CAE 464/517 HVAC Systems Design

Spring 2021

January 21, 2021

Intro to the course and HVAC drawings

Built
Environment
Research
@ IIT

Advancing energy, environmental, and sustainability research within the built environment

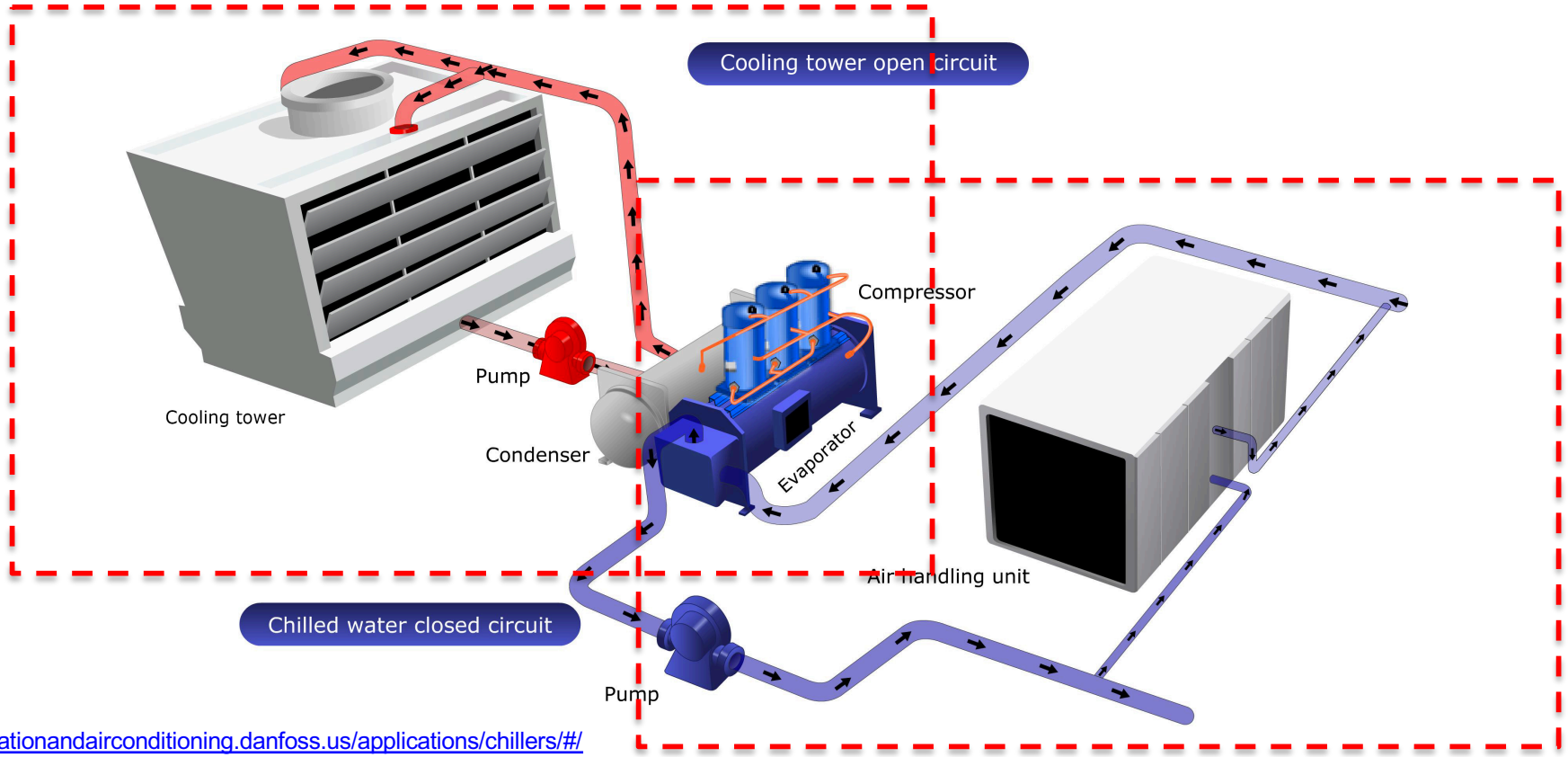
www.built-envi.com

Dr. Mohammad Heidarinejad, Ph.D., P.E.
Civil, Architectural and Environmental Engineering
Illinois Institute of Technology
muh182@iit.edu

RECAP

Recap

- HVAC system may include main parts:
  - ❑ Primary systems or central plant
  - ❑ Distribution system
  - ❑ Terminal devices
  - ❑ Controls



http://refrigerationandairconditioning.danfoss.us/applications/chillers/#/

Recap

- Secondary system(s) may have different working fluids:
  - ❑ Hydronic systems (Water or steam)
    - Heat transfer to space by natural or forces convection
    - Only sensible load is met this way
  - ❑ Air systems (Air)
    - Both sensible and latent loads are met by a single supply air stream to each space
    - Deliver the required air ventilation
    - Require large volume of air

Recap

- Secondary systems entail:
  - ❑ Distribution system:
    - Ducts or pipes to carry working fluids
  - ❑ Equipment to compensate for pressure drop and move the working fluids:
    - Fans or pumps
  - ❑ Heat exchanger devices to transfer cool or heat from the working fluid to air:
    - Cooling or heating coils
  - ❑ Terminal devices to control, distribute, and deliver cooled or heated air to different zones:
    - Radiators, fan coils, room diffusers
  - ❑ Control devices to modulate the flow:
    - Temperature sensors, valves, dampers, thermostats

BUILDING HVAC SYSTEMS

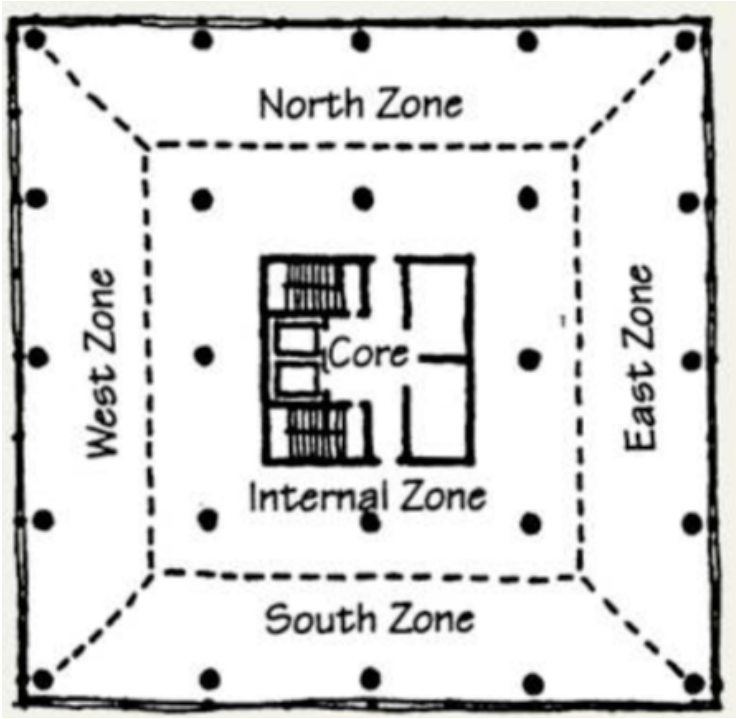
Building HVAC Systems

- Heating equipment, energy, distribution, and cycle options:
  - **Equipment:** Boiler, furnace, heat pump, electric resistance
  - **Energy:** Natural gas, oil, steam, electrical, renewable, waste heat
  - **Distribution:** Air, steam, water
  - **Cycle:** Vapor compression, combustion, renewable

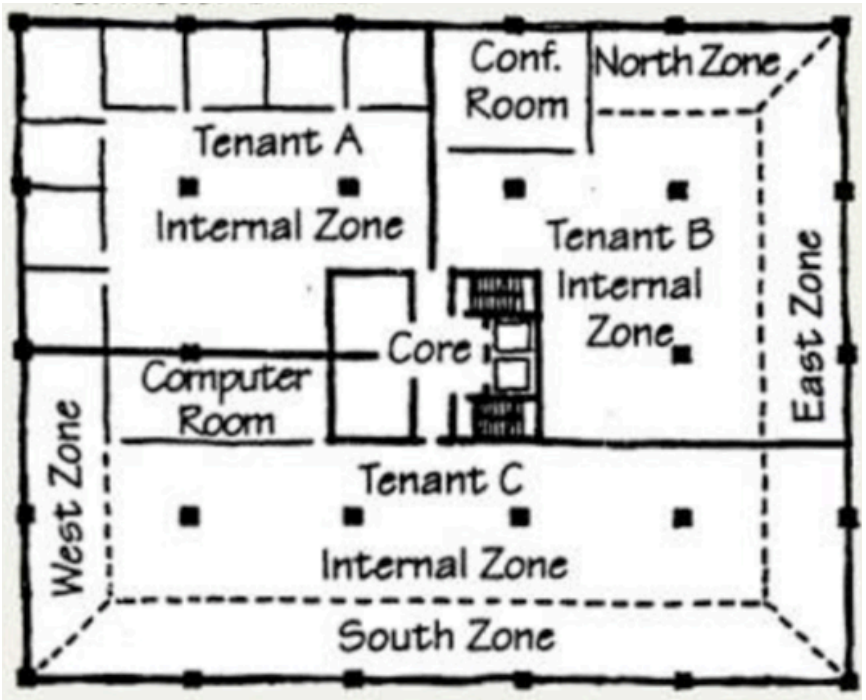
- Cooling equipment, energy, distribution, and cycle options:
  - **Equipment:** Air conditioner, chiller, heat pump
  - **Energy:** Electrical, natural gas, steam, waste heat, renewable
  - **Distribution:** Chilled water, air
  - **Cycle:** Vapor compression, absorption

Building HVAC Systems

- Thermal zone or zone:
  - ❑ Is a space or collection of spaces having similar space-conditioning requirements
  - ❑ Has the same heating and cooling setpoint



Based on orientation and floor



Based on spaces

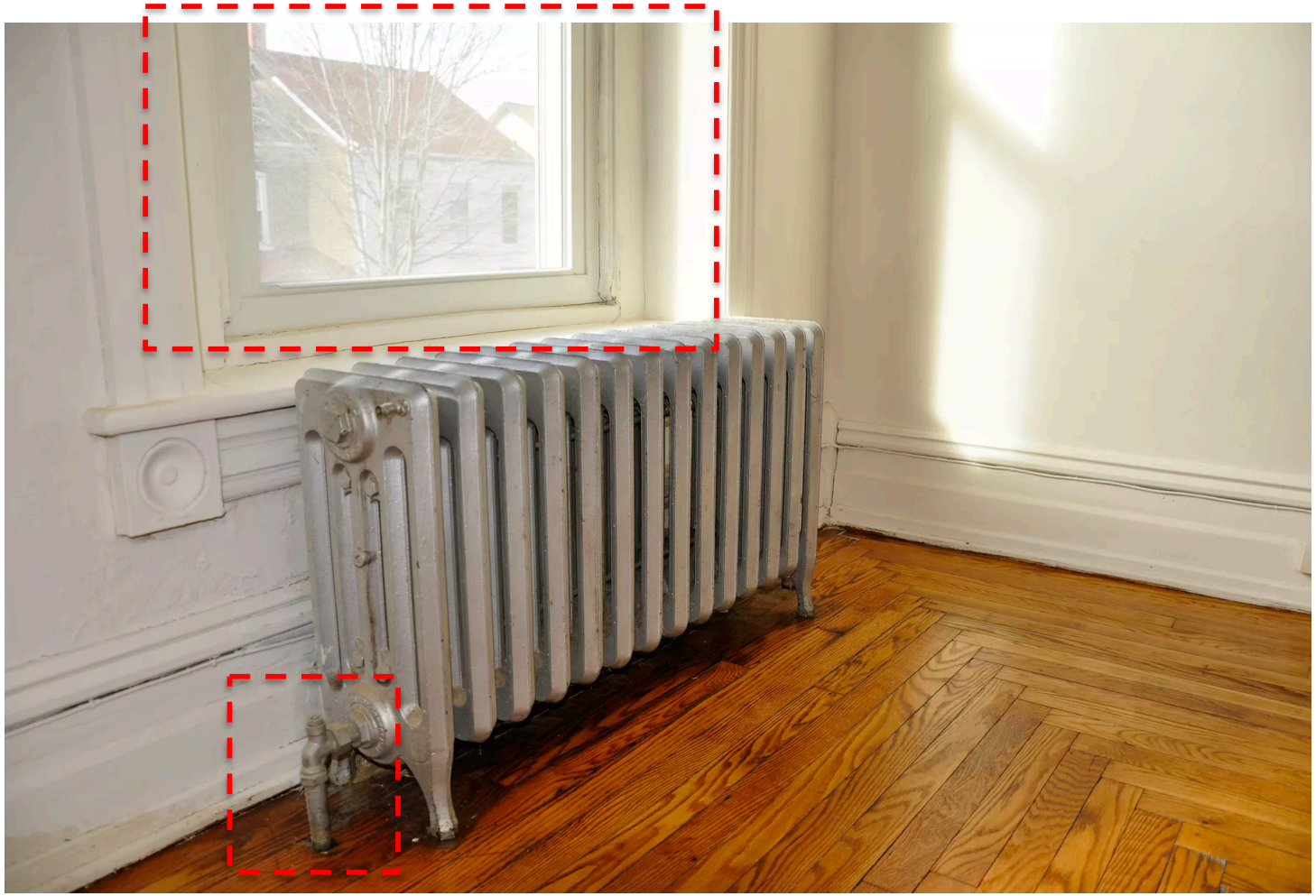
Reddy et al. 2017

Building HVAC Systems

- Common ventilation types:
  - ❑ Constant Air Volume (CAV):
    - Hold the system airflow rate constant
    - Let the space thermostat modulate the supply air temperature
  - ❑ Variable Air Volume (VAV):
    - Modulate supply airflow rate
    - Hold the supply air inlet temperature constant
  - ❑ Dedicated Outdoor Air System (DOAS):
    - Consist of two parallel systems
    - Deliver outdoor to handle both latent and sensible loads
    - Include a parallel system to handle mostly sensible loads

Building HVAC Systems

- Can we have a system with no ventilation type?



Why do you think most of the radiators are located under the windows?

https://ny.curbed.com/2018/1/3/16845686/weather-nyc-311-heat-hot-water-complaint

Building HVAC Systems

- Strategies to understand the topics in this class is to identify:

  - ❑ System types:
    - Air distribution systems
    - Hydronic systems
    - Refrigeration systems
  - ❑ Energy sources
  - ❑ Primary and secondary
  - ❑ Ventilation types

Building HVAC Systems

- HVAC systems categories in terms of their distribution and integration of components are categorized as:

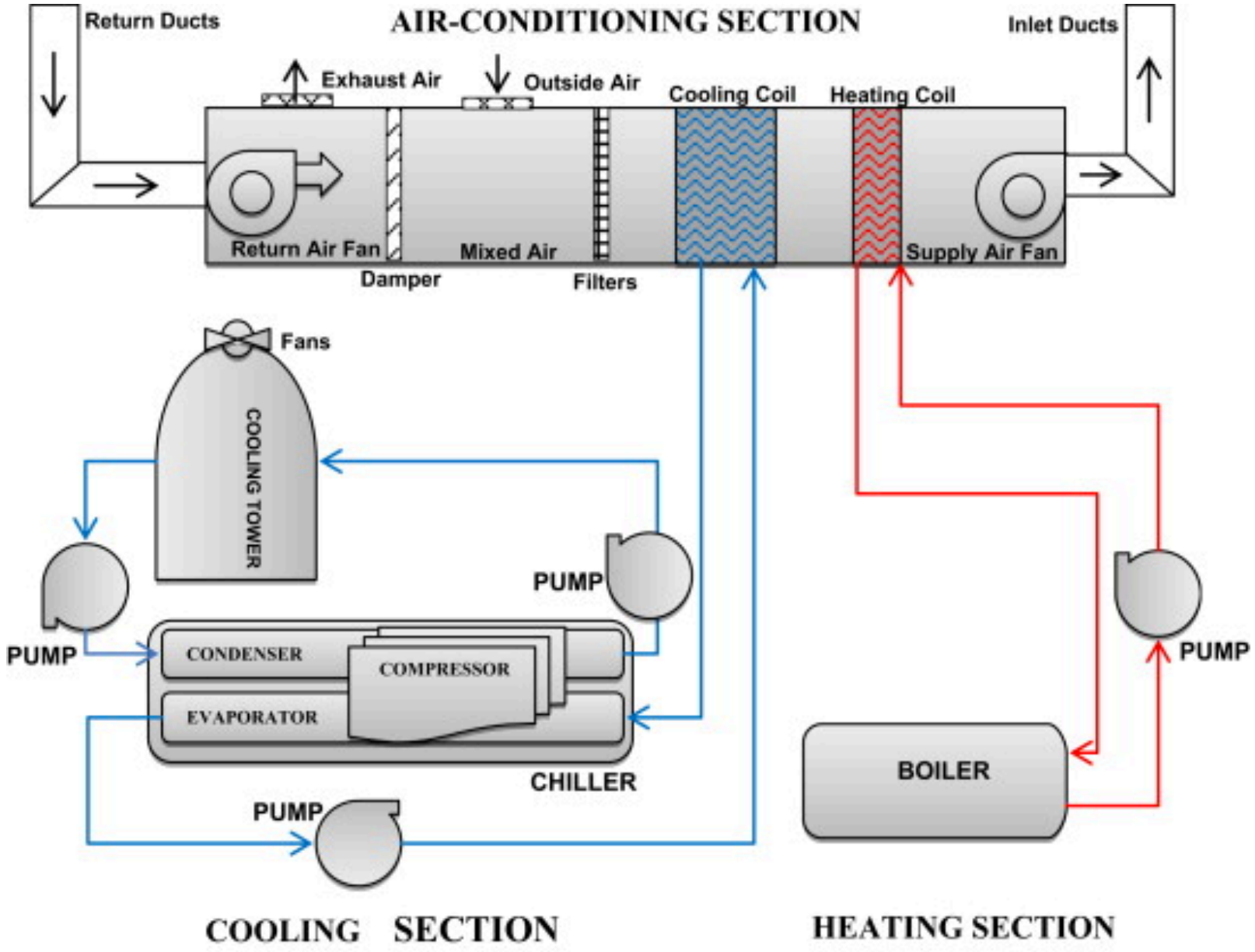
  - ❑ Unitary
    - Local systems
    - Each room has an HVAC system
  - ❑ Centralized
    - Central systems (all HVAC equipment in one room)
    - Semi-central systems
  - ❑ District
    - Central systems (all HVAC equipment in one room)
    - Semi-central systems

Building HVAC Systems

- How do we select HVAC systems?

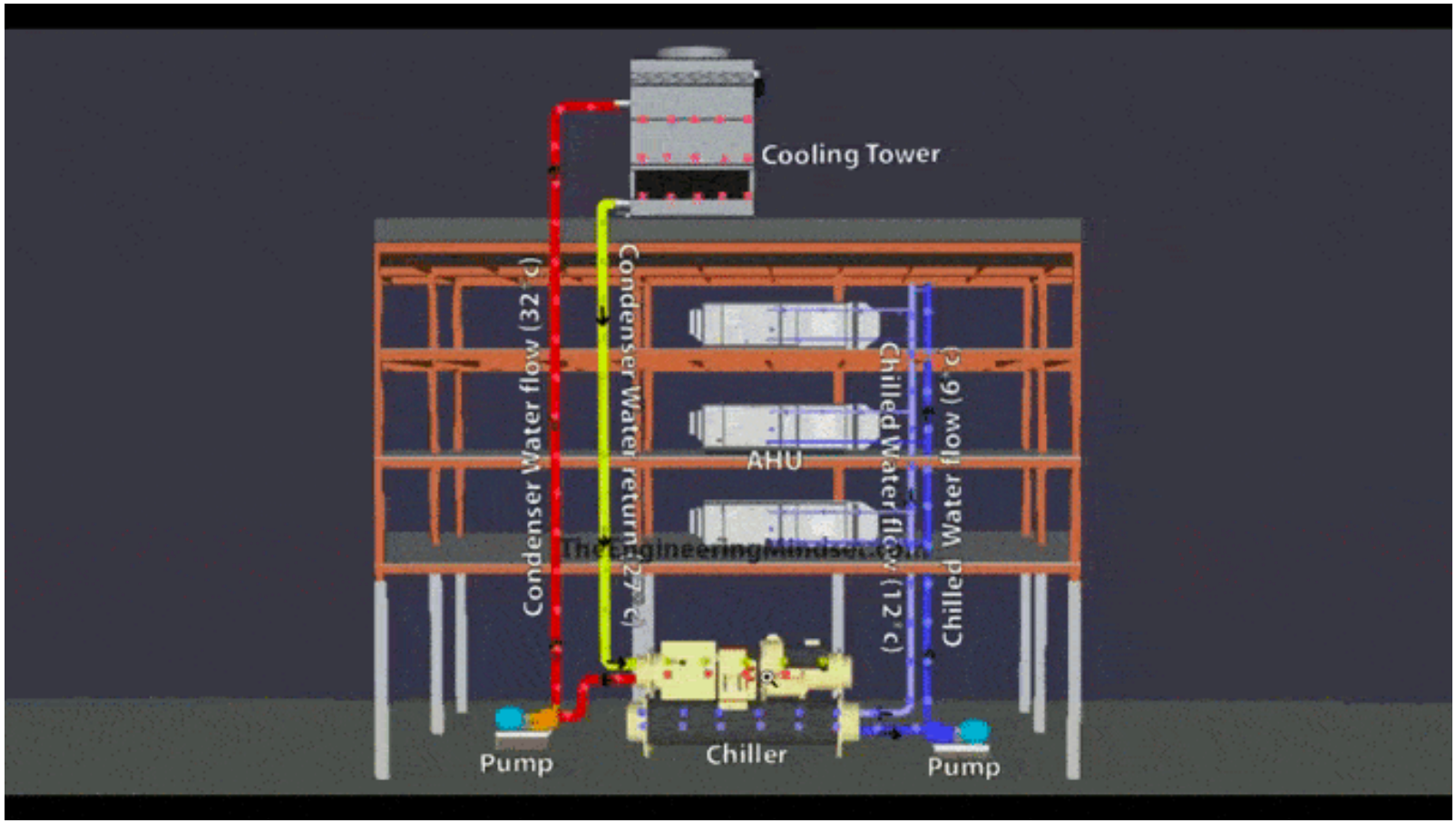
  - ❑ Performance requirements (loads, process)
  - ❑ Capacity requirements (building types, loads)
  - ❑ Spatial requirements (building types)
  - ❑ First costs (location, size of HVAC, investment)
  - ❑ Operating costs
  - ❑ Reliability
  - ❑ Flexibility
  - ❑ Maintainability

Building HVAC Systems



Building HVAC Systems

- How many loops do you see here?

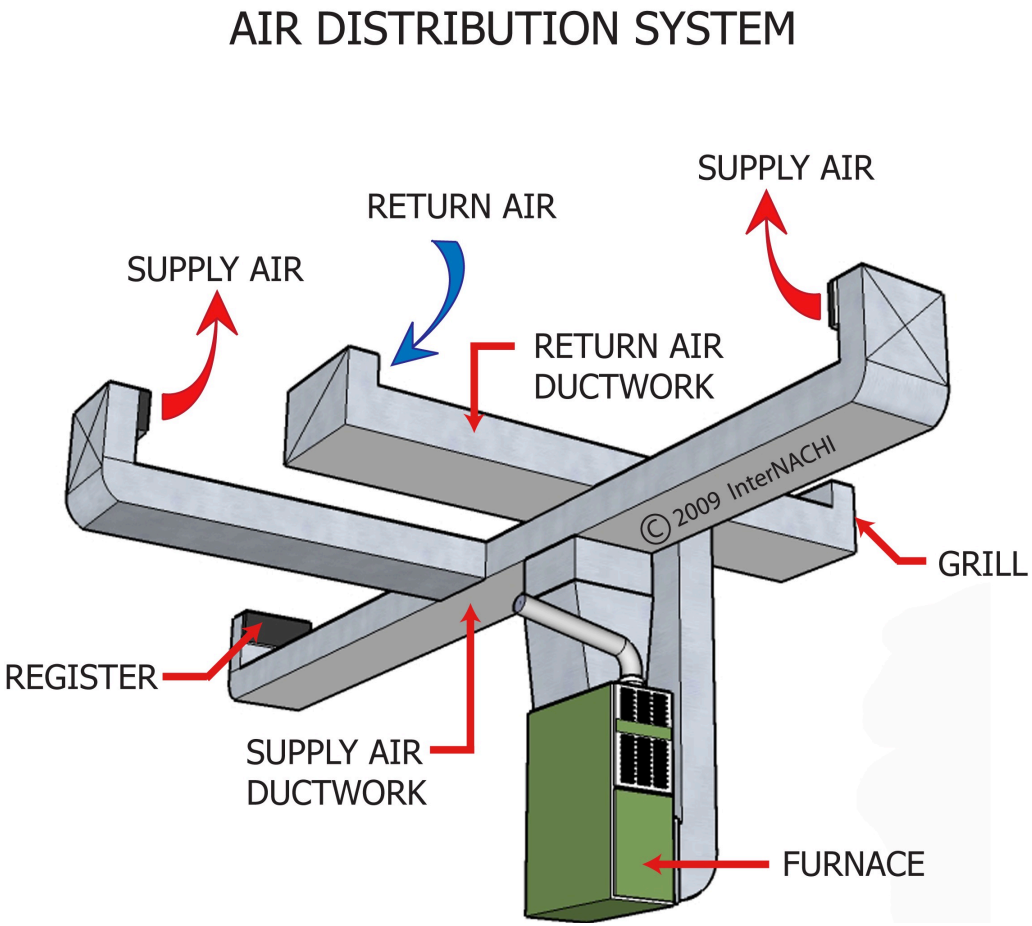


https://theengineeringmindset.com/chiller-cooling-tower-air-handling-unit-work-together/

INTRODUCTION TO AIR DISTRIBUTION SYSTEMS

Air Distribution Systems

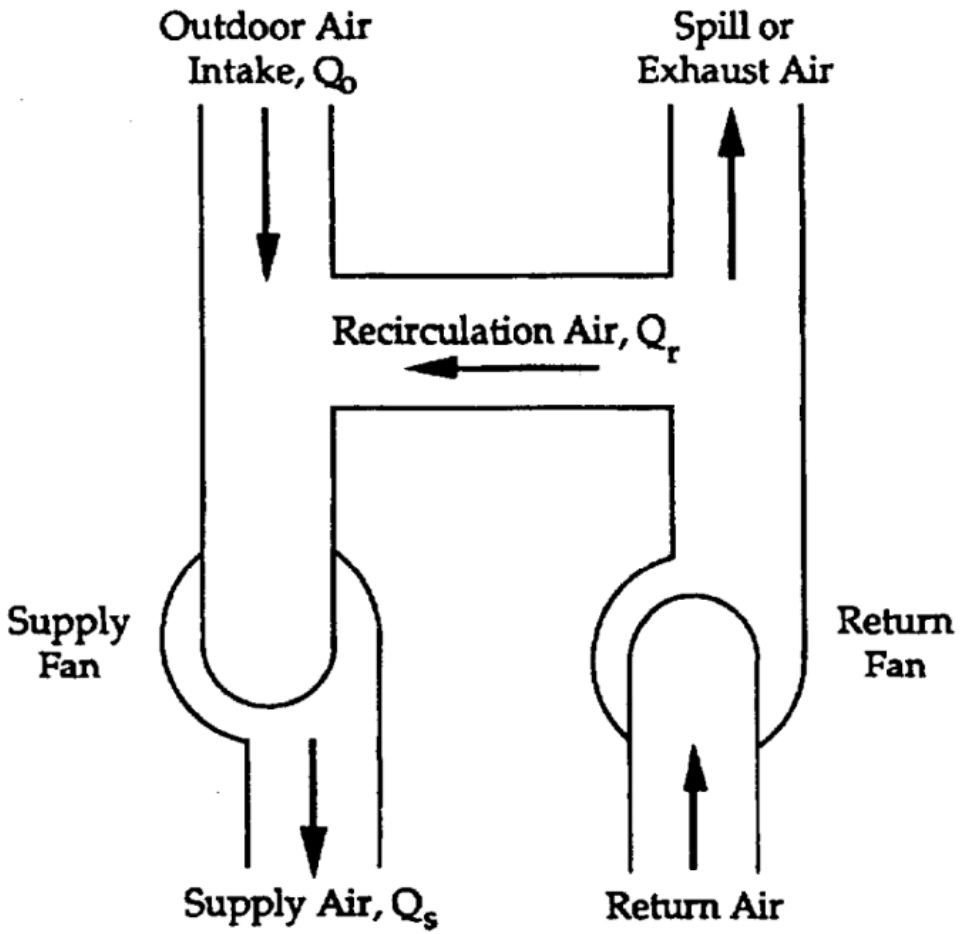
- Air distribution components:
  - ❑ Air handlers (known as AHU)
  - ❑ Air distribution devices
  - ❑ Ductwork
  - ❑ Heating and cooling coils
  - ❑ Dampers
  - ❑ Fans
  - ❑ Controls



https://www.nachi.org/gallery/?level=picture&id=1578

Air Distribution Systems

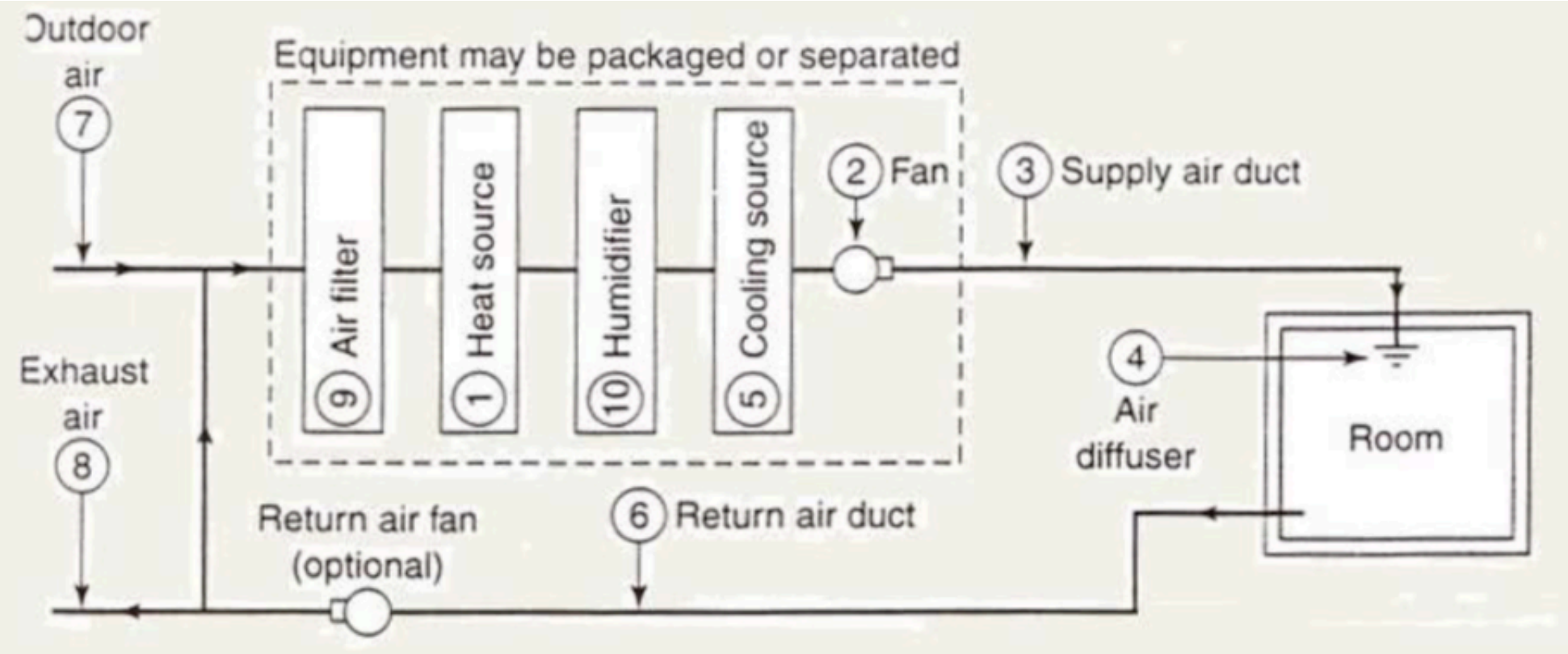
- An AHU system may include:



Persliy 1997

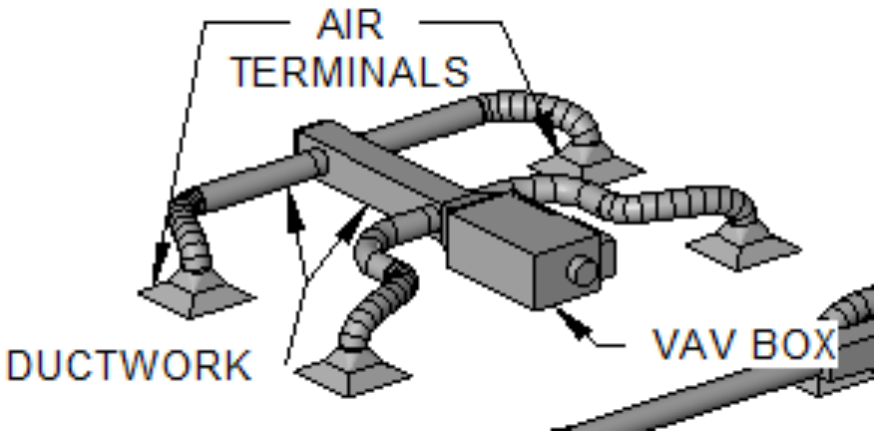
Air Distribution Systems

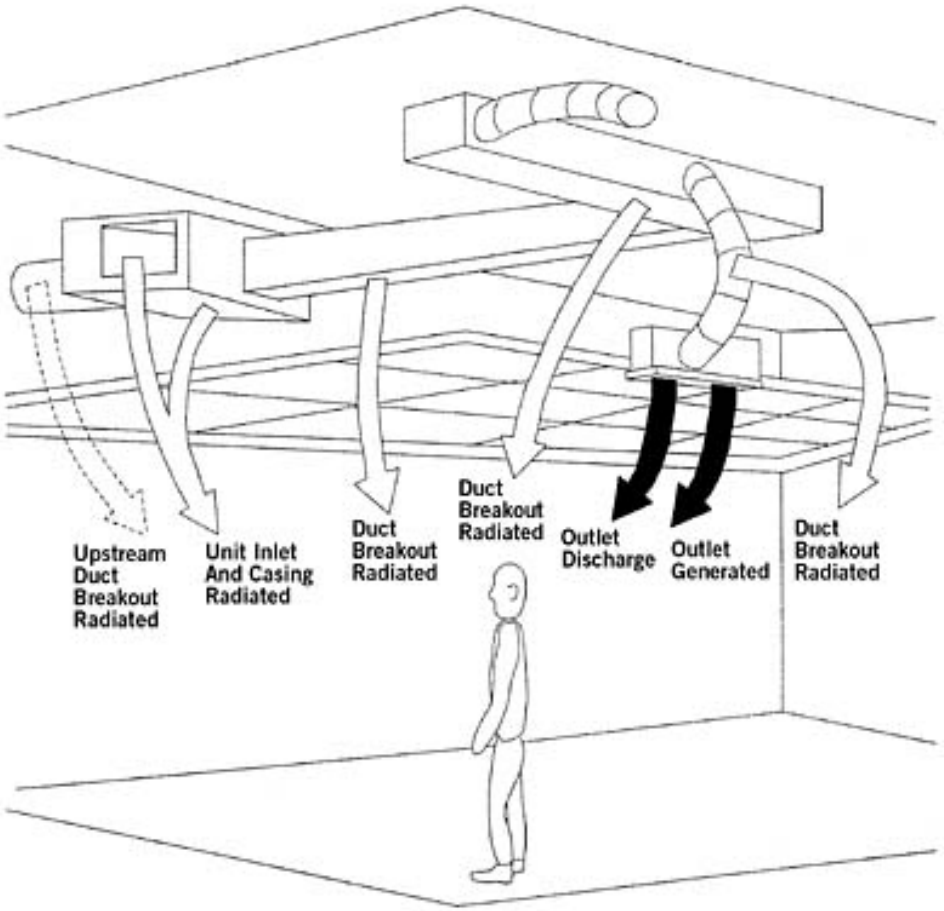
- All air systems:



Air Distribution Systems

- Energy is transferred to the room air by
  - ❑ Terminal devices such as radiators and fan units
  - ❑ Air stream that needs to supply via terminal boxes or room diffusers



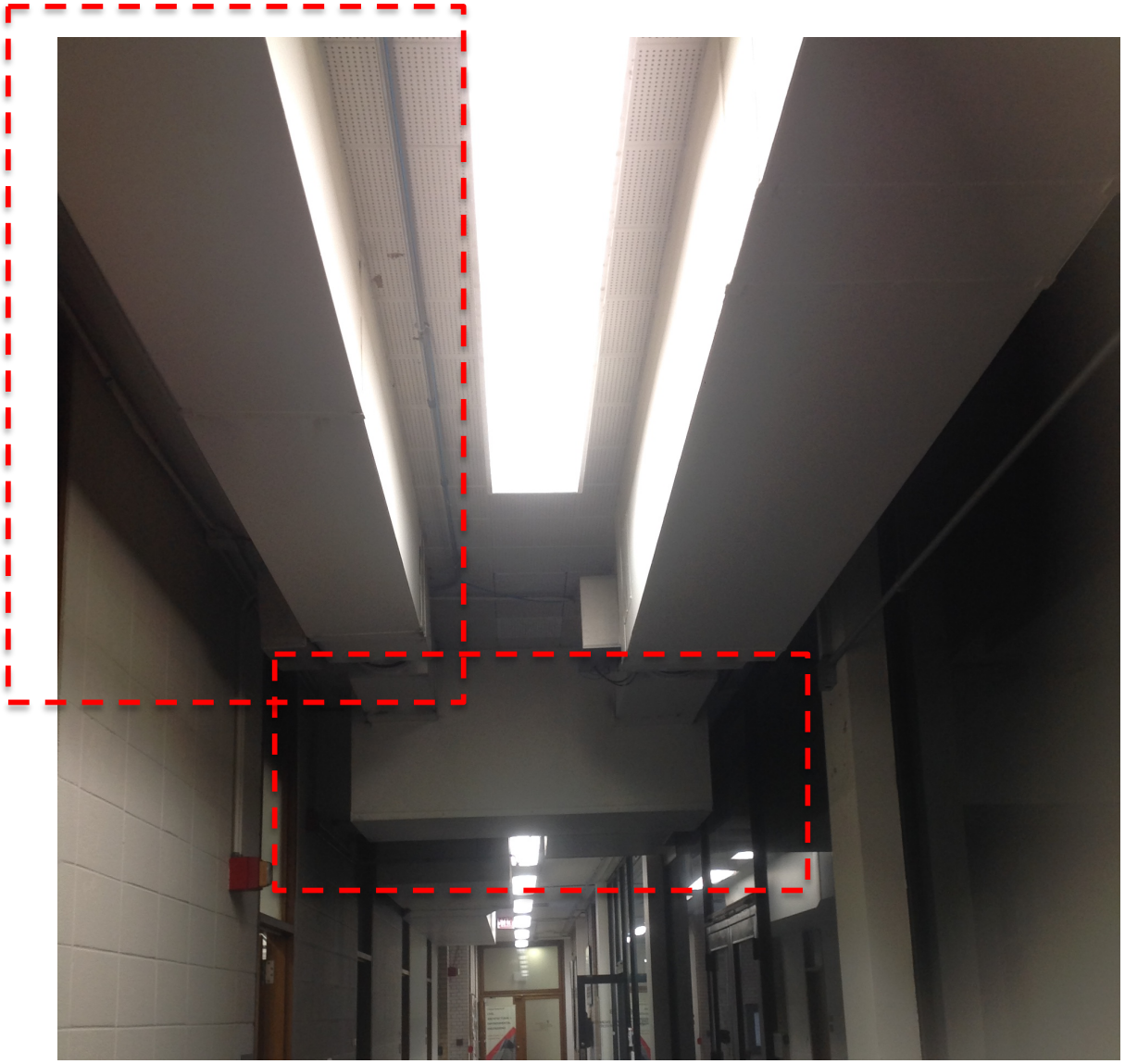


Air Distribution Systems

- Terminal boxes are located in:
  - ❑ Space above the suspended ceiling in a zone
  - ❑ Air travels from them through ductwork (flexible or rigid) to diffusers
  - ❑ There are many variations in the terminal boxes
  - ❑ The spaces above the suspended ceiling can be as a return air plenum
  - ❑ Some cases such as laboratories, there are return grills connected directly to the return air ducted named as ducted return
  - ❑ Installation of the grills need design, e.g. heat sources

Air-Distribution Systems

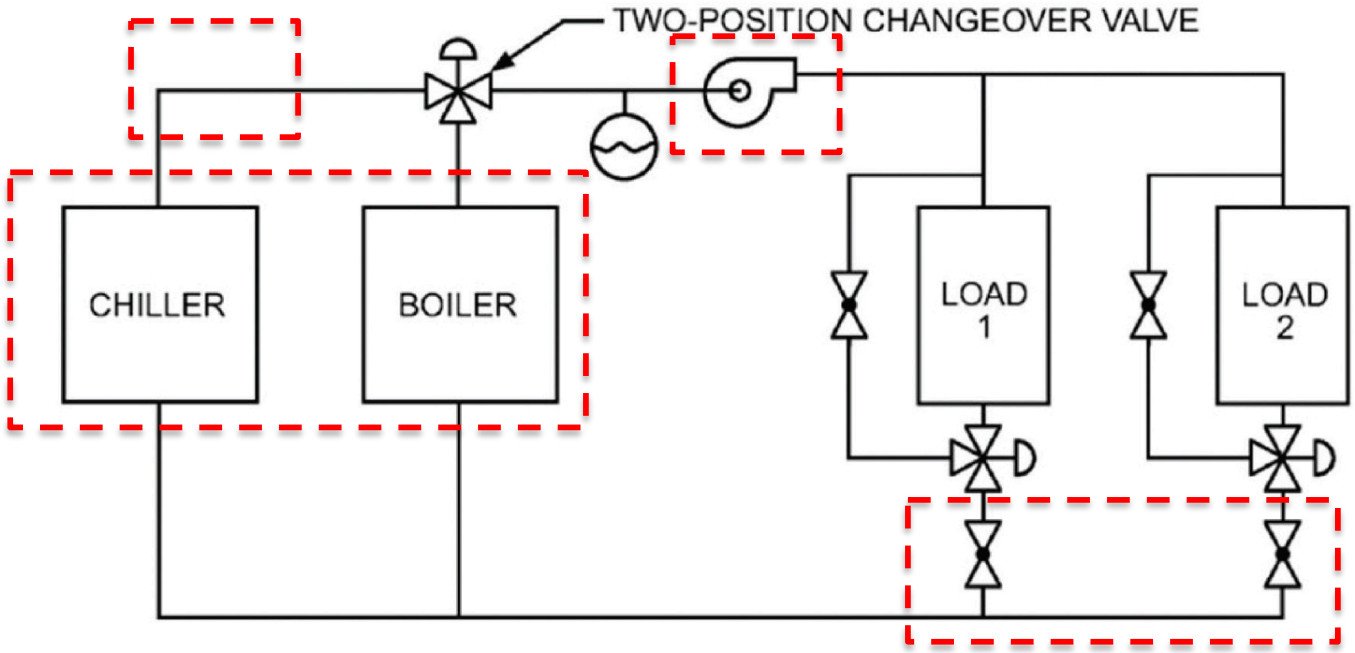
- Do we use this system at IIT?



INTRODUCTION TO AIR HYDRONIC SYSTEMS

Hydronic Systems

- **Hydronics** refers to systems focused on heating or cooling with water:
- Components of a steam or chiller water systems are:
  - ❑ Boiler or chiller
  - ❑ Piping
  - ❑ Valves
  - ❑ Pumps
  - ❑ Controls



https://insulation.org/io/articles/understanding-thermal-systems-hydronic-heating-and-cooling-systems/

Hydronic Systems

- Do we use this system at IIT?

Heating Plant



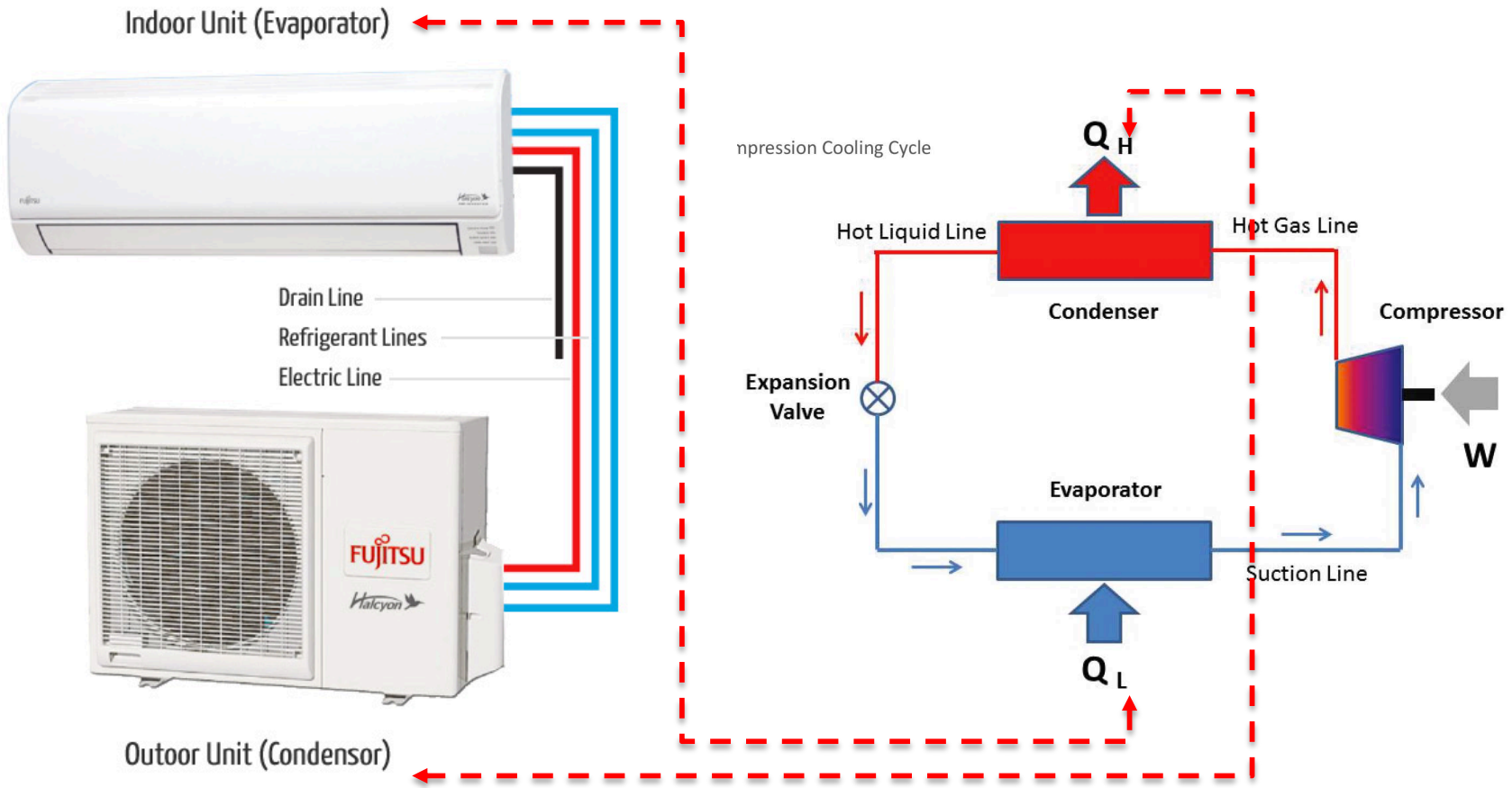
Ludwig Mies van der Rohe
Frank J. Kornacker; Alschuler & Sincere, associated architects; Sargent and Lundy, mechanical engineers
1945-50 (addition 1964)
3430 South Federal Street

http://buildinghistory.iit.edu/buildings/plant

INTRODUCTION TO REFRIGERATION SYSTEMS

Refrigeration Systems

- **Refrigeration** refers to the process of removing heat from a low-temperature reservoir and transferring it to a high-temperature reservoir

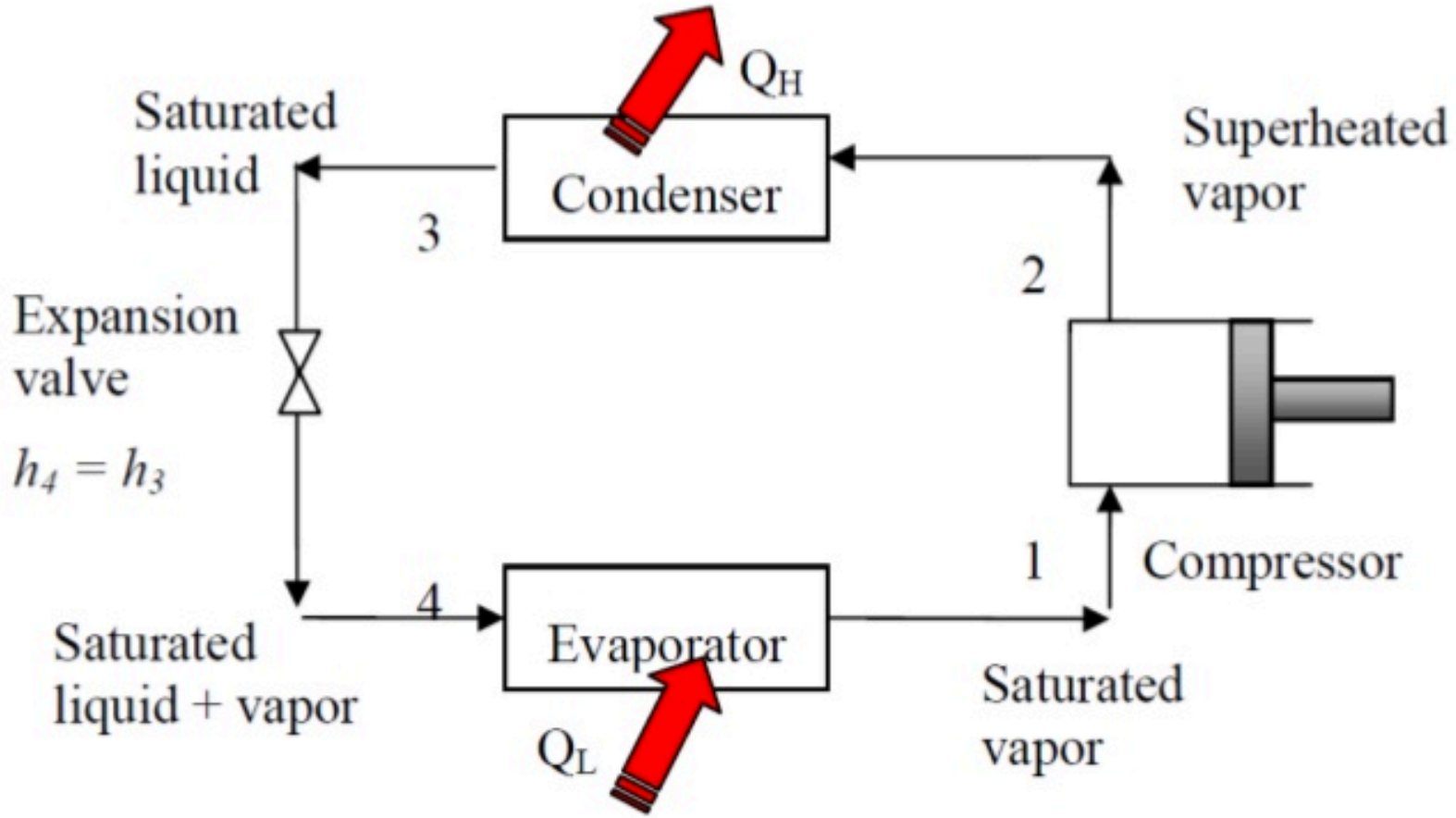


http://www.fujitsugeneral.com/us/residential/what-is-a-mini-split.html

https://insulation.org/io/articles/understanding-thermal-systems-industrial-refrigeration-systems/

Refrigeration Systems

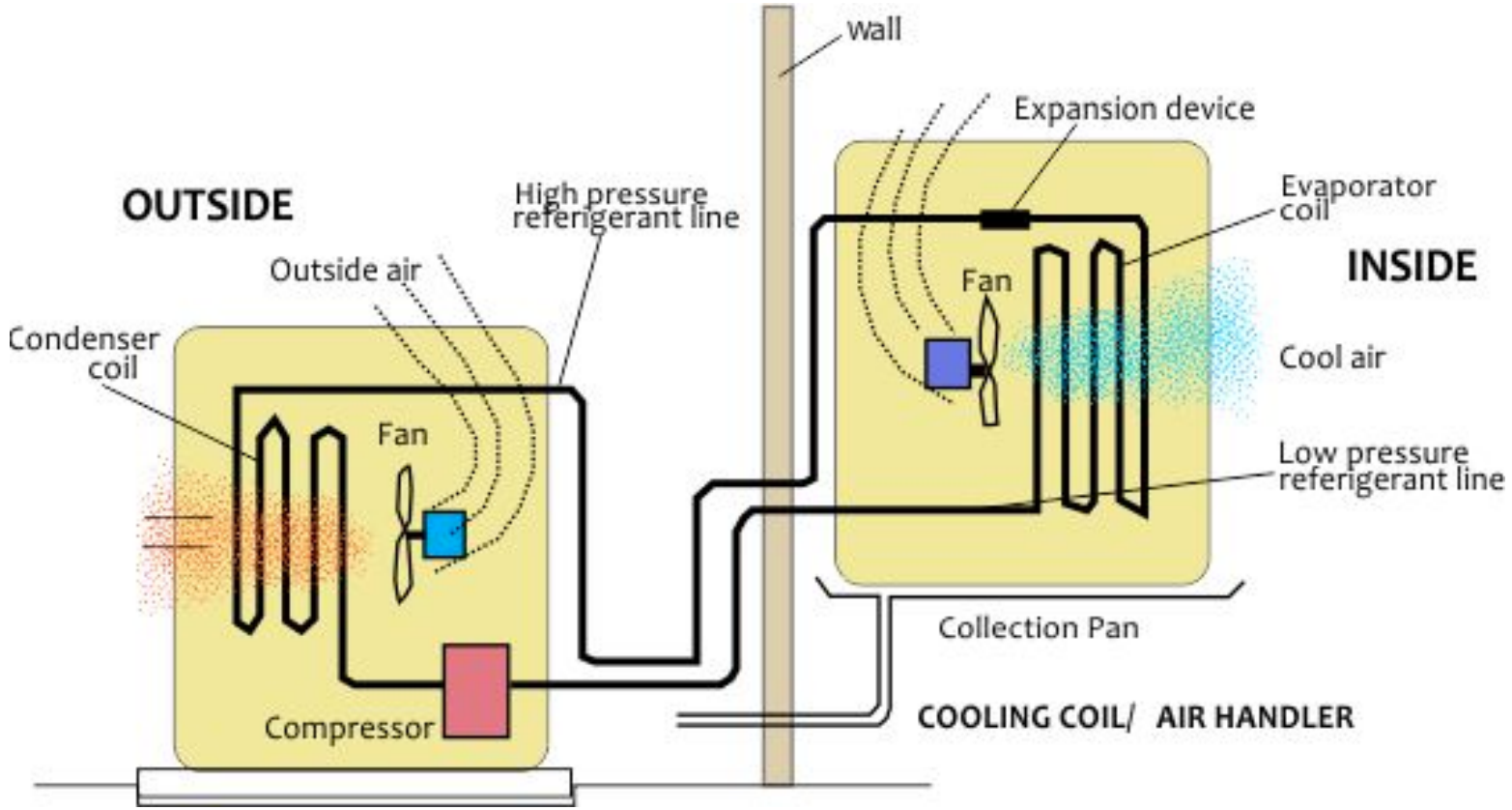
- A vapor compression cycle entails:



https://www.slideshare.net/ilovemylifesomuch/simple-vapour-compression-refrigeration-system

Refrigeration Systems

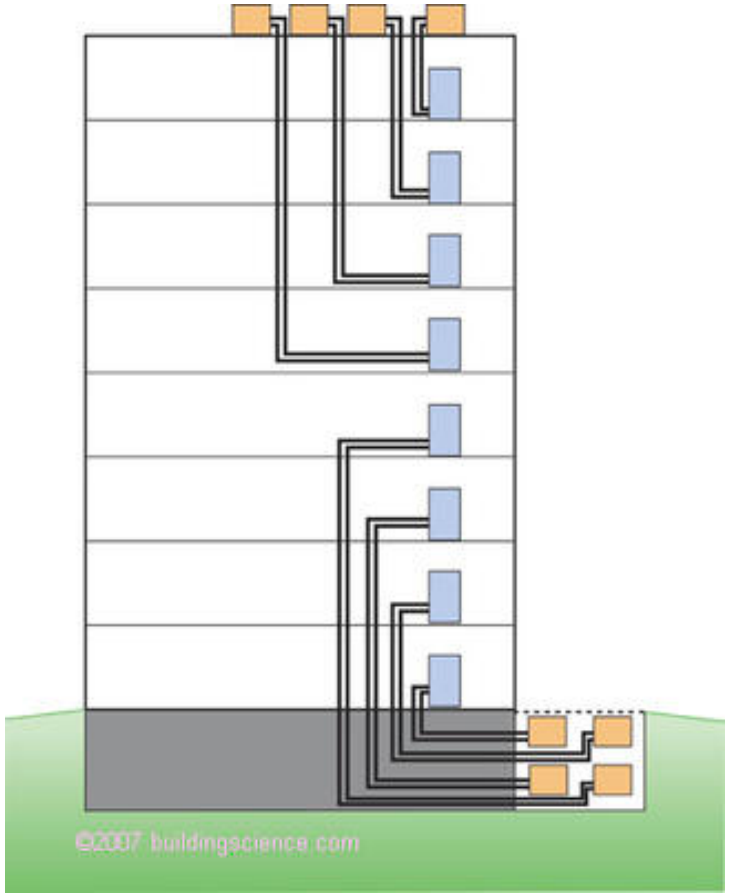
- An example of an application of the vapor compression cycle in a residential building is:



http://www.nzeb.in/knowledge-centre/hvac-2/cooling-equipment/

Refrigeration Systems

- An example of installing heat pump in a multi-family building

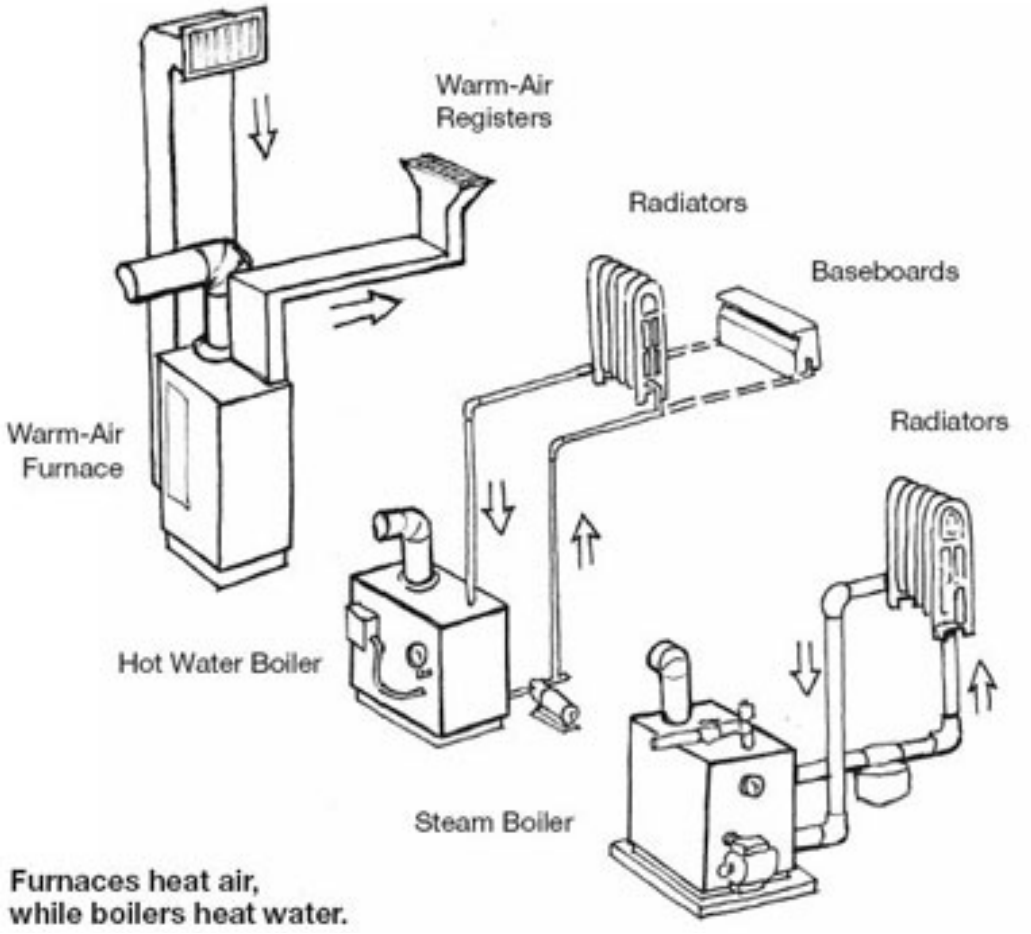


https://www.buildingscience.com/documents/digests/bsd-110-hvac-in-multifamily-buildings

INTRODUCTION TO HEATING SYSTEMS

Heating Systems

- Majority of single family homes in the U.S. use “furnace”



What’s the main difference between furnace and boiler?

https://smarterhouse.org/heating-systems/types-heating-systems

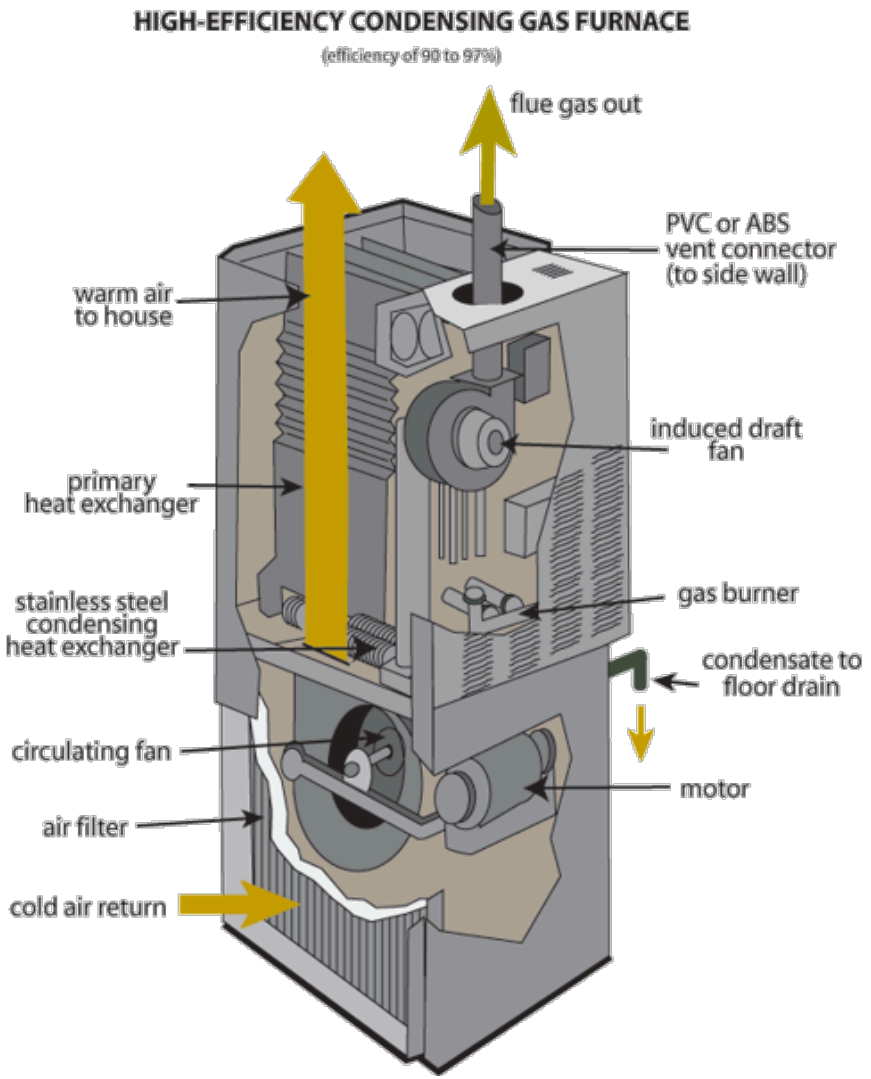
Heating Systems

- Hydronic vs electric baseboards considerations:
  - ❑ Initial cost
  - ❑ Energy efficiency
  - ❑ Performance (e.g., warm up and duration)

https://homeverity.com/hydronic-baseboard-heaters-vs-electric/
https://www.primebuyersreport.org/industry/atlantic-county-nj/atlantic-county/air-conditioning-heating-ventilation-contractors/

Heating Systems

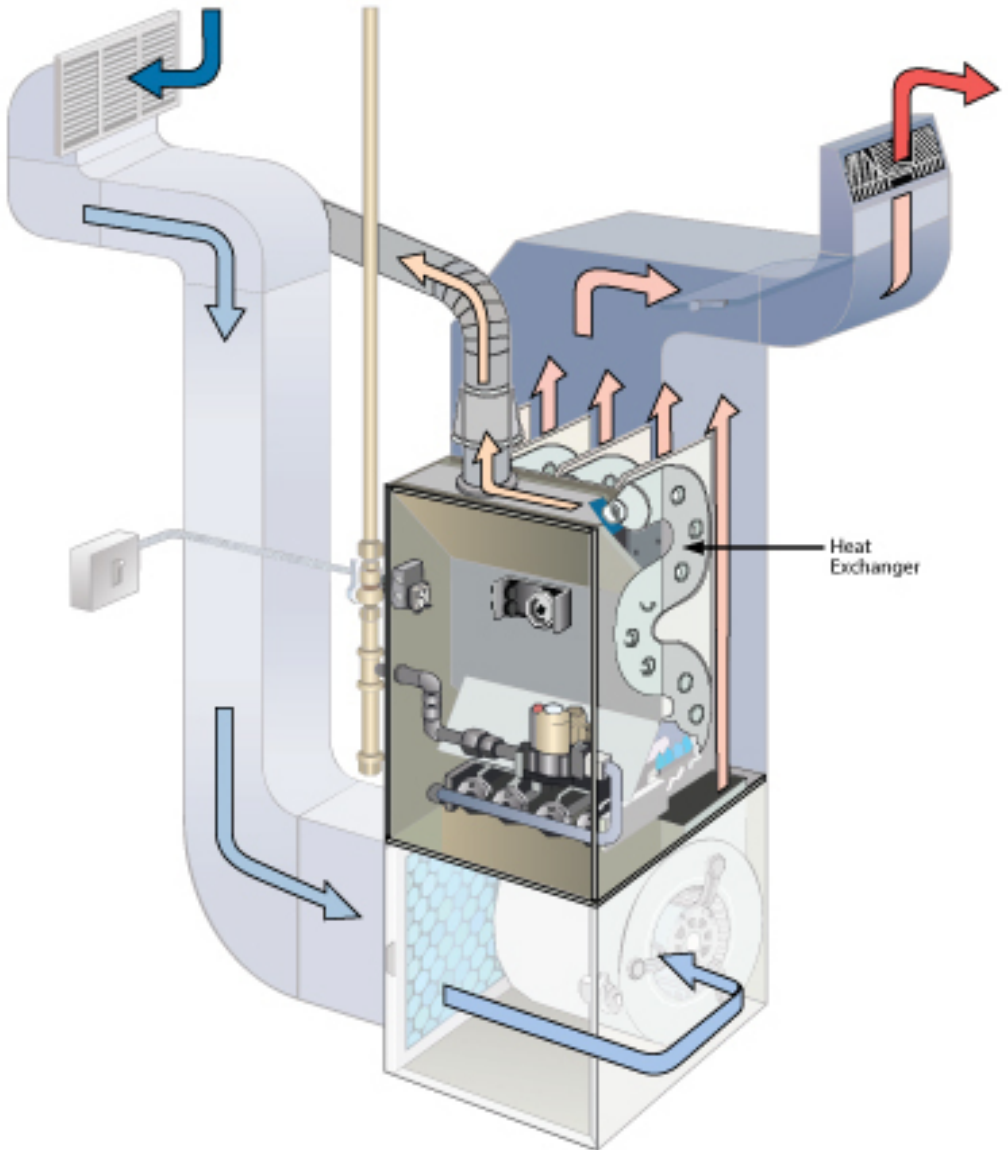
- Furnace:
  - ❑ Deliver hot air through a central furnace and ductwork to the zones through registers or grills
  - ❑ Named as a ducted warm-air or a forced warm-air distribution system
  - ❑ The combustion heat is transferred via a heat exchanger to air
  - ❑ Fan or “Blower” push the air through the ductwork
  - ❑ Vent the byproducts to atmosphere
  - ❑ Use induced fan and temperature control of exhaust (140 F) to recover energy in condensing furnaces



https://www.google.com/url?sa=i&source=images&cd=&cad=rja&uact=8&ved=2ahUKEwi-24vo4__fAhXC24MKHSeZDOIQjhx6BAgBEAM&url=https%3A%2F%2Fwww.anthonyphc.com%2Fblog%2Ffurnace-repair-in-kansas-city%2F&psig=AOvVaw3zCUG1IFn3oFEasiYMZJe2&ust=1548191182255906

Heating Systems

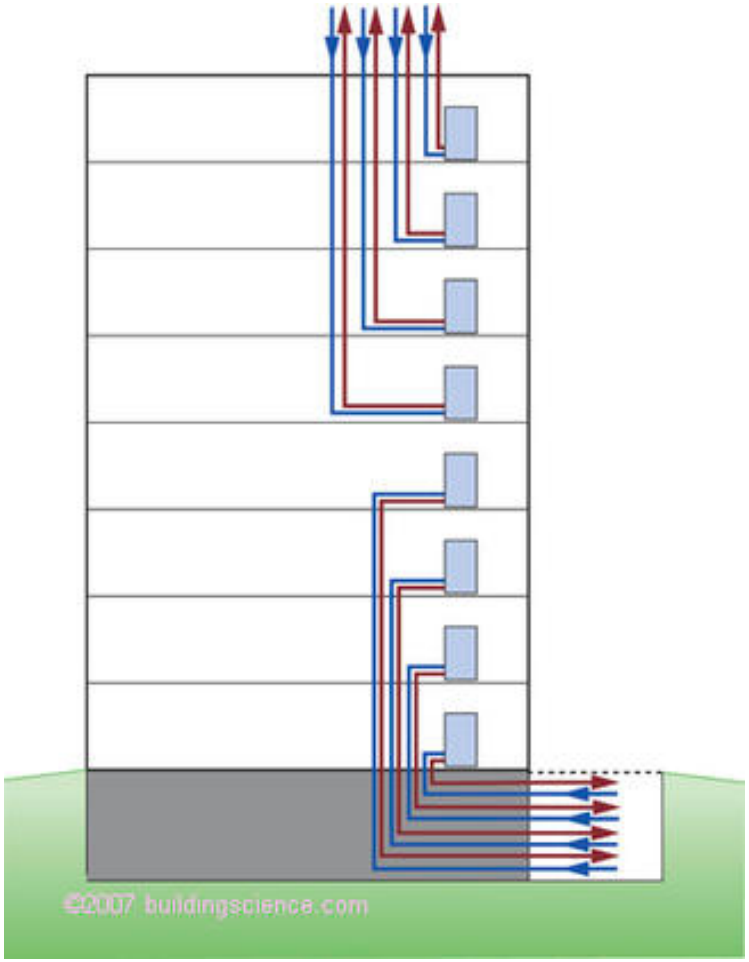
- Furnace:



https://plumblineservices.com/help-guides/how-much-does-it-cost-to-replace-a-heat-exchanger-in-denver

Heating Systems

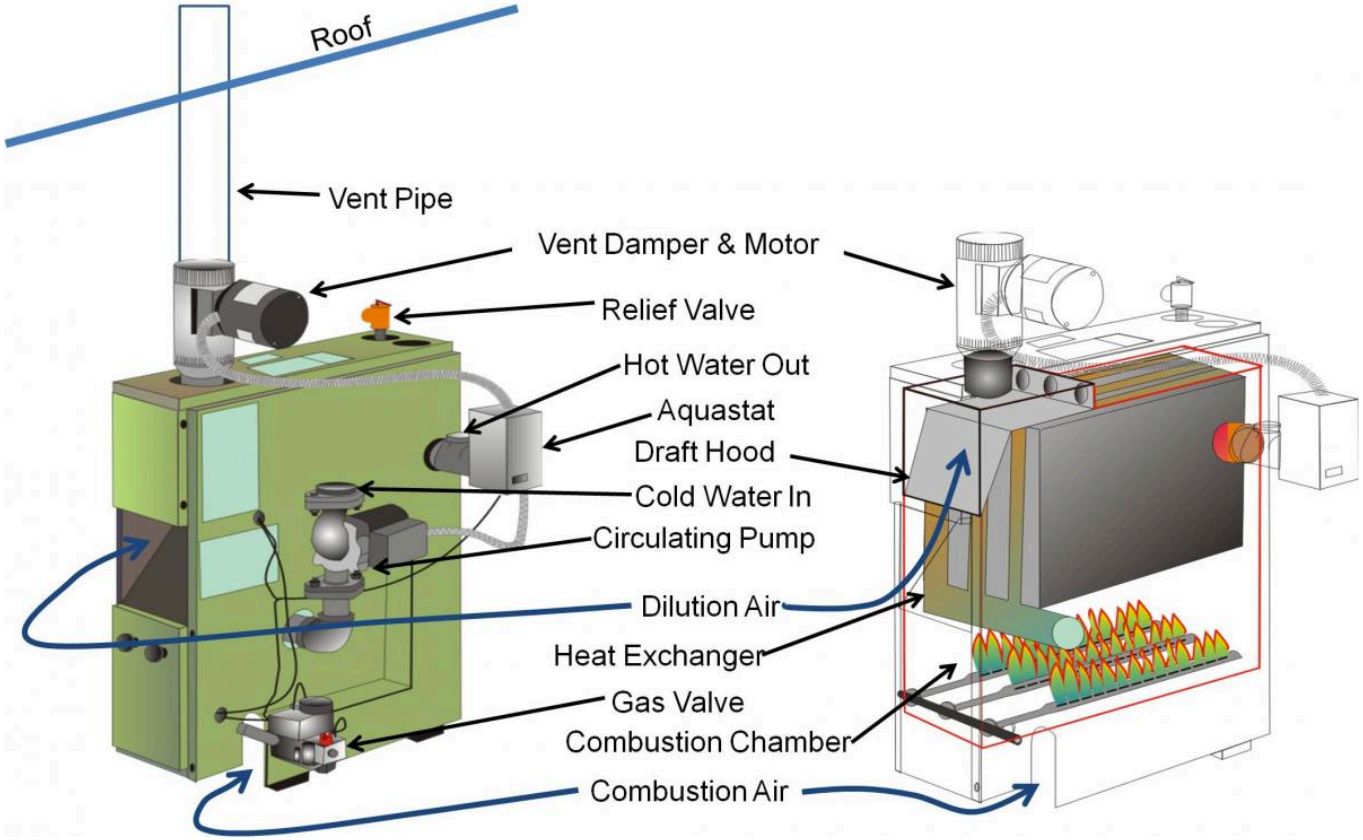
- Example of installing a furnace in a multi-family building:



https://www.buildingscience.com/documents/digests/bsd-110-hvac-in-multifamily-buildings

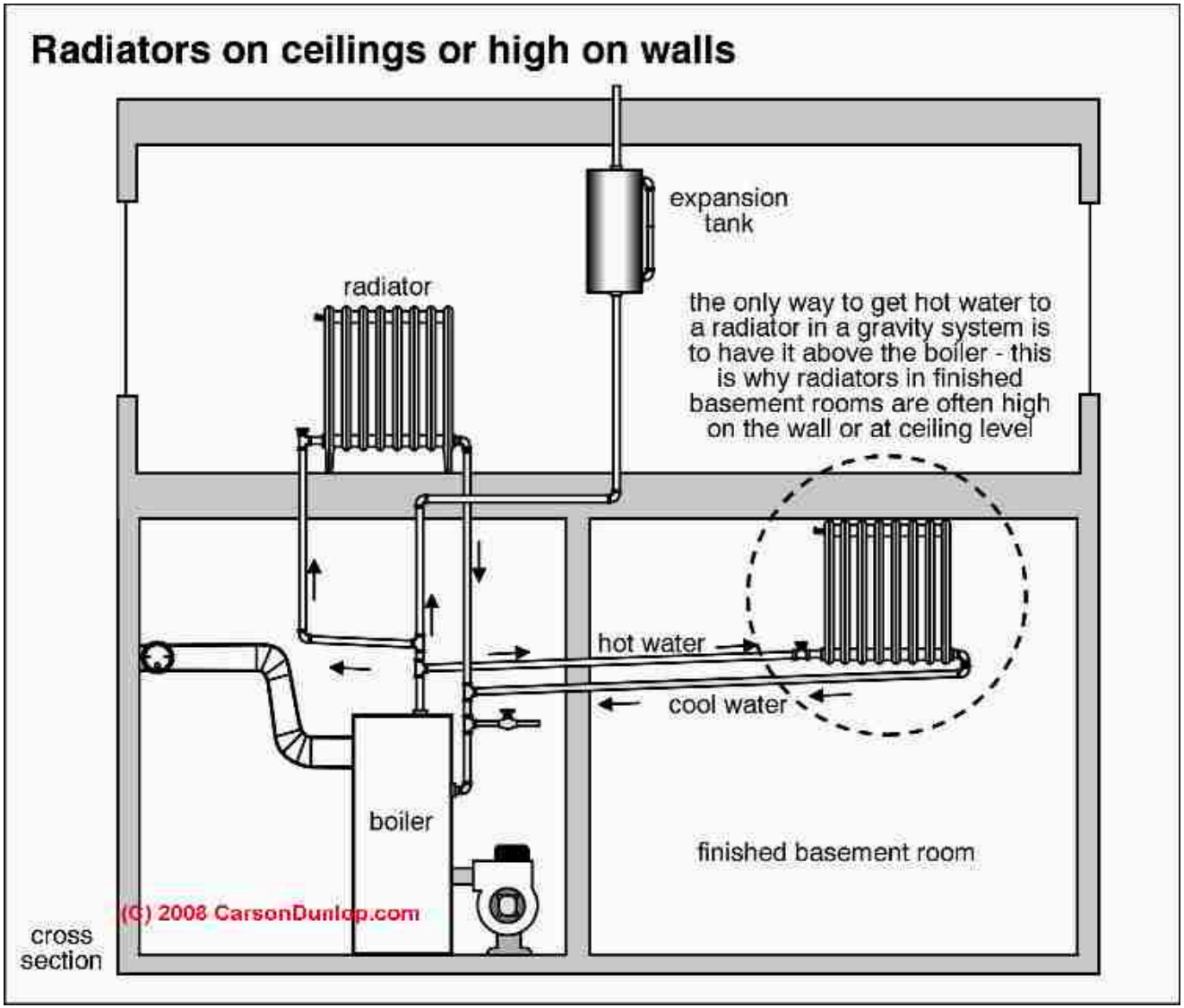
Heating Systems

- Boilers
  - ❑ Instead of air, they warm water “or steam” and distribute it
  - ❑ It is a closed system
  - ❑ Named as hydronic systems



Heating Systems

- Boilers



https://inspectapedia.com/heat/Cold_Radiator_Repair.php

Heating Systems

- Heat Pumps
  - ❑ Two types of air-source and ground-source
  - ❑ Use outside as a heat sink in summer and heat source in winter

https://smarterhouse.org/heating-systems/types-heating-systems

INTRODUCTION TO UNITARY SYSTEMS

Unitary

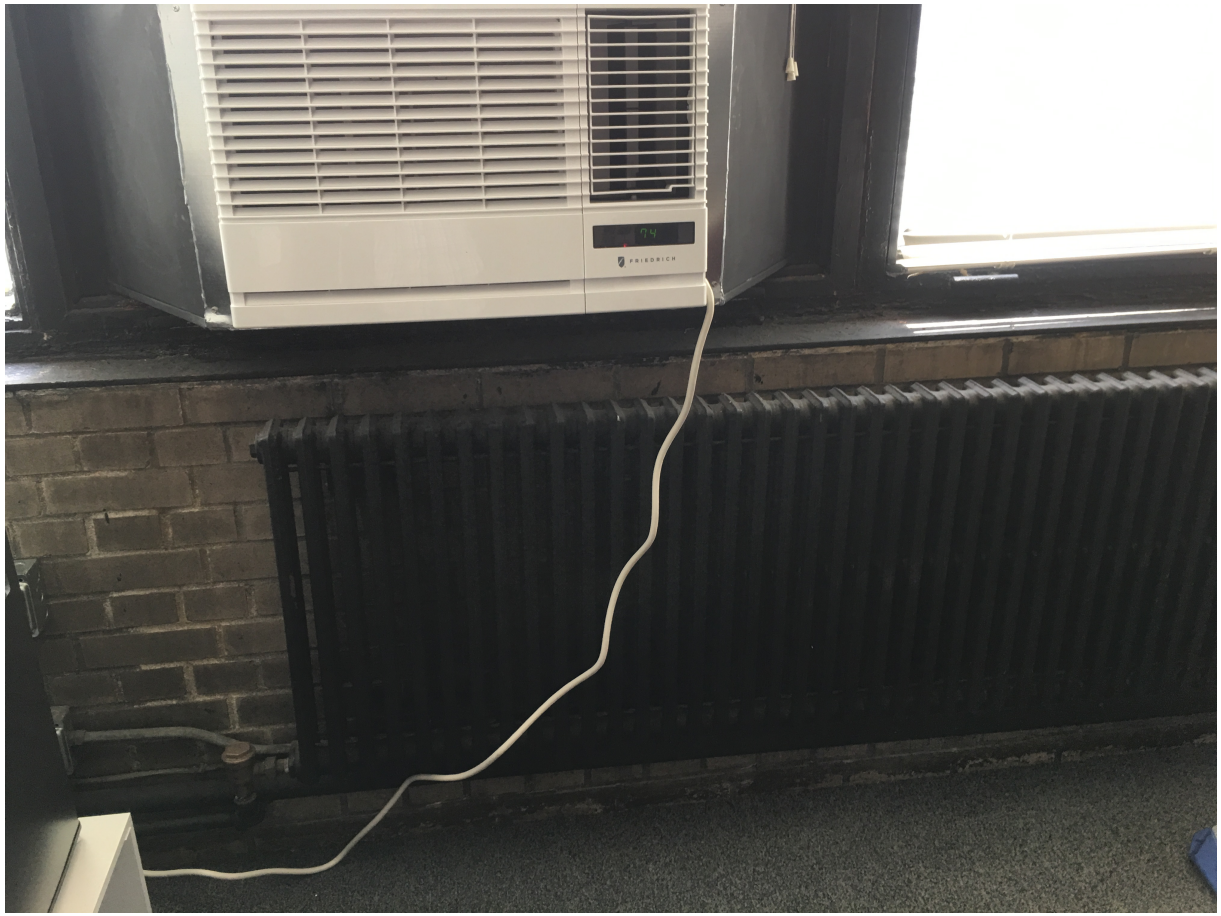
- Unitary or packaged terminal unit:
  - ❑ All components are factory assembled into major pieces (1-2 pieces)
  - ❑ Coils, fans, controls, .. are all included one major package
  - ❑ Named as decentralized system
  - ❑ Easy to install
  - ❑ Suitable for small to mid size buildings (Less than three stories)
    - ❑ Offices, motels, hotels
    - ❑ 5 to 460 kW (1.5 tons to 130 tons)
  - ❑ Lower initial cost and 10-15 years
  - ❑ Less efficient
  - ❑ Require maintenance
  - ❑ Can be used for perimeter zones

What's the main working fluid?

Can you distinguish primary and secondary systems here?

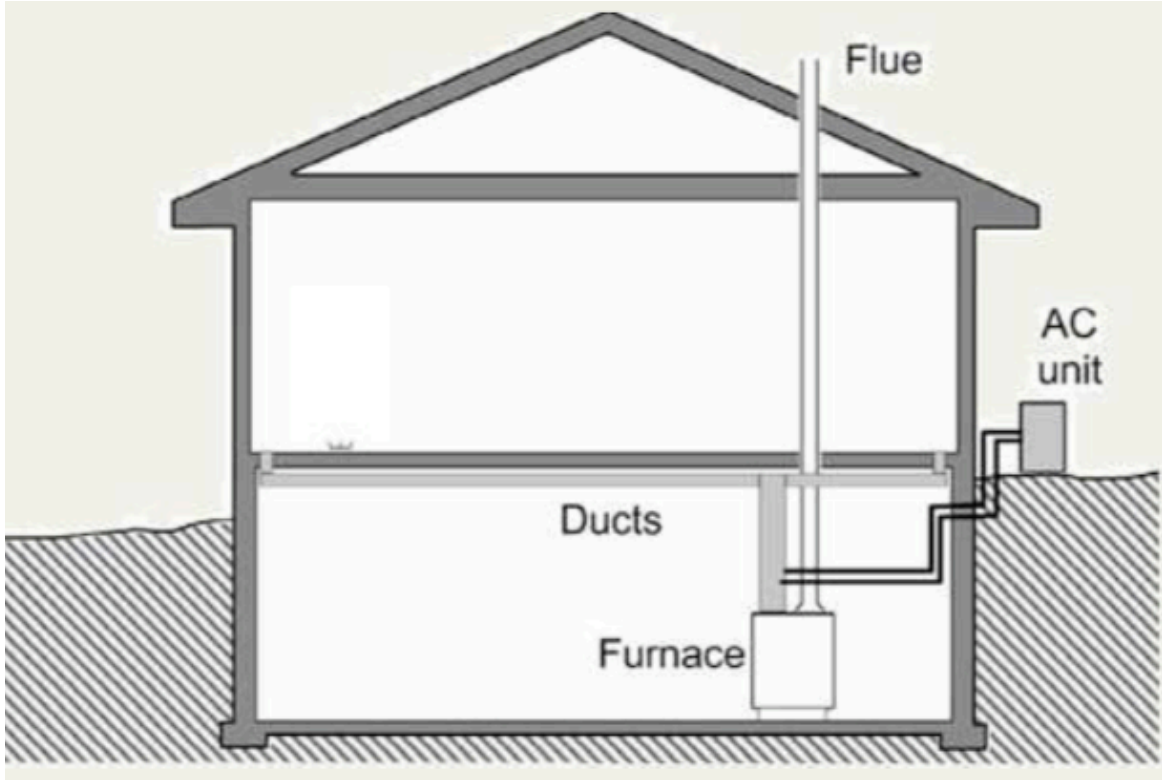
Unitary

- One type of unitary or packaged terminal unit is Packaged Terminal Air Conditioning (PTAC). For example:
  - ❑ A 15,000 BTU self-contained AC system in my office



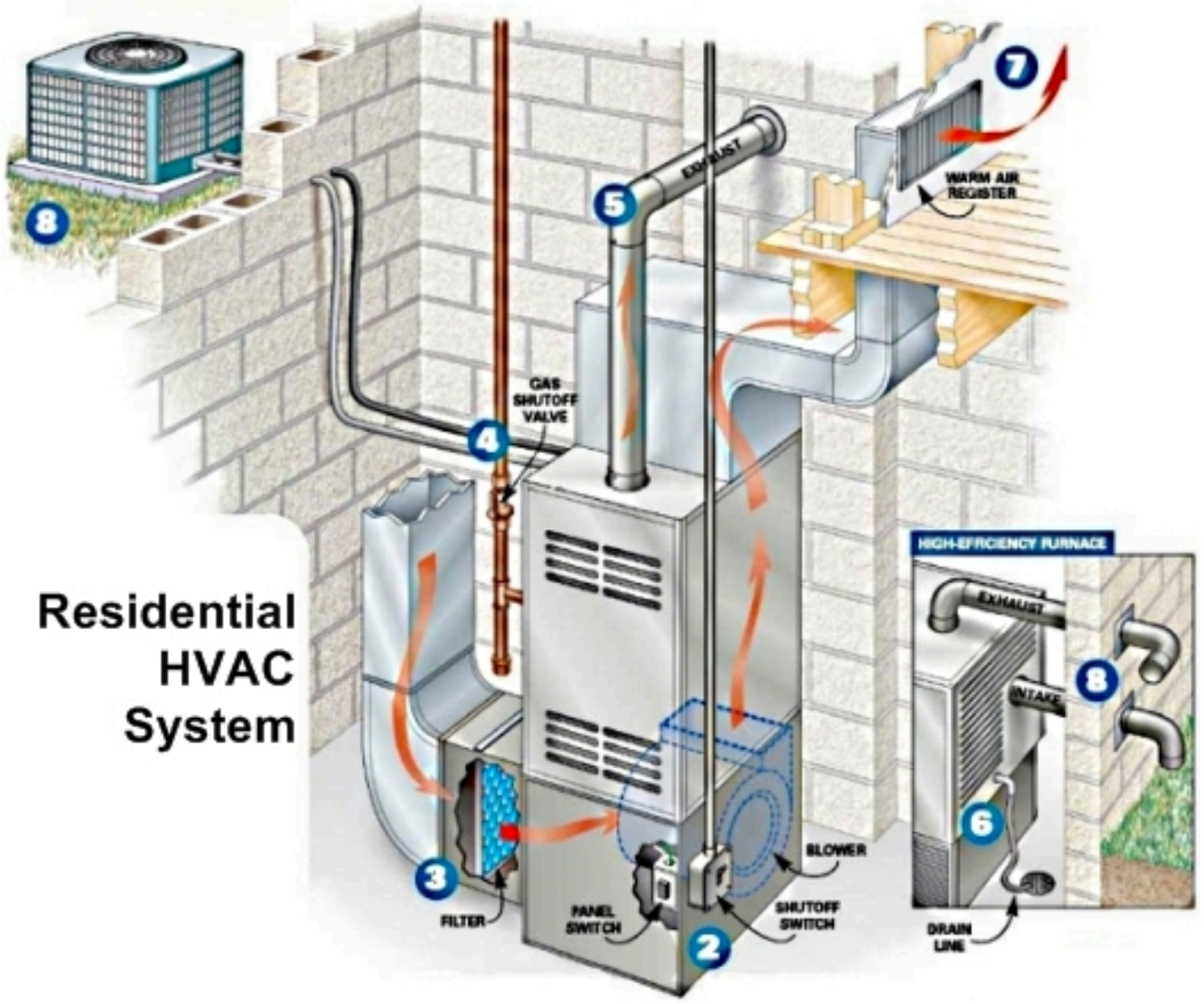
Unitary

- Residential unitary systems
  - ❑ Two separate systems:
    - Furnace: Heating
    - AC: Cooling
  - ❑ Minimum maintenance required to change filter



Unitary

- Residential unitary systems



https://alternativeaire.com/maintenance-plans/

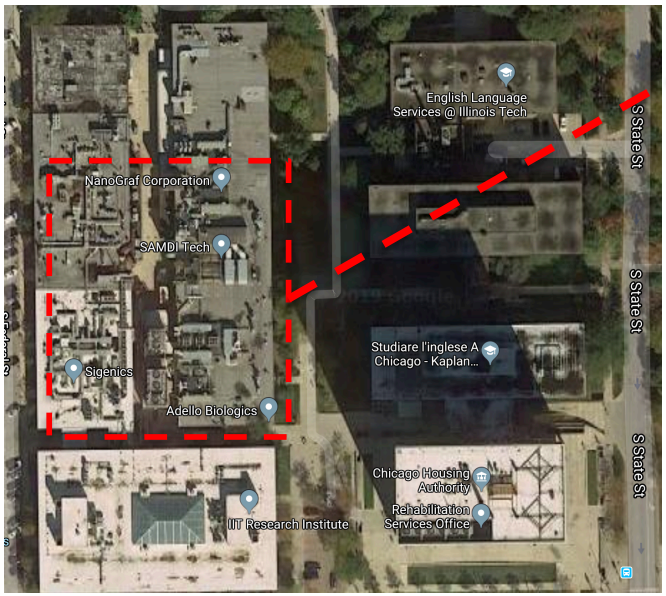
Split Systems

- Split systems:
  - ❑ Newer version of unitary systems
  - ❑ Heat transfer occurs through coils
  - ❑ Condenser coils and the compressor of the refrigerant outside
  - ❑ Evaporator coil or (DX)

https://luxuryheatingco.com/category/ductless-split-systems/

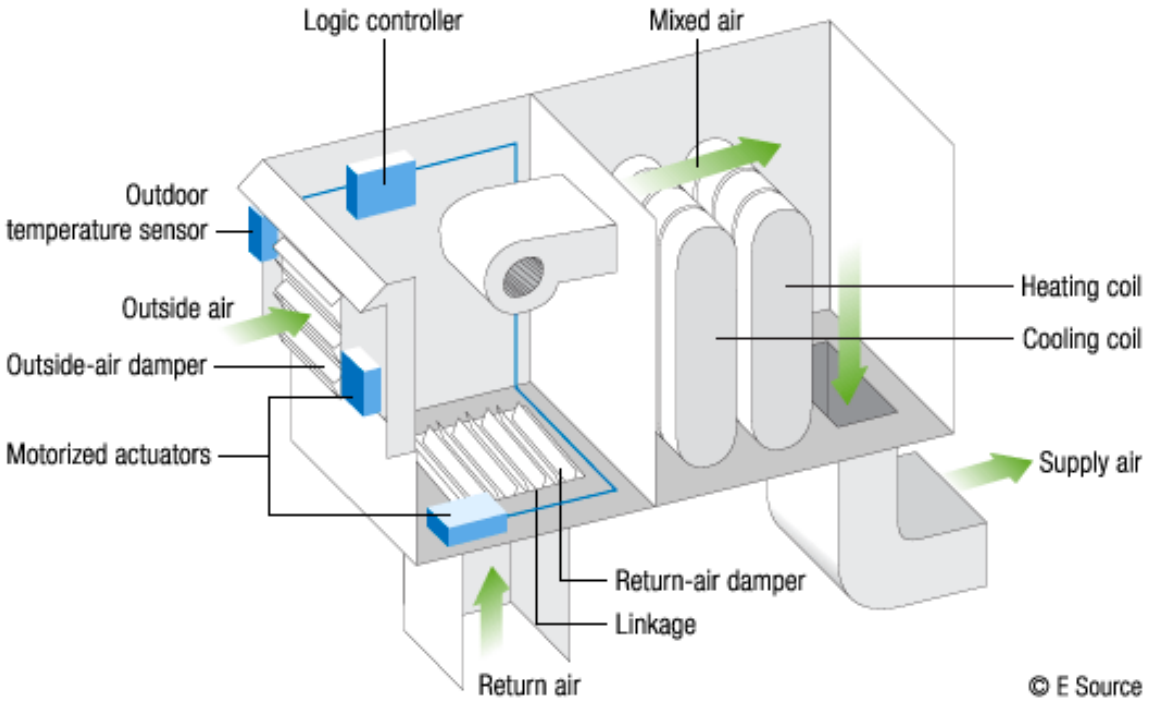
Split Systems

- What do you see here?



Unitary

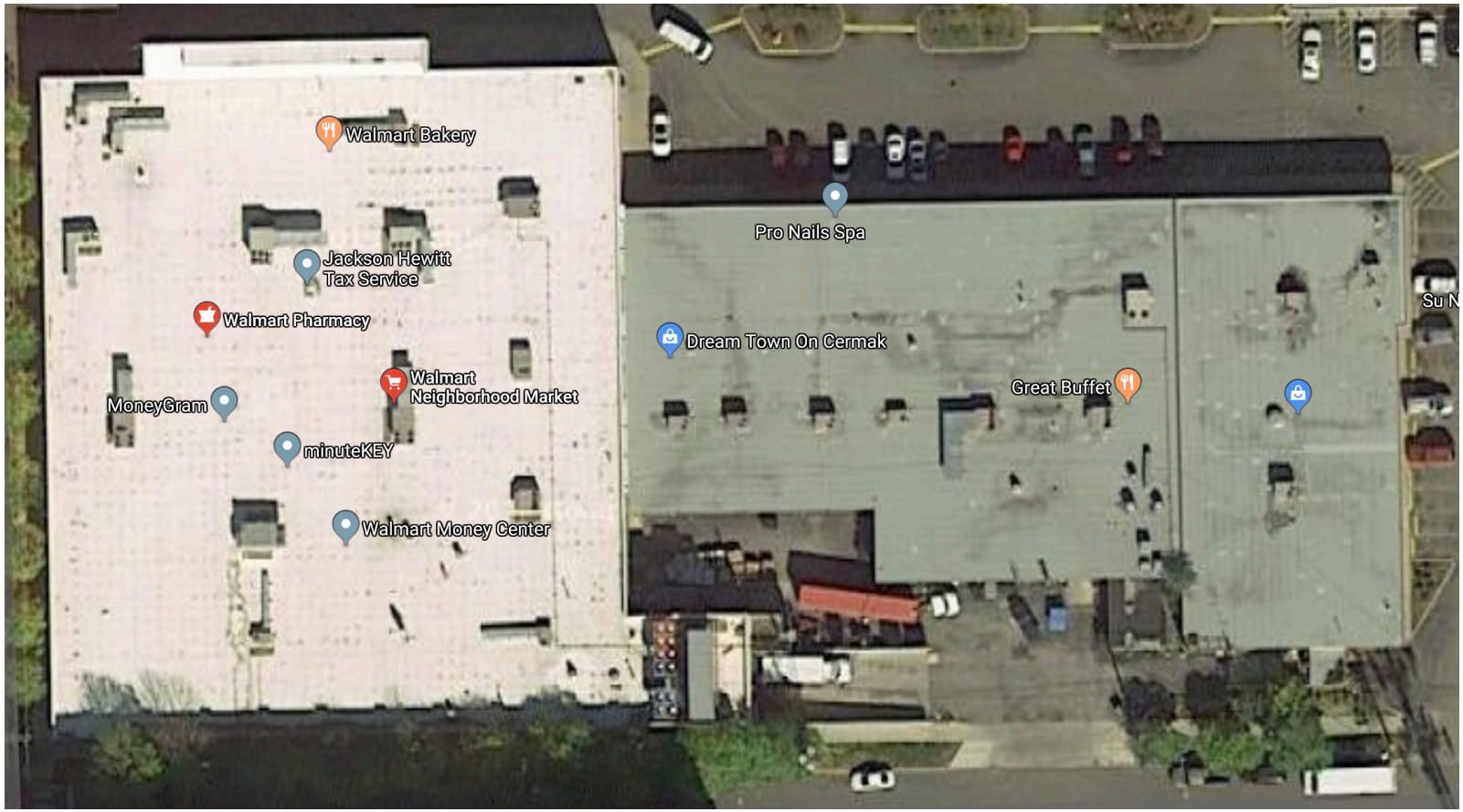
- Rooftop units or packaged unit
  - ❑ DX Coil
  - ❑ Gas heating



https://ouc.bizenergyadvisor.com/article/economizers
https://www.shipleyenergy.com/commercial/hvac-services/installations/rooftop-hvac-units

Unitary

- Rooftop units or package unit
  - ❑ Suitable for store boxes “retail” or low-rise offices
  - ❑ Can serve different zones



Packaged Equipment

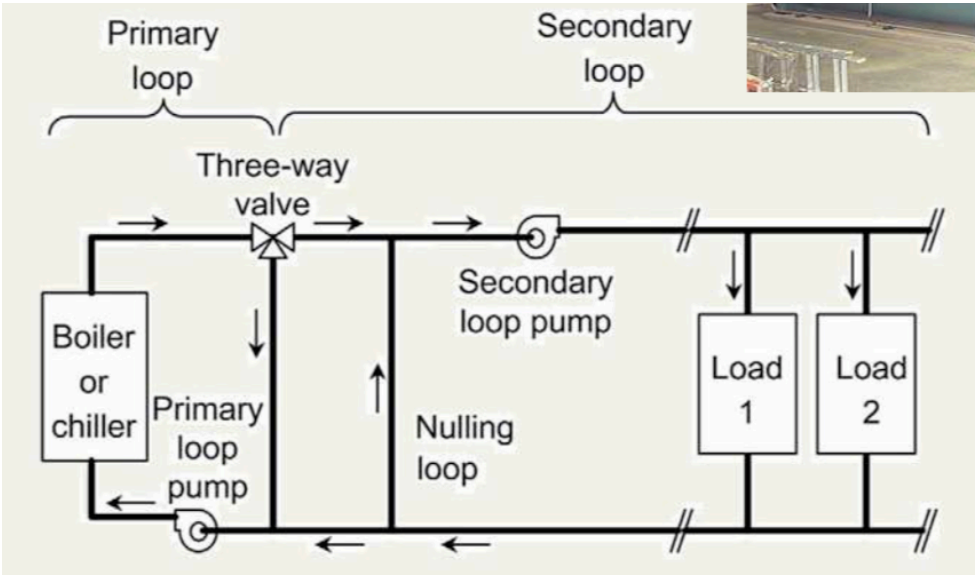
- Advantages and disadvantages of packaged equipment

Disadvantages	Advantages
Limited performance due to fixed sizing	Individual control is allowed
Limited humidity control	Simultaneous heating and cooling
Mostly on-off meaning swing in room temperature	Ventilation can be included
Short life span	Certified capacity by the manufacturer
Less efficient due to oversizing	Turn off units for unoccupied zones
Limited air distribution option	Simple operation
Complexity in using economizers	Low first cost
Noisy	No duct work
Pooe aesthetics	Simple installation
Limited air filtering options	
Maintenance issues	

INTRODUCTION TO CENTRALIZED SYSTEMS

Centralized Systems

- Centralized systems:
  - ❑ Include various components and contractor needs to put together the system
  - ❑ Suitable for medium to large buildings
  - ❑ Hydronic system is an example of this system
    - ❑ Radiators are obsolete
    - ❑ More efficient heat transfer are fan coil units



Centralized Systems

- Centralized systems:

https://www.123rf.com/photo_92933742_central-heating-and-cooling-system-control-in-a-boiler-room-.html

INTRODUCTION TO DISTRICT SYSTEMS

District Systems

- District systems:
  - ❑ Usually requires for campuses and neighborhoods
  - ❑ Suitable for a collection of building with different load profiles
  - ❑ Include different loops, chilled water or steam loops
  - ❑ Typically well-insulated or buried
  - ❑ Heat transfer at the building level
  - ❑ Primary loop setpoint 35 ºF to 45 ºF (1.7 ºC to 7.2 ºC) about 5 ºF to 10 ºF (2.7 ºC to 5.5 ºC) below the secondary temperature 40 ºF to 50 ºF (4.4 ºC to 10 ºC)

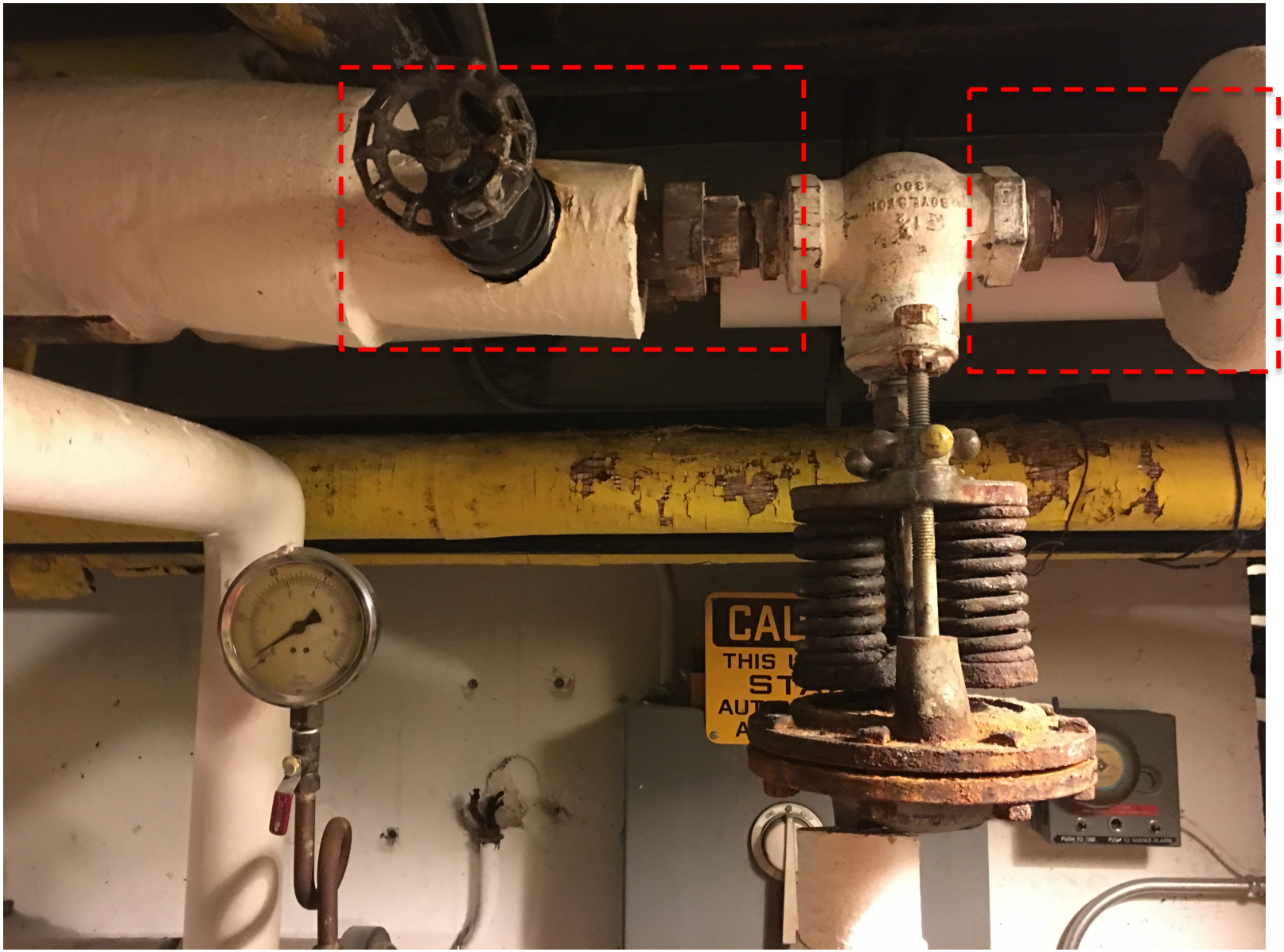
District Systems

- IIT Heating plant

District Systems

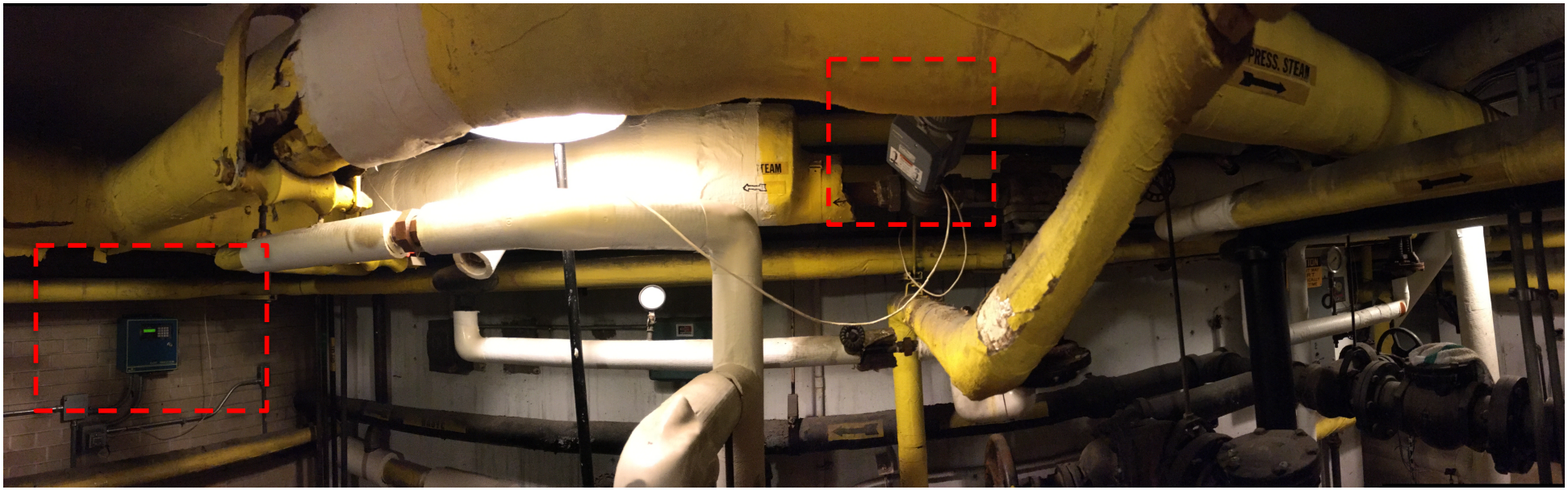
- Alumni Hall and Herman Hall buildings steam system

District Systems



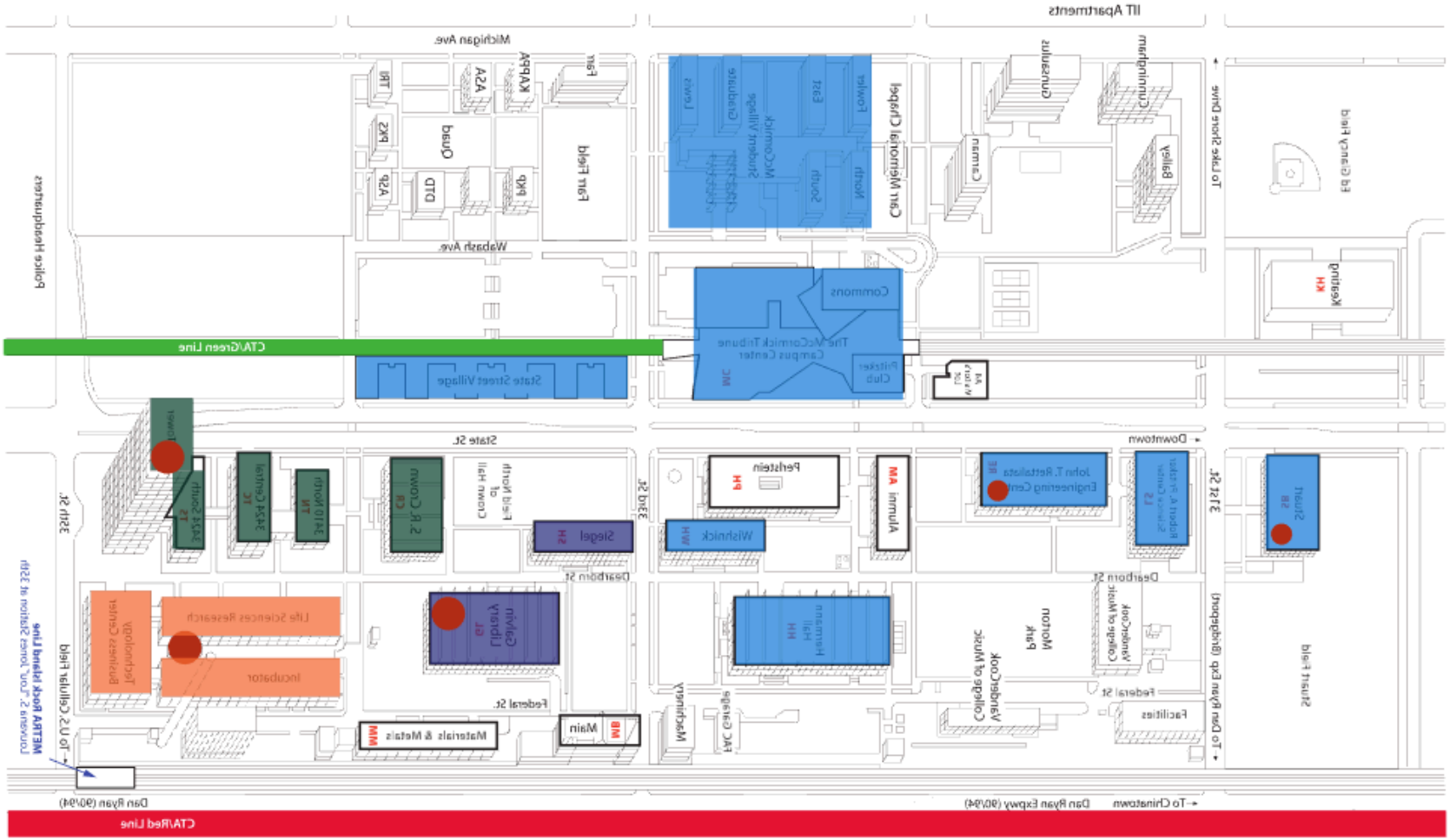
District Systems

- Alumni Hall and Herman Hall buildings steam system



District Systems

- IIT Cooling plant



Brian Bozell Presentation

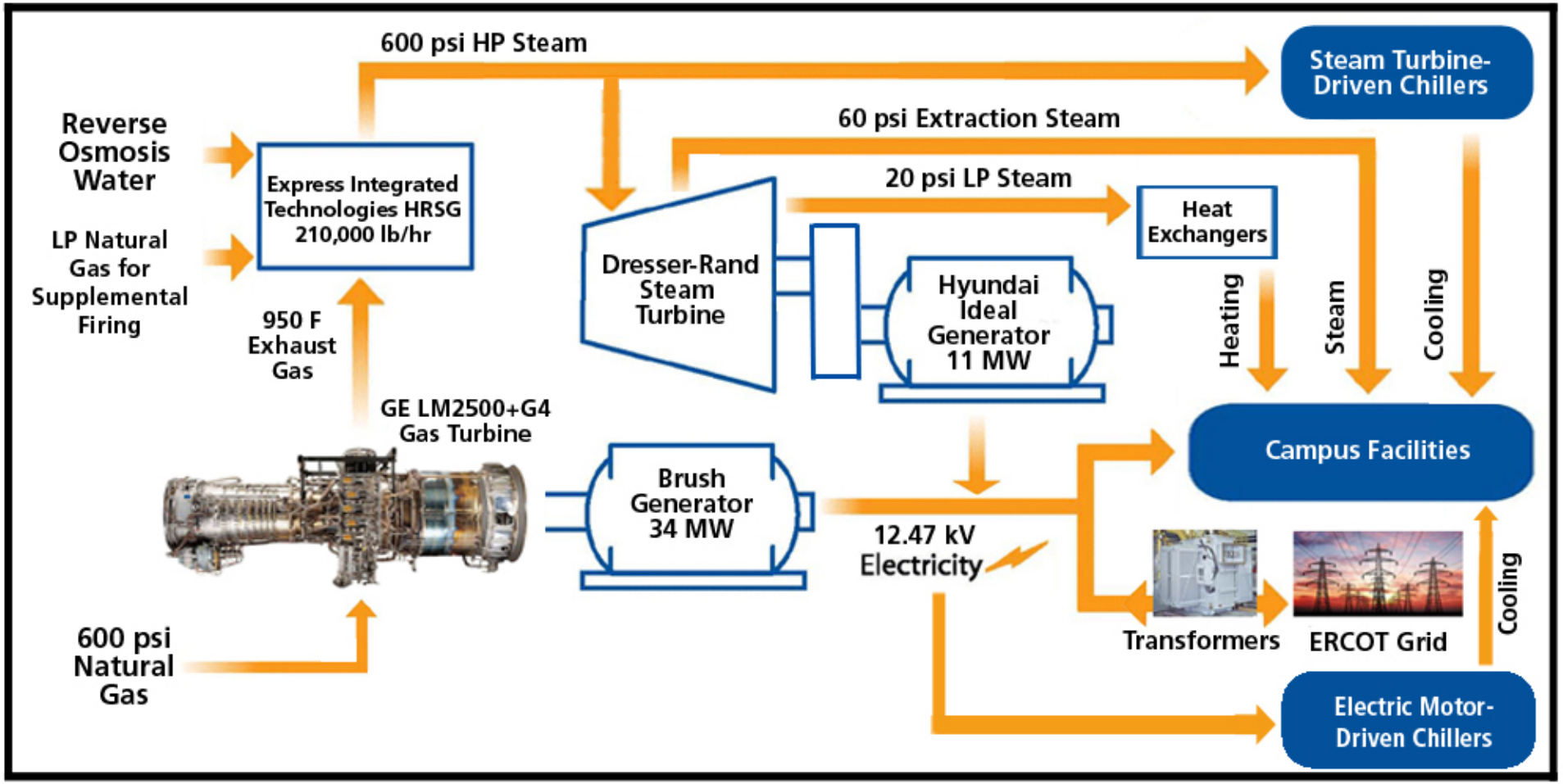
District Systems

- Example of other campuses: Hershey Medical Center
  - Three chiller plants
  - 12 chillers
  - Cool 2.6 million square feet
  - Two hospitals, five institutes and College of Medicine

https://www.hfmmagazine.com/articles/2925-hershey-medical-center-chiller-plant-optimization-cuts-energy-use-costs

District Systems

- A combined heat and power example at a campus:



https://utilities.tamu.edu/combined-heat-power/

HVAC SYSTEM DRAWINGS

HVAC System Drawings

- Please, see Chapter 38 of ASHRAE Fundamentals: Abbreviations and Symbols. This chapter entails:

  - ❑ Abbreviations
  - ❑ Letter symbols
  - ❑ Graphical symbols

HVAC System Drawings

- Few examples of the graphical symbols:

Refrigeration

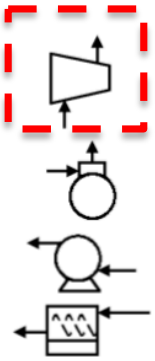
Compressors

Centrifugal

Reciprocating

Rotary

Rotary screw

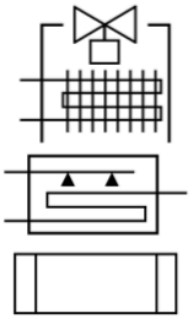


Condensers

Air cooled

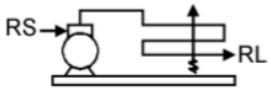
Evaporative

Water cooled, (specify type)



Condensing Units

Air cooled[b]



Air Moving Devices and Components

***Fans* (indicate use)[a]**

Axial flow

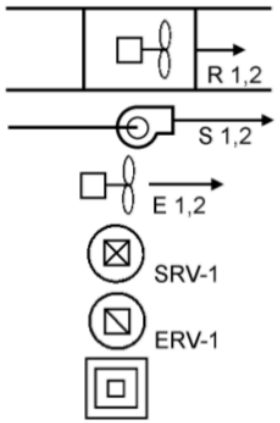
Centrifugal

Propeller

Roof ventilator, intake

Roof ventilator, exhaust

Roof ventilator, louvered



***Ductwork*[b]**

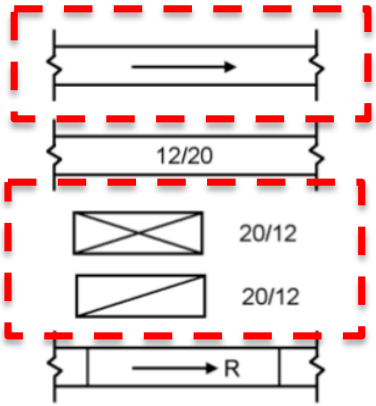
Direction of flow

Duct size, first figure is side down

Duct section, positive pressure, first figure is top

Duct section, negative pressure

Change of elevation rise (R) drop (D)

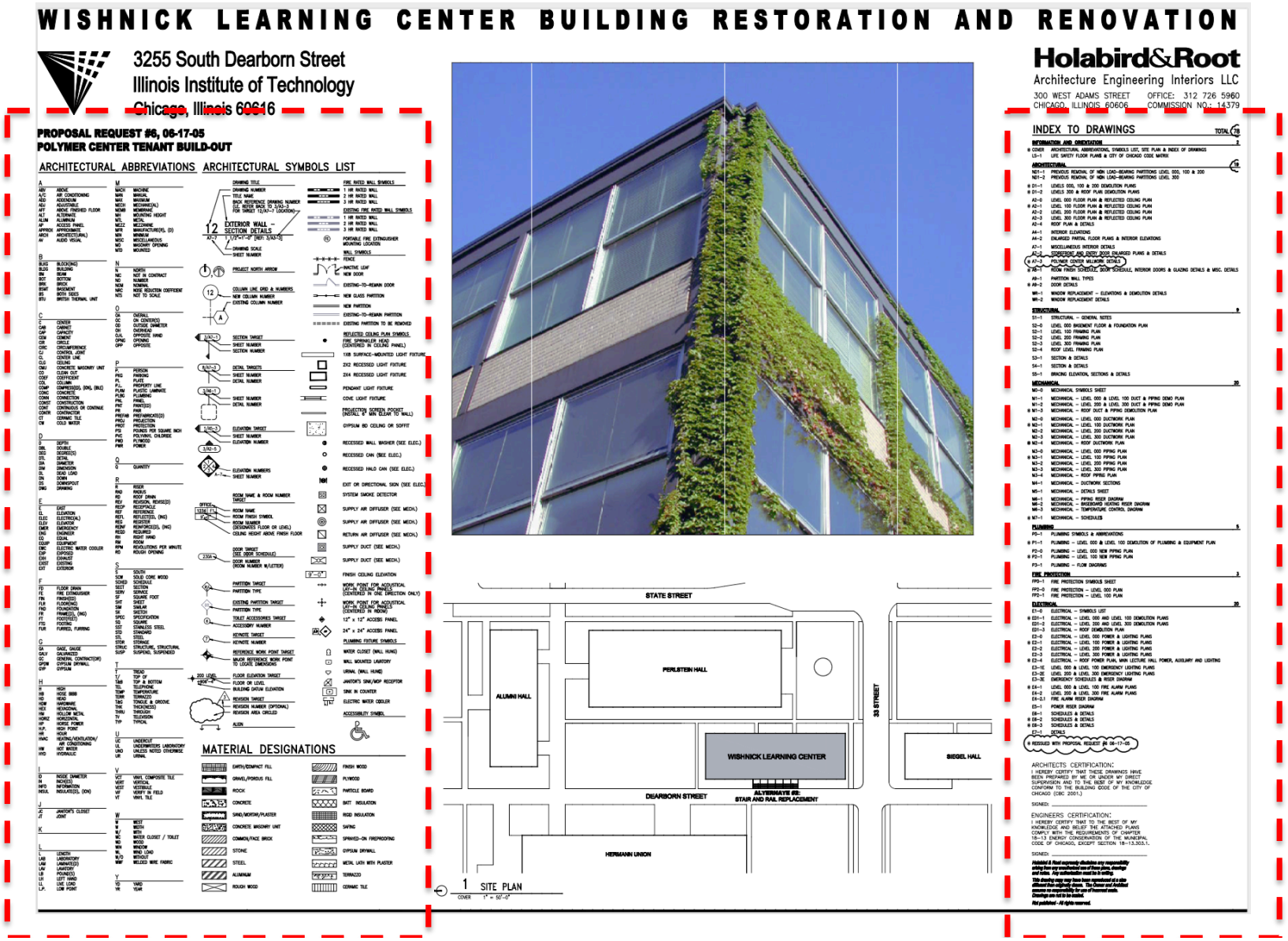


HVAC System Drawings

- It is a good practice in the drawings to:
  - ❑ Include list of all drawing files in the drawing cover page
  - ❑ Name files based on the file number, building name, drawing type
    - A: Architectural
    - S: Structural
    - M: Mechanical
  - ❑ Pay attention to the example drawings provided for Wishnick Hall
    - ❑ Files are available on Blackboard
    - ❑ “0-0”: Symbols
    - ❑ “1-x”: Ductwork (If there is a demolition plan it is usually 1-x and the rest start at 2-x)
    - ❑ “3-x”: Piping
    - ❑ “4-x”: Sections
    - ❑ “5-x”: Controls (It can go to “6-x” and more than that)
    - ❑ “6-x”: Mechanical schedules (It is the last one usually)

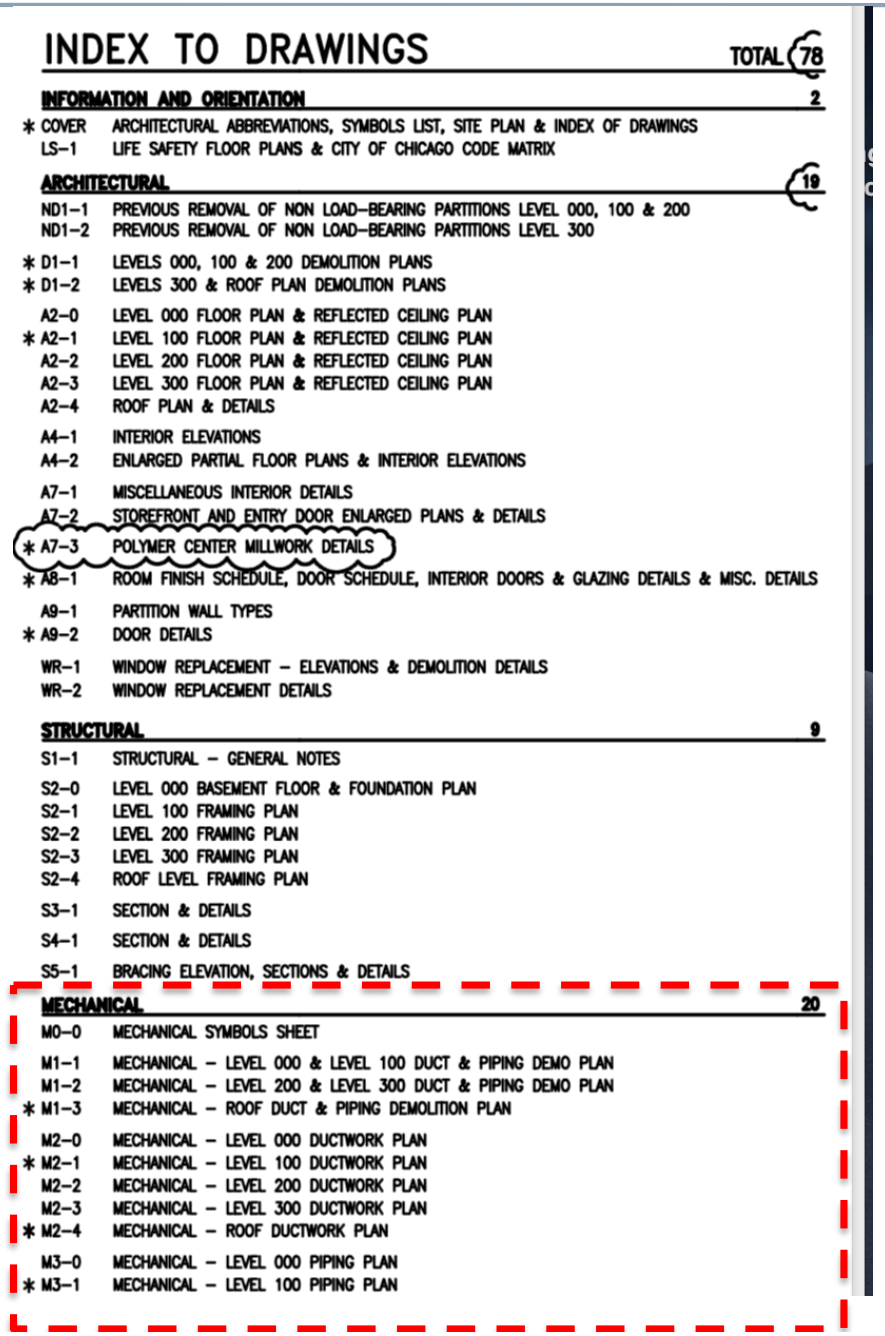
HVAC System Drawings

- Wishnick Hall



HVAC System Drawings

- Wishnick Hall



INDEX TO DRAWINGS

TOTAL 78

INFORMATION AND ORIENTATION 2

*	COVER	ARCHITECTURAL ABBREVIATIONS, SYMBOLS LIST, SITE PLAN & INDEX OF DRAWINGS
	LS-1	LIFE SAFETY FLOOR PLANS & CITY OF CHICAGO CODE MATRIX

ARCHITECTURAL 19

	ND1-1	PREVIOUS REMOVAL OF NON LOAD-BEARING PARTITIONS LEVEL 000, 100 & 200
	ND1-2	PREVIOUS REMOVAL OF NON LOAD-BEARING PARTITIONS LEVEL 300
*	D1-1	LEVELS 000, 100 & 200 DEMOLITION PLANS
*	D1-2	LEVELS 300 & ROOF PLAN DEMOLITION PLANS
	A2-0	LEVEL 000 FLOOR PLAN & REFLECTED CEILING PLAN
*	A2-1	LEVEL 100 FLOOR PLAN & REFLECTED CEILING PLAN
	A2-2	LEVEL 200 FLOOR PLAN & REFLECTED CEILING PLAN
	A2-3	LEVEL 300 FLOOR PLAN & REFLECTED CEILING PLAN
	A2-4	ROOF PLAN & DETAILS
	A4-1	INTERIOR ELEVATIONS
	A4-2	ENLARGED PARTIAL FLOOR PLANS & INTERIOR ELEVATIONS
	A7-1	MISCELLANEOUS INTERIOR DETAILS
	A7-2	STOREFRONT AND ENTRY DOOR ENLARGED PLANS & DETAILS
*	A7-3	POLYMER CENTER MILLWORK DETAILS
*	A8-1	ROOM FINISH SCHEDULE, DOOR SCHEDULE, INTERIOR DOORS & GLAZING DETAILS & MISC. DETAILS
	A9-1	PARTITION WALL TYPES
*	A9-2	DOOR DETAILS
	WR-1	WINDOW REPLACEMENT - ELEVATIONS & DEMOLITION DETAILS
	WR-2	WINDOW REPLACEMENT DETAILS

STRUCTURAL 9

	S1-1	STRUCTURAL - GENERAL NOTES
	S2-0	LEVEL 000 BASEMENT FLOOR & FOUNDATION PLAN
	S2-1	LEVEL 100 FRAMING PLAN
	S2-2	LEVEL 200 FRAMING PLAN
	S2-3	LEVEL 300 FRAMING PLAN
	S2-4	ROOF LEVEL FRAMING PLAN
	S3-1	SECTION & DETAILS
	S4-1	SECTION & DETAILS
	S5-1	BRACING ELEVATION, SECTIONS & DETAILS

MECHANICAL 20

	M0-0	MECHANICAL SYMBOLS SHEET
	M1-1	MECHANICAL - LEVEL 000 & LEVEL 100 DUCT & PIPING DEMO PLAN
	M1-2	MECHANICAL - LEVEL 200 & LEVEL 300 DUCT & PIPING DEMO PLAN
*	M1-3	MECHANICAL - ROOF DUCT & PIPING DEMOLITION PLAN
	M2-0	MECHANICAL - LEVEL 000 DUCTWORK PLAN
*	M2-1	MECHANICAL - LEVEL 100 DUCTWORK PLAN
	M2-2	MECHANICAL - LEVEL 200 DUCTWORK PLAN
	M2-3	MECHANICAL - LEVEL 300 DUCTWORK PLAN
*	M2-4	MECHANICAL - ROOF DUCTWORK PLAN
	M3-0	MECHANICAL - LEVEL 000 PIPING PLAN
*	M3-1	MECHANICAL - LEVEL 100 PIPING PLAN

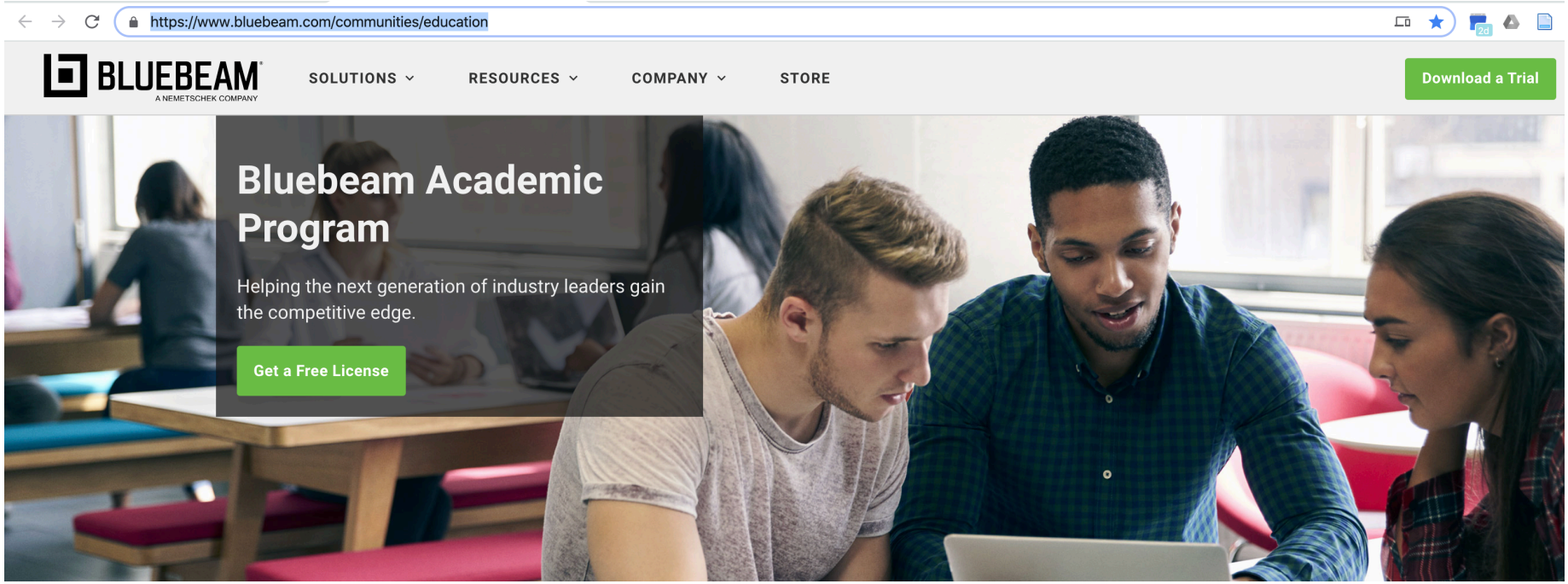
CLASS ACTIVITY

Class Activity

- Form six groups
- Spend 15 – 30 minutes to review the drawings
- Summarize your findings:
  - ❑ Formatting and layout
  - ❑ Brief overview of the equipment and systems
  - ❑ Details

BLUEBEAM

BlueBeam



A head start with Revu

The Bluebeam Academic Program is committed to supporting student competitors in regional and national AEC competitions. An early start using Bluebeam® Revu® in competitions better prepares students for careers in the AEC industry. Bluebeam's partnerships with organizations like ASC support the combined effort of educators and industry professionals to give students the skills they need to innovate on the building projects of the future.

https://www.bluebeam.com/communities/education