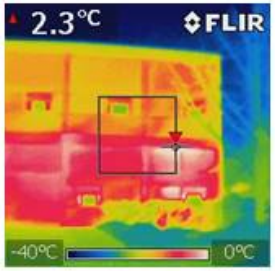
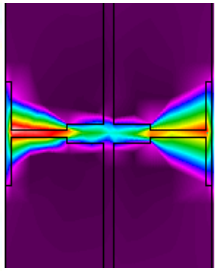
CAE 331/513 Building Science

Fall 2016





Week 8: October 13, 2016

Finishing psychrometric processes

Introduction to HVAC systems

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Illinois Institute of Technology

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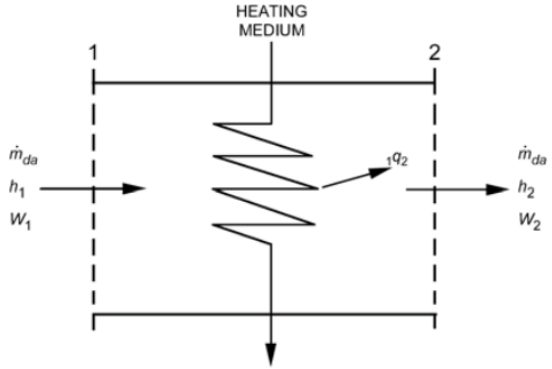
Last time

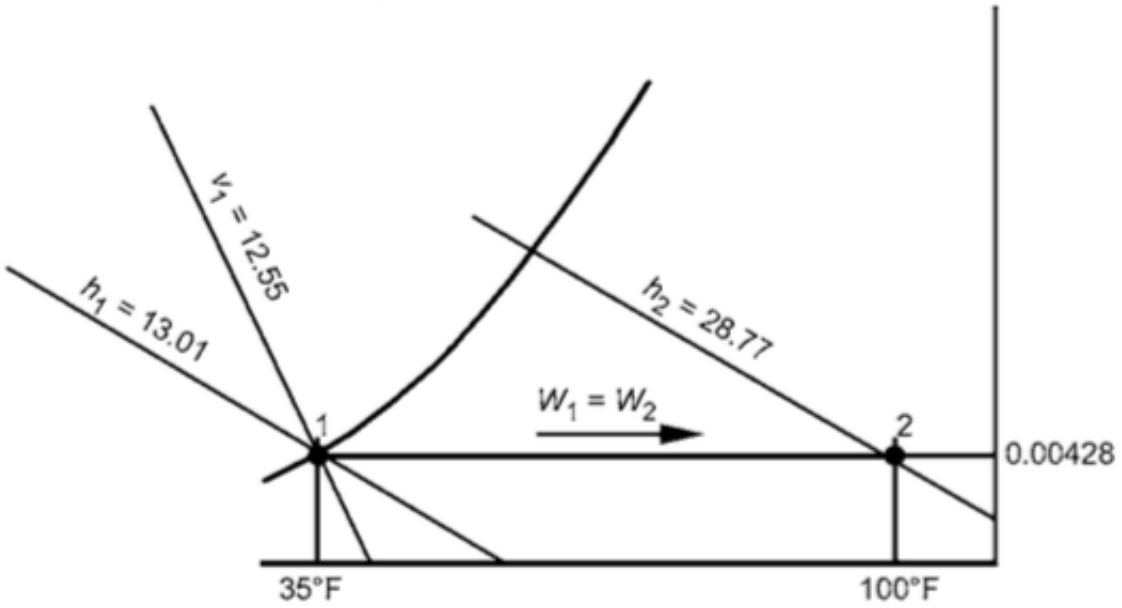
- Energy and mass balances on psychrometric processes
  - Sensible heating and cooling
  - Heating and humidifying
  - Cooling and dehumidifying
  - Mixing of airstreams
  - Evaporative cooling

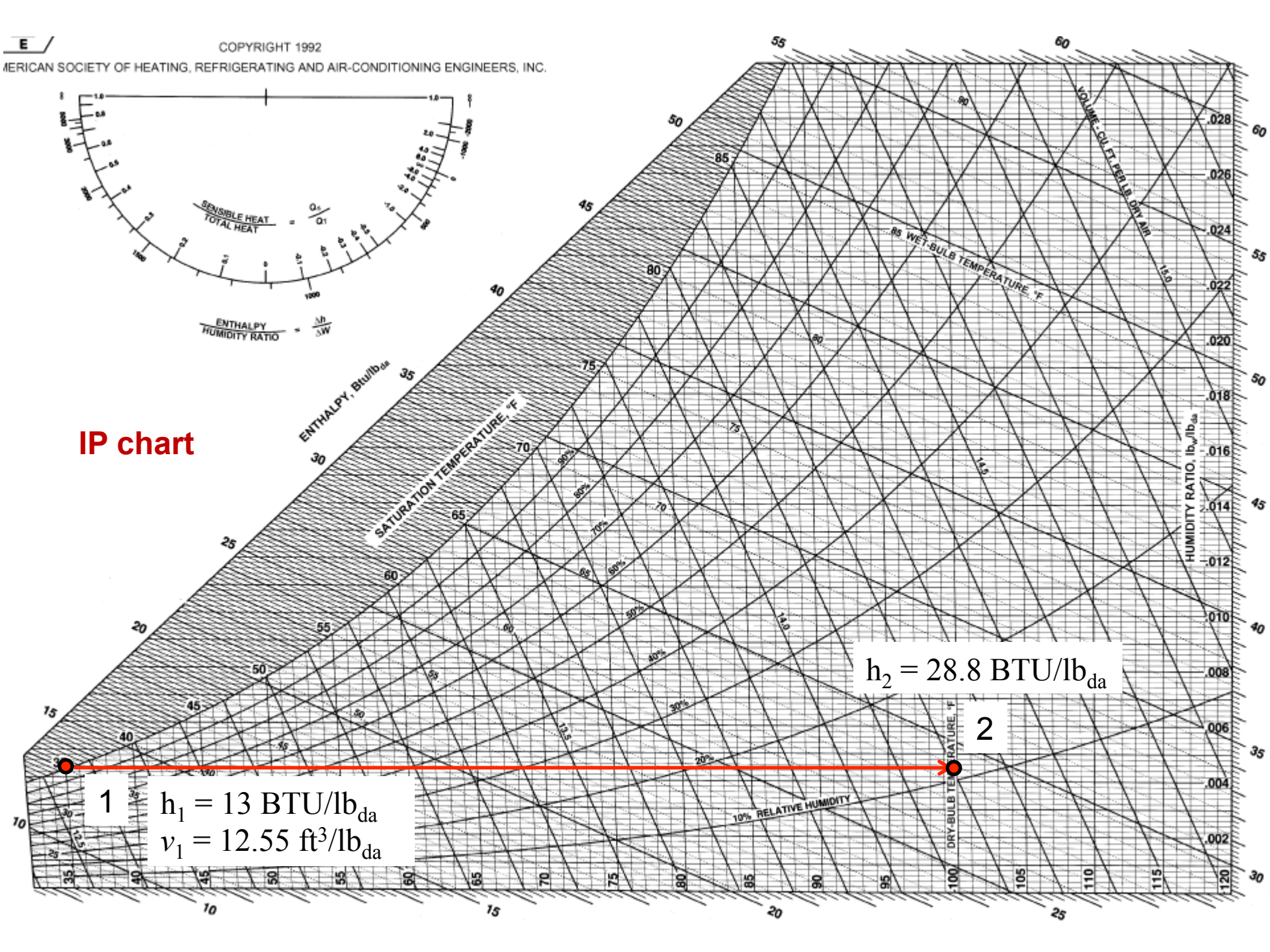
- HW 4 assigned
  - Due Tuesday October 18

IP unit examples

- Moist air, saturated at 35°F, enters a heating coil at a rate of 20,000 CFM and air leaves the coil at 100°F
  - What process is this?
  - Find the required rate of heat addition

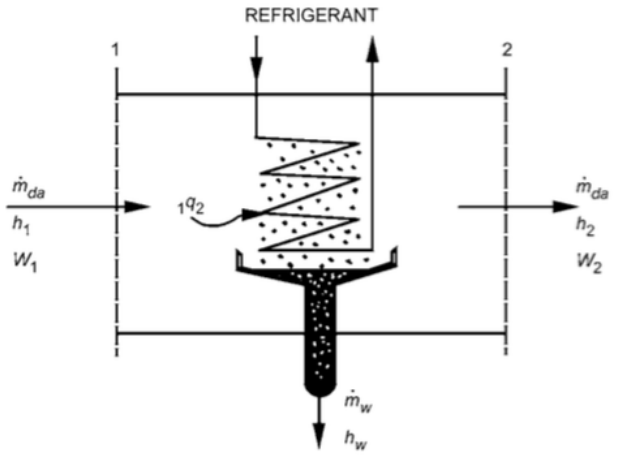


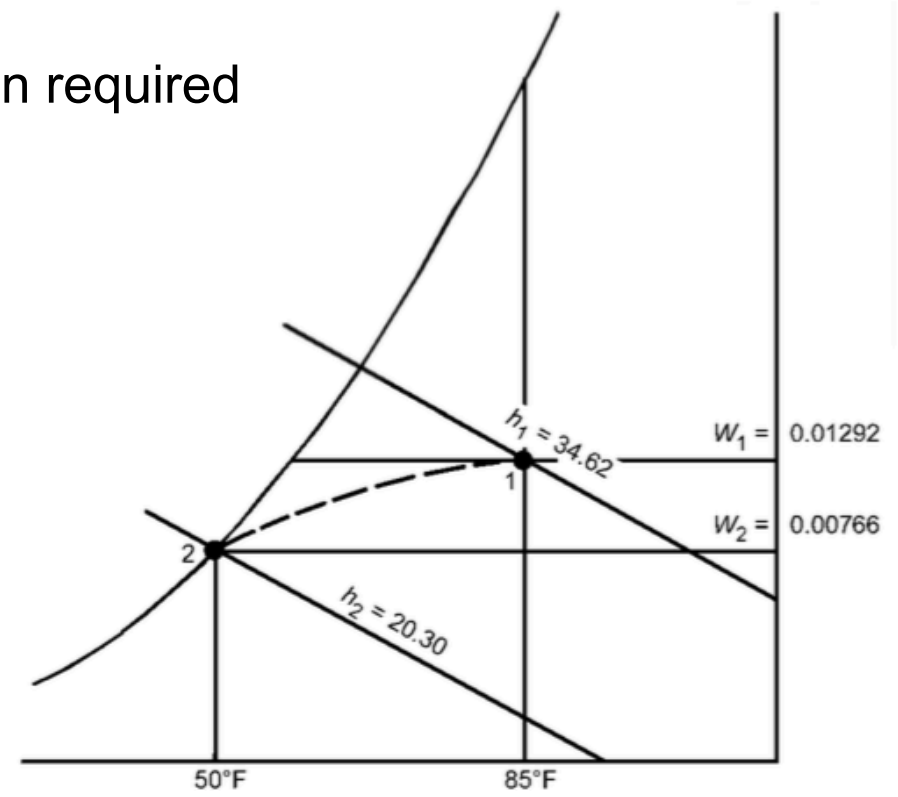


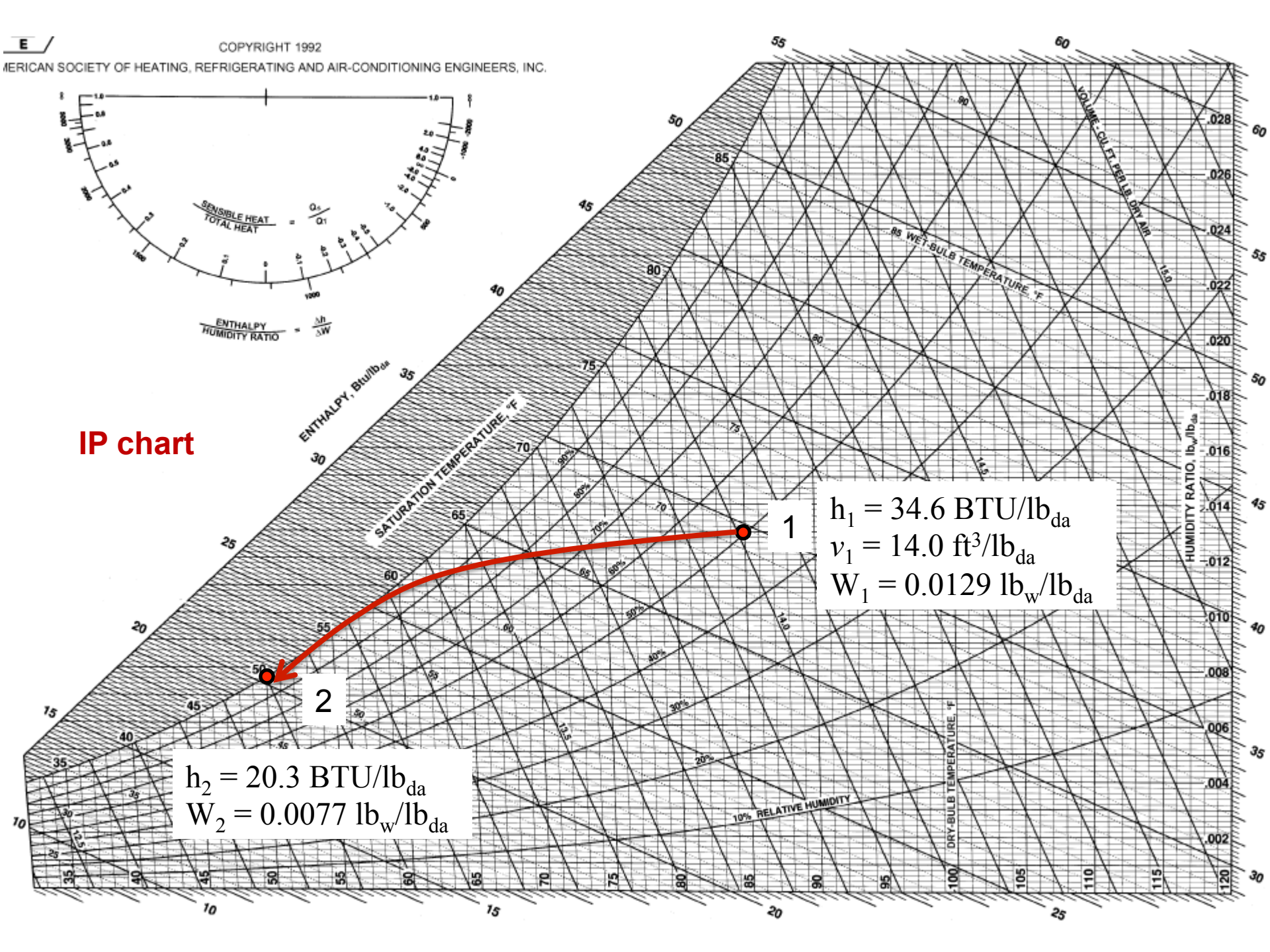

E
COPYRIGHT 1992
MERICAN SOCIETY OF HEATING, REFRIGERATING AND AIR-CONDITIONING ENGINEERS, INC.
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
IP chart
ENTHALPY, Btu/lbda
SATURATION TEMPERATURE, °F
HUMIDITY RATIO, lbw/lbda
VOLUME, CU FT PER LB DRY AIR
WET-BULB TEMPERATURE, °F
DRY-BULB TEMPERATURE, °F
10% RELATIVE HUMIDITY
h2 = 28.8 BTU/lbda
2
1
h1 = 13 BTU/lbda
v1 = 12.55 ft3/lbda

IP unit examples

- Moist air at 85°F dry-bulb temperature and 50% RH enters a cooling coil at 10,000 CFM and is processed to final saturation conditions at 50°F
  - What processes is this?
  - Find the tons of refrigeration required



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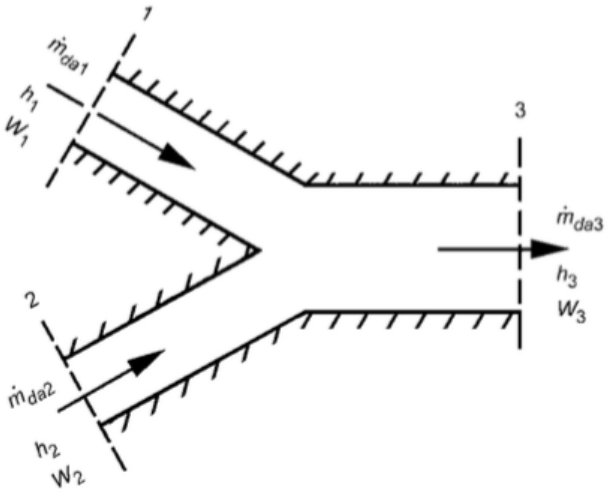
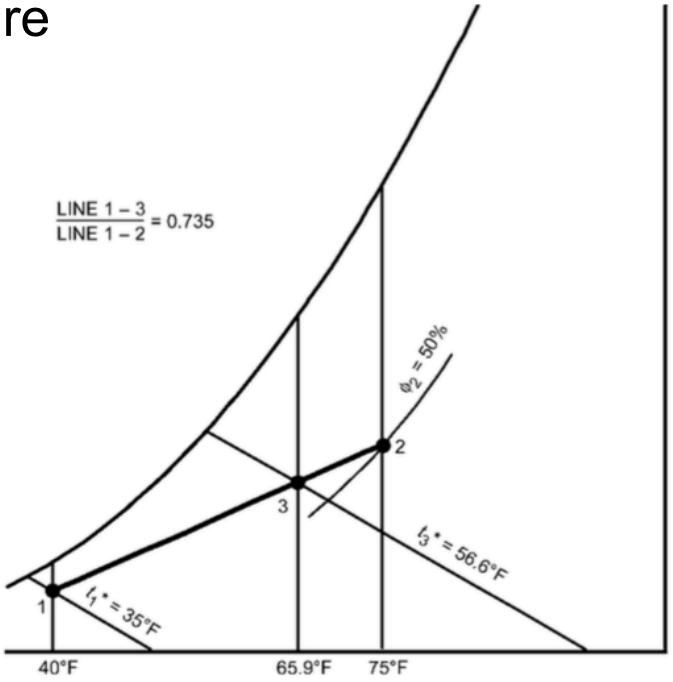
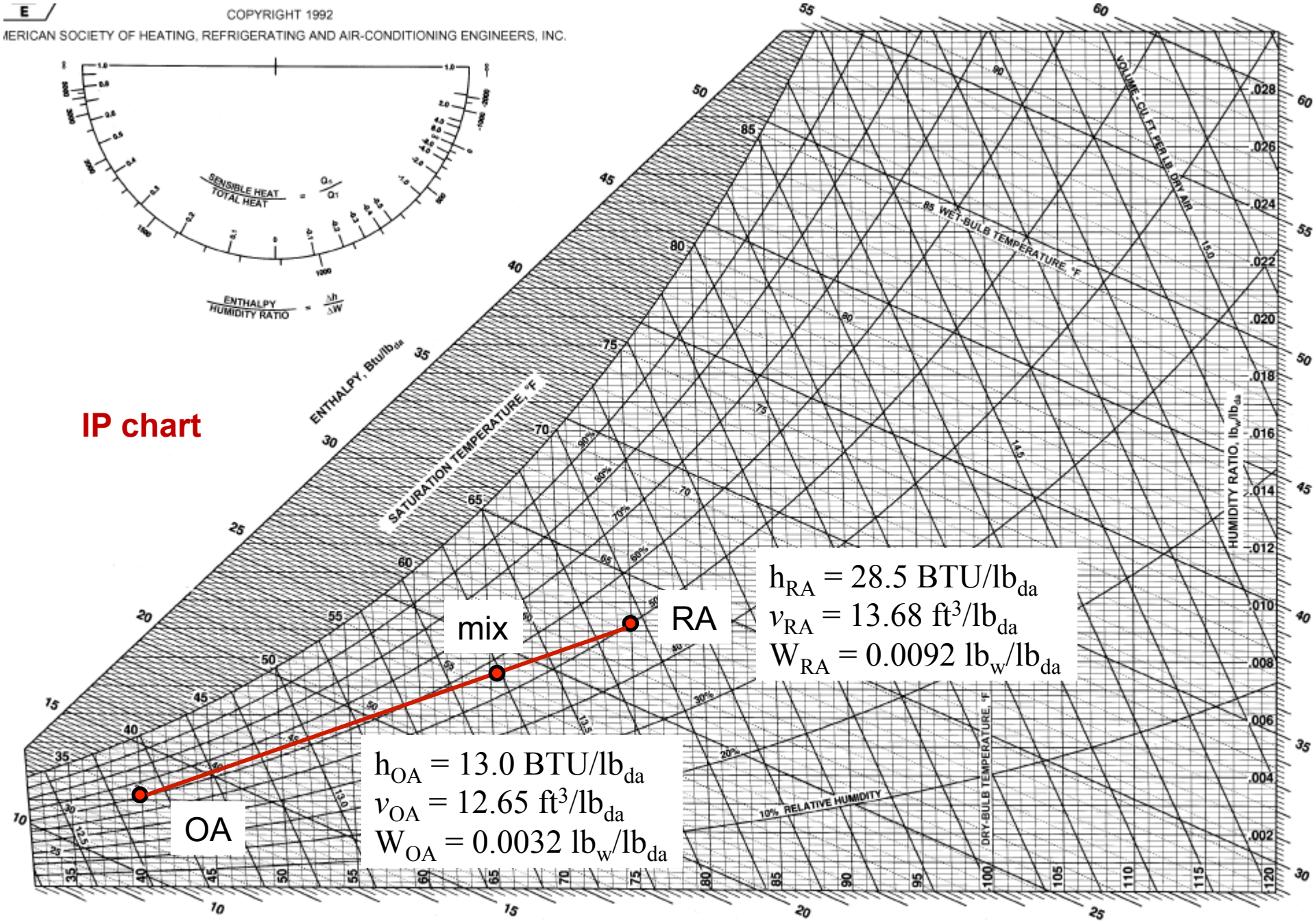
SENSIBLE HEAT / TOTAL HEAT = Qs / Qt
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
IP chart
ENTHALPY, Btu/lbda
SATURATION TEMPERATURE, °F
VOLUME, CU FT PER LB DRY AIR
WET-BULB TEMPERATURE, °F
HUMIDITY RATIO, lbw/lbda
DRY-BULB TEMPERATURE, °F
10% RELATIVE HUMIDITY
1
2
h1 = 34.6 BTU/lbda
v1 = 14.0 ft3/lbda
W1 = 0.0129 lbw/lbda
h2 = 20.3 BTU/lbda
W2 = 0.0077 lbw/lbda

IP unit examples

- A stream of 5000 CFM of outdoor air at 40°F dry bulb temperature and 35°F thermodynamic wet bulb temperature is adiabatically mixed with 15,000 CFM of recirculated air at 75°F dry bulb temperature and 50% RH
  - What processes is this?
  - Find the dry bulb temperature and thermodynamic wet bulb temperature of the resulting mixture



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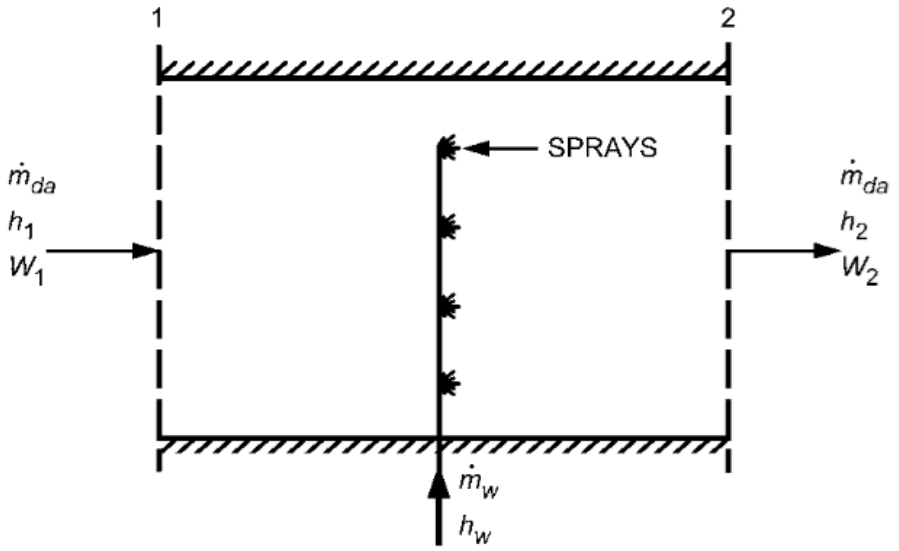
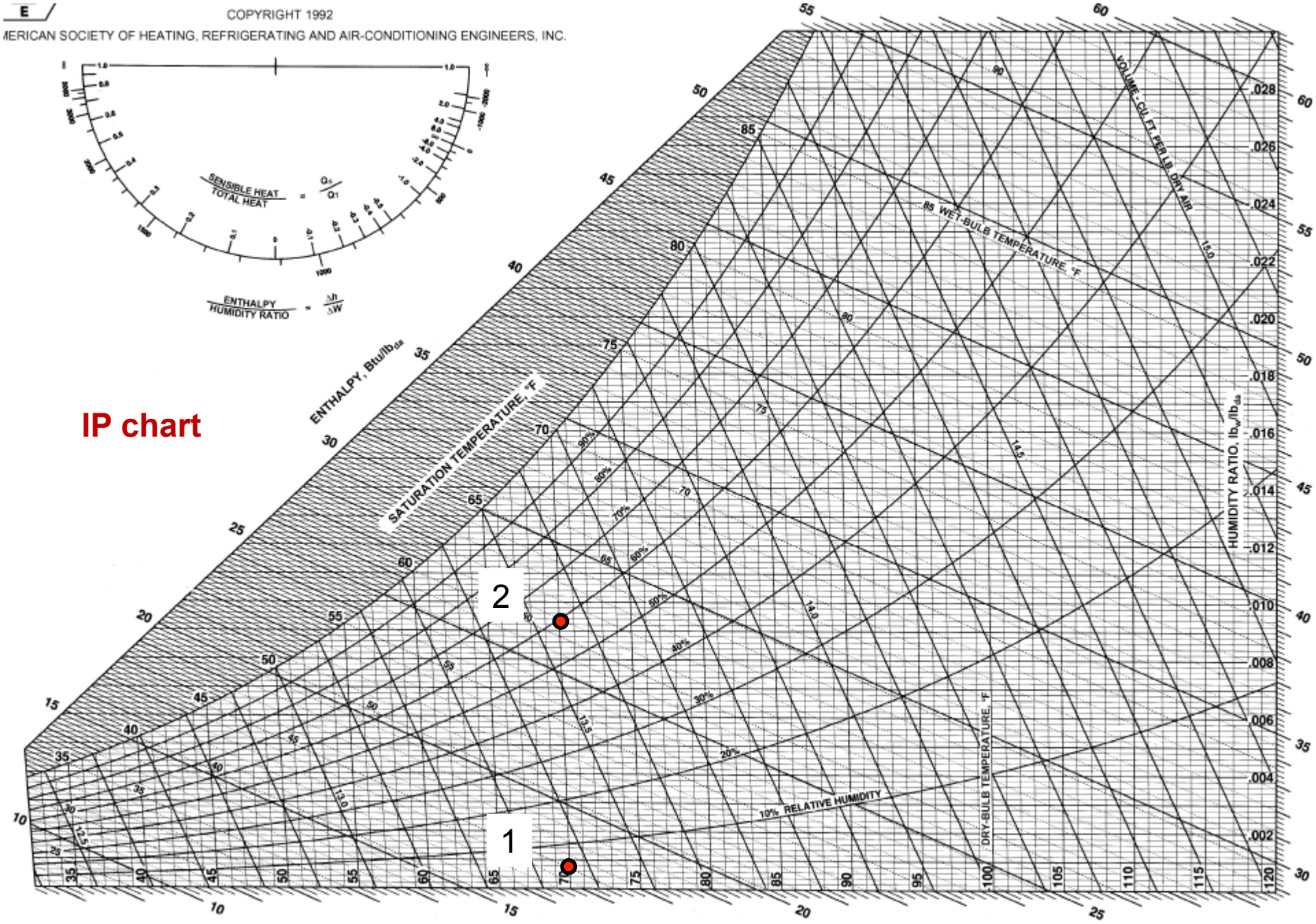
SENSIBLE HEAT / TOTAL HEAT = Qs/Qt
ENTHALPY / HUMIDITY RATIO = Δh/ΔW
IP chart
ENTHALPY, Btu/lbda
SATURATION TEMPERATURE, °F
VOLUME, CU FT PER LB DRY AIR
WET-BULB TEMPERATURE, °F
HUMIDITY RATIO, lbw/lbda
DRY-BULB TEMPERATURE, °F
10% RELATIVE HUMIDITY
mix
RA
OA
hRA = 28.5 BTU/lbda
vRA = 13.68 ft3/lbda
WRA = 0.0092 lbw/lbda
hOA = 13.0 BTU/lbda
vOA = 12.65 ft3/lbda
WOA = 0.0032 lbw/lbda

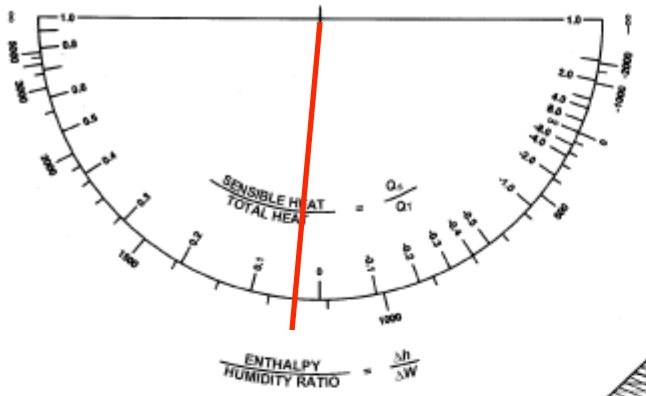
IP unit examples

- Moist air at 70°F dry bulb temperature and 45°F wet bulb temperature is to be processed to a final dew point of 55°F by adiabatic injection of saturated steam at 230°F
- The air flow rate is 10,000 CFM
  - Find the rate of steam flow required

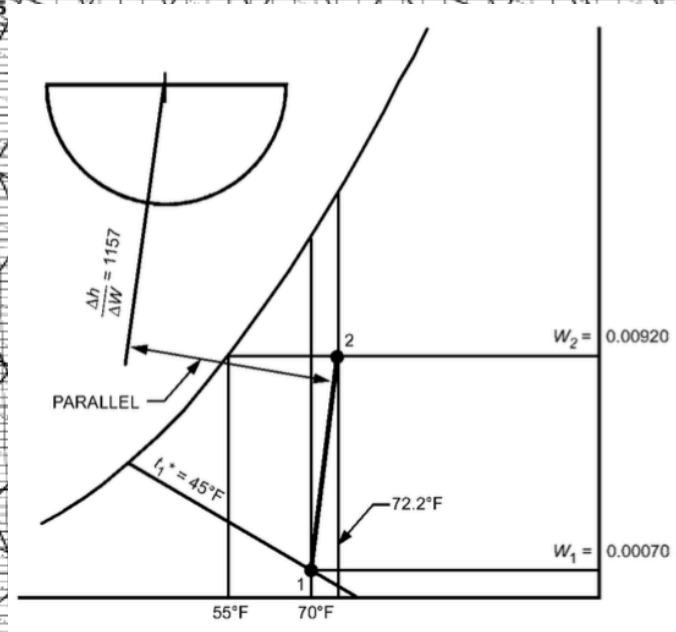




IP chart



$$\frac{\Delta h}{\Delta W} = 1157 \frac{\text{BTU}}{\text{lb}_w}$$



2

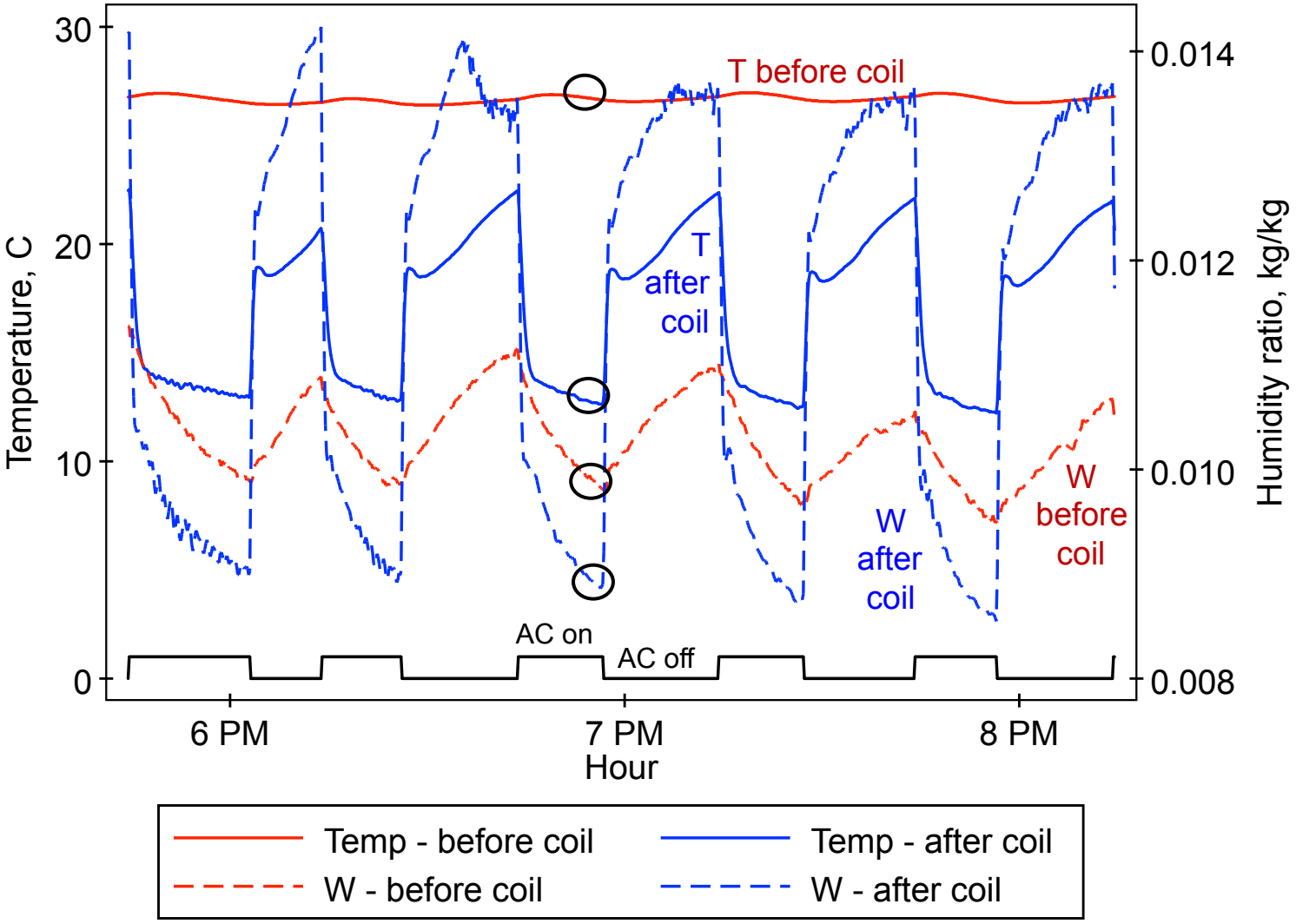
2'
$T_{2'} = 72.2°F$

1

ENTHALPY, Btu/lb$_{da}$
SATURATION TEMPERATURE, °F
DRY-BULB TEMPERATURE, °F
HUMIDITY RATIO, lb$_w$/lb$_{da}$
10% RELATIVE HUMIDITY
VOLUME, CU. FT. PER LB. DRY AIR

Real data: ASHRAE RP-1299
Energy implications of filters

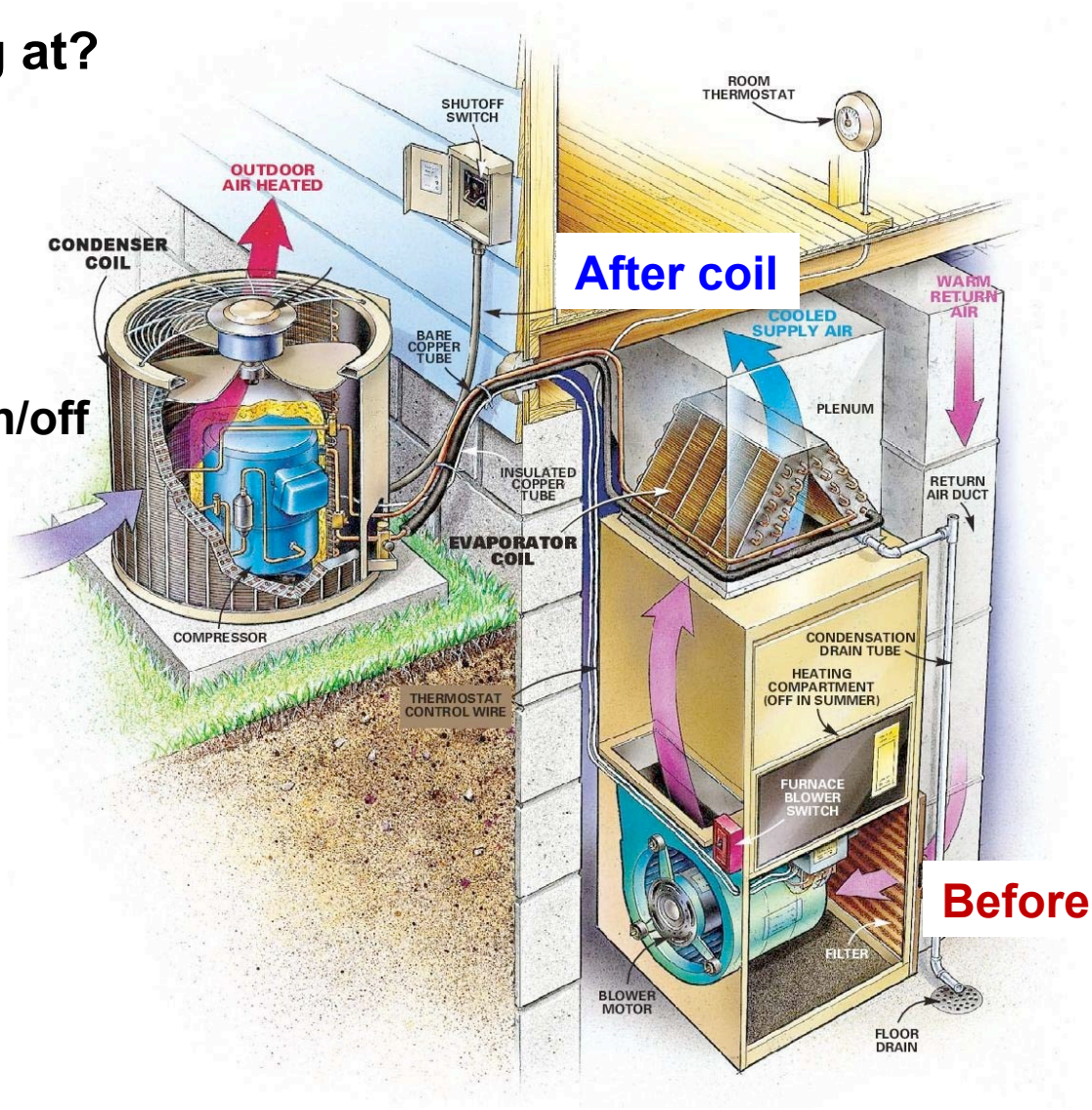
Temperature and humidity ratio differences across AC coils in homes

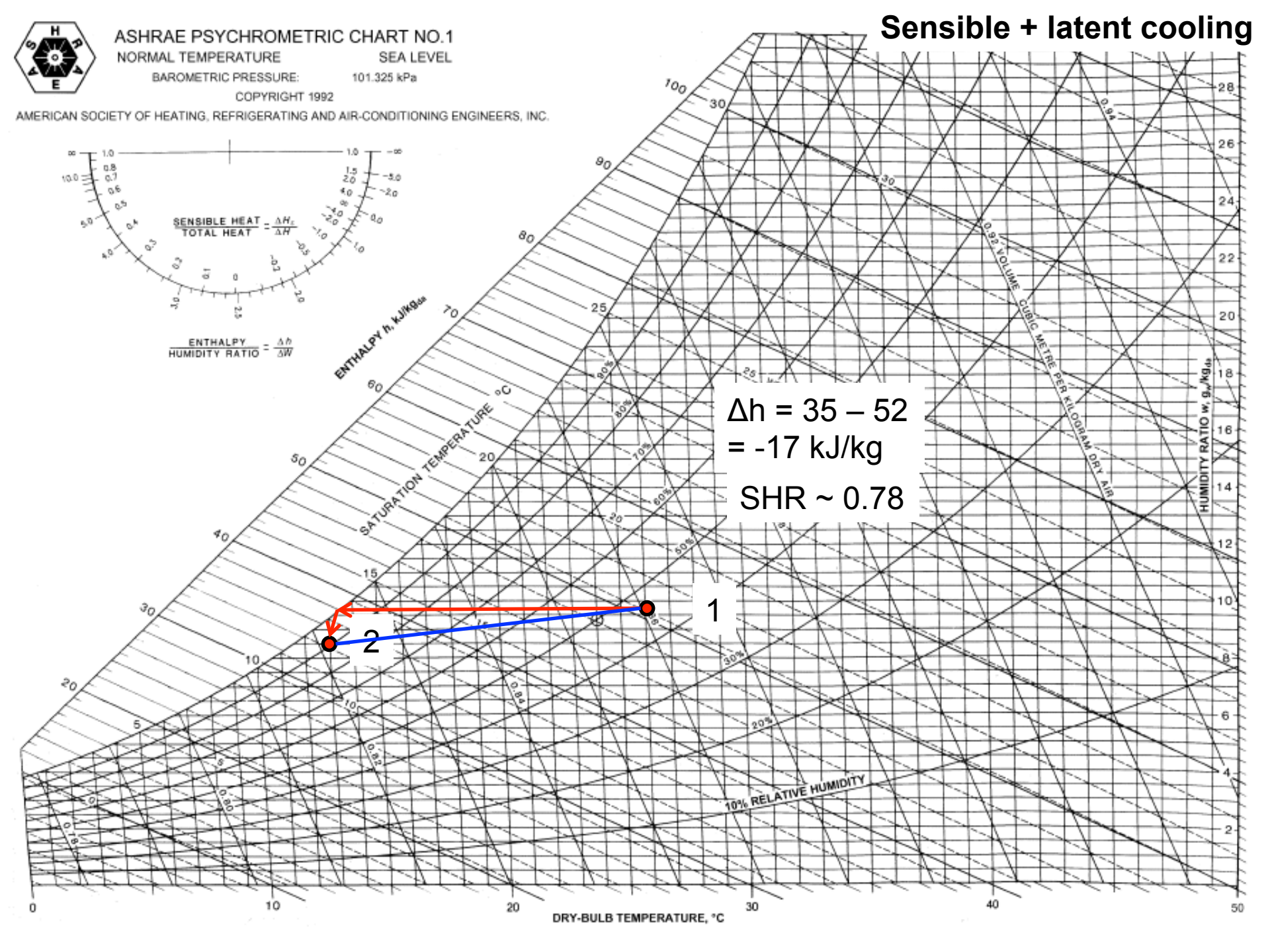


Real data: ASHRAE RP-1299
Energy implications of filters

What are we looking at?

AC on/off




Sensible + latent cooling
ASHRAE PSYCHROMETRIC CHART NO.1
NORMAL TEMPERATURE
SEA LEVEL
BAROMETRIC PRESSURE: 101.325 kPa
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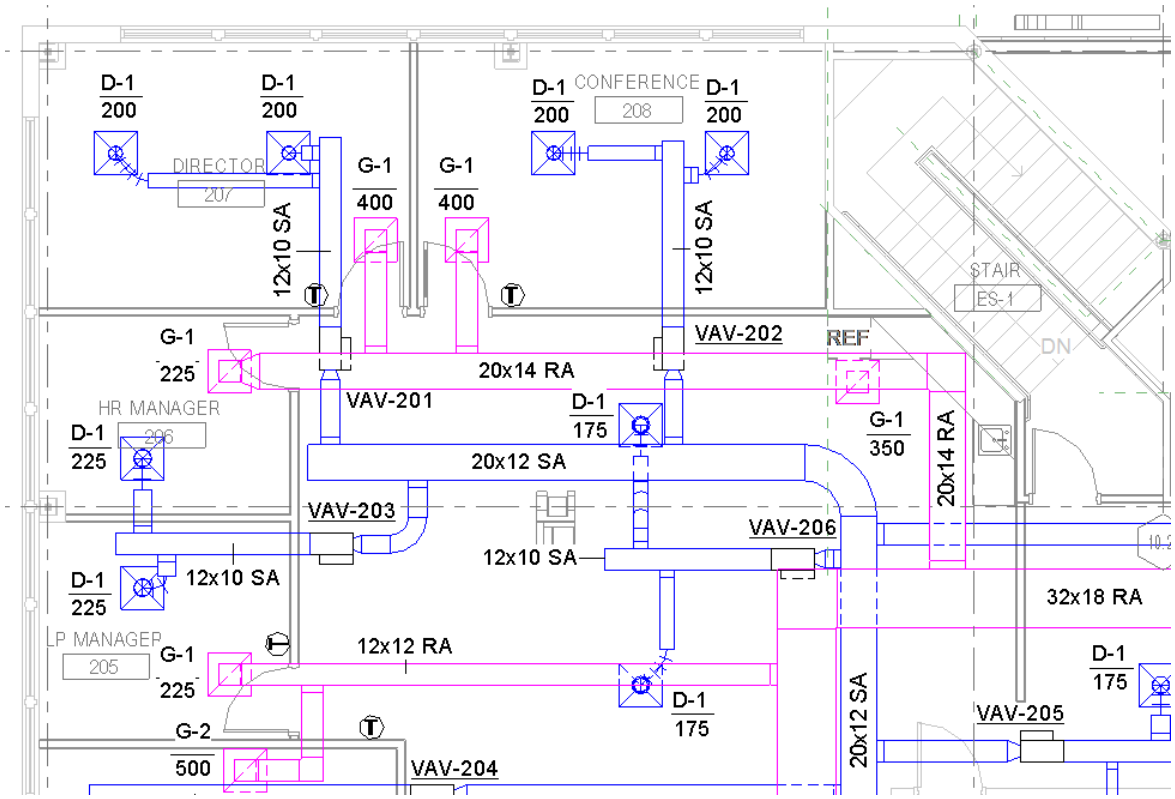
SENSIBLE HEAT / TOTAL HEAT = ΔH_s / ΔH
ENTHALPY / HUMIDITY RATIO = Δh / ΔW
ENTHALPY h, kJ/kg_da
SATURATION TEMPERATURE °C
HUMIDITY RATIO w, g_w/kg_da
0.92 VOLUME CUBIC METRE PER KILOGRAM DRY AIR
10% RELATIVE HUMIDITY
DRY-BULB TEMPERATURE, °C
Δh = 35 – 52
= -17 kJ/kg
SHR ~ 0.78
1
2



OVERVIEW OF HVAC SYSTEMS

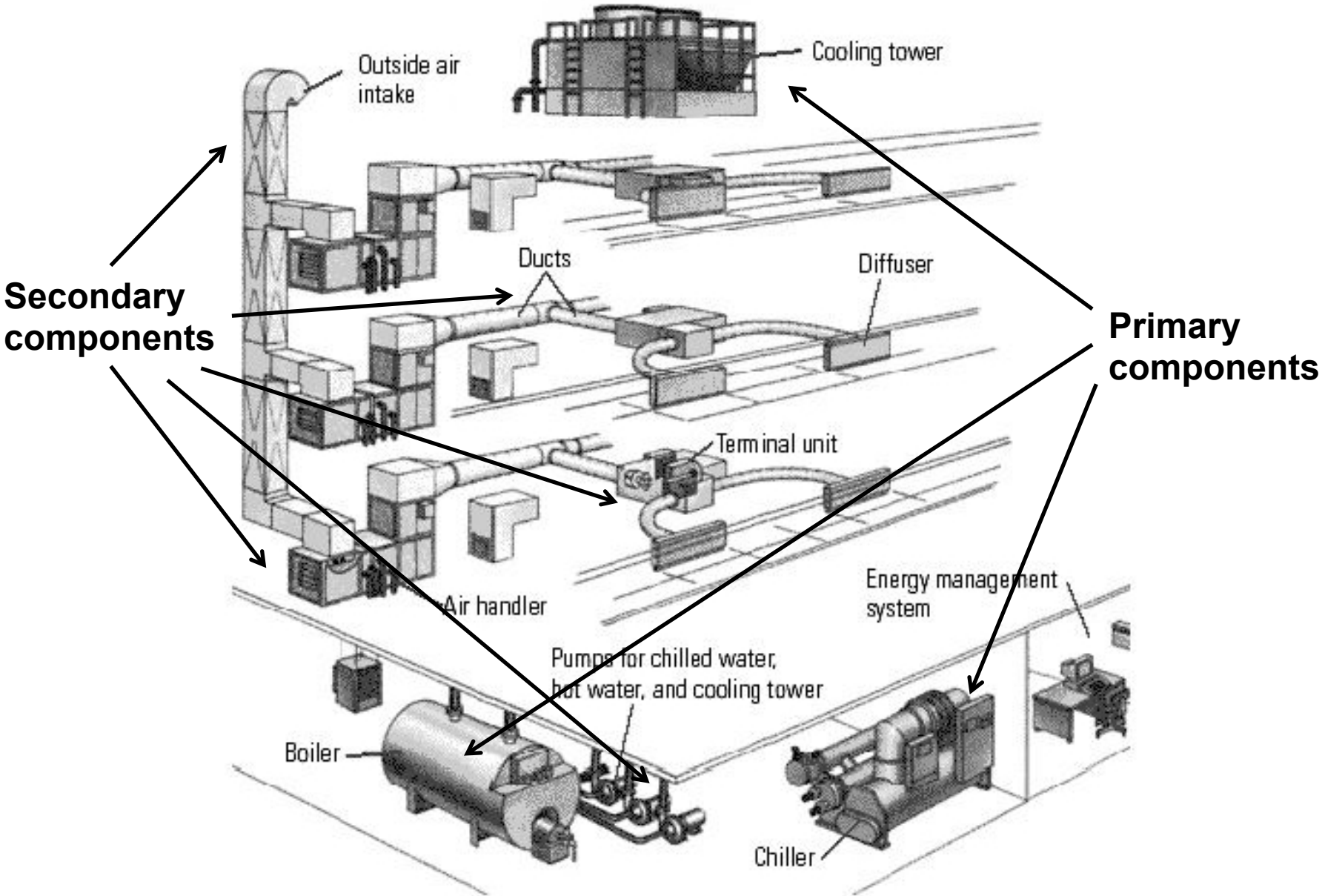
What do they look like and what are common processes?

HVAC systems overview

- Primary mechanical systems
  - Vapor compression systems (i.e., chillers and condenser units)
    - Electrically driven
    - Thermally driven
  - Cooling towers
  - Evaporative coolers

- Secondary mechanical systems
  - Distribution systems (both air and water)

Typical components of an HVAC system



HVAC system design options

- We can rely on **central** HVAC systems
  - One system per building
  - May control all zones similarly or different zones differently
    - Depends on system type
- Or we can rely on **distributed** HVAC systems for every zone
  - Motels, strip malls, apartment buildings
- Need to figure out what medium we will use for heat transfer
  - Air, steam, water?
- Need to determine what capacity and efficiency we need
  - More on this in future lectures

Central vs. distributed systems

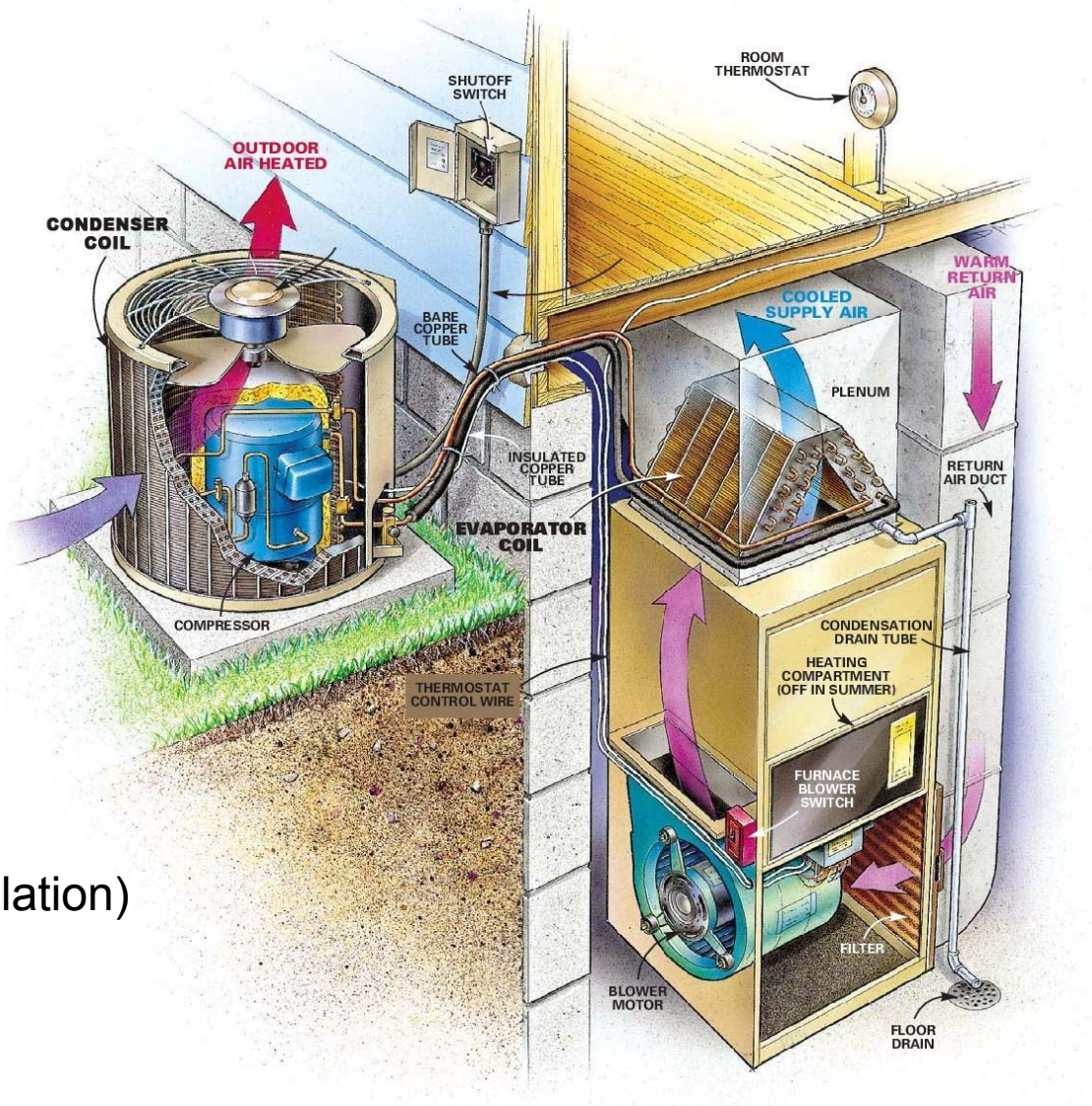
Central systems

- Large equipment has higher quality, efficiency, and durability
- Maintenance is concentrated in one place
- Noise is removed from zone
- Diversity of loads allows lower installed capacity
- Can use thermal storage solutions

Distributed systems

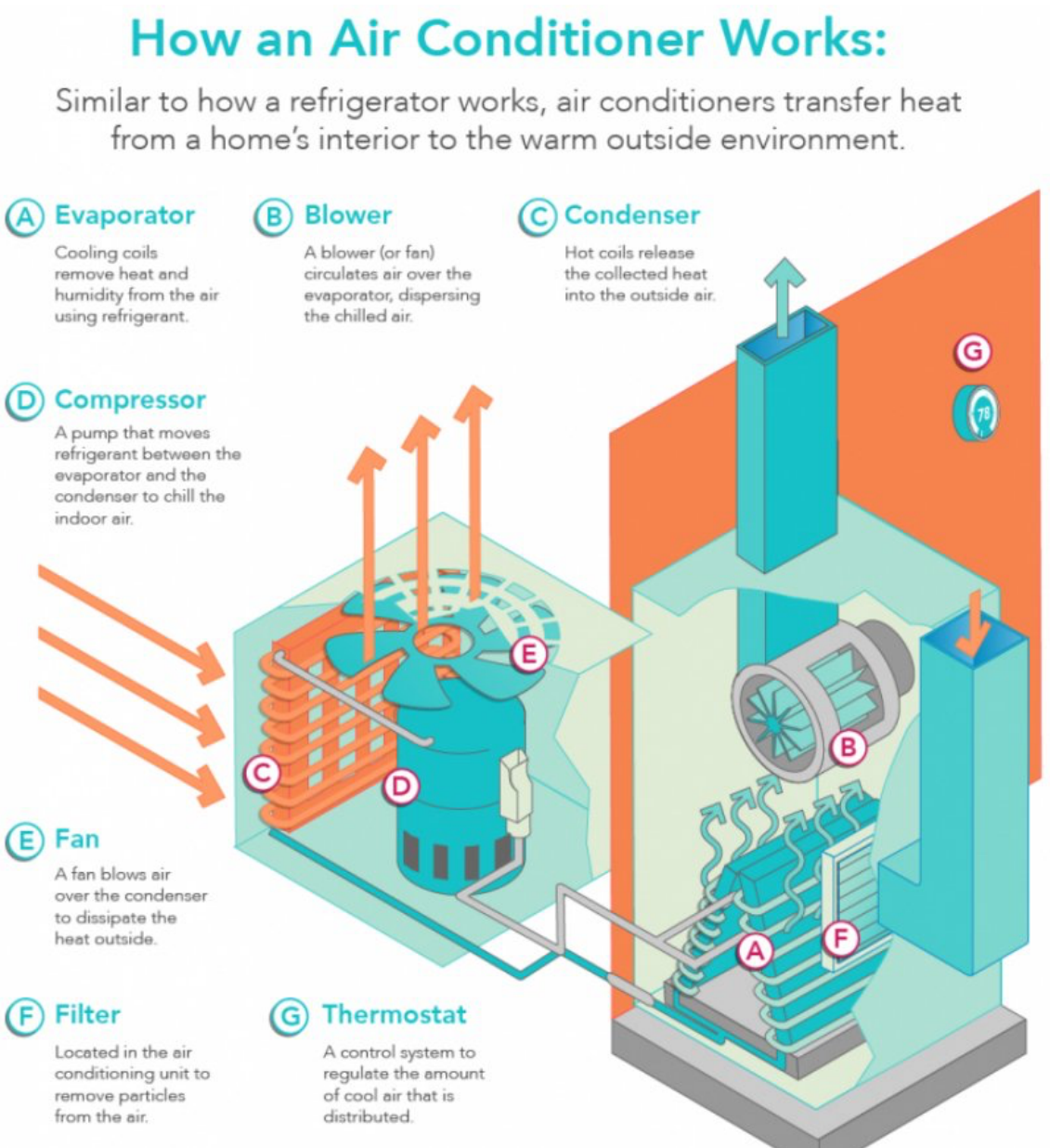
- Easy to provide zoning
- Direct control by occupants
- Easier independent scheduling for energy savings
- Generally lower capital costs and shorter lead time for equipment
- Don’t need dedicated maintenance staff
- Can often install on roof (saves room in the building)

Typical central residential system

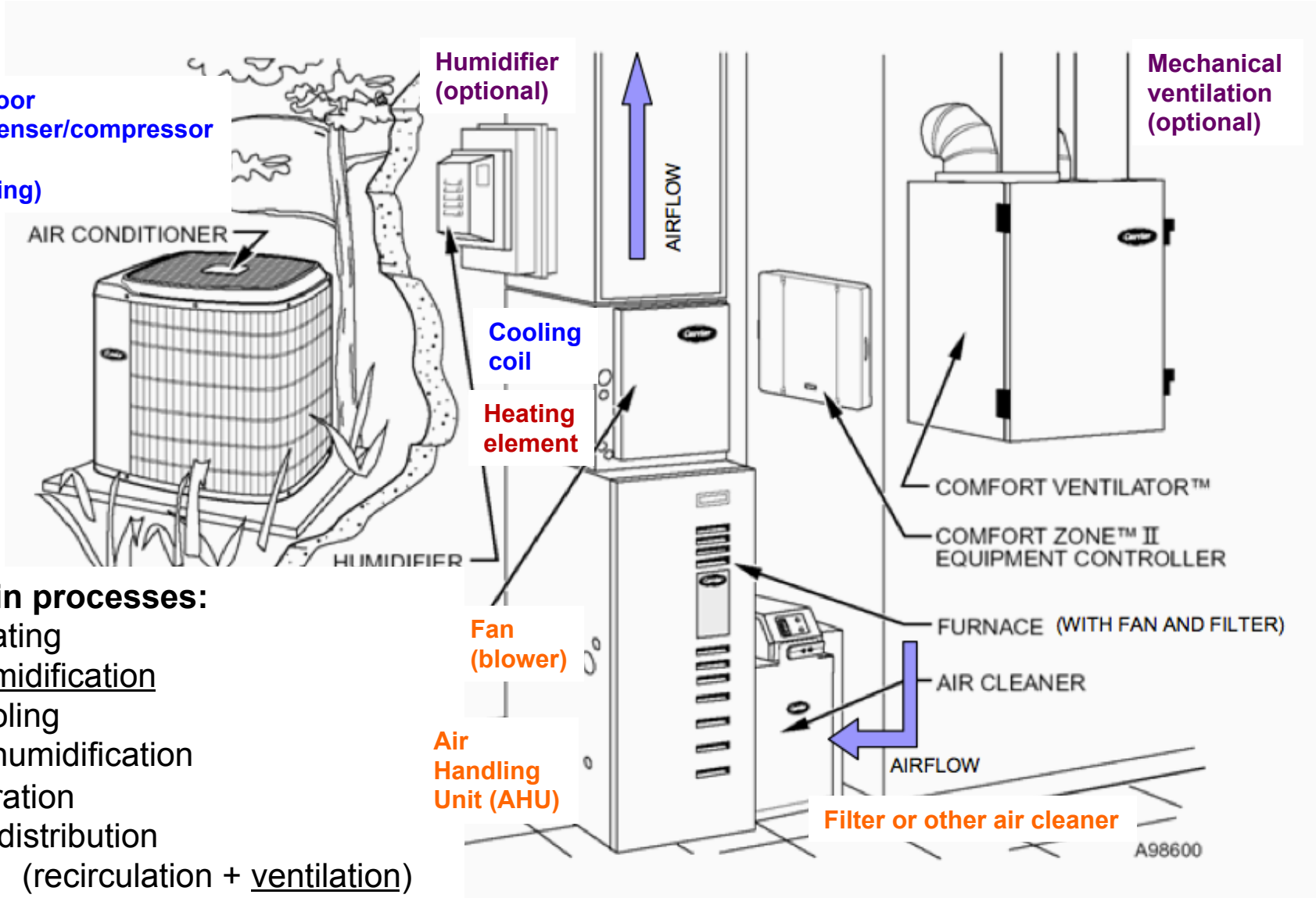


Main processes:
Heating
Cooling
Dehumidification
Filtration
Air distribution (recirculation)
On/off control

Typical central residential system



Typical central residential system w/ upgrades



Main processes:

Heating

Humidification

Cooling

Dehumidification

Filtration

Air distribution

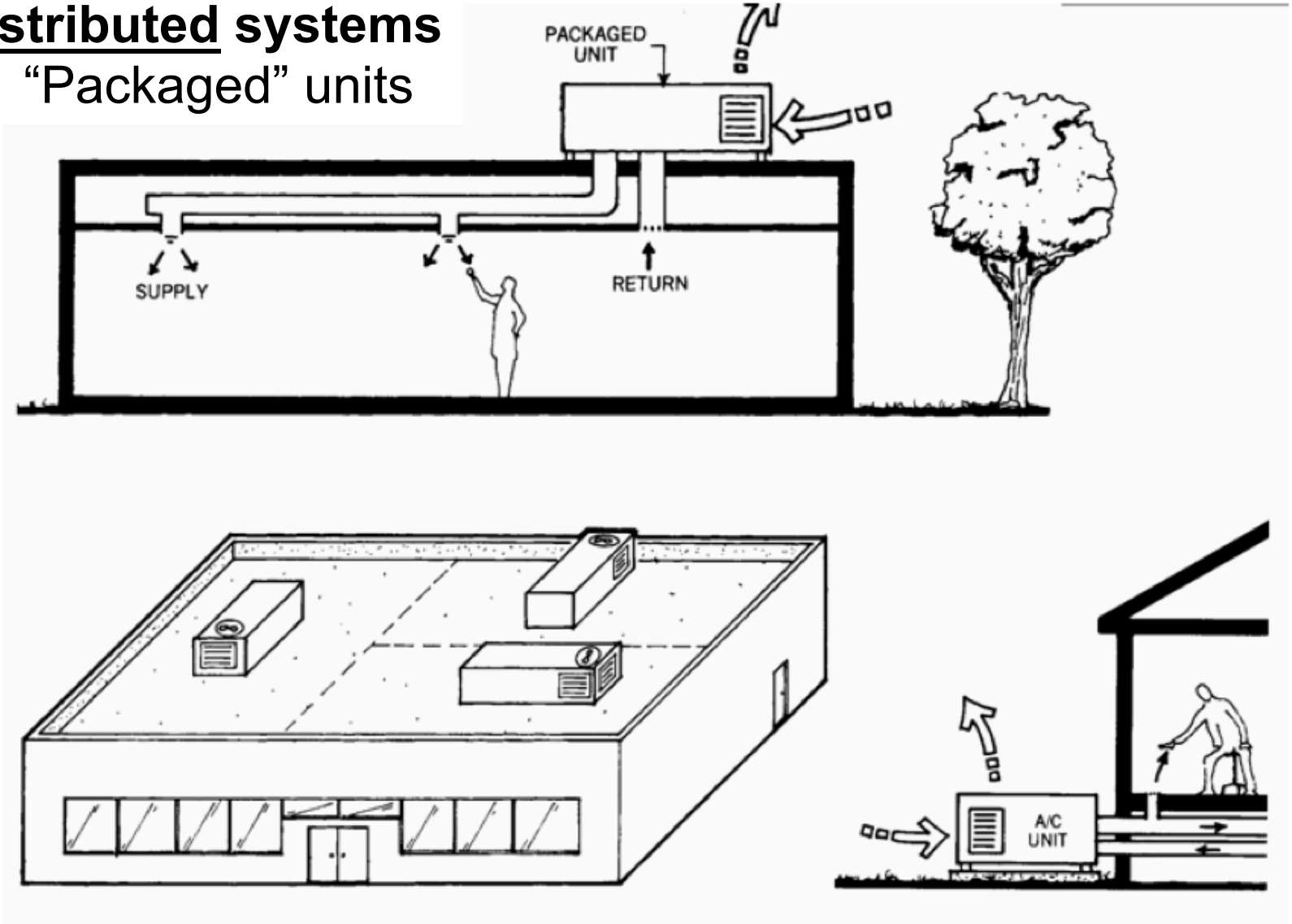
(recirculation + ventilation)

On/off control (or variable control)

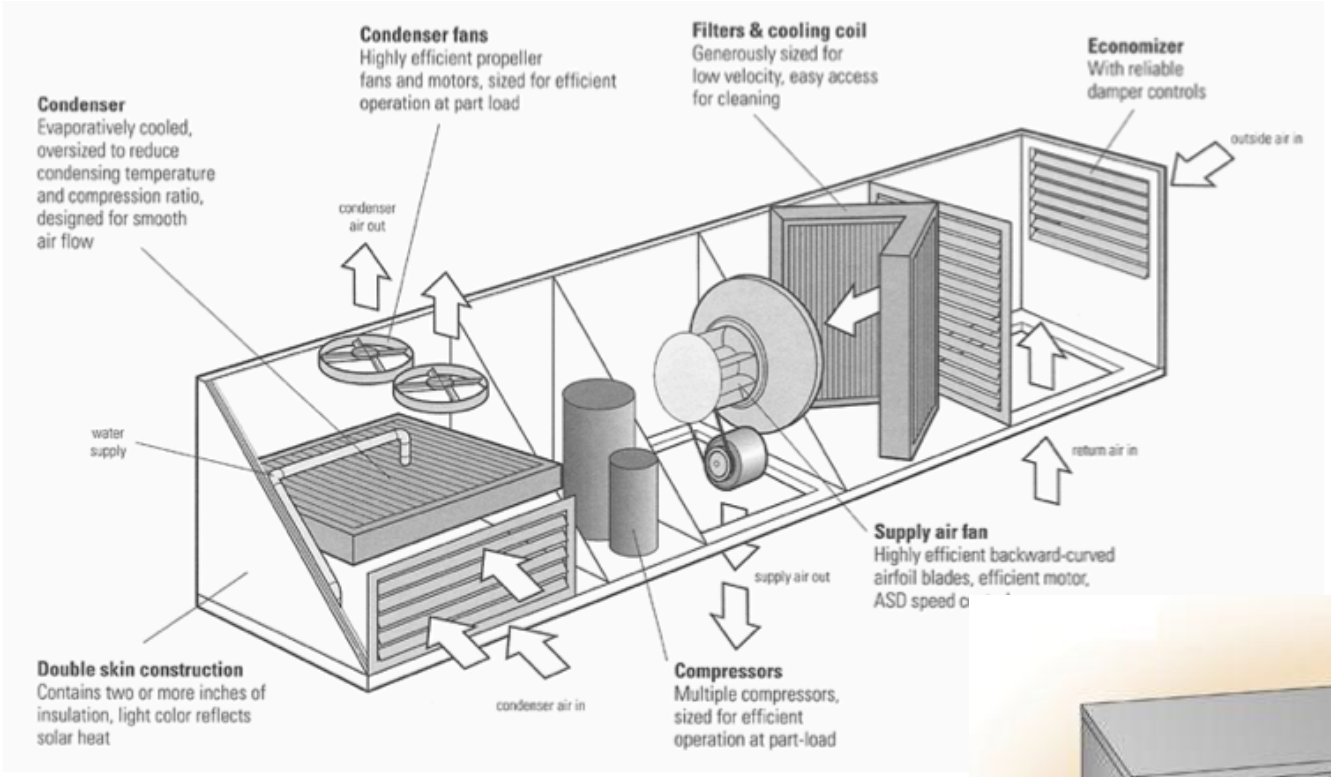
Typical large distributed commercial systems

Distributed systems

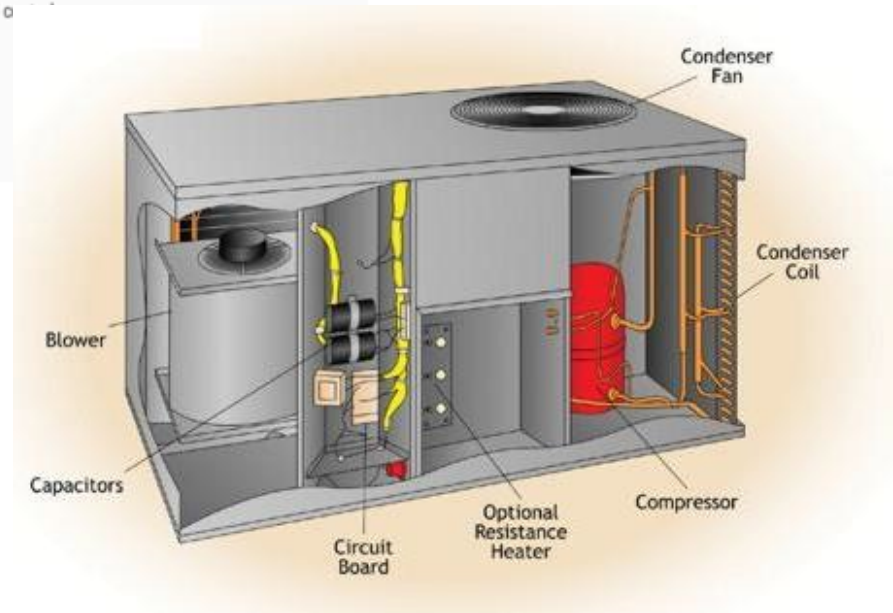
"Packaged" units



Typical large distributed commercial systems



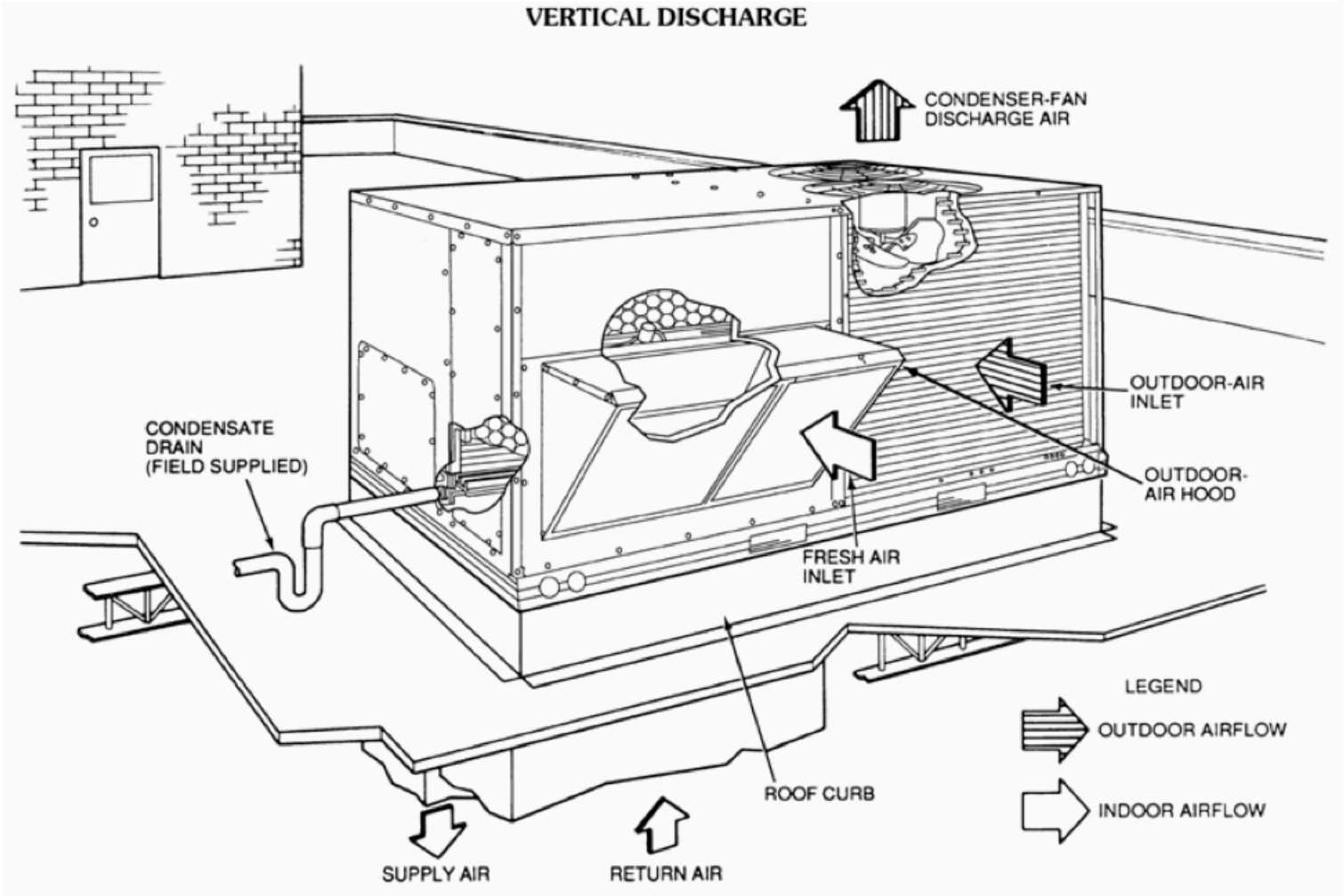
Packaged systems



Typical large distributed commercial systems

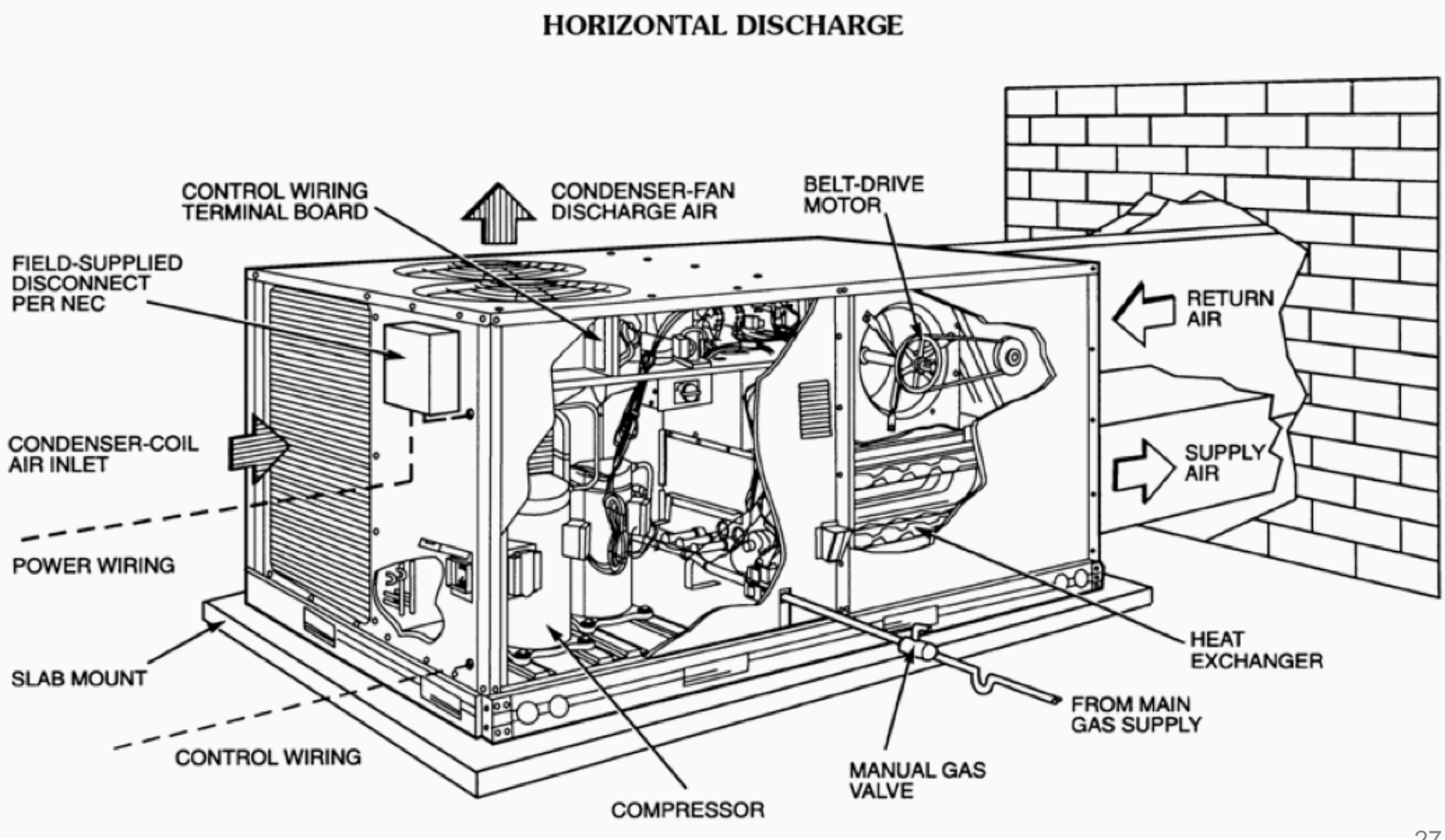
Typical large distributed commercial systems

Packaged roof-top units (RTUs)



Typical large distributed commercial systems

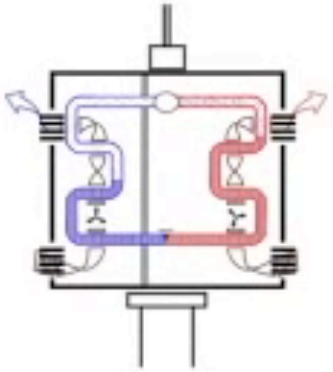
Packaged slab installations



Heating and cooling of larger buildings

Air Conditioning for Big Buildings

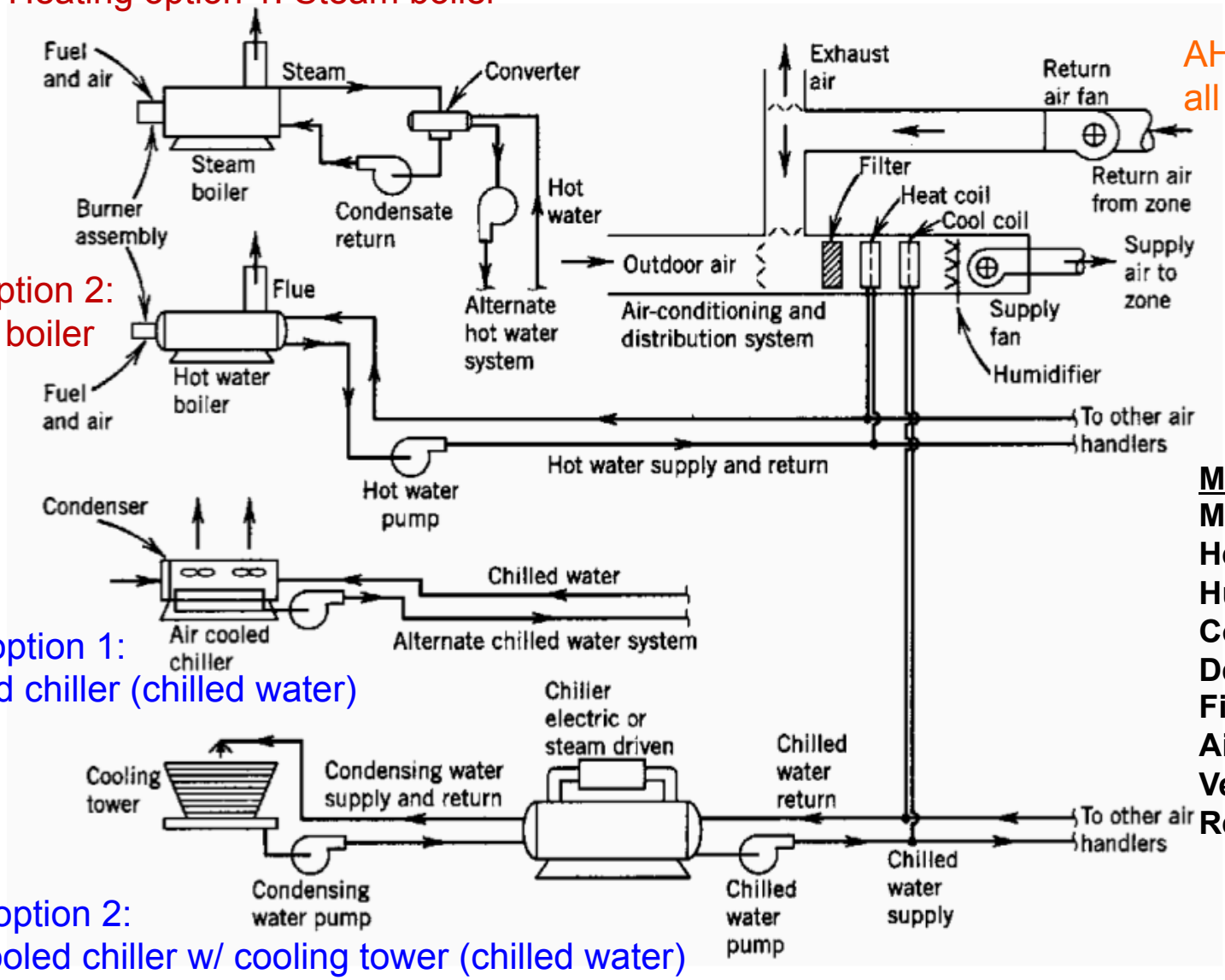
by: Michael Ermann and Clark Coots



https://www.youtube.com/watch?v=j1nYipLAv0U

Typical large central commercial systems

Heating option 1: Steam boiler



AHU serves all rooms

Heating option 2: Hot water boiler

Cooling option 1: Air cooled chiller (chilled water)

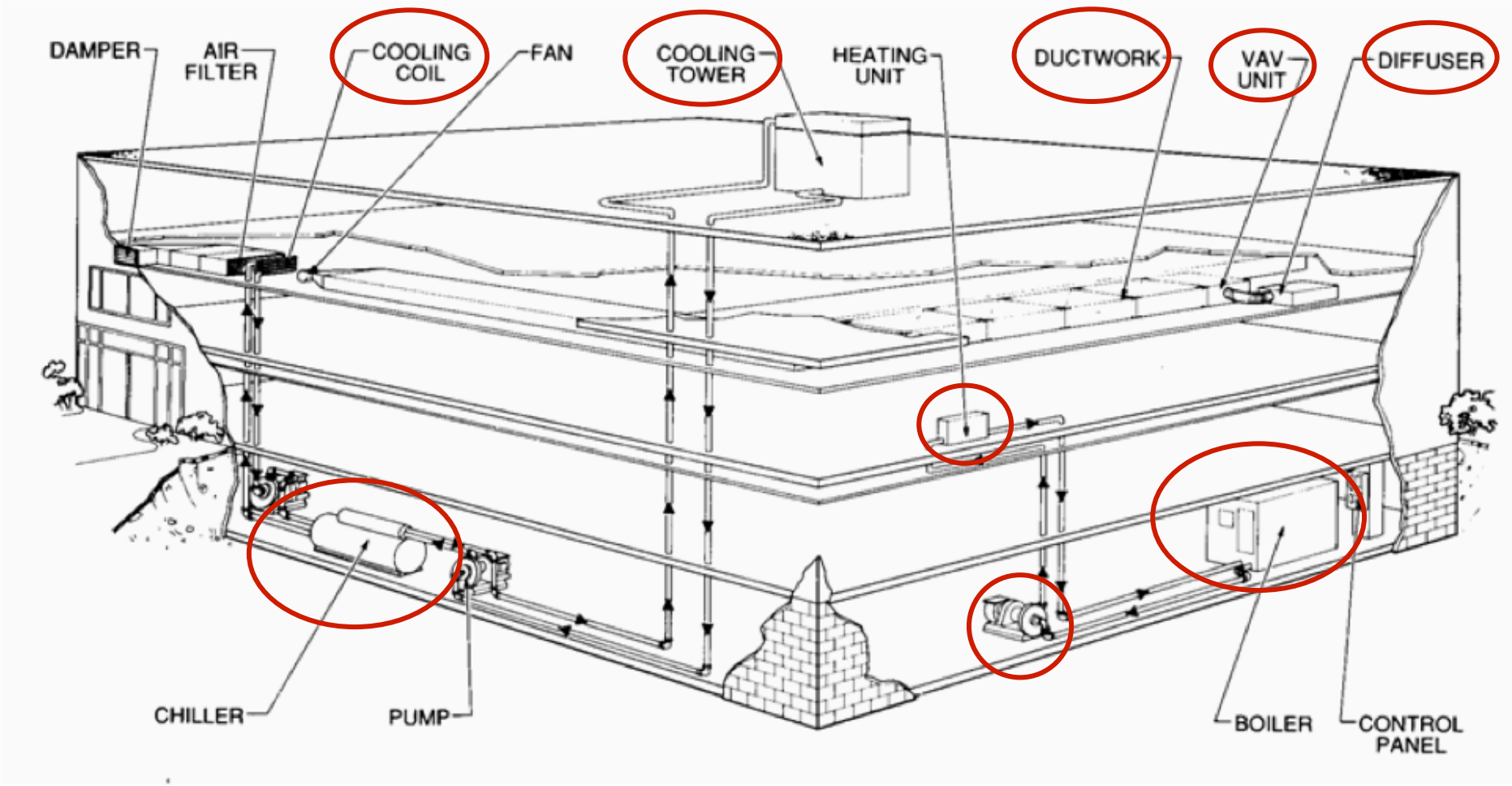
Cooling option 2: Water cooled chiller w/ cooling tower (chilled water)

Main processes:

Mixing
Heating
Humidification
Cooling
Dehumidification
Filtration
Air distribution
Ventilation
Recirculation

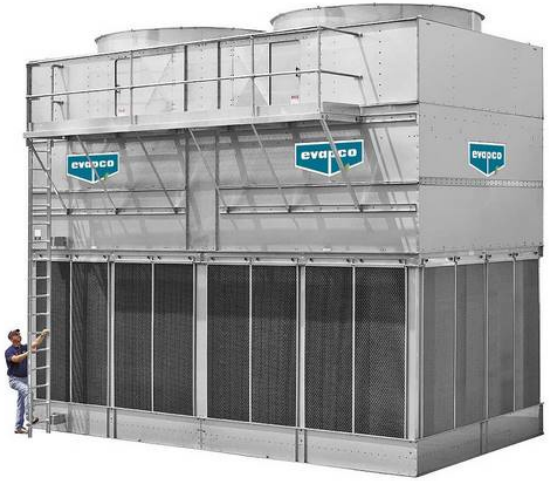
Typical large central commercial systems

Heating and cooling distribution done separately:



Typical large central commercial system components

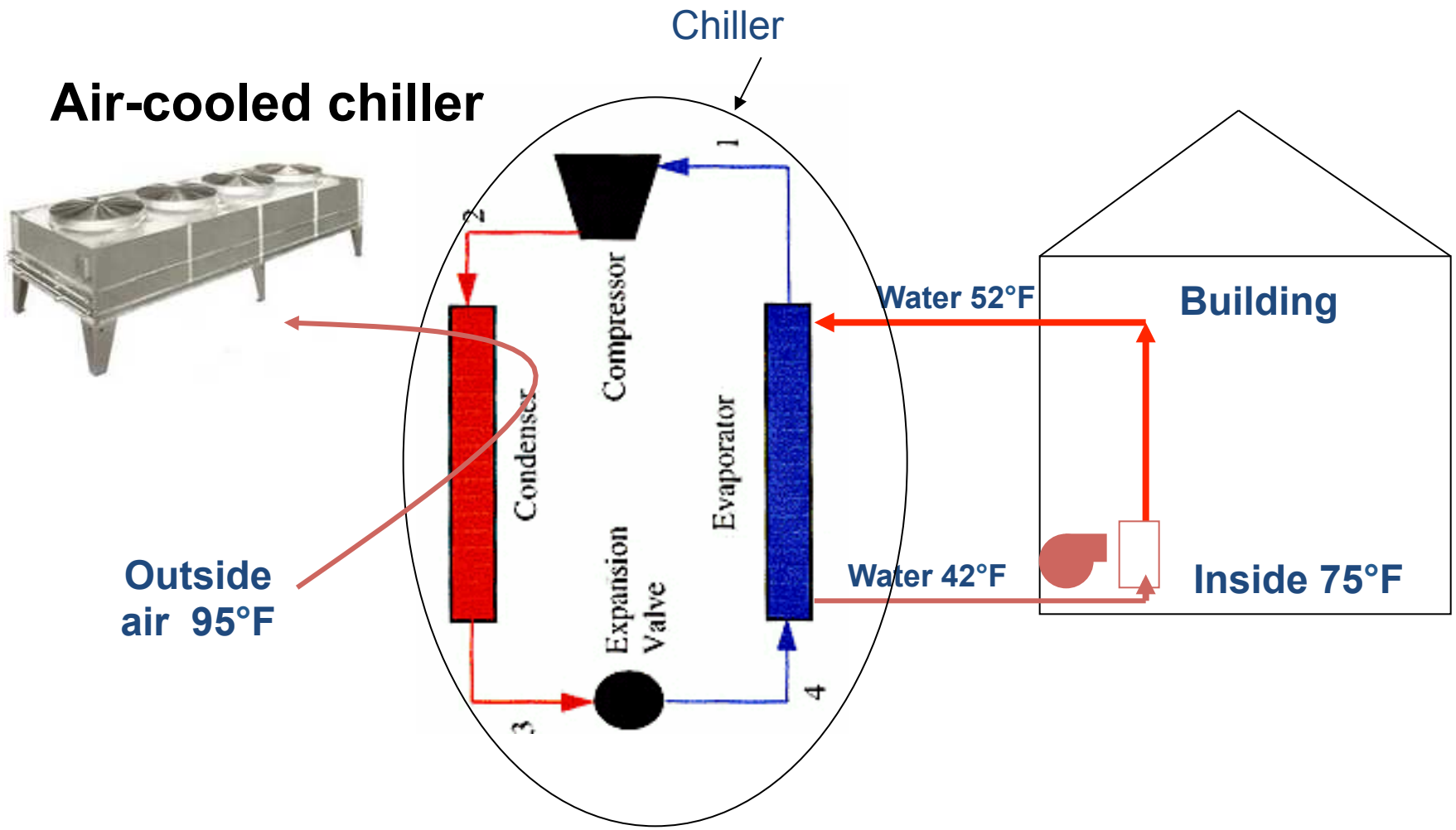
Air cooled chiller
Smaller capacity



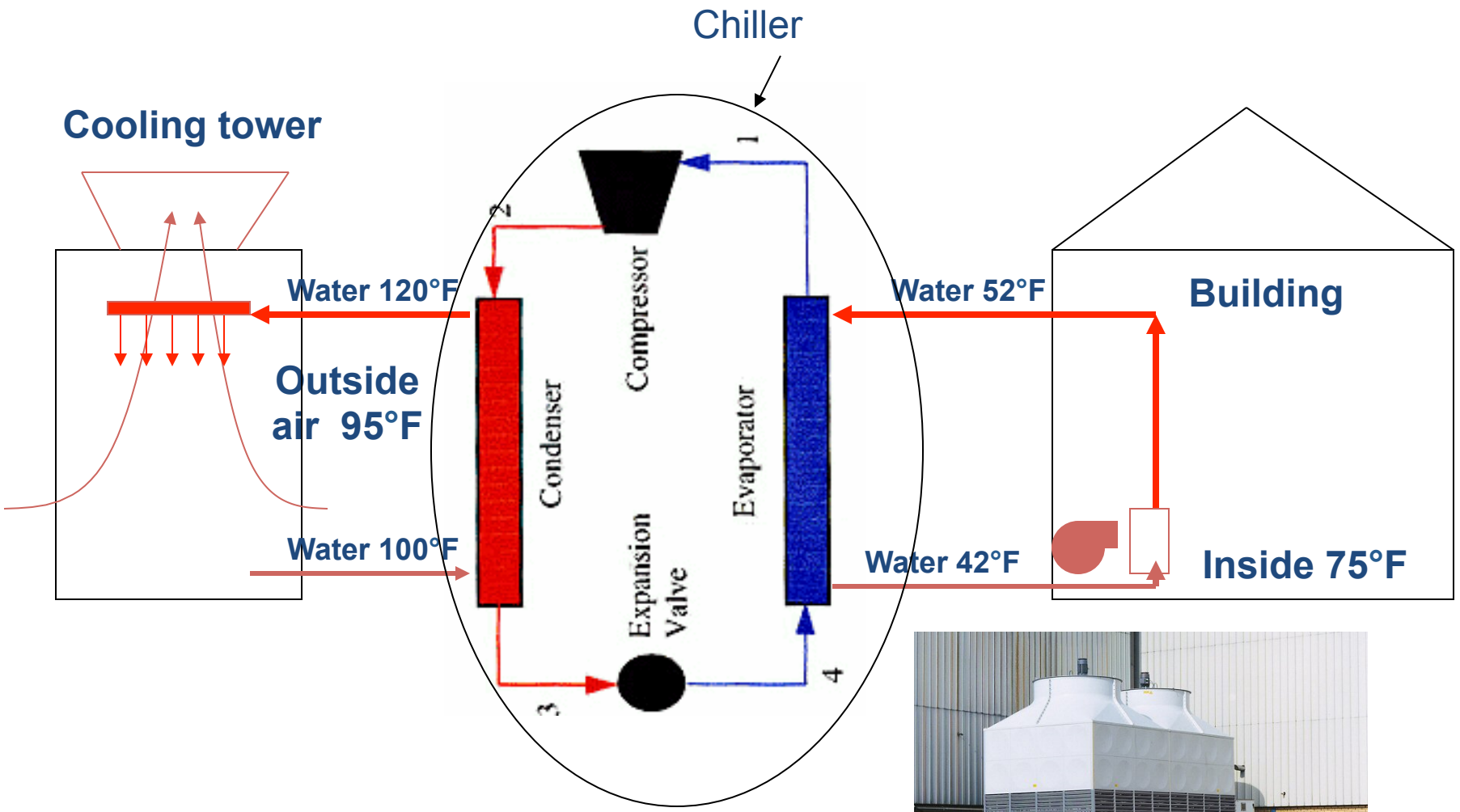
Water-cooled chiller
(w/ cooling tower – larger capacity & more efficient)

Air-cooled chillers

- Chillers use vapor compression or absorption systems to produce chilled water for cooling spaces

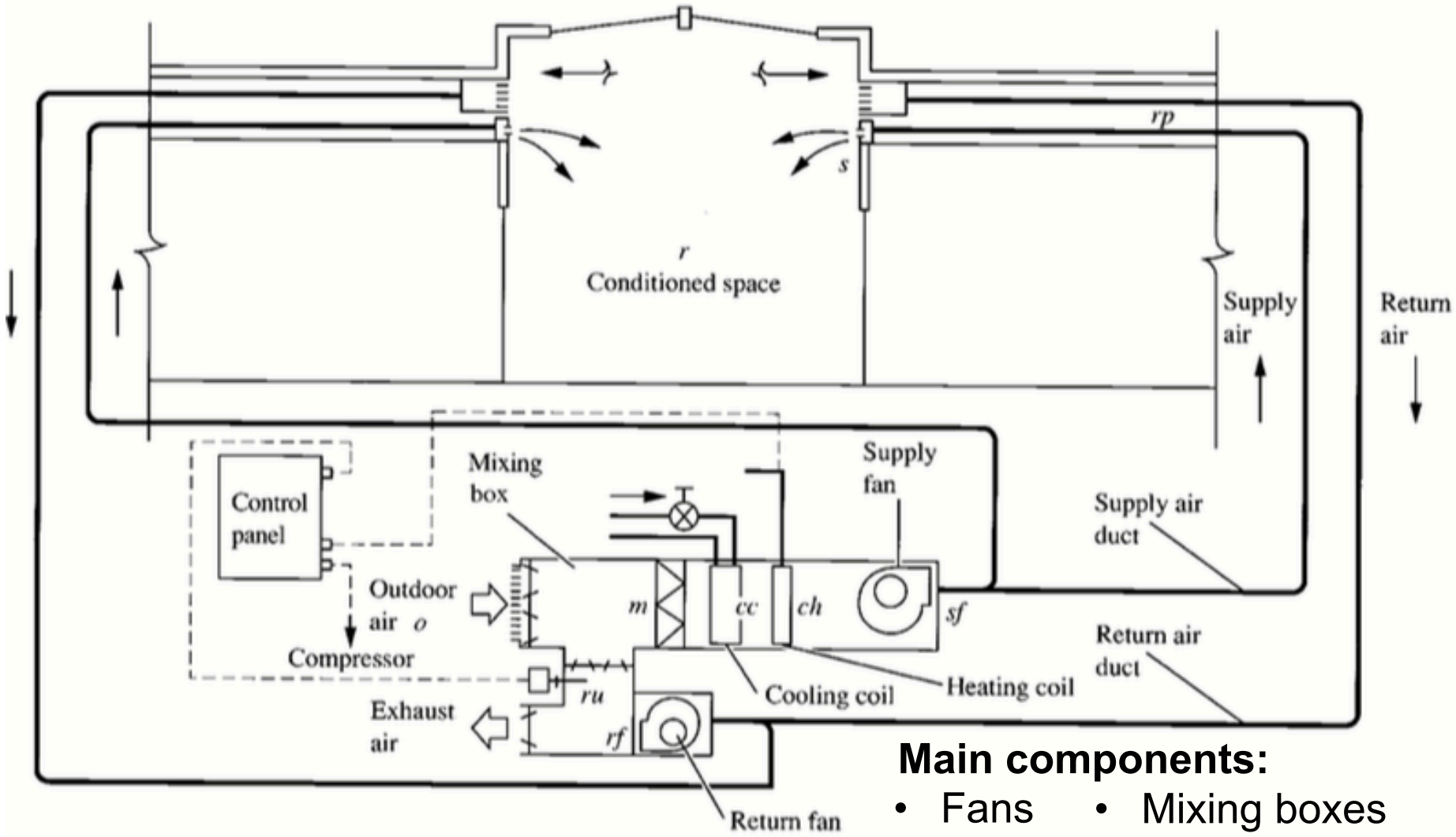


Water-cooled chillers (i.e., “cooling tower”)



AIR DISTRIBUTION SYSTEMS

Typical central commercial air distribution system



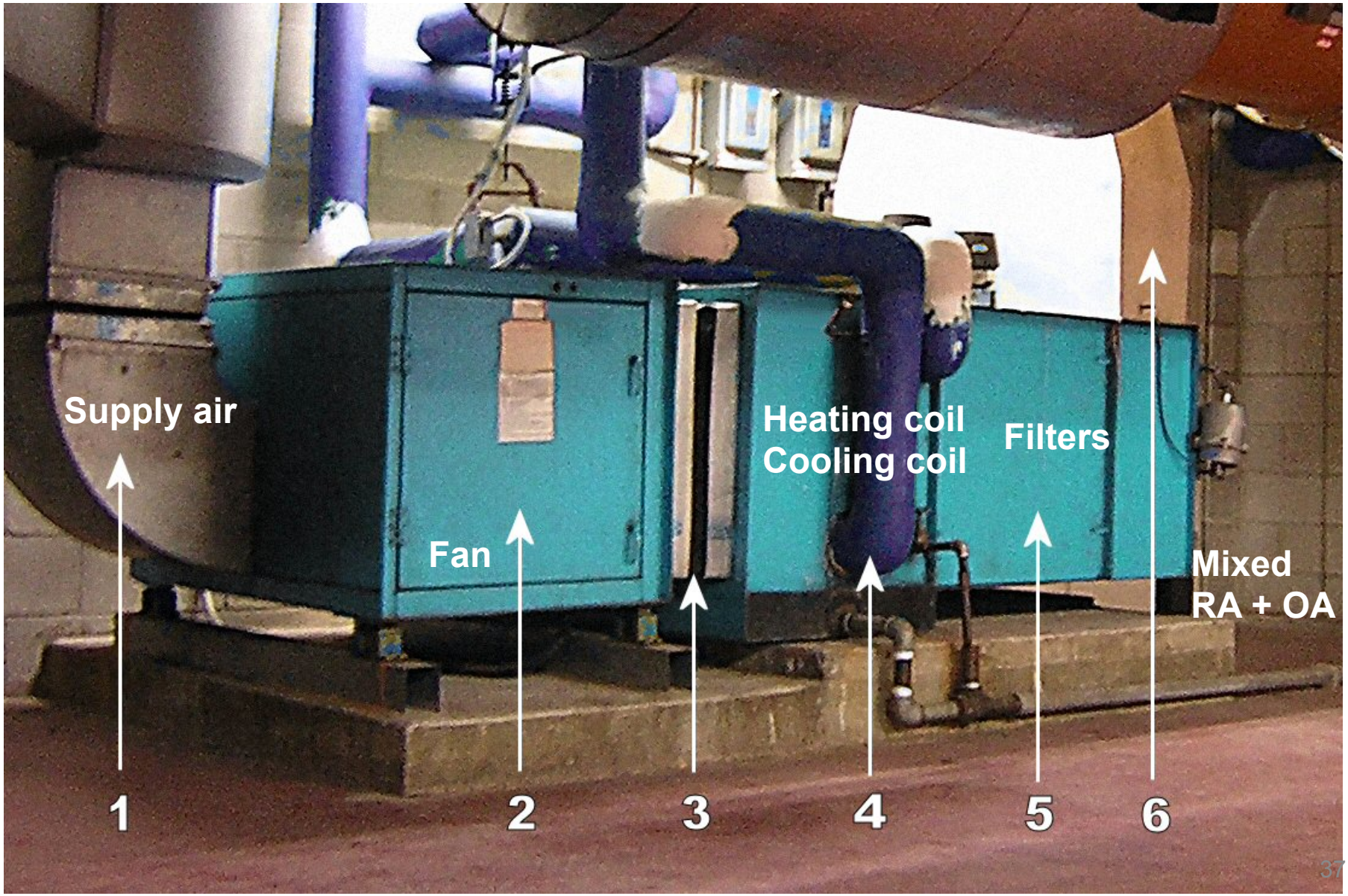
Main components:

- Fans
- Coils
- Filters
- Mixing boxes
- Ducts
- Diffusers

Typical central commercial air handling unit (AHU)

Air Handling Unit (AHU)

Typical central commercial air handling unit (AHU)



Typical large central commercial AHU components

Fan (or “blower”)

Variable frequency drives (VFDs)

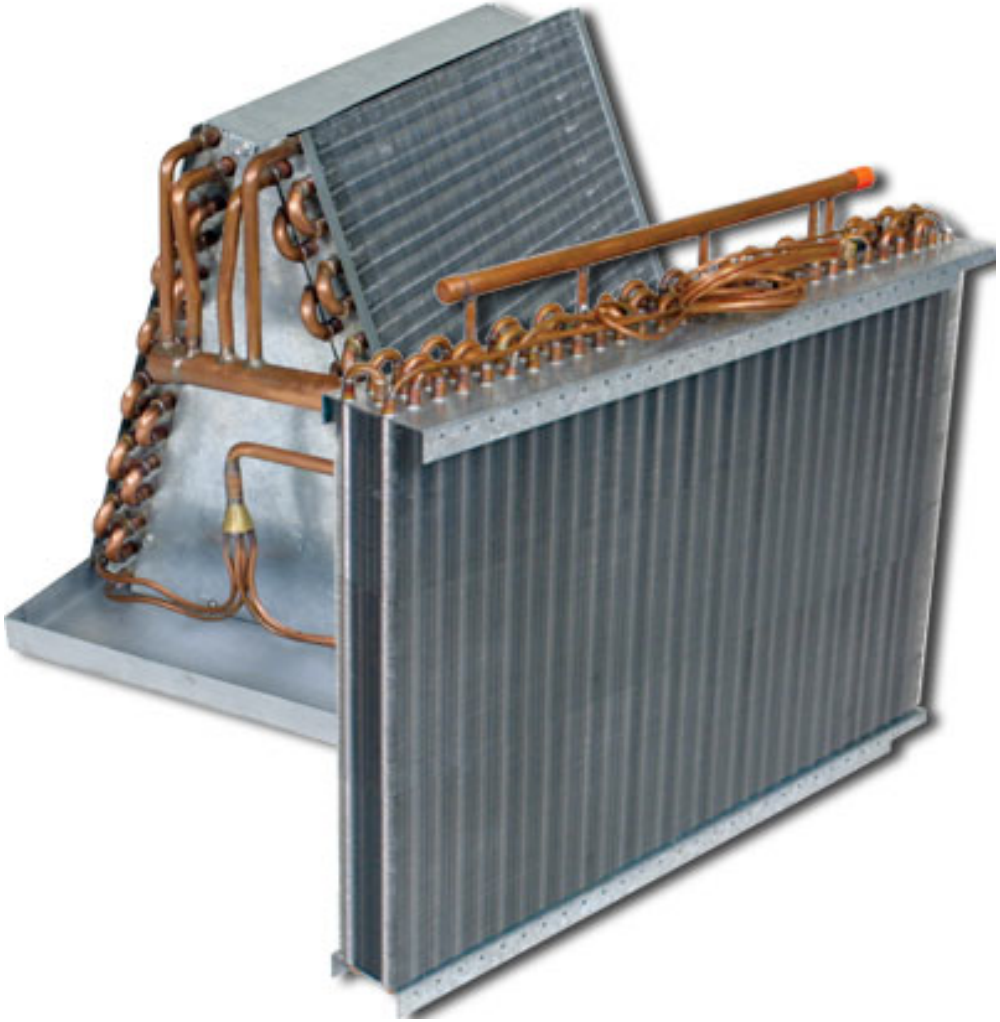
Typical large central commercial AHU components

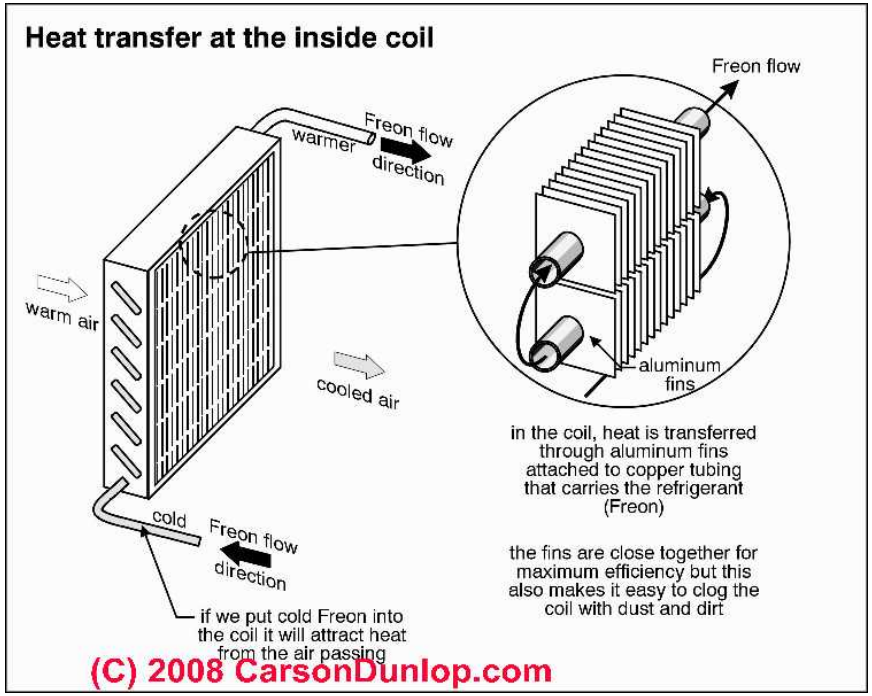
Mixing box

Dampers

Typical large central commercial AHU components

Heating and cooling coils





Heat exchangers: ∈-NTU method

$$\varepsilon_{dry} = \frac{1 - \exp[-NTU(1 - C)]}{1 - C\exp[-NTU(1 - C)]}$$

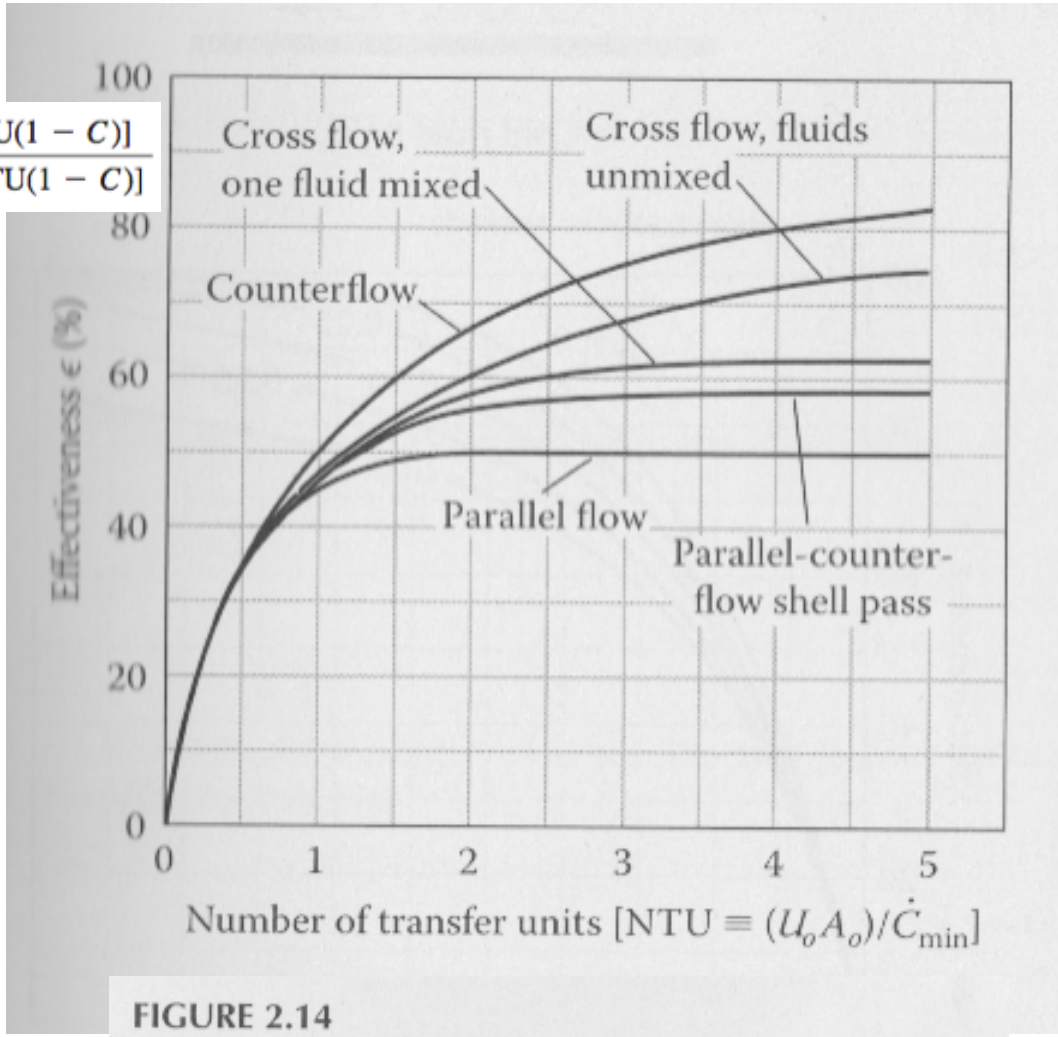
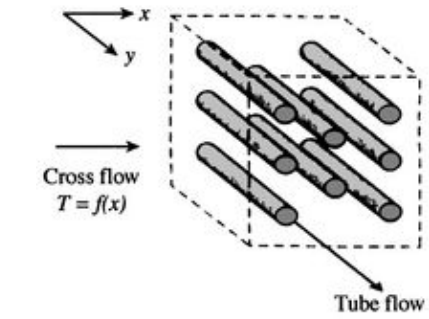
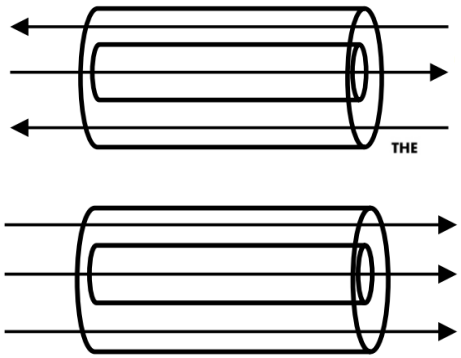


FIGURE 2.14
Comparison of effectiveness of several heat exchanger designs for equal hot- and cold-side capacitance rates, $\dot{C}_{min} = \dot{C}_{max}$.

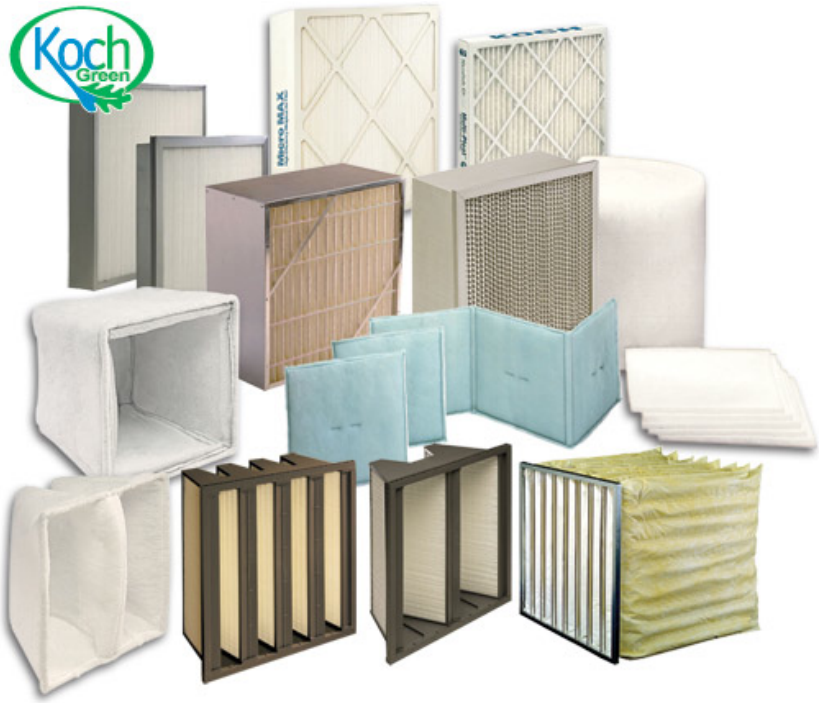




This subject is covered in detail in CAE 464 HVAC Design

Typical large central commercial AHU components

Filter bank



Typical large central commercial AHU components

Filter bank

Typical large central commercial systems

Center for Care and Discovery
University of Chicago Medicine

Typical large central commercial systems

Typical large central commercial systems

Typical large central commercial systems

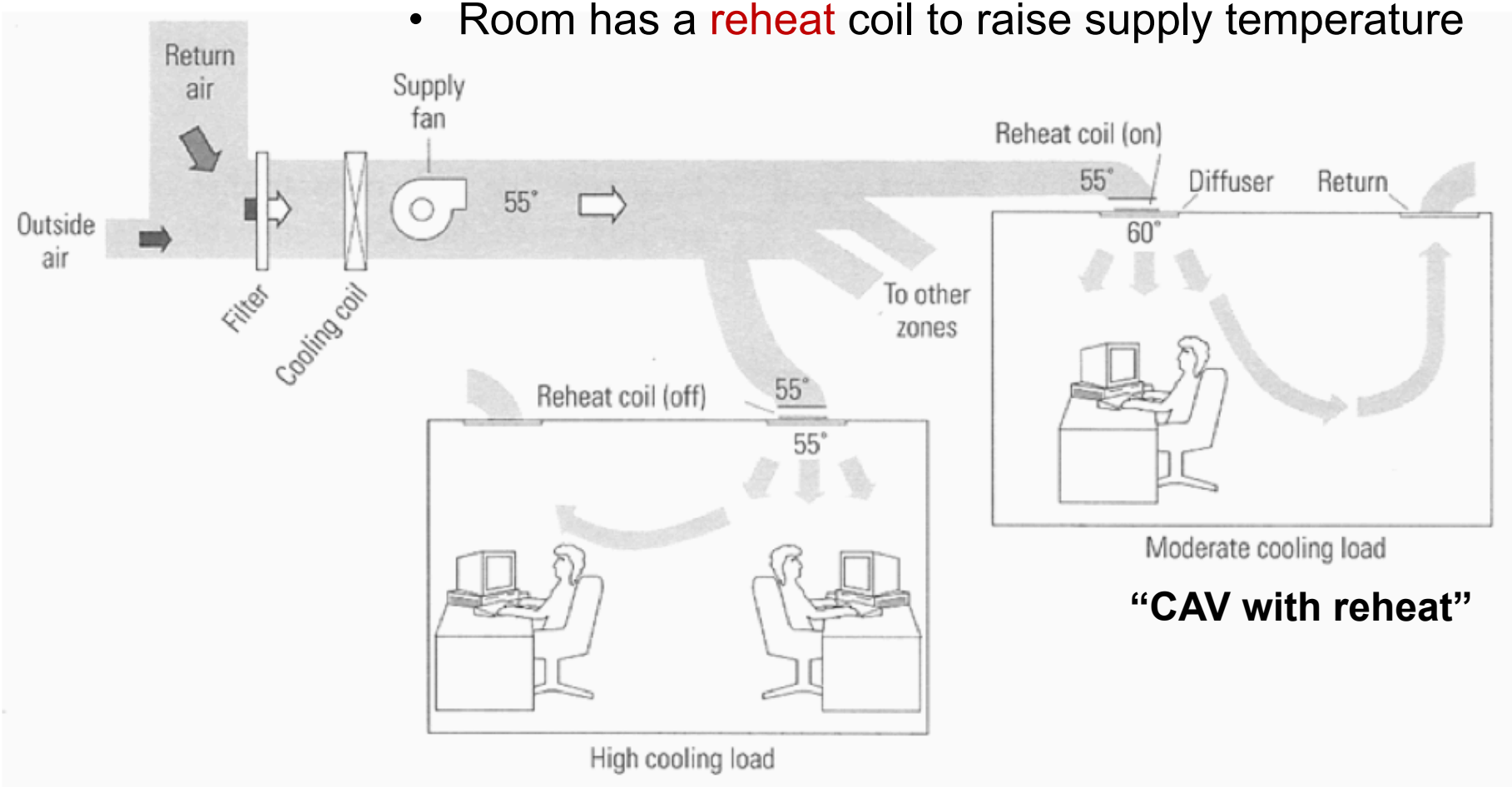
Common commercial air distribution systems

- Constant air volume (**CAV**)
- Variable air volume (**VAV**)
- Dual duct (**DD**)
- Multizone (**MZ**)

Typical constant air volume (CAV) system

Constant airflow rate and temperature to each room

- Cold air delivered to room
- Room has a reheat coil to raise supply temperature



"CAV with reheat"

Typical constant air volume (CAV) system

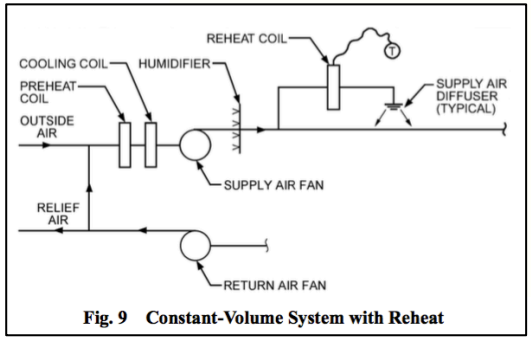
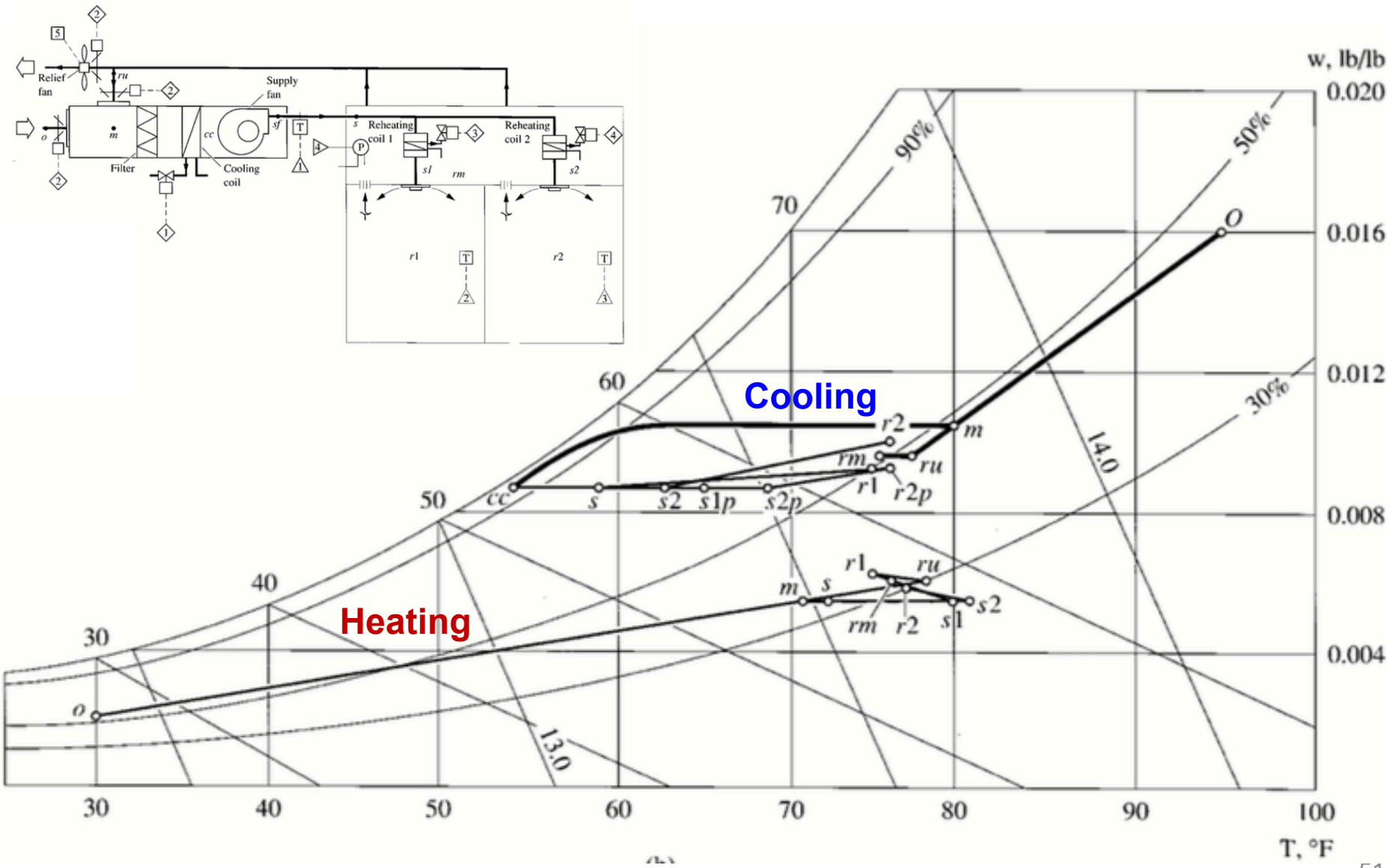


Fig. 9 Constant-Volume System with Reheat

ASHRAE Systems and Equipment Handbook

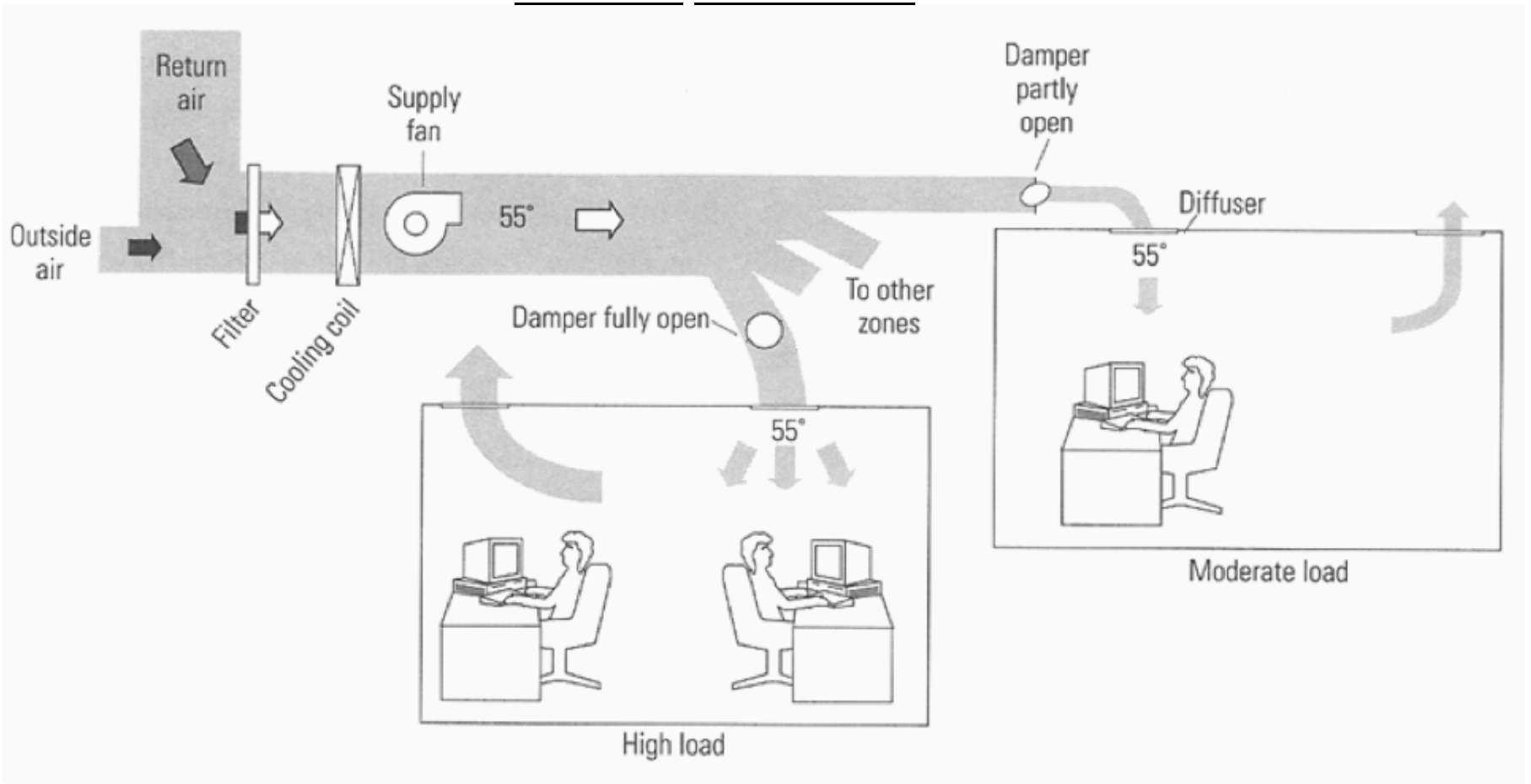
Typical constant air volume (CAV) system



Typical variable air volume (VAV) system

Same temperature air delivered to each room

- Different airflow rate delivered to each room



Typical variable air volume (VAV) system

Same temperature air delivered to each room

- Different airflow rate delivered to each room

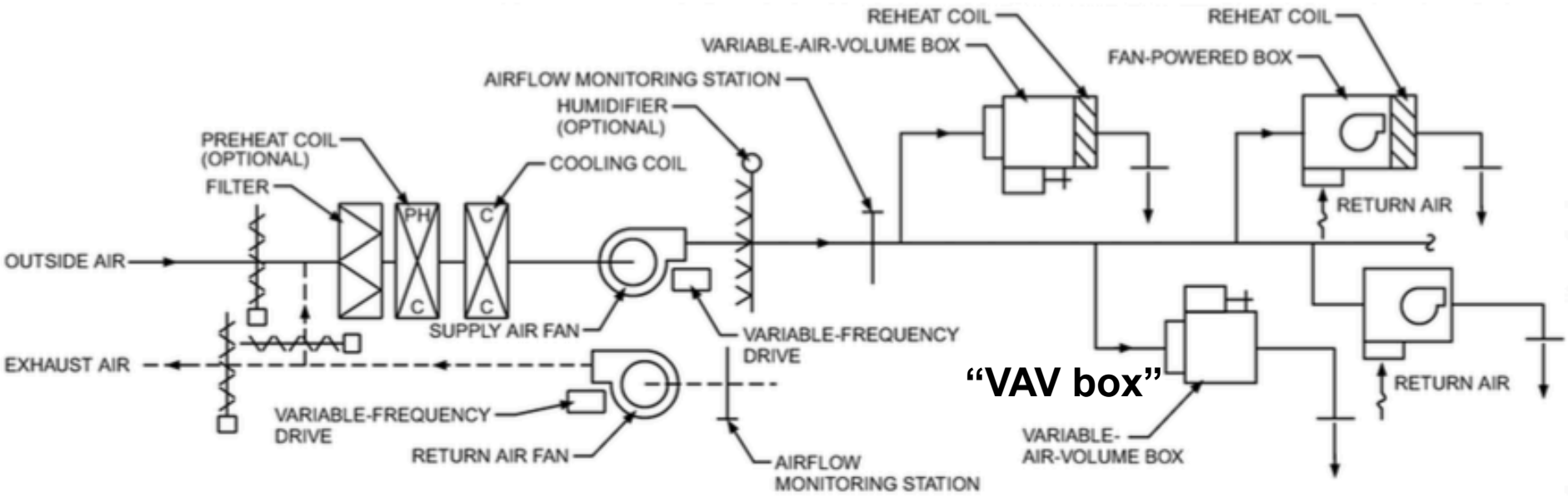
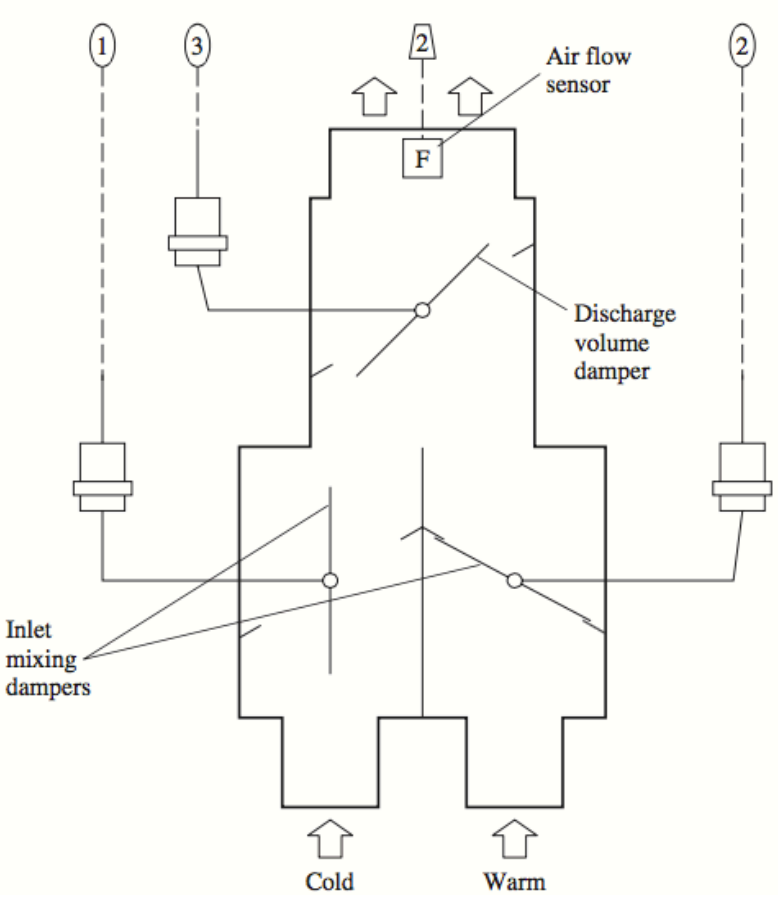
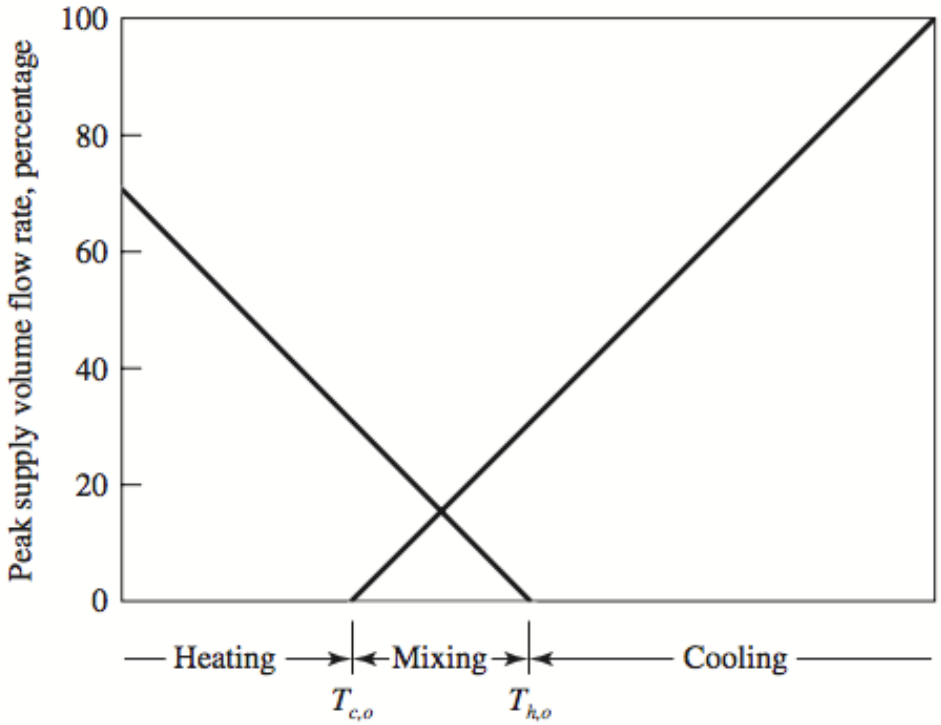


Fig. 10 Variable-Air-Volume System with Reheat and Induction and Fan-Powered Devices

Typical variable air volume (VAV) system



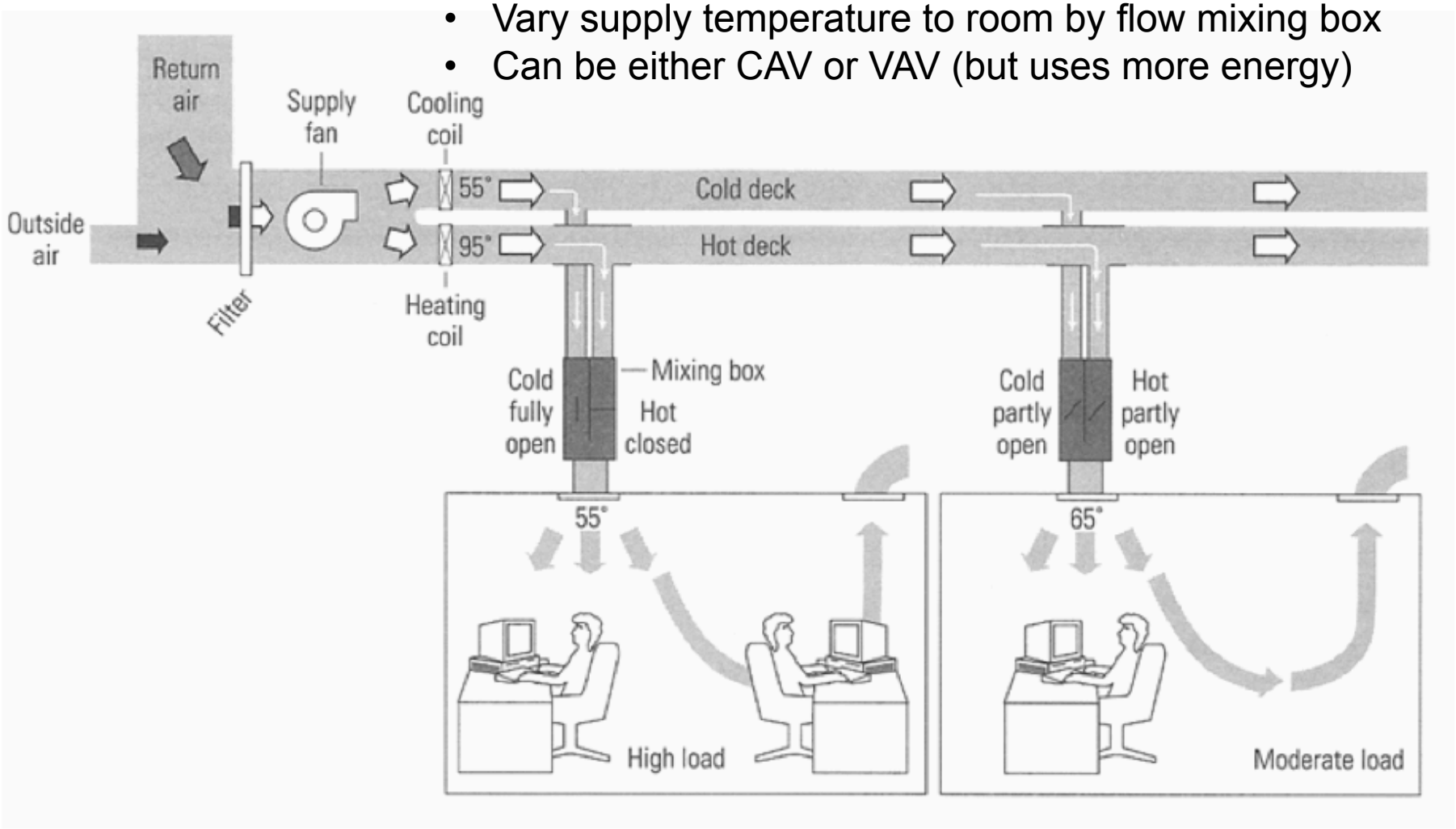
VAV box



Typical dual duct (DD) system (older systems)

1 hot deck and 1 cold deck

- Vary supply temperature to room by flow mixing box
- Can be either CAV or VAV (but uses more energy)



Typical dual duct (DD) system (older systems)

1 hot deck and 1 cold deck

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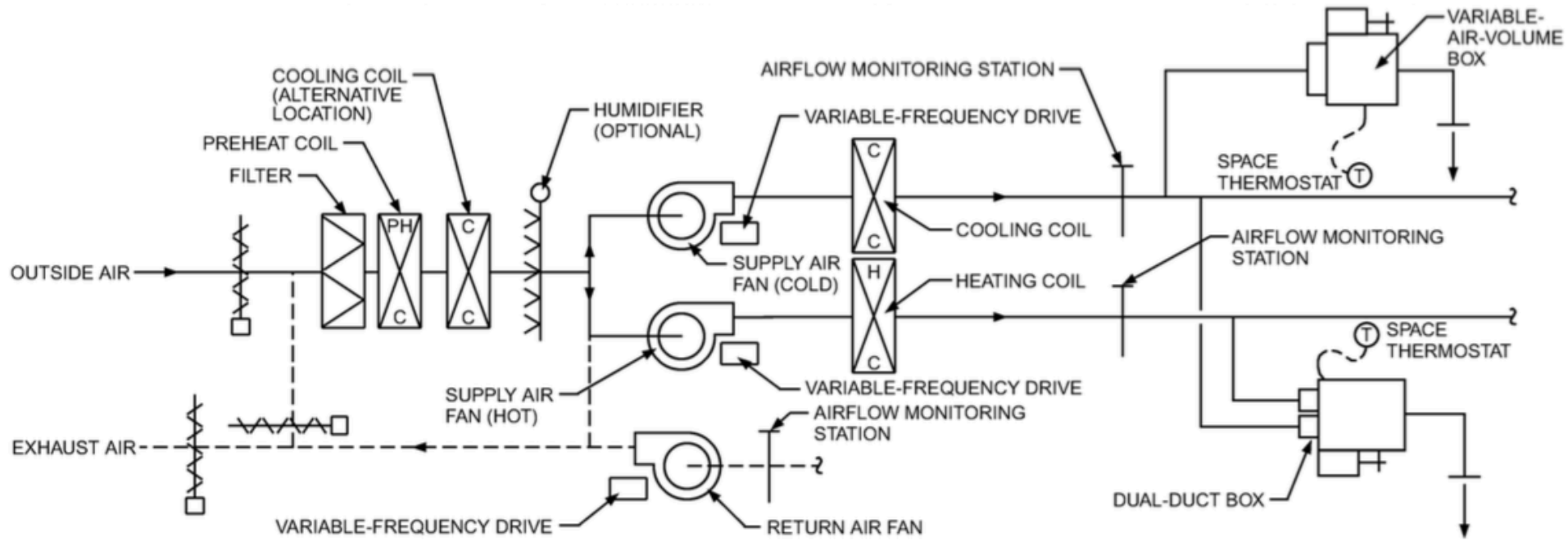
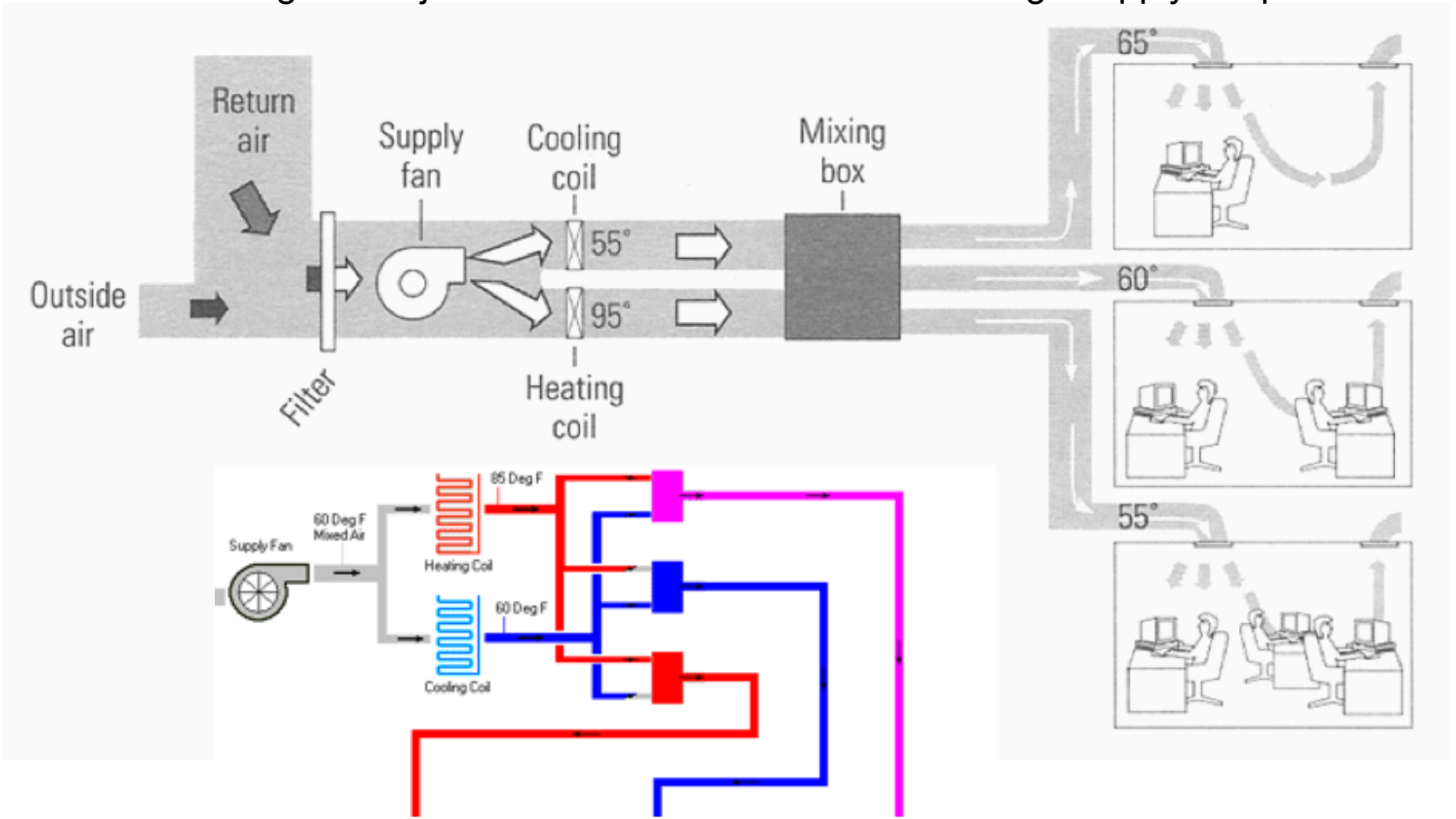


Fig. 12 Dual-Fan, Dual-Duct System

Typical multi-zone (MZ) system

Same airflow rate to each room

- Mixing box adjusts mixture of hot and cold to change supply temperature



Typical multi-zone (MZ) system

Same airflow rate to each room

- Mixing box adjusts mixture of hot and cold to change supply temperature

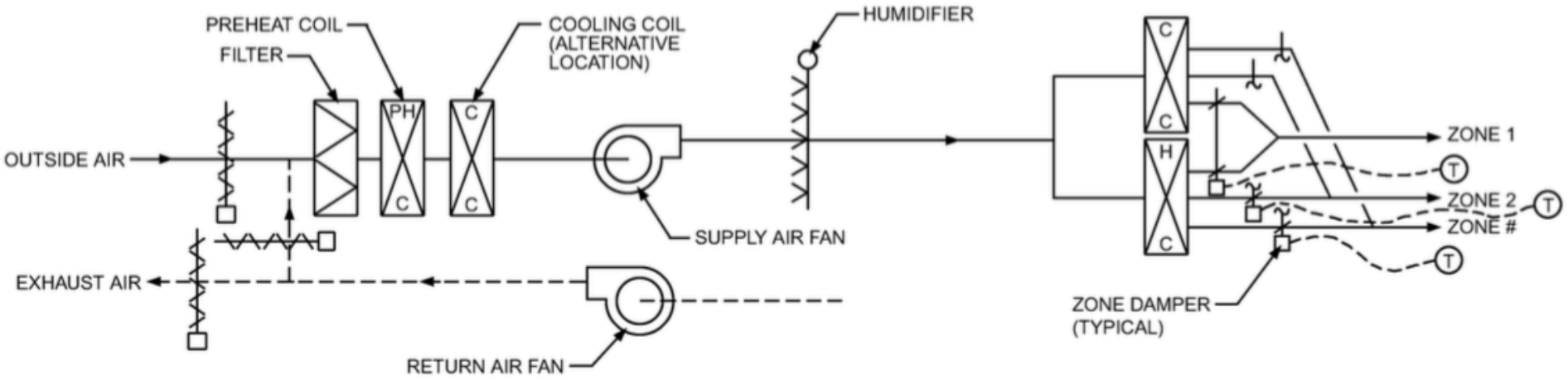
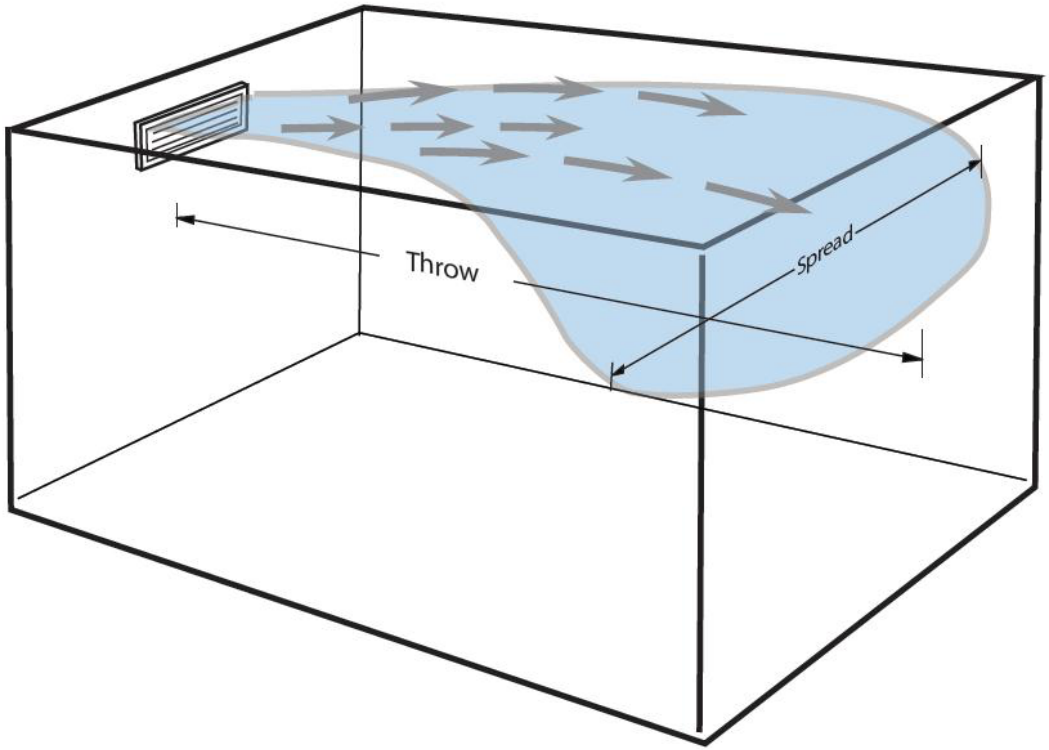
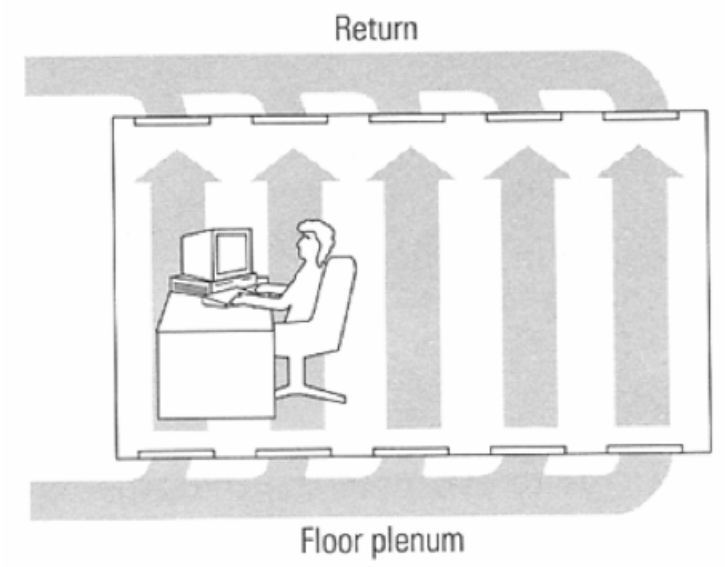


Fig. 13 Multizone System

Air supply and diffusers

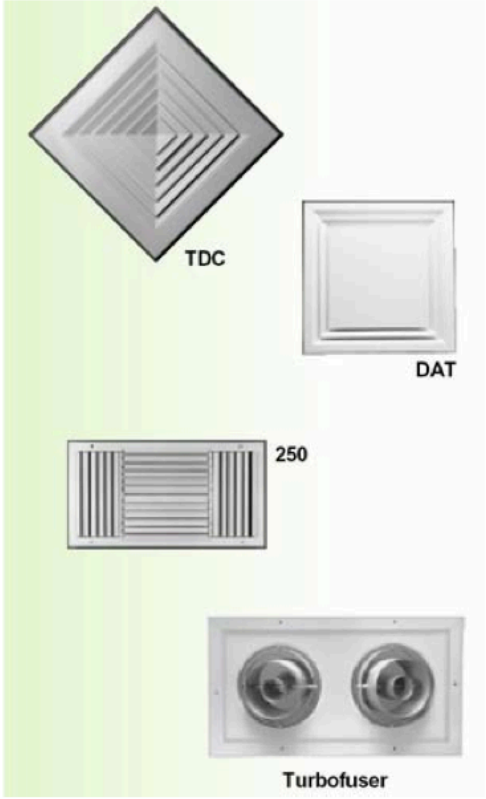
- Mixed versus displacement ventilation
- Diffuser selection

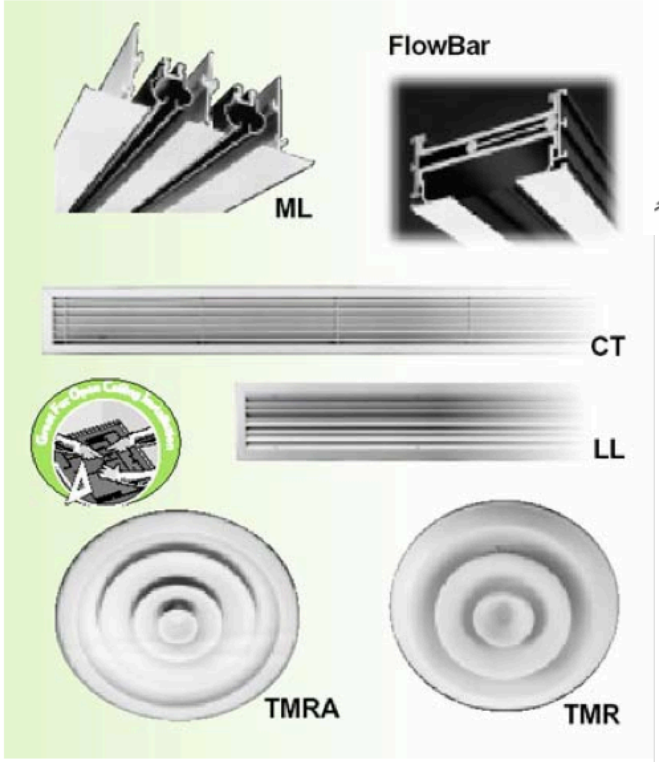


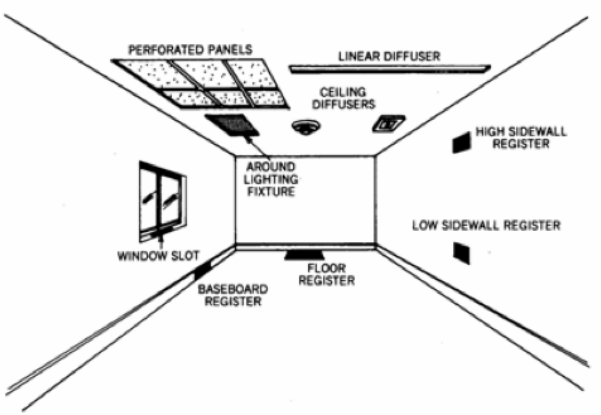


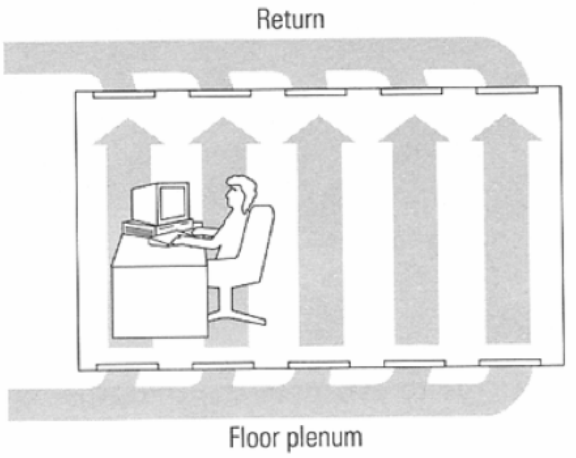
Air supply and diffusers

- Mixed versus displacement ventilation
- Diffuser selection







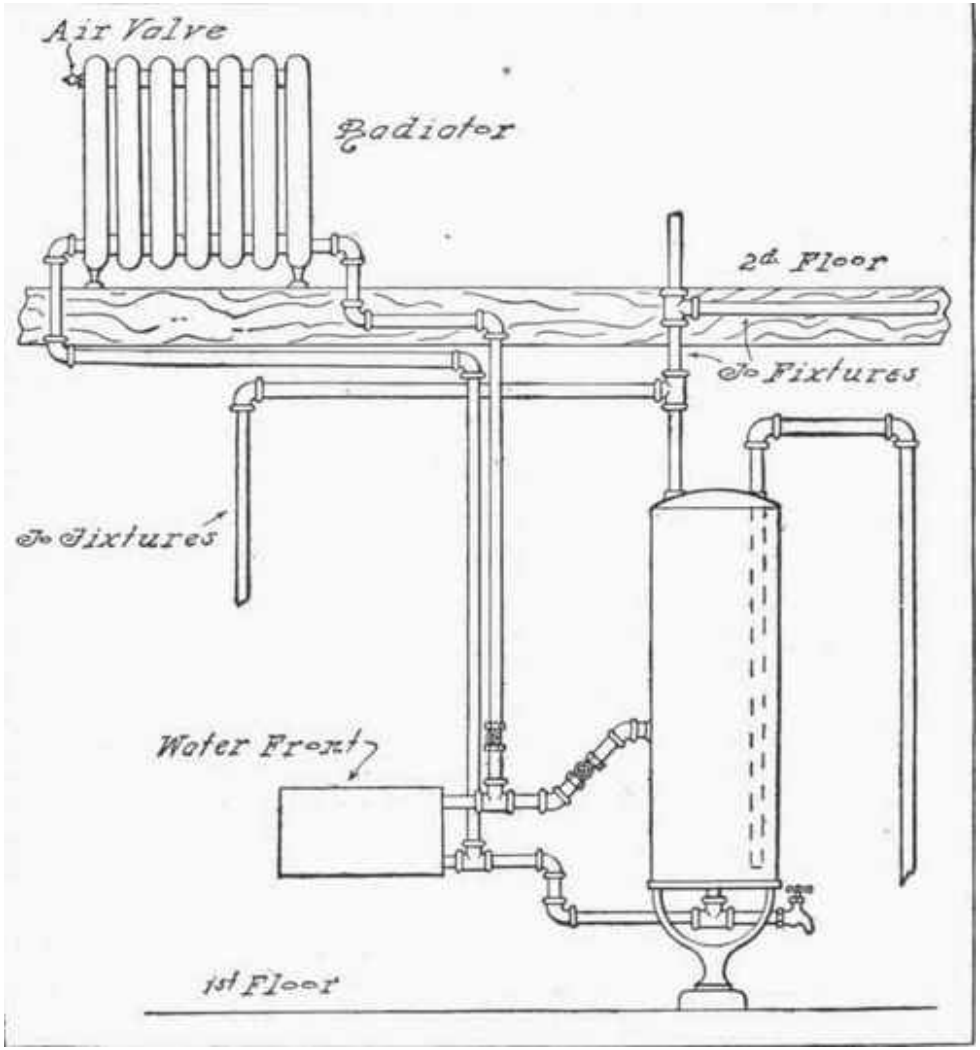


Air + water systems

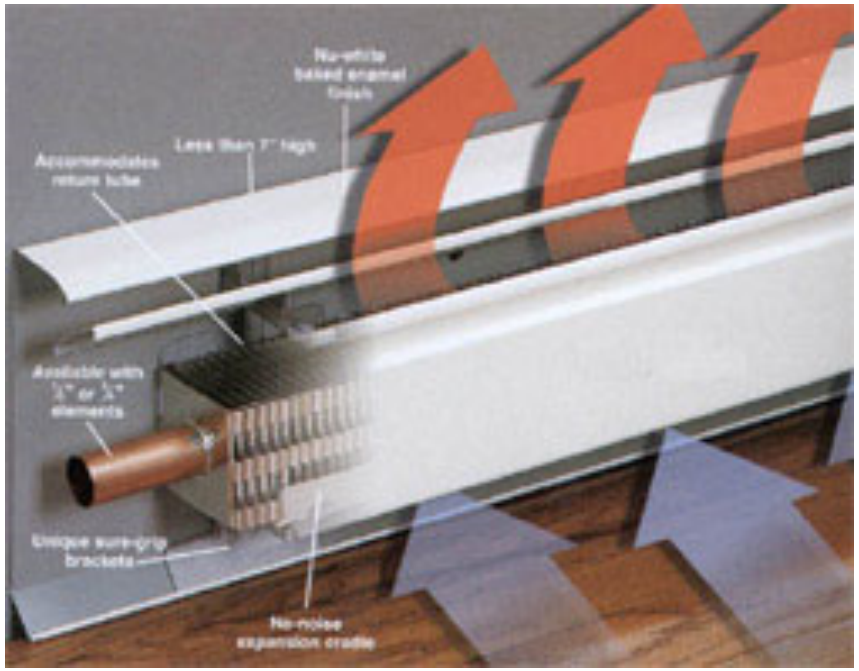
- Many commercial buildings use a combination of conditioned air and zone water coils
- Ventilation requires air movement
- But zone heating and cooling loads can be met with coils
  - We mostly use fan coils now
  - We previously mostly used radiators (like in Alumni Hall)

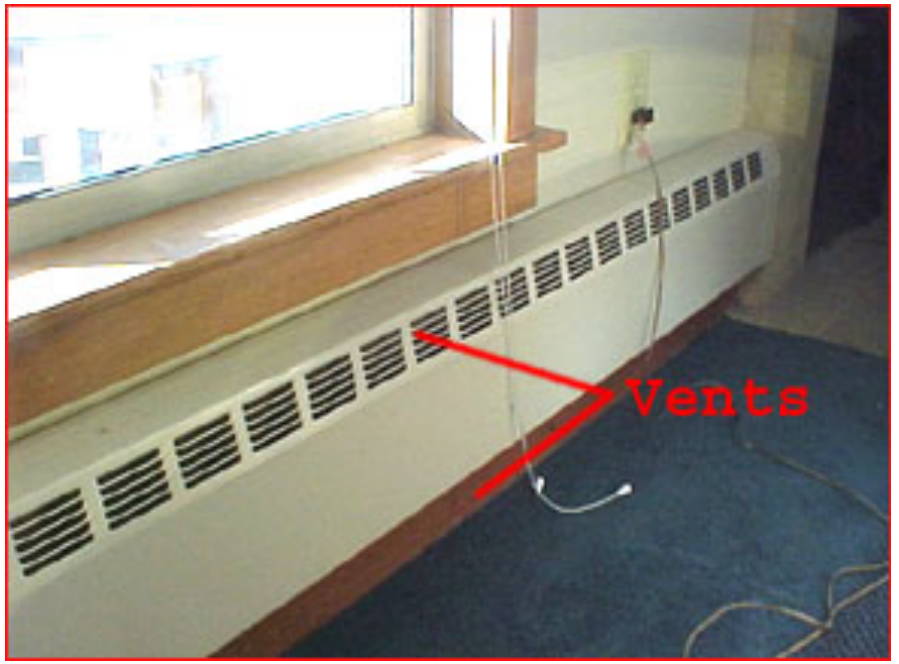
Radiator systems (for heating)

What modes of heat transfer are involved?



Water-based baseboard systems (heating)





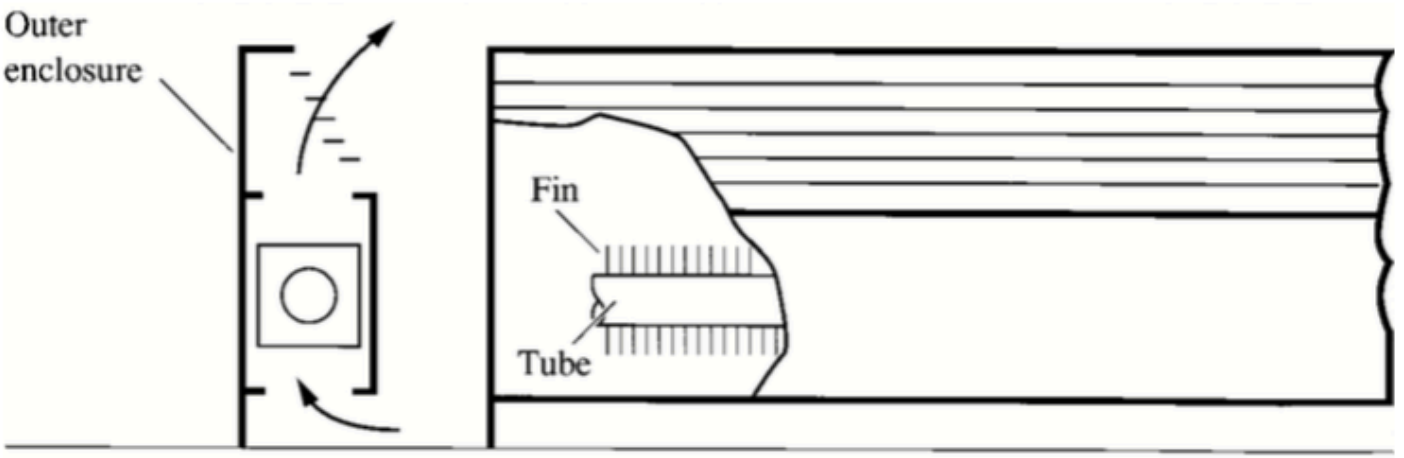


FIGURE 8.8 Baseboard finned-tube heater.

Water-based baseboard systems (heating)

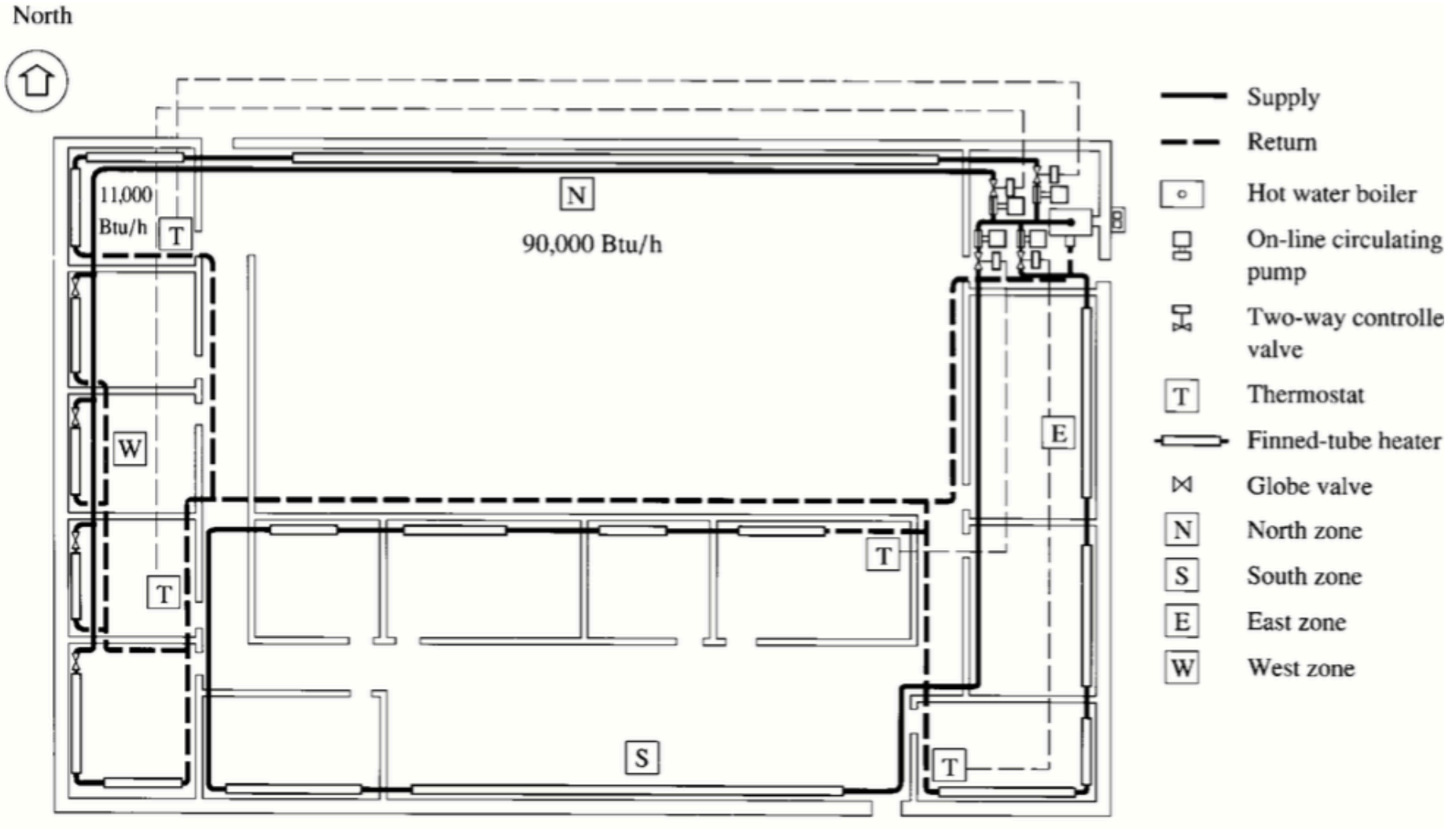
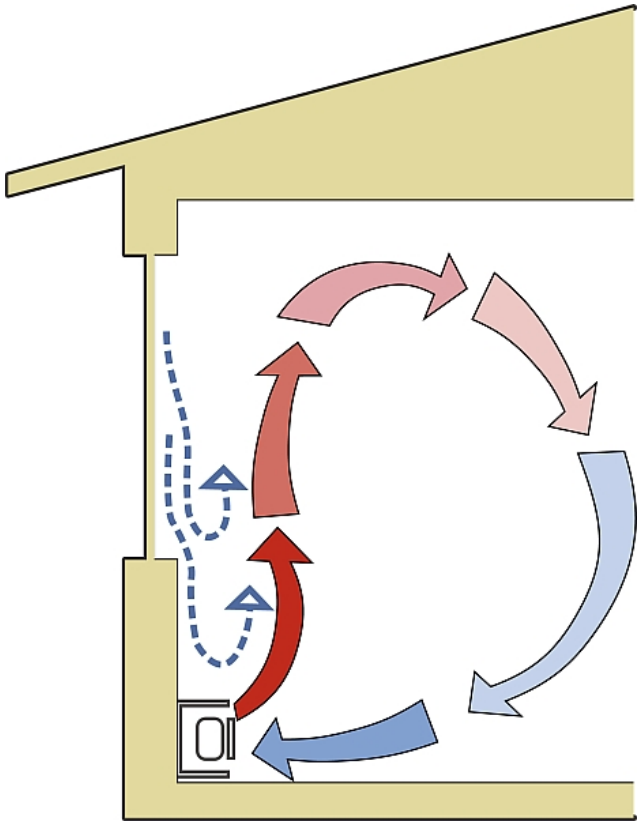
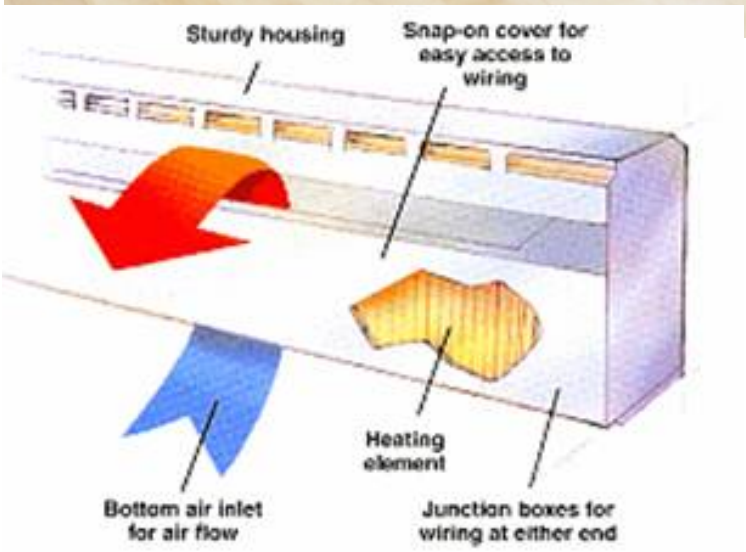


FIGURE 8.7 A two-pipe individual-loop low-temperature hot water heating system for a factory.

Electric baseboard systems (for heating)





Fan coils: Modern radiator replacement w/ fan

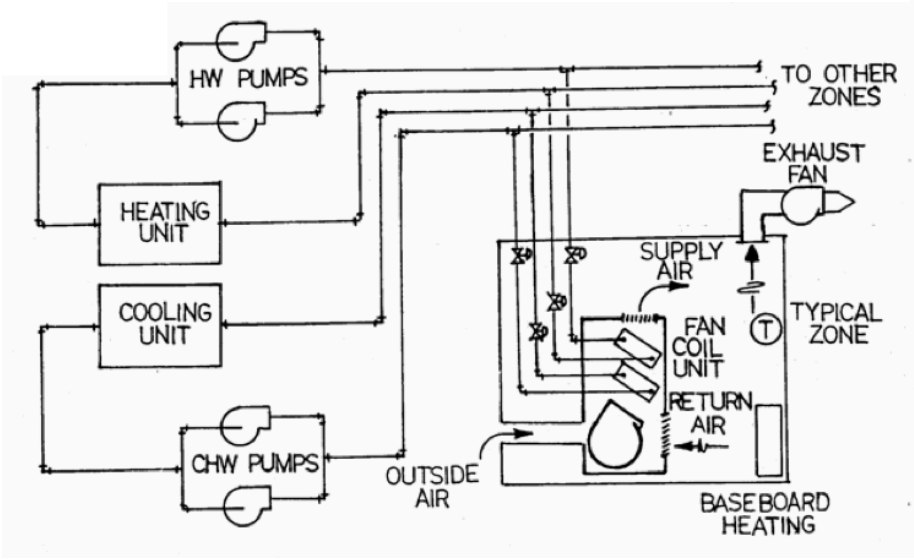
Wall installation

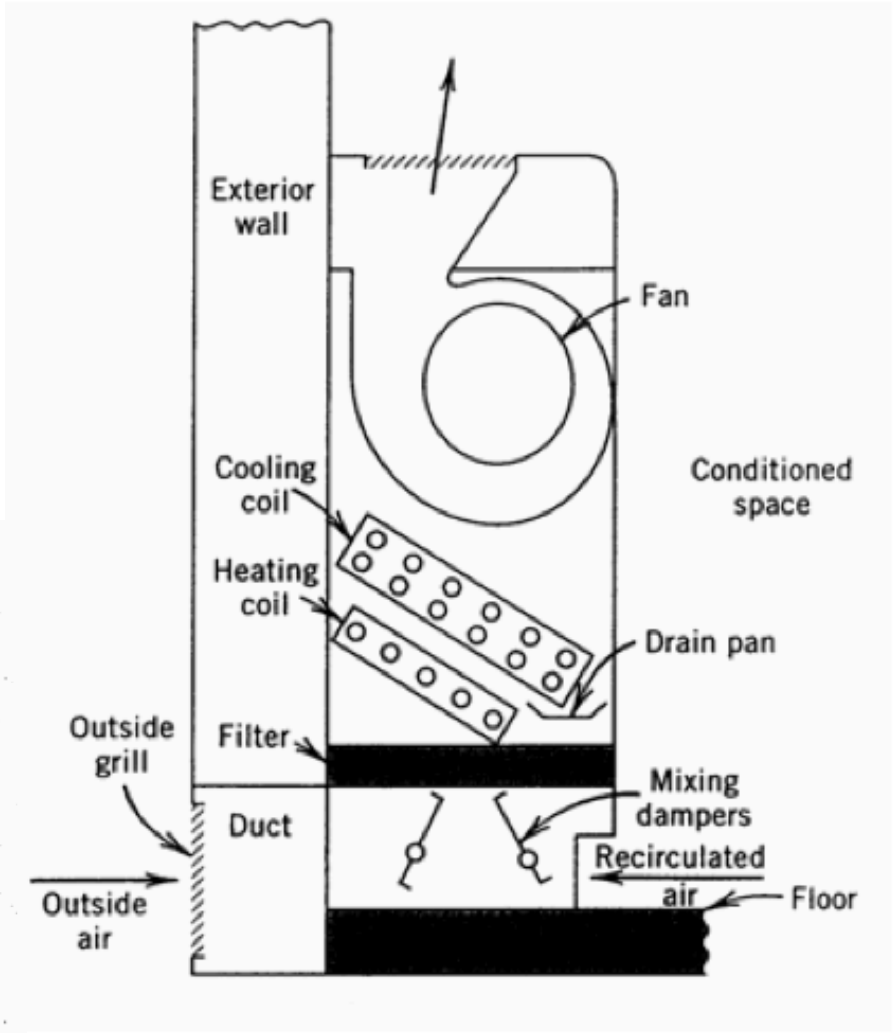
Combines air and water

Overhead/ceiling installation

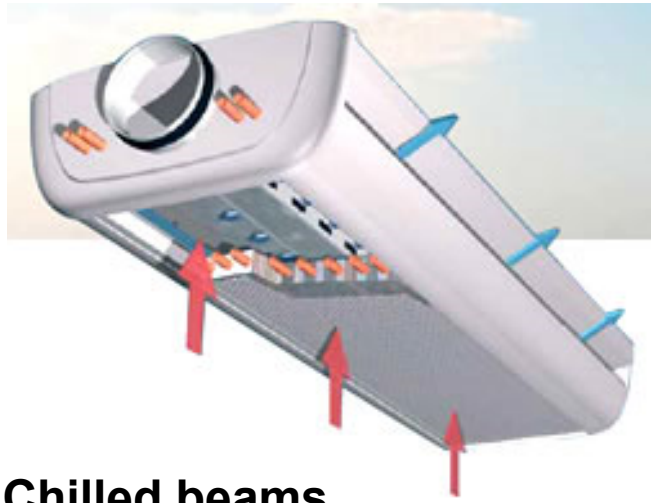
Fan coils: Modern radiator replacement w/ fan

- One or two coils (H or C)
- Thermostat controls water flow
- Ventilation is met with conditioned or unconditioned outdoor air





Other: Chilled beams and radiant panels



Chilled beams

Radiant panels