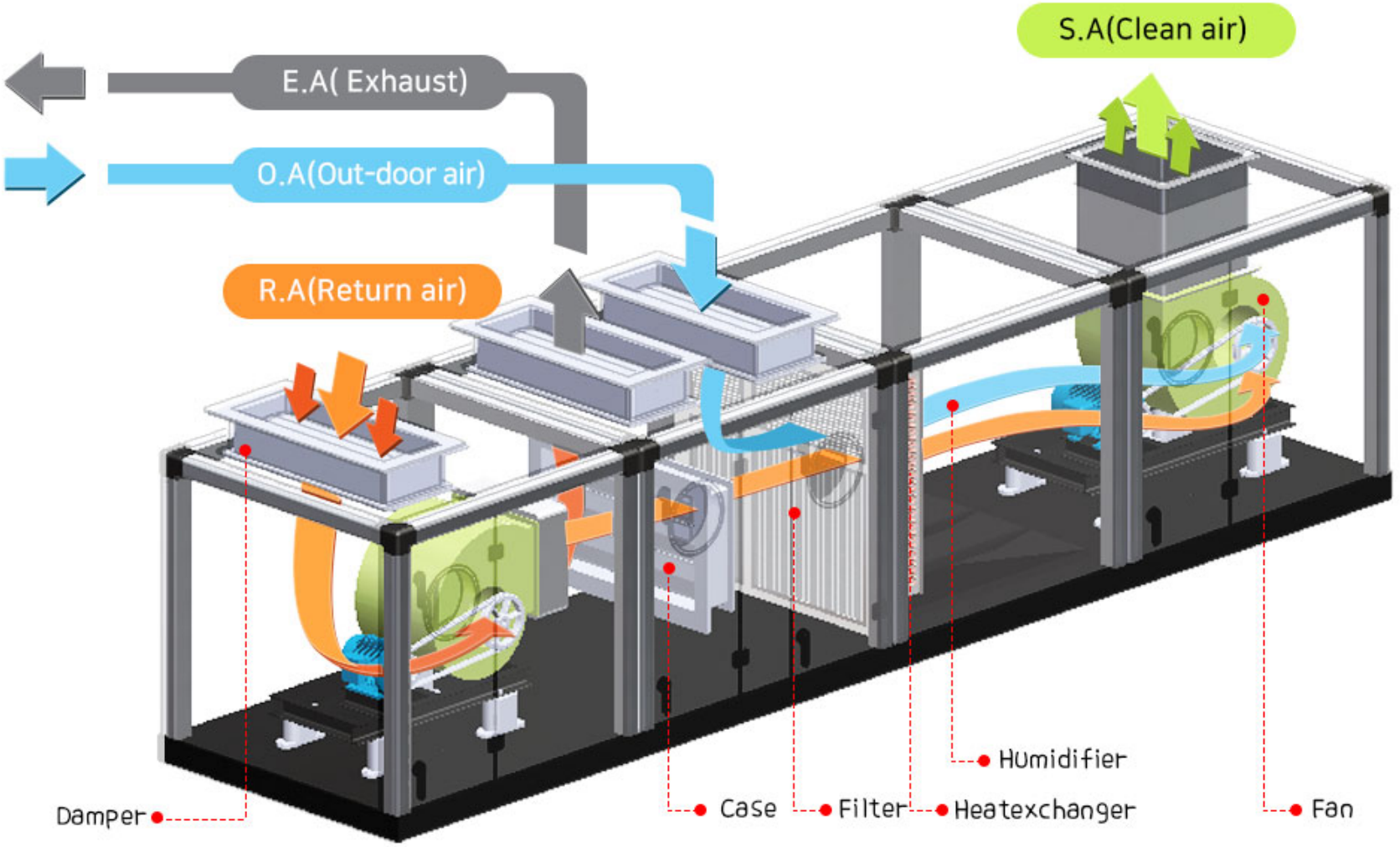
Water Cooled

Central Plant: Cooling Tower

Energy Code Checks

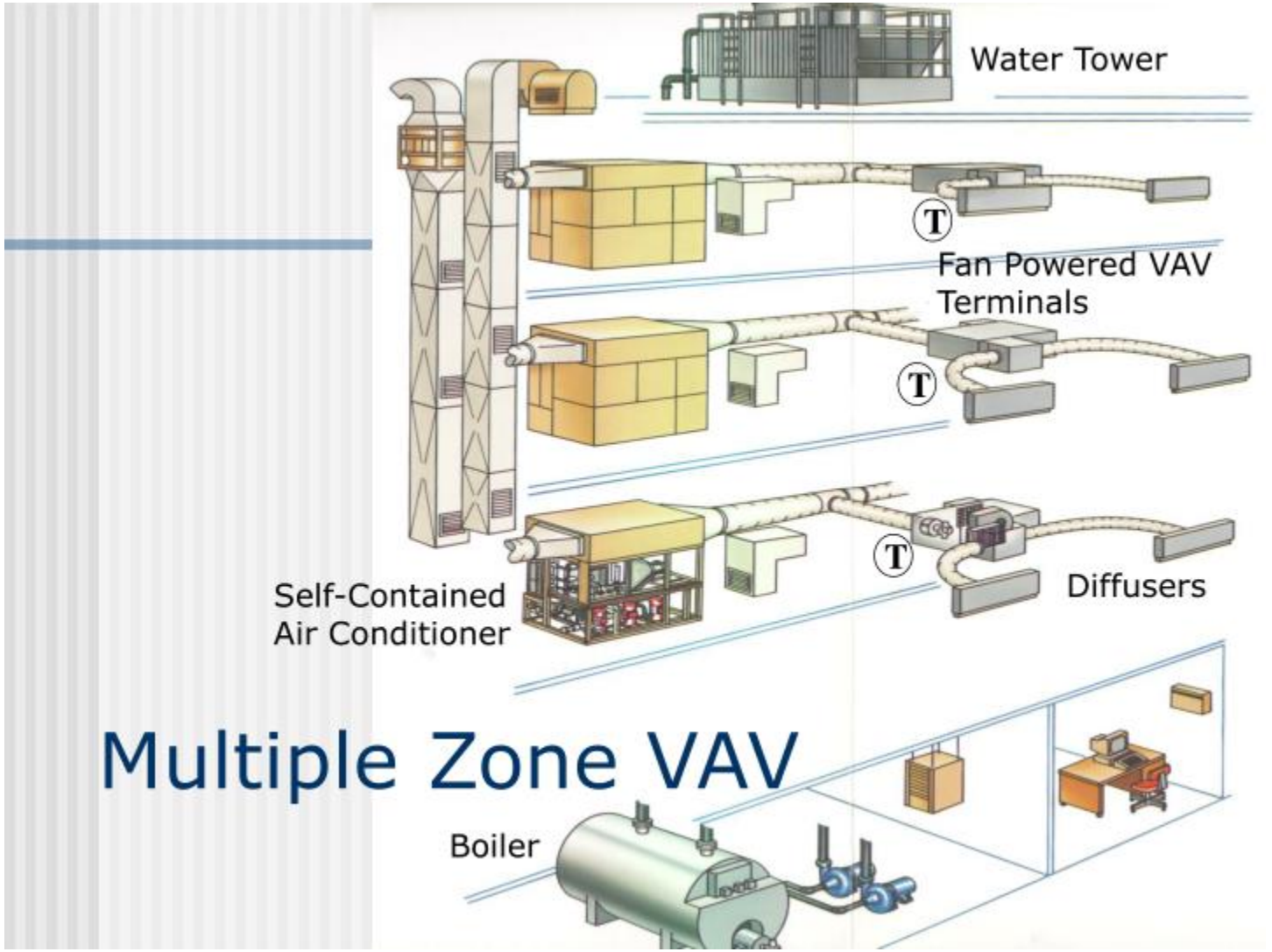
Complex Secondary HVAC Systems

Secondary HVAC System Air Handlers



Distribution: Heating Coils, Radiant Heaters

VAV Multiple Zone System Concept



Multiple Zone System Example: VAV Terminal Unit (VAV Box)