CAE 464/517 HVAC Systems Design

Spring 2023

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Intro to the course and HVAC drawings

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RECAP AND INTRO

Recap and Intro

- HVAC stands for Heating, Ventilation, and Air-Conditioning:
  - Heating: Boiler, furnace, heat pump, waste heat, heating coils
  - Ventilation: Outdoor air required for the spaces (e.g., ASHRAE 62.1)
  - Air-Conditioning: Chilled-water systems, cooling coils, Direct Expansion (DX) refrigerant systems

https://www.indiamart.com/proddetail/direct-expansion-cooling-coil-11707532291.html & http://acscomfort.com/hvac-central-systems

Recap and Intro

- Primary systems are major energy consumers
  - In small buildings, we usually call them heating and cooling devices
  - In large buildings, we usually call them equipment and systems
- For large buildings sometimes they are called “plants” or “loops”
- Examples of a heating device is a boiler or furnace
- An example of a cooling system is a vapor compression

Recap and Intro

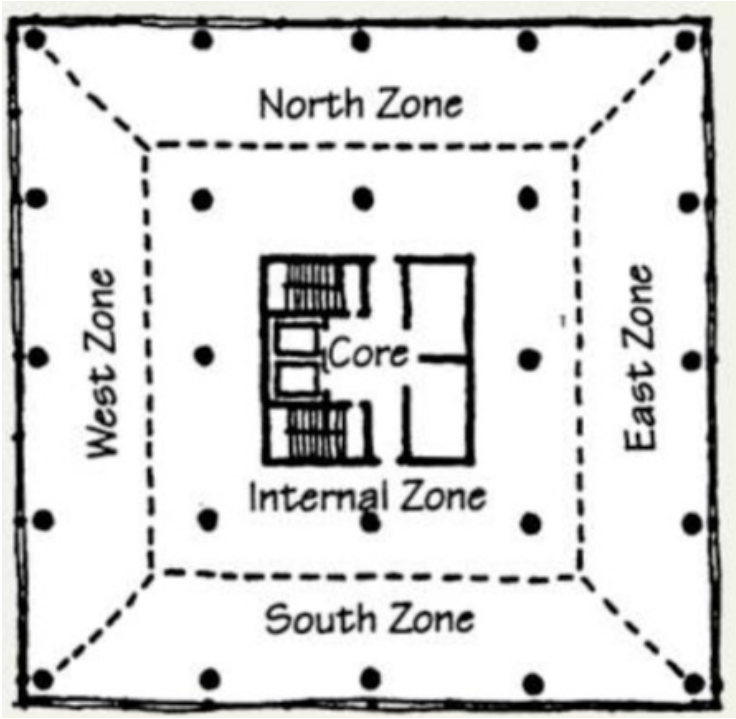
- Secondary systems distribute the cooling (or heating) produced by the primary systems (e.g., chillers or boilers) to the building spaces (e.g., specific rooms or thermal zones). Four types are:

  - ❑ All-water
  - ❑ All-air
  - ❑ Air-water systems
  - ❑ Refrigerant
  - ❑ Air-water-refrigerant
  - ❑ Air-refrigerant

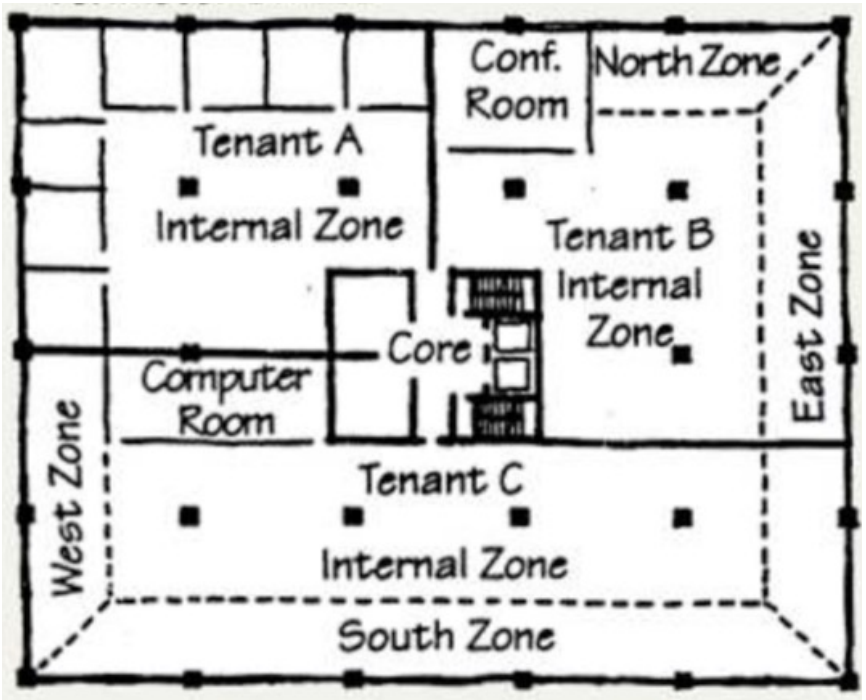
What are the advantages and disadvantages of each type?

Recap and Intro

- 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

Recap and Intro

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

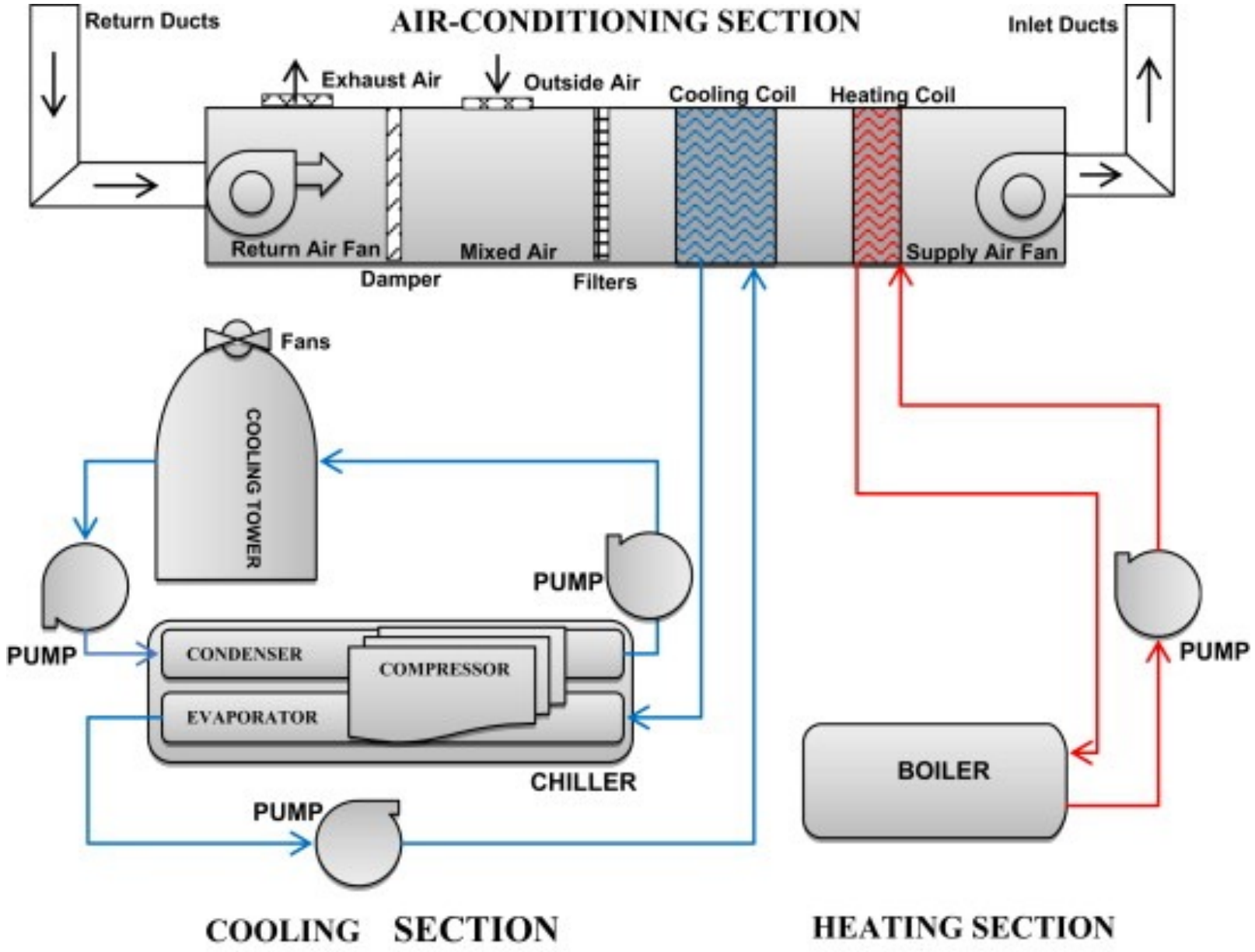
  - Unitary
    - Local systems
    - Each room has an HVAC system
  - Centralized
    - Central systems (all HVAC equipment in one room)
    - Semi-central systems
  - District
    - Central systems (all HVAC equipment in one room)
    - Semi-central systems

Recap and Intro

- 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

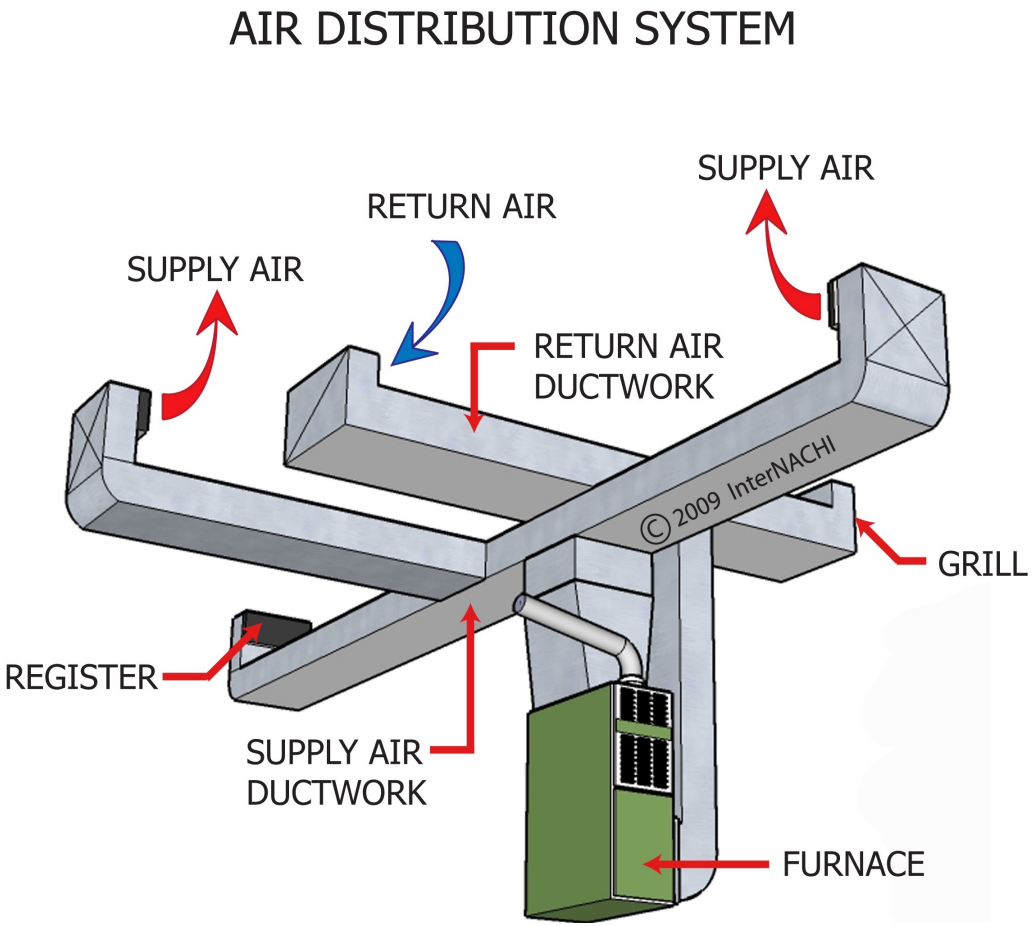
Building HVAC Systems



INTRODUCTION TO AIR DISTRIBUTION SYSTEMS

Air Distribution Systems

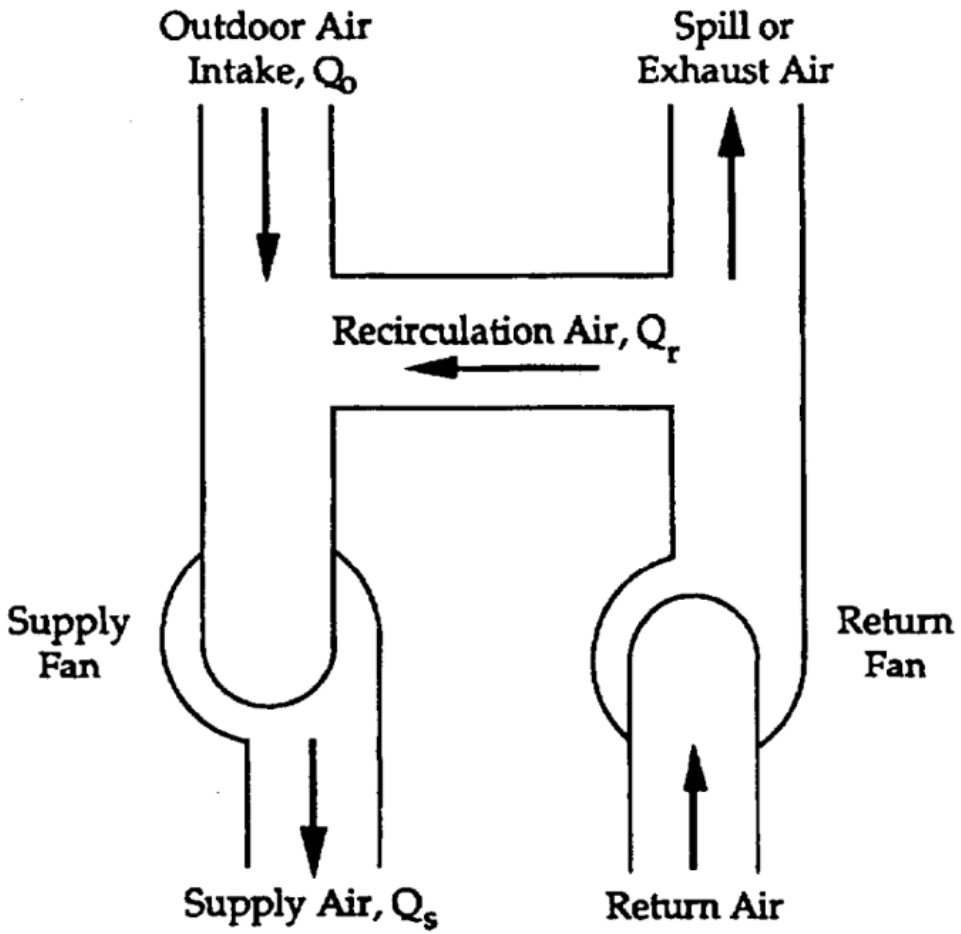
- Air distribution components:
  - ❑ Air handlers (known as AHU)
  - ❑ Air distribution devices
  - ❑ Ductwork
  - ❑ Heating and cooling coils
  - ❑ Dampers
  - ❑ Fans
  - ❑ Controls



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

Air Distribution Systems

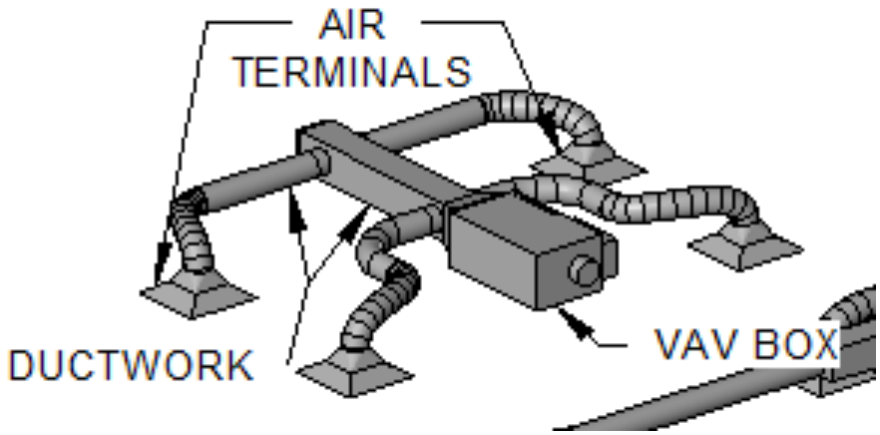
- An AHU system may include:

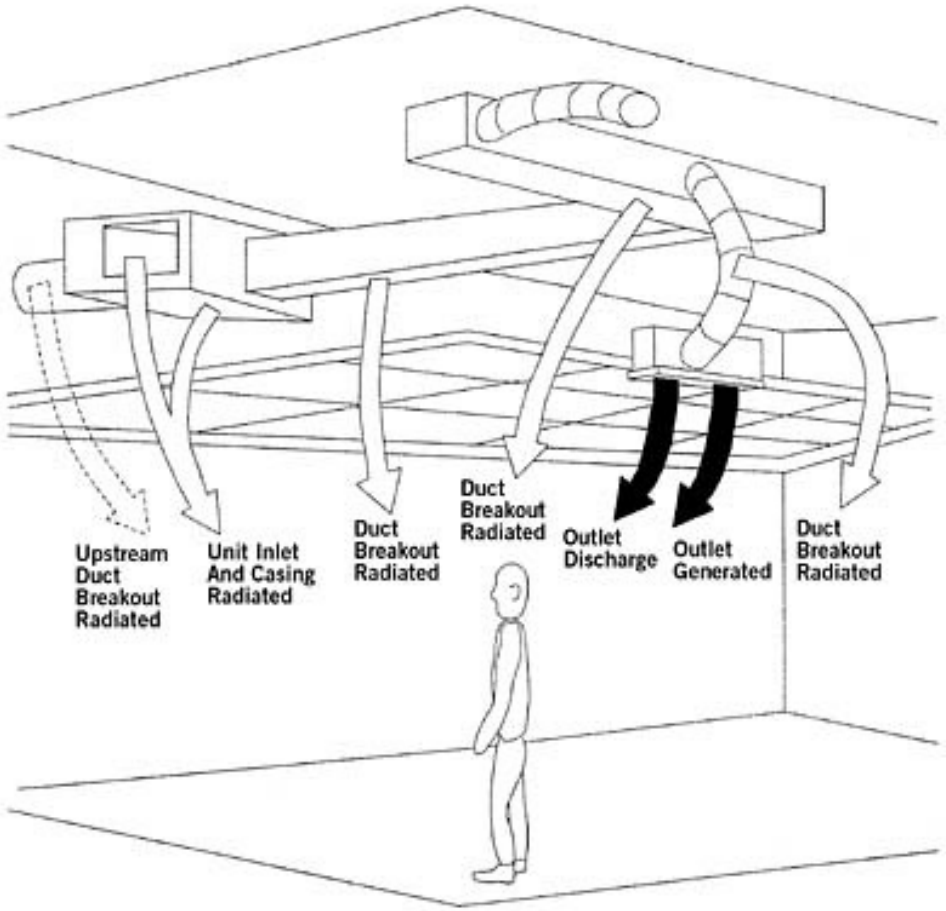


Persliy 1997

Air Distribution Systems

- 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



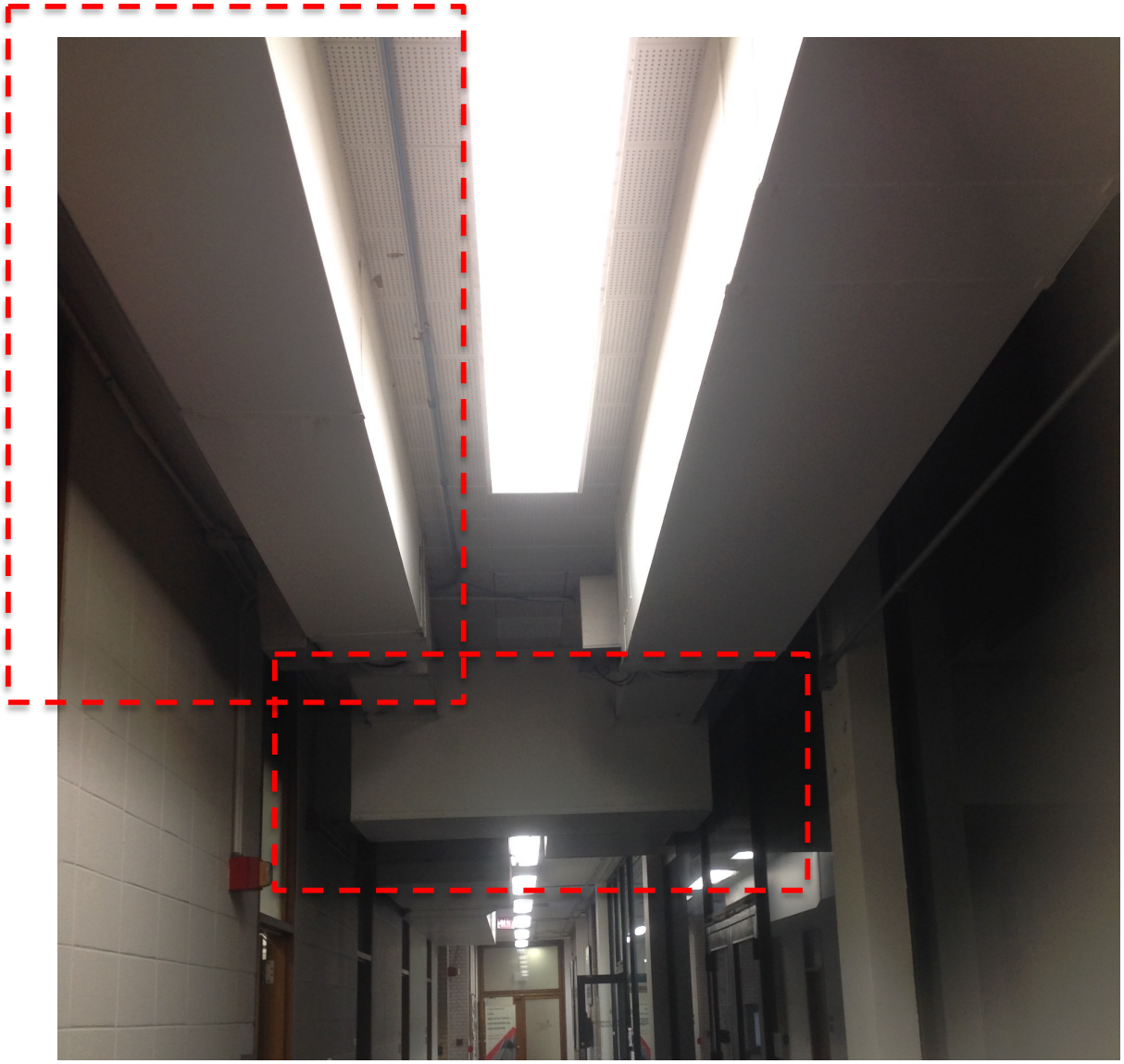


Air Distribution Systems

- 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

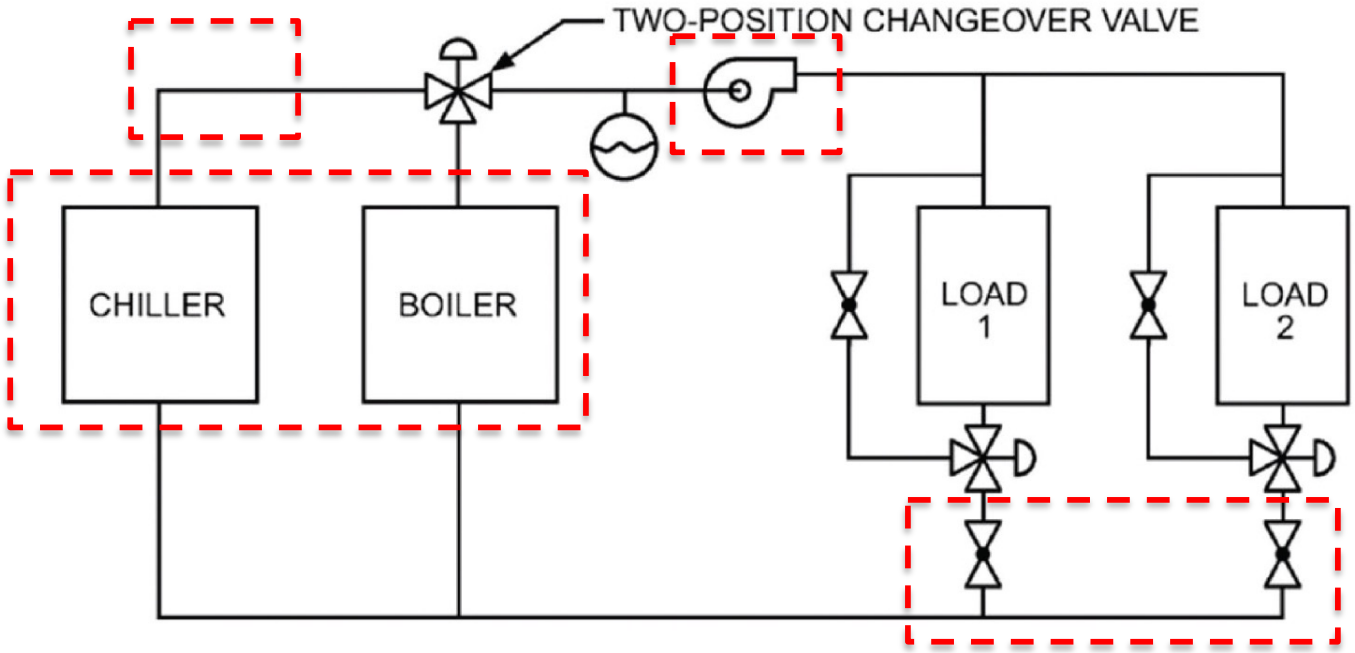
- Do we use this system at IIT?



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



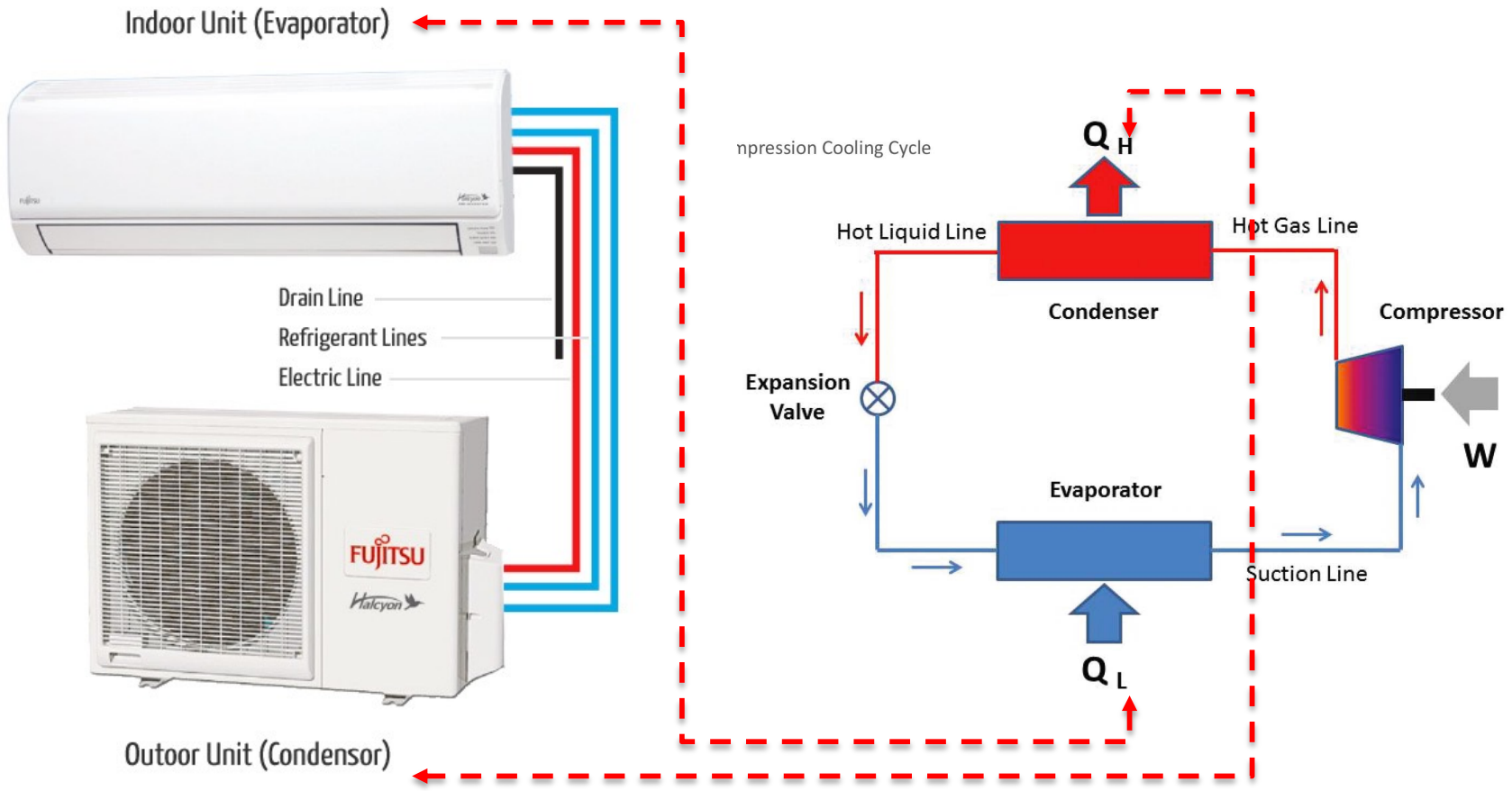
Ludwig Mies van der Rohe
Frank J. Kornacker; Alschuler & Sincere, associated architects; Sargent and Lundy, mechanical engineers
1945-50 (addition 1964)
3430 South Federal Street

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

INTRODUCTION TO REFRIGERATION SYSTEMS

Refrigeration Systems

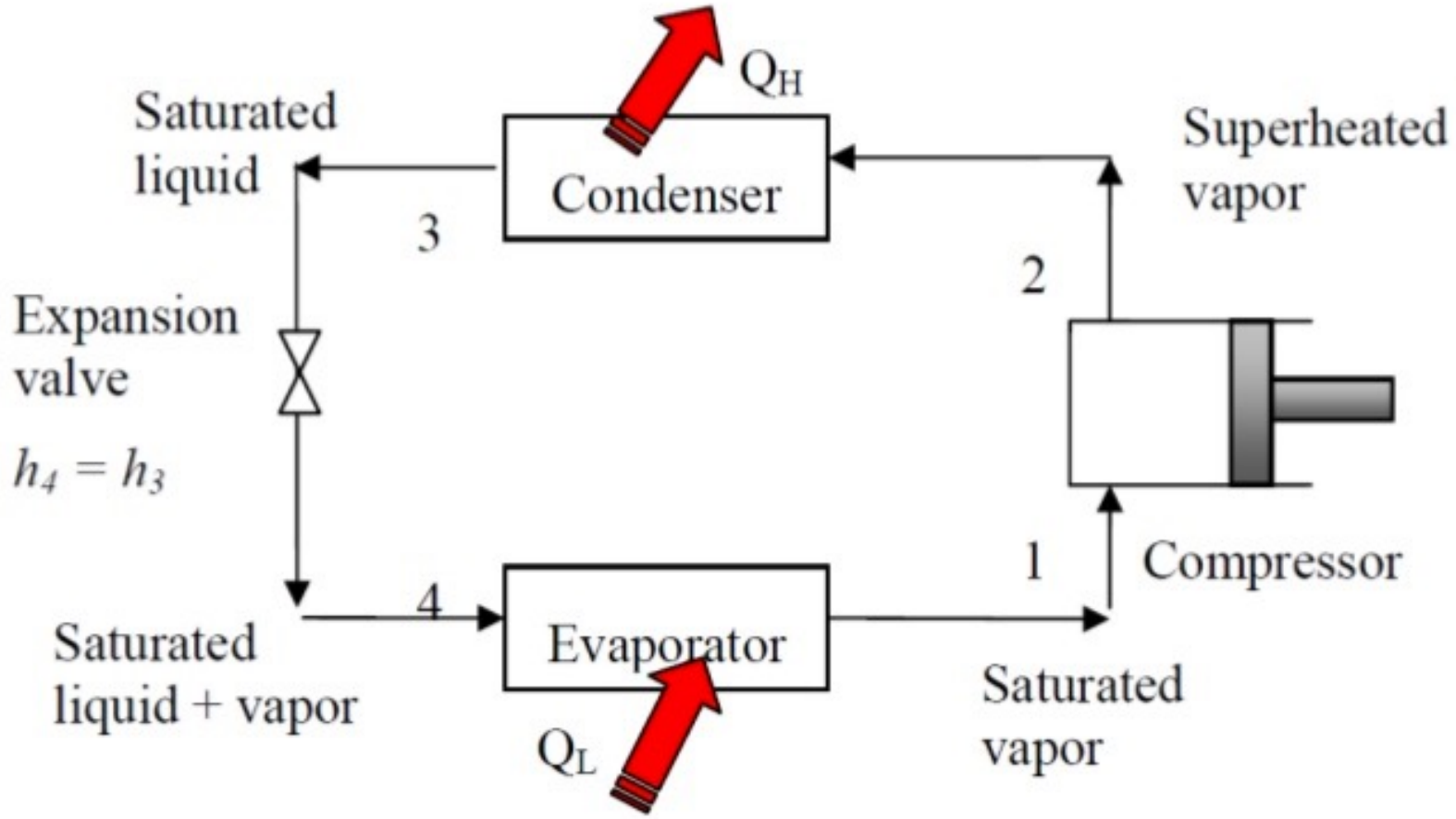
- **Refrigeration** refers to the process of removing heat from a low-temperature reservoir and transferring it to a high-temperature reservoir



https://insulation.org/io/articles/understanding-thermal-systems-industrial-refrigeration-systems/. & http://www.fujitsugeneral.com/us/residential/what-is-a-mini-split.html

Refrigeration Systems

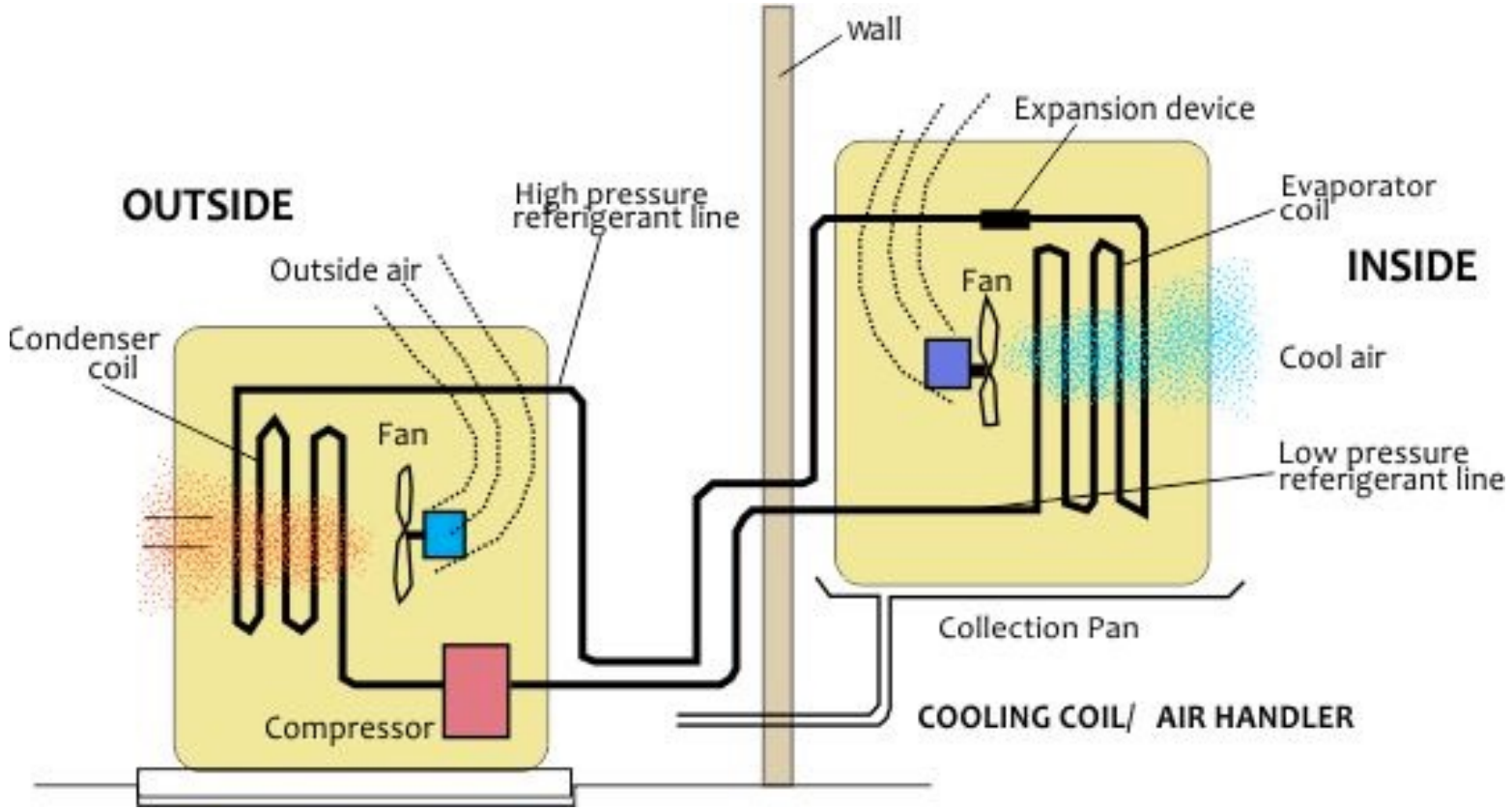
- A vapor compression cycle entails:



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

Refrigeration Systems

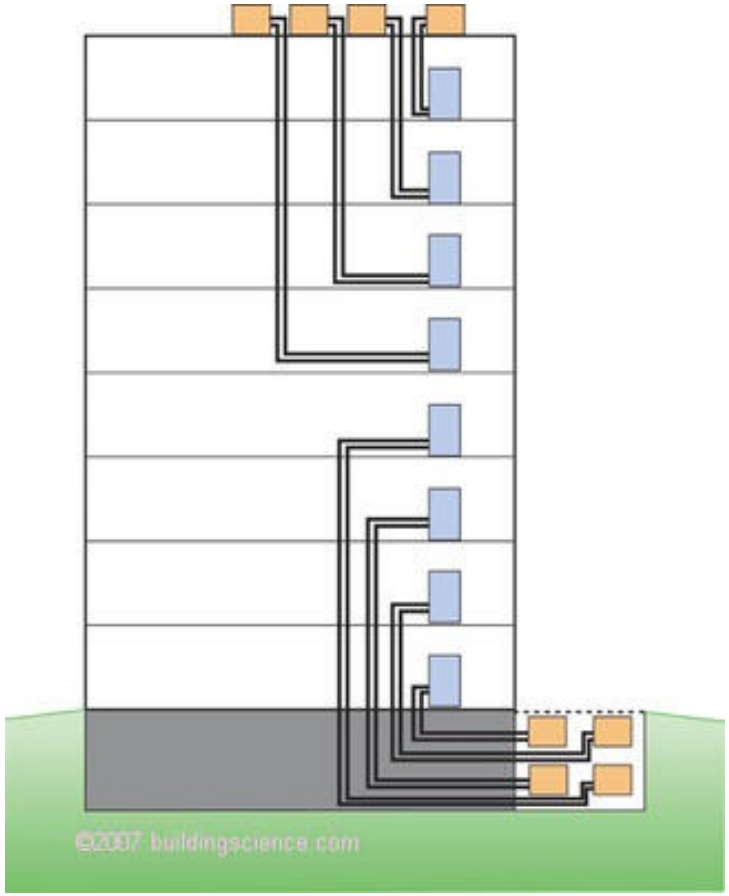
- An example of an application of the vapor compression cycle in a residential building is:



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

Refrigeration Systems

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

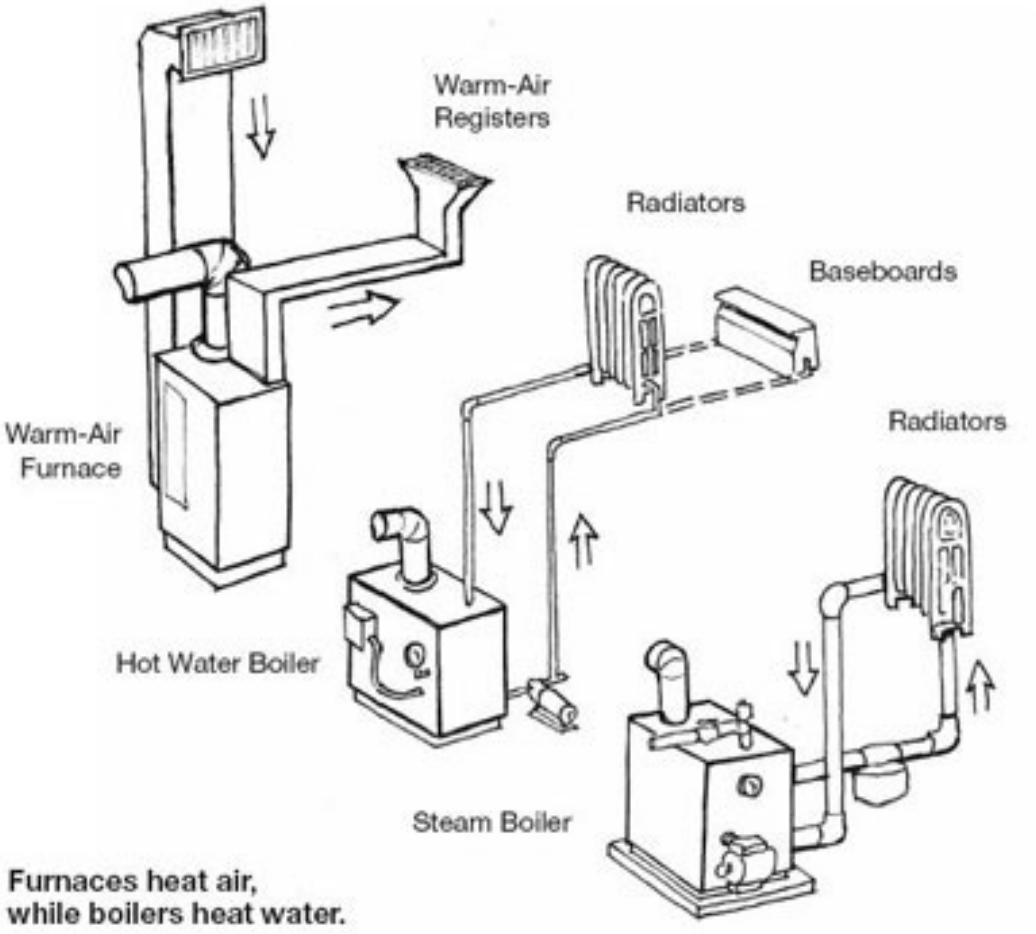


https://www.buildingscience.com/documents/digests/bsd-110-hvac-in-multifamily-buildings

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

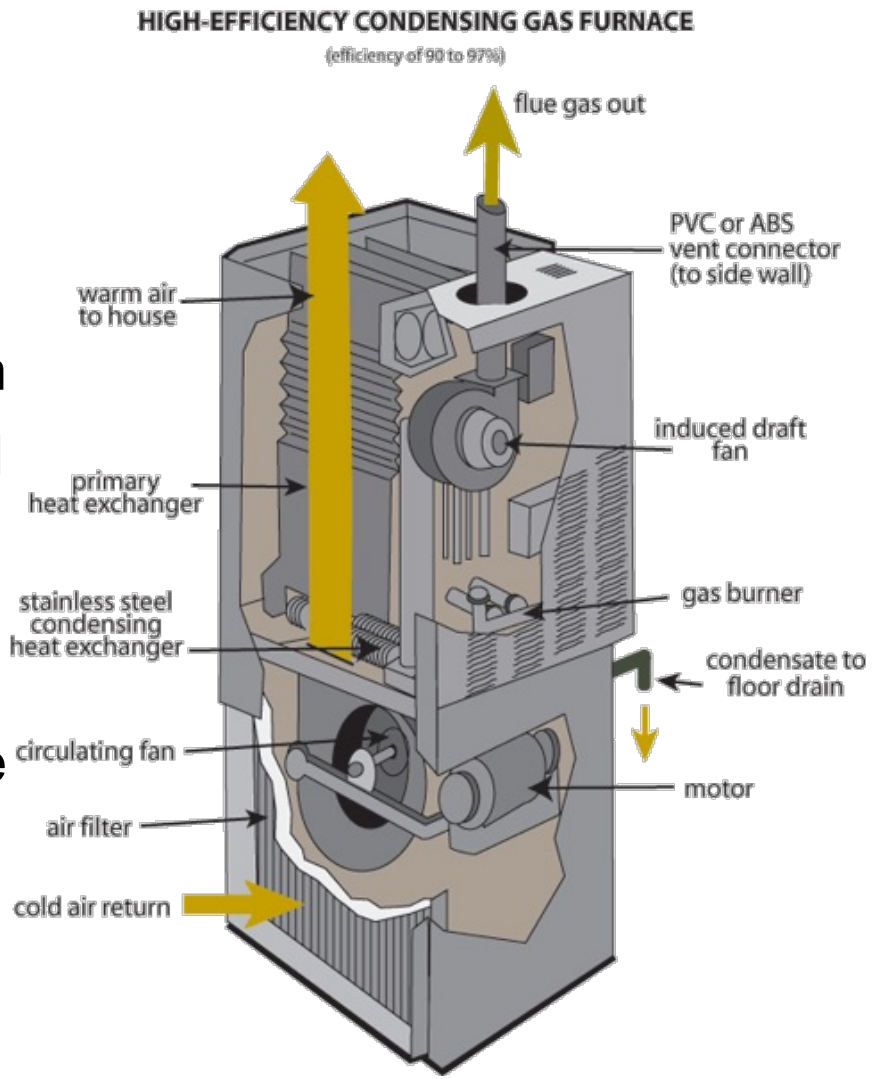
Heating Systems

- 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

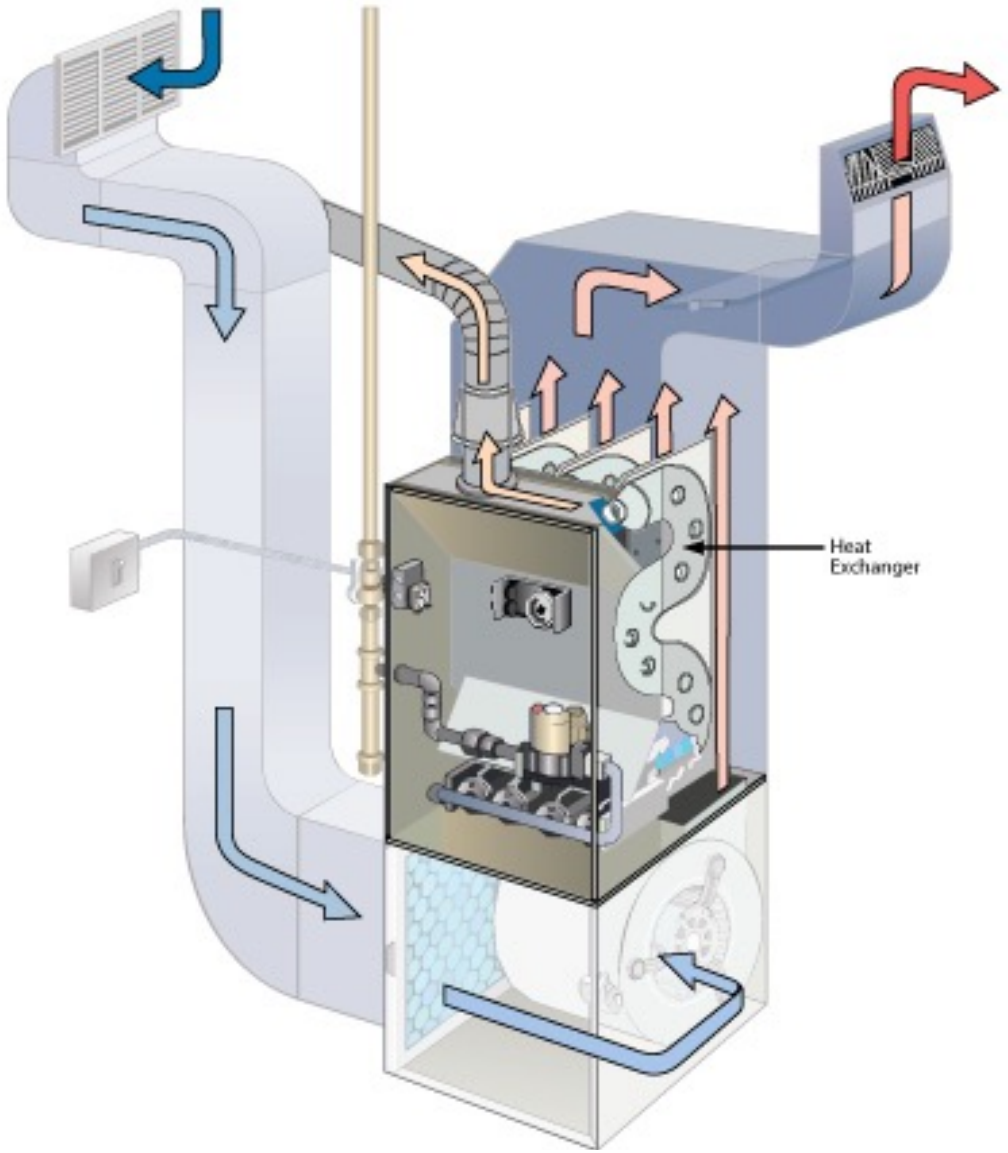
- Furnace:
  - ❑ Deliver hot air through a central furnace and ductwork to the zones through registers or grills
  - ❑ Named as a ducted warm-air or a forced warm-air distribution system
  - ❑ The combustion heat is transferred via a heat exchanger to air
  - ❑ Fan or “Blower” push the air through the 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

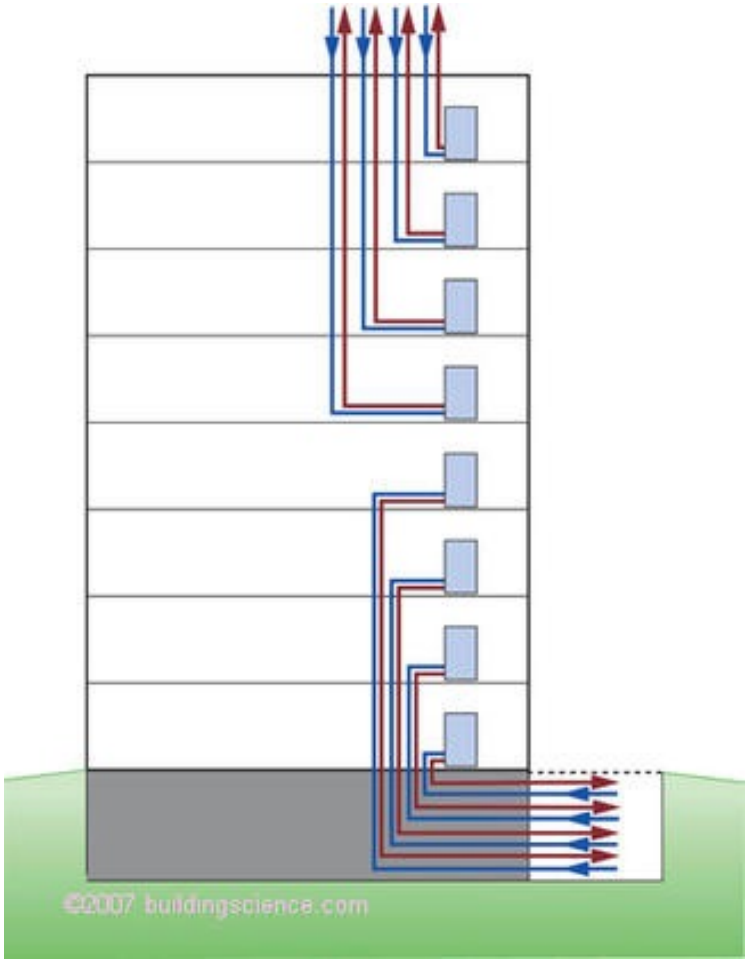
- Furnace:



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

Heating Systems

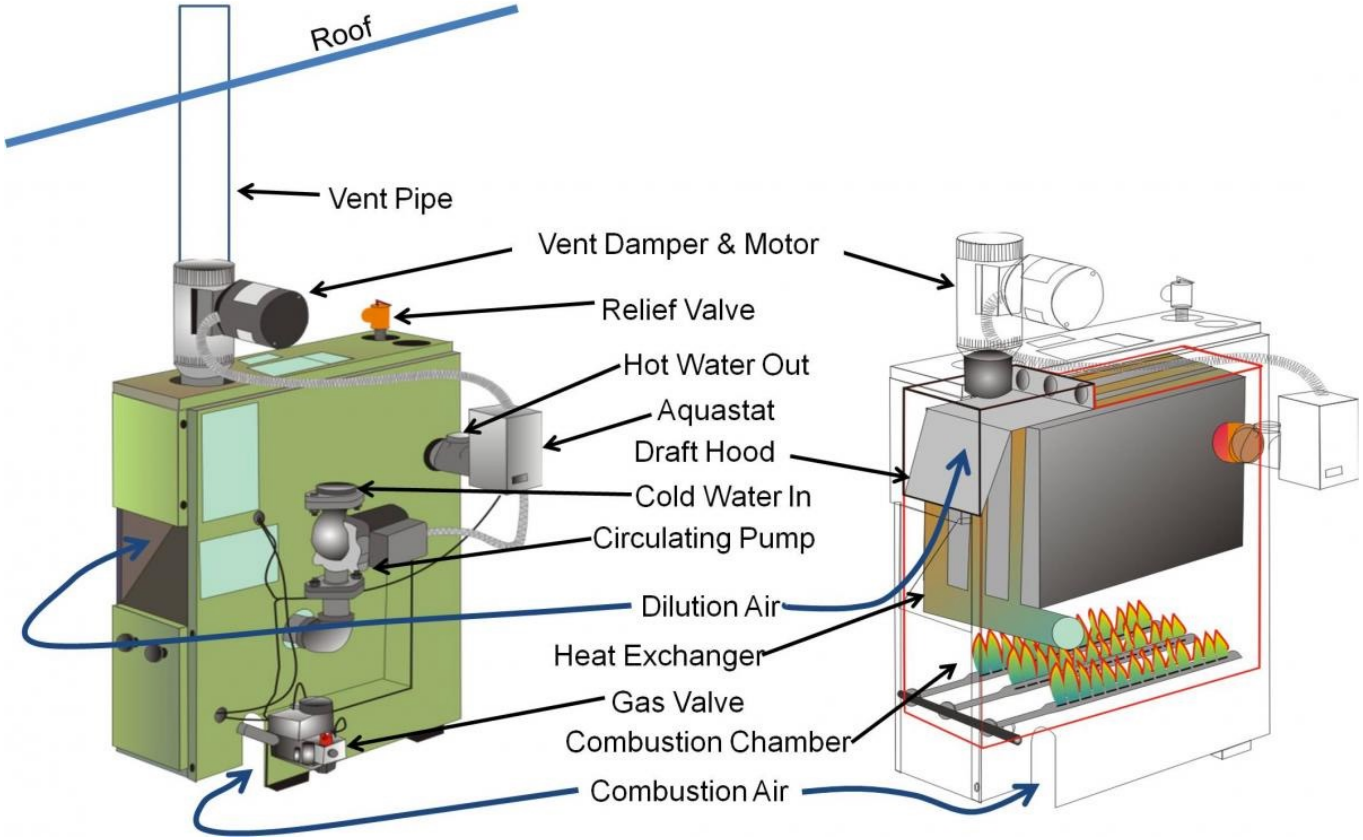
- Example of installing a furnace in a multi-family building:



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

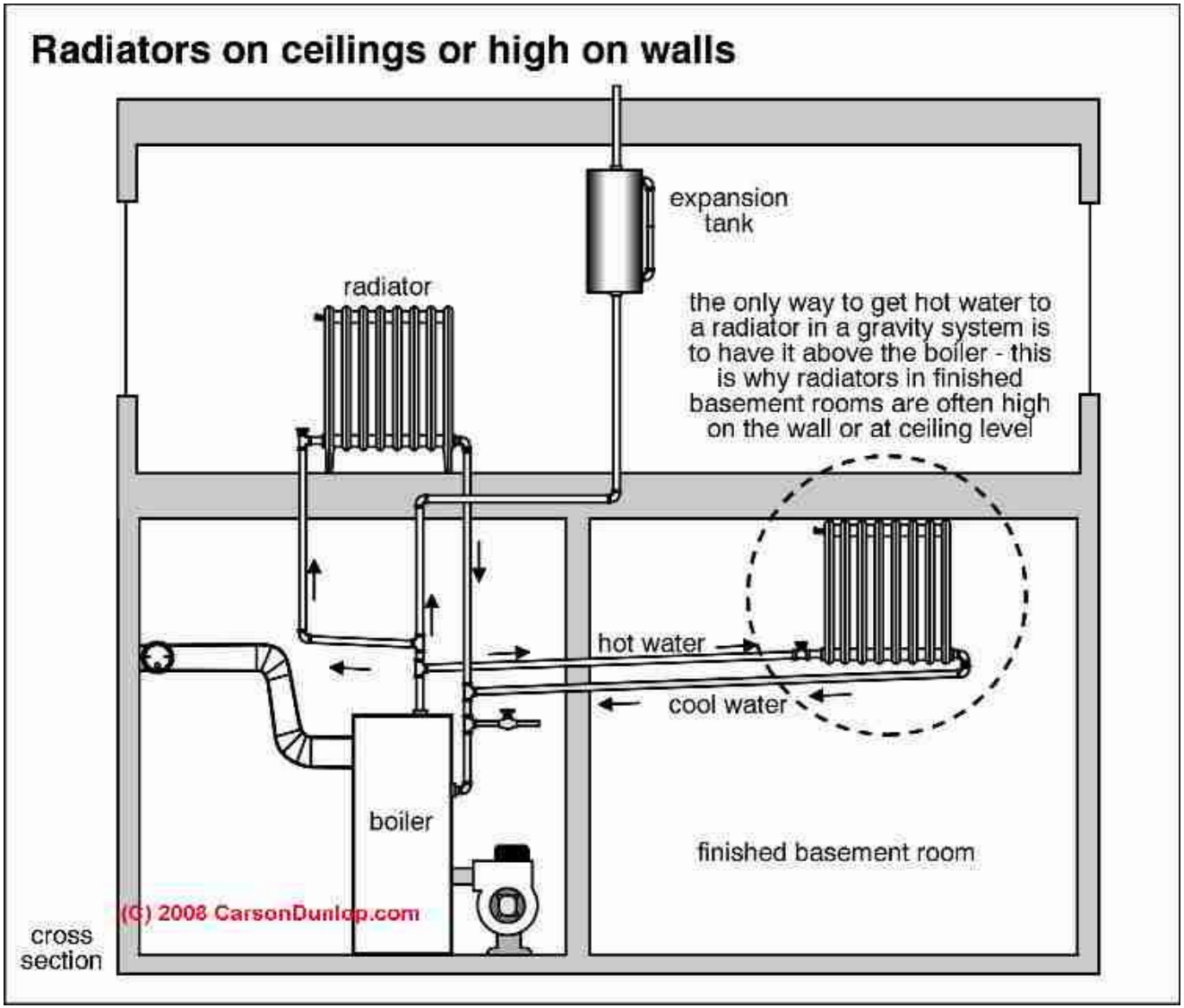
Heating Systems

- 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

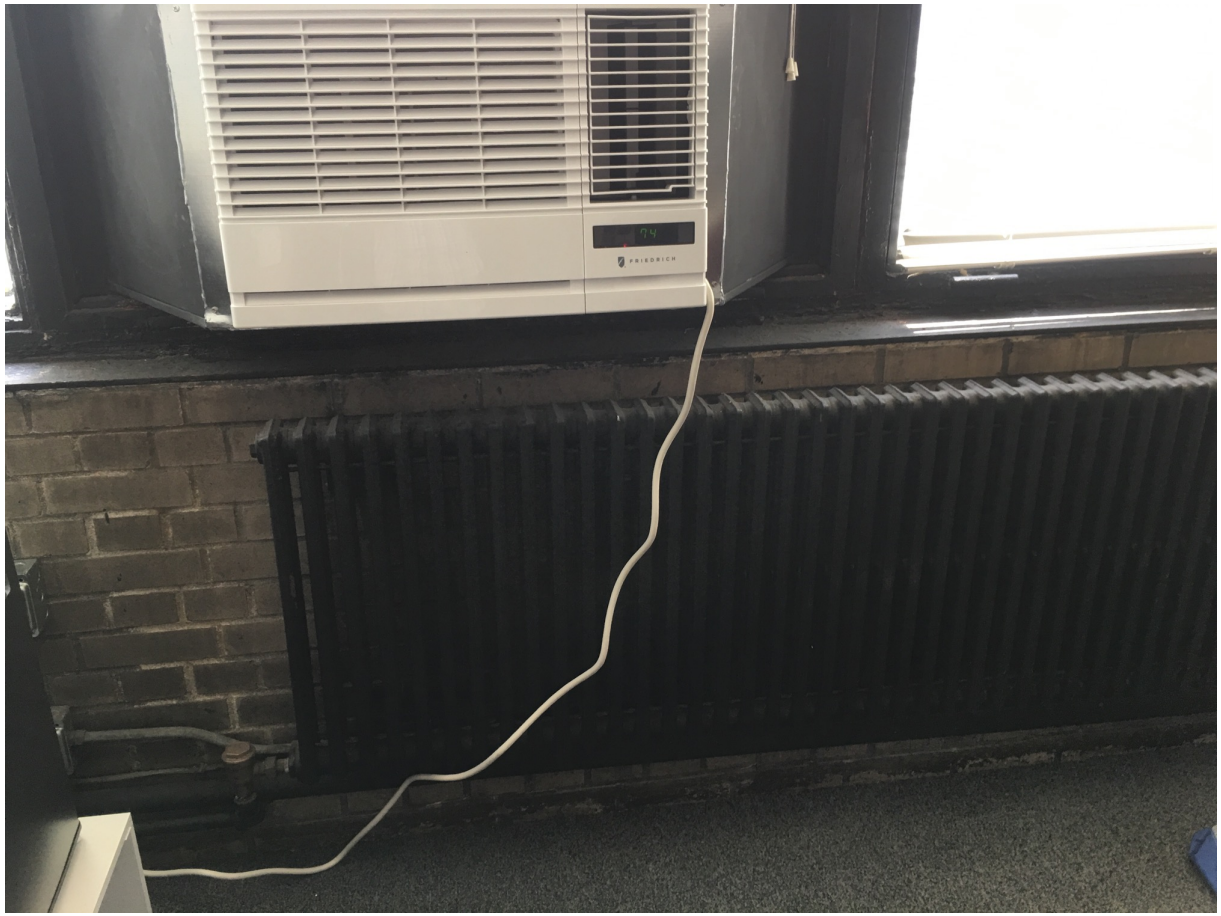
- Unitary or packaged terminal unit:
  - ❑ All components are factory assembled into major pieces (1-2 pieces)
  - ❑ Coils, fans, controls, .. are all included one major package
  - ❑ Named as decentralized system
  - ❑ Easy to install
  - ❑ Suitable for small to mid size buildings (Less than three stories)
    - ❑ 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?

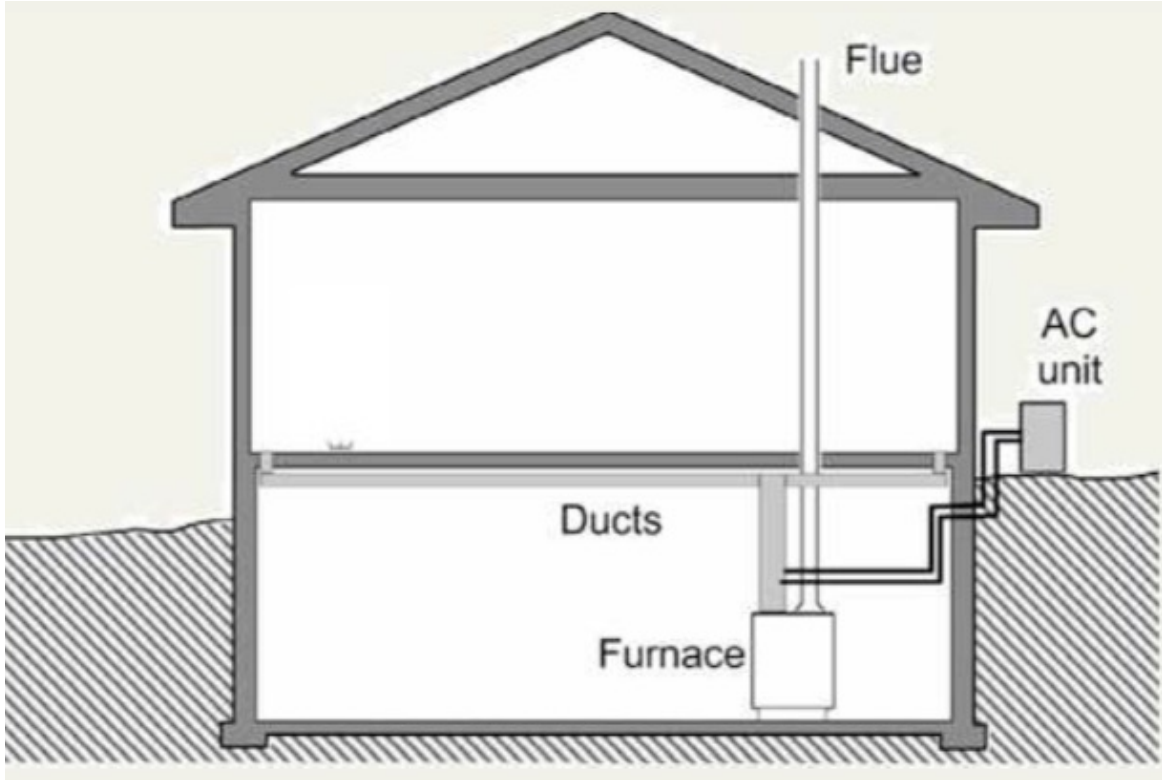
Unitary

- 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



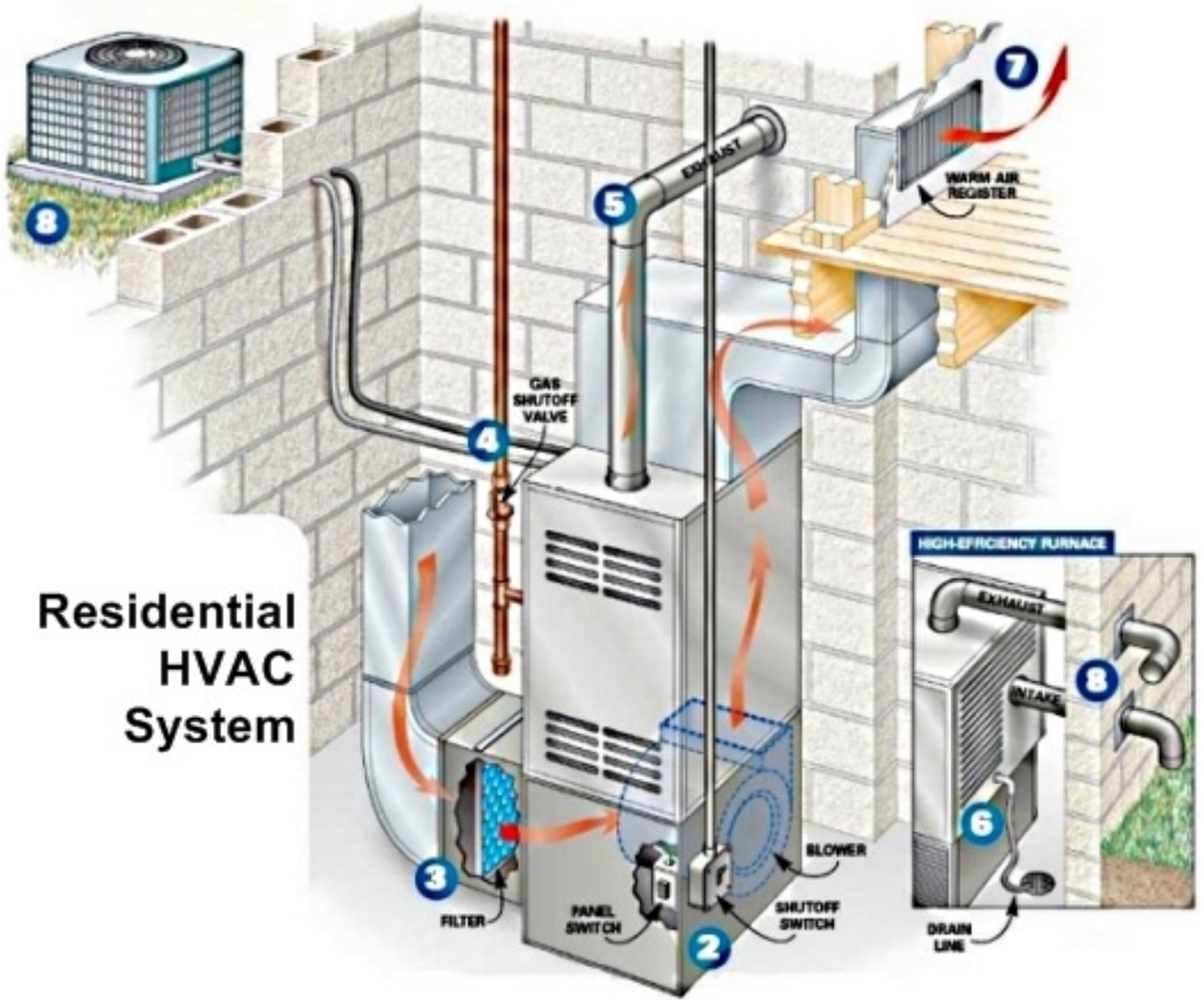
Unitary

- 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/

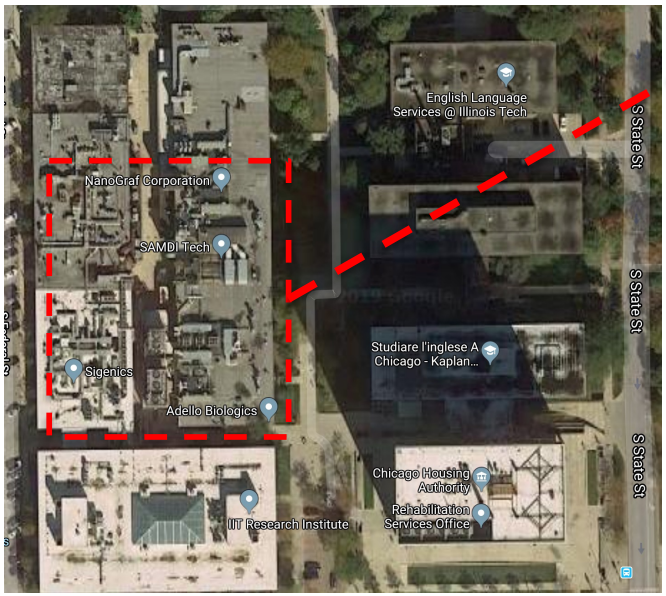
Split Systems

- 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/

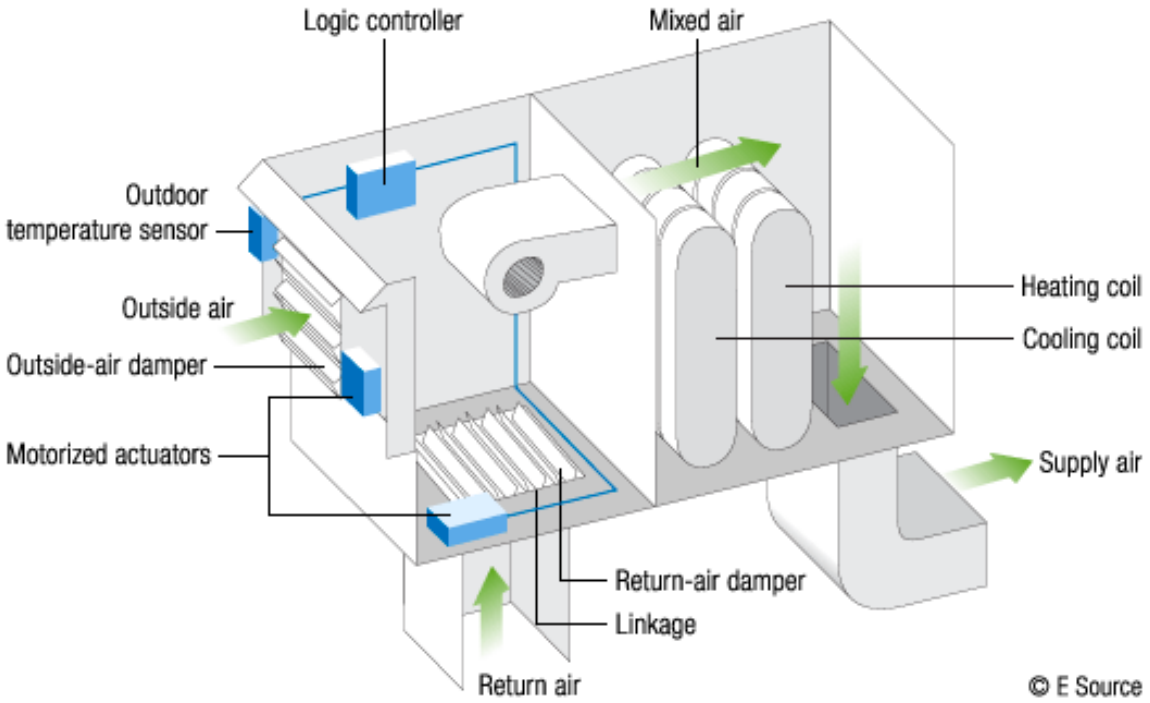
Split Systems

- What do you see here?



Unitary

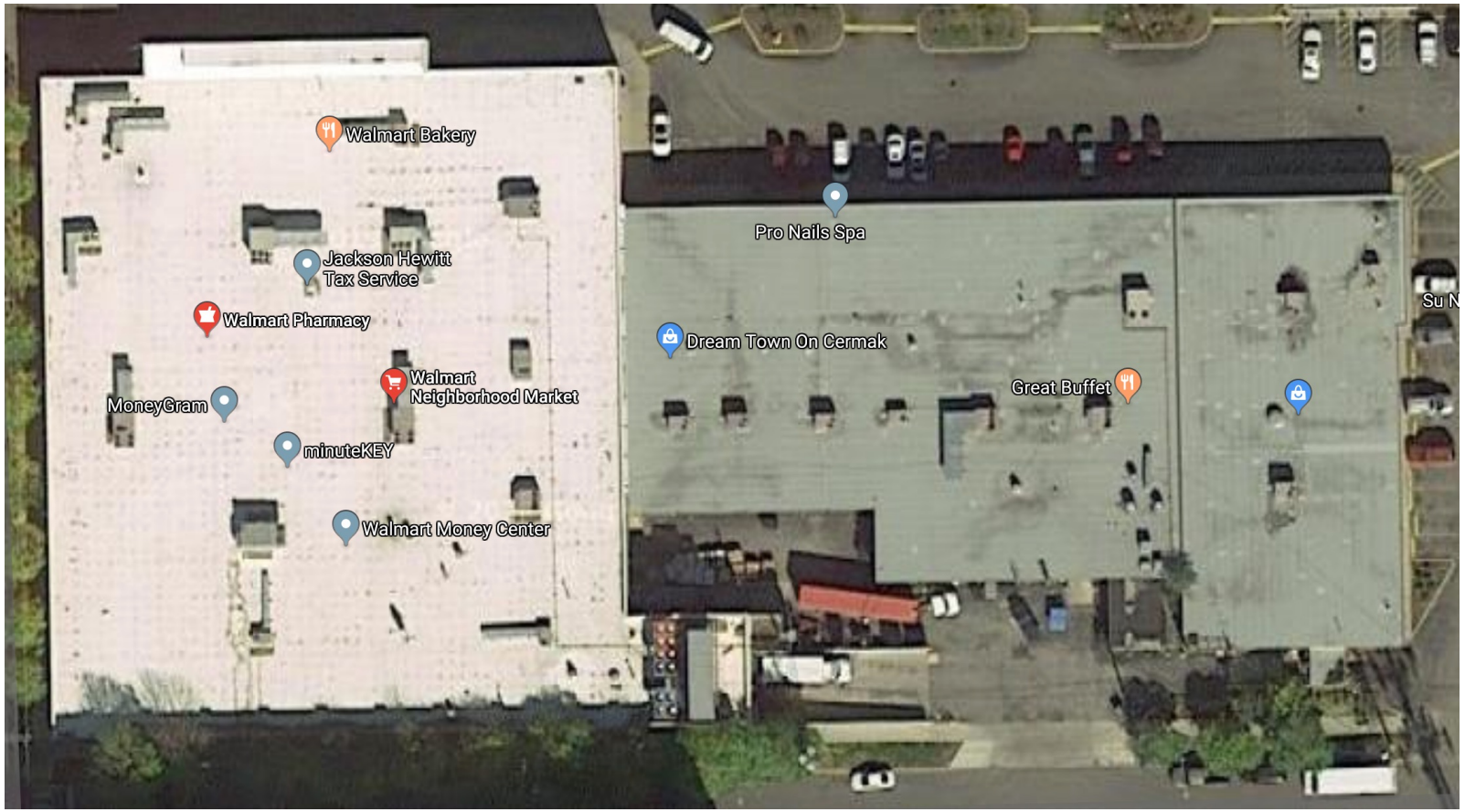
- Rooftop units or packaged unit
  - ❑ DX Coil
  - ❑ Gas heating



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

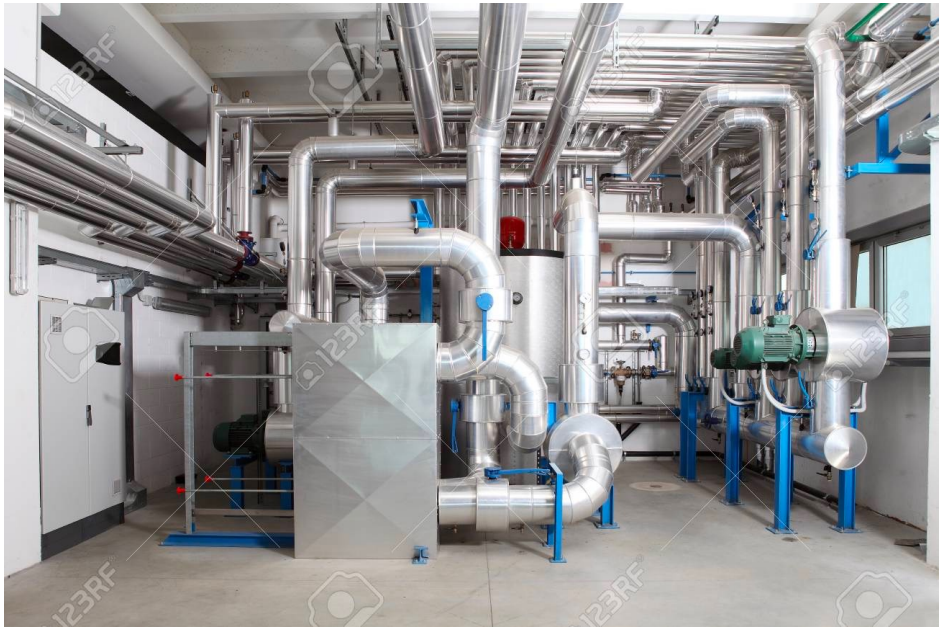
- Advantages and disadvantages of packaged equipment

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



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)

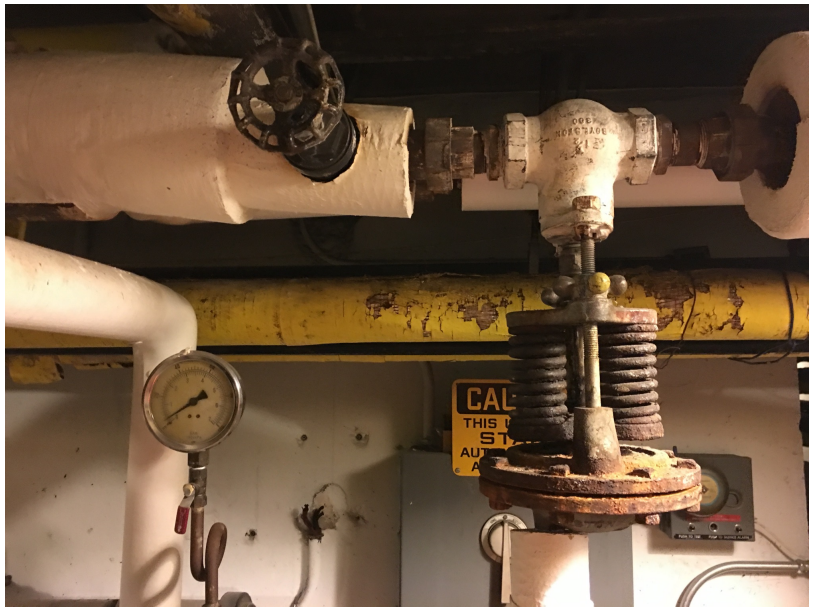
District Systems

- IIT Heating plant

Brian Bozell Presentation

District Systems

- Alumni Memorial Hall building steam system



District Systems

- IIT Cooling plant

Brian Bozell Presentation

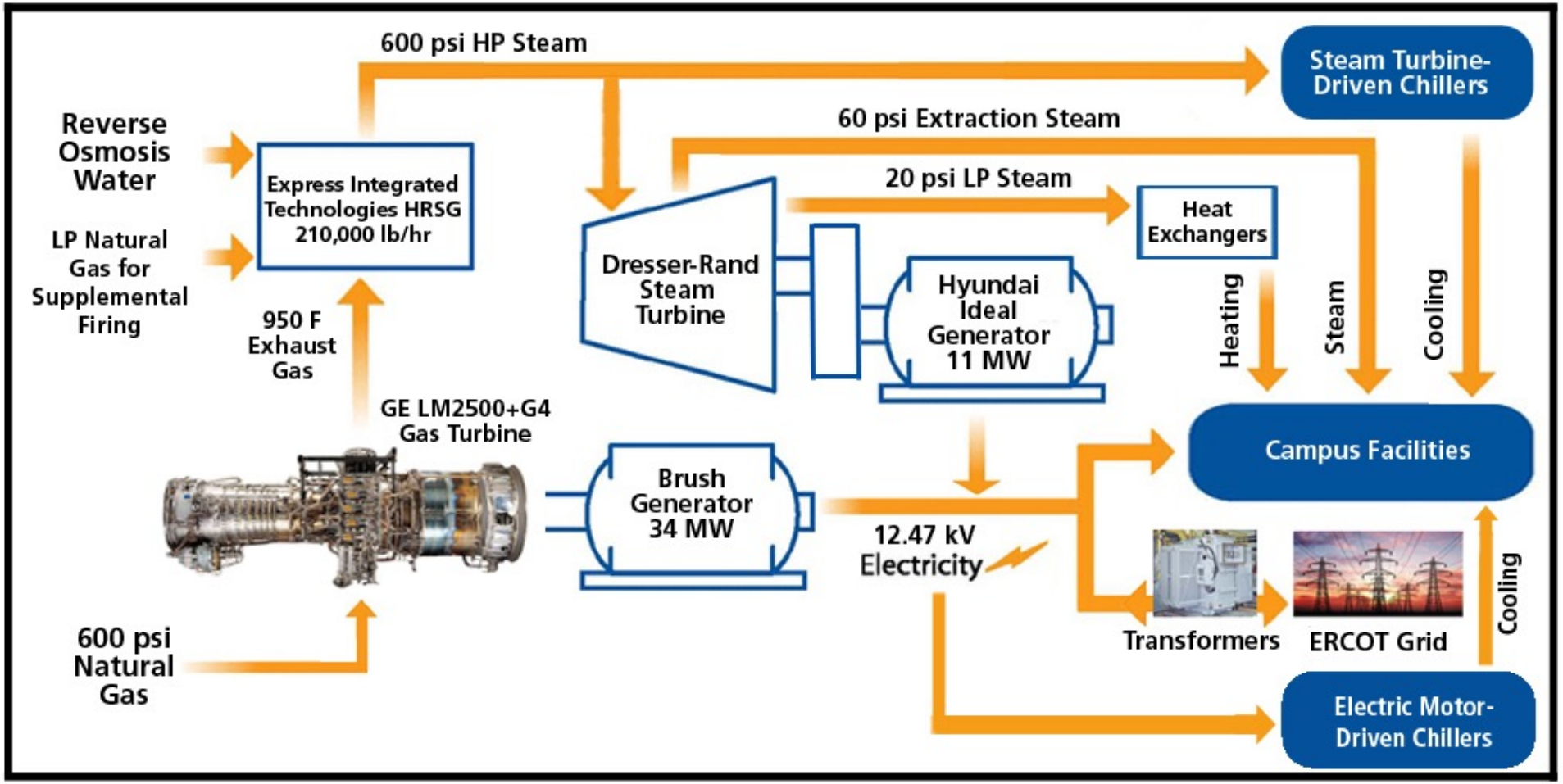
District Systems

- 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 2017 ASHRAE Fundamentals (Or Chapter 39 in the 2021 version): Abbreviations and Symbols. This chapter entails:

  - ❑ Abbreviations
  - ❑ Letter symbols
  - ❑ Graphical symbols

HVAC System Drawings

- Few examples of the graphical symbols:

Refrigeration

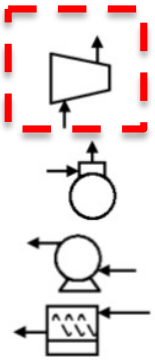
Compressors

Centrifugal

Reciprocating

Rotary

Rotary screw

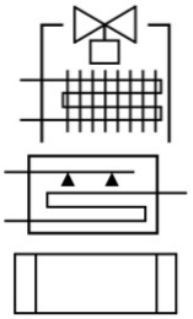


Condensers

Air cooled

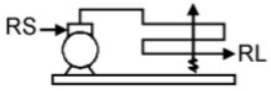
Evaporative

Water cooled, (specify type)



Condensing Units

Air cooled[b]



Air Moving Devices and Components

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

Axial flow

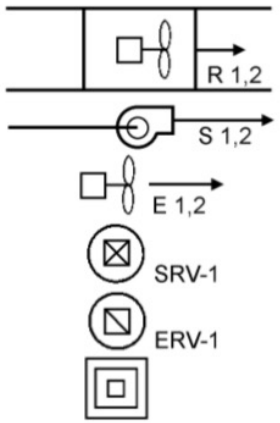
Centrifugal

Propeller

Roof ventilator, intake

Roof ventilator, exhaust

Roof ventilator, louvered



***Ductwork*[b]**

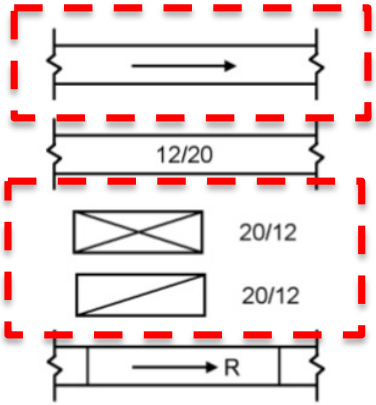
Direction of flow

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)

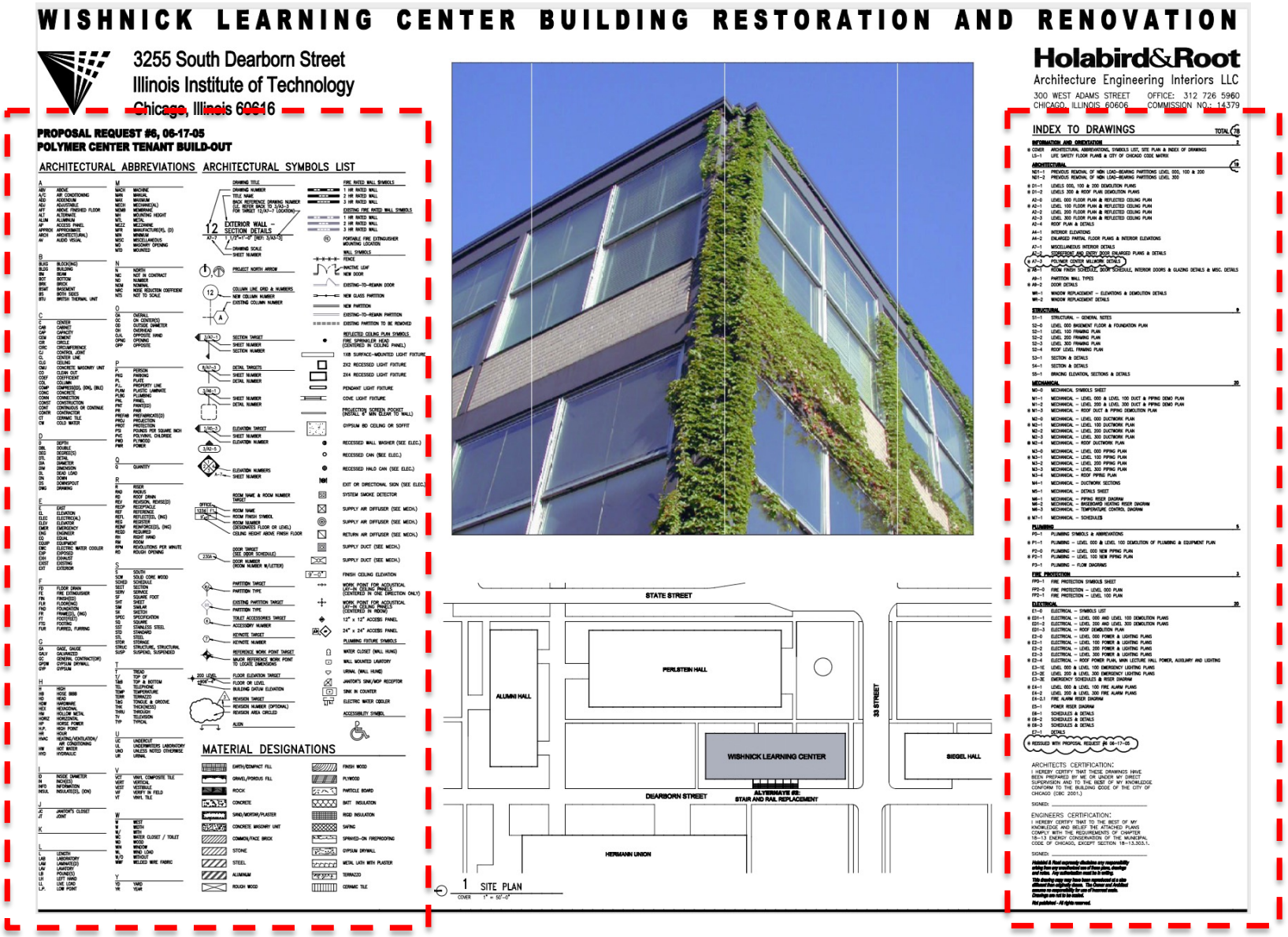


HVAC System Drawings

- 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



- Wishnicl

VENTILATION SYMBOLS

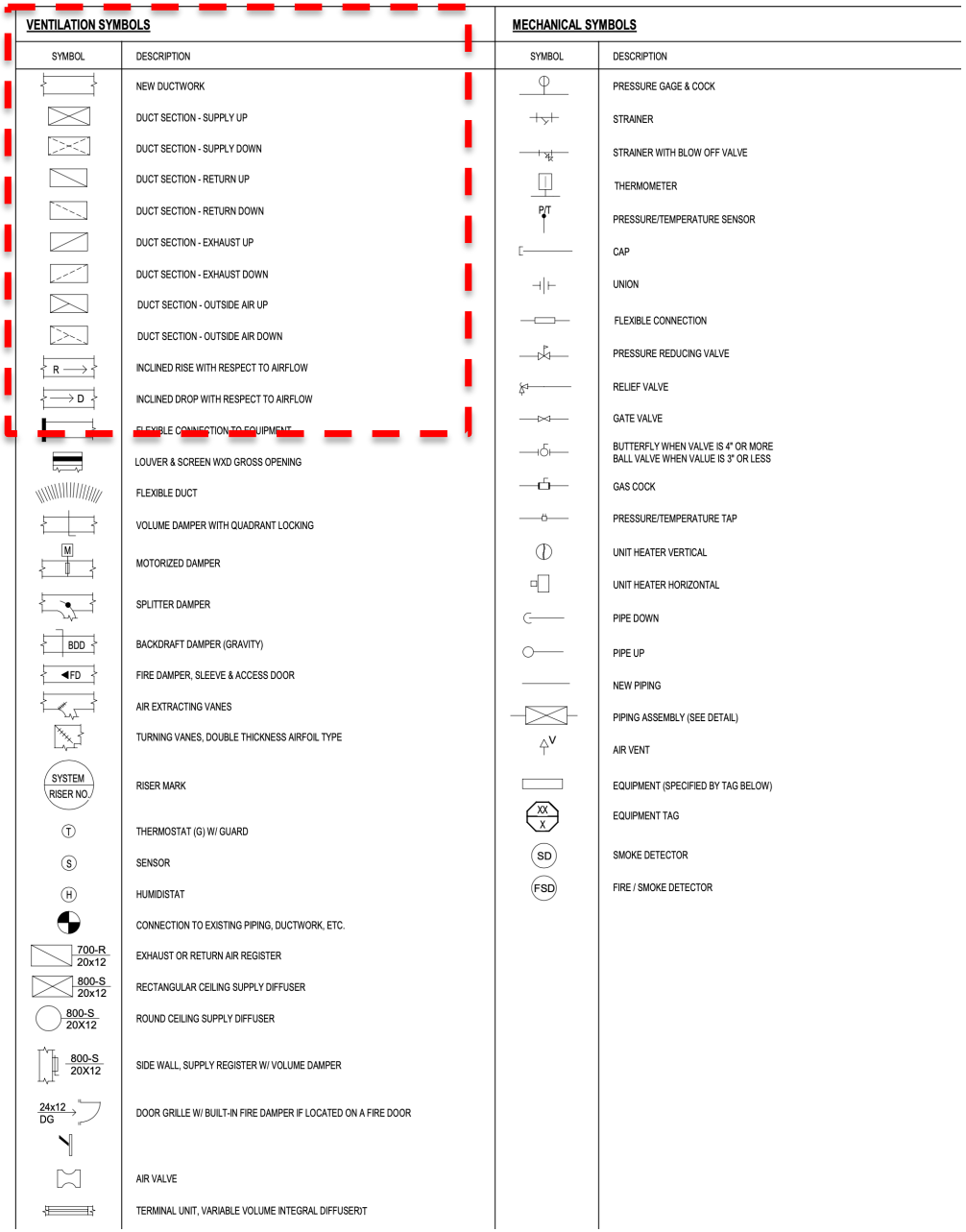
SYMBOL	DESCRIPTION
	NEW DUCTWORK
	DUCT SECTION - SUPPLY UP
	DUCT SECTION - SUPPLY DOWN
	DUCT SECTION - RETURN UP
	DUCT SECTION - RETURN DOWN
	DUCT SECTION - EXHAUST UP
	DUCT SECTION - EXHAUST DOWN
	DUCT SECTION - OUTSIDE AIR UP
	DUCT SECTION - OUTSIDE AIR DOWN
R	INCLINED RISE WITH RESPECT TO AIRFLOW
D	INCLINED DROP WITH RESPECT TO AIRFLOW
	FLEXIBLE CONNECTION TO EQUIPMENT
	LOUVER & SCREEN WXD GROSS OPENING
	FLEXIBLE DUCT
	VOLUME DAMPER WITH QUADRANT LOCKING
M	MOTORIZED DAMPER
	SPLITTER DAMPER
BDD	BACKDRAFT DAMPER (GRAVITY)
FD	FIRE DAMPER, SLEEVE & ACCESS DOOR
	AIR EXTRACTING VANES
	TURNING VANES, DOUBLE THICKNESS AIRFOIL TYPE
SYSTEM RISER NO.	RISER MARK
T	THERMOSTAT (G) W/ GUARD
S	SENSOR
H	HUMIDISTAT
	CONNECTION TO EXISTING PIPING, DUCTWORK, ETC.
700-R 20x12	EXHAUST OR RETURN AIR REGISTER
800-S 20x12	RECTANGULAR CEILING SUPPLY DIFFUSER
800-S 20X12	ROUND CEILING SUPPLY DIFFUSER
800-S 20X12	SIDE WALL, SUPPLY REGISTER W/ VOLUME DAMPER
24x12 DG	DOOR GRILLE W/ BUILT-IN FIRE DAMPER IF LOCATED ON A FIRE DOOR
	AIR VALVE
	TERMINAL UNIT, VARIABLE VOLUME INTEGRAL DIFFUSER)T

MECHANICAL SYMBOLS

SYMBOL	DESCRIPTION
	PRESSURE GAGE & COCK
	STRAINER
	STRAINER WITH BLOW OFF VALVE
	THERMOMETER
P/T	PRESSURE/TEMPERATURE SENSOR
	CAP
	UNION
	FLEXIBLE CONNECTION
	PRESSURE REDUCING VALVE
	RELIEF VALVE
	GATE VALVE
	BUTTERFLY WHEN VALVE IS 4" OR MORE BALL VALVE WHEN VALUE IS 3" OR LESS
	GAS COCK
	PRESSURE/TEMPERATURE TAP
	UNIT HEATER VERTICAL
	UNIT HEATER HORIZONTAL
	PIPE DOWN
	PIPE UP
	NEW PIPING
	PIPING ASSEMBLY (SEE DETAIL)
V	AIR VENT
	EQUIPMENT (SPECIFIED BY TAG BELOW)
XX X	EQUIPMENT TAG
SD	SMOKE DETECTOR
FSD	FIRE / SMOKE DETECTOR

HVAC System Drawings

- Cunningham Hall



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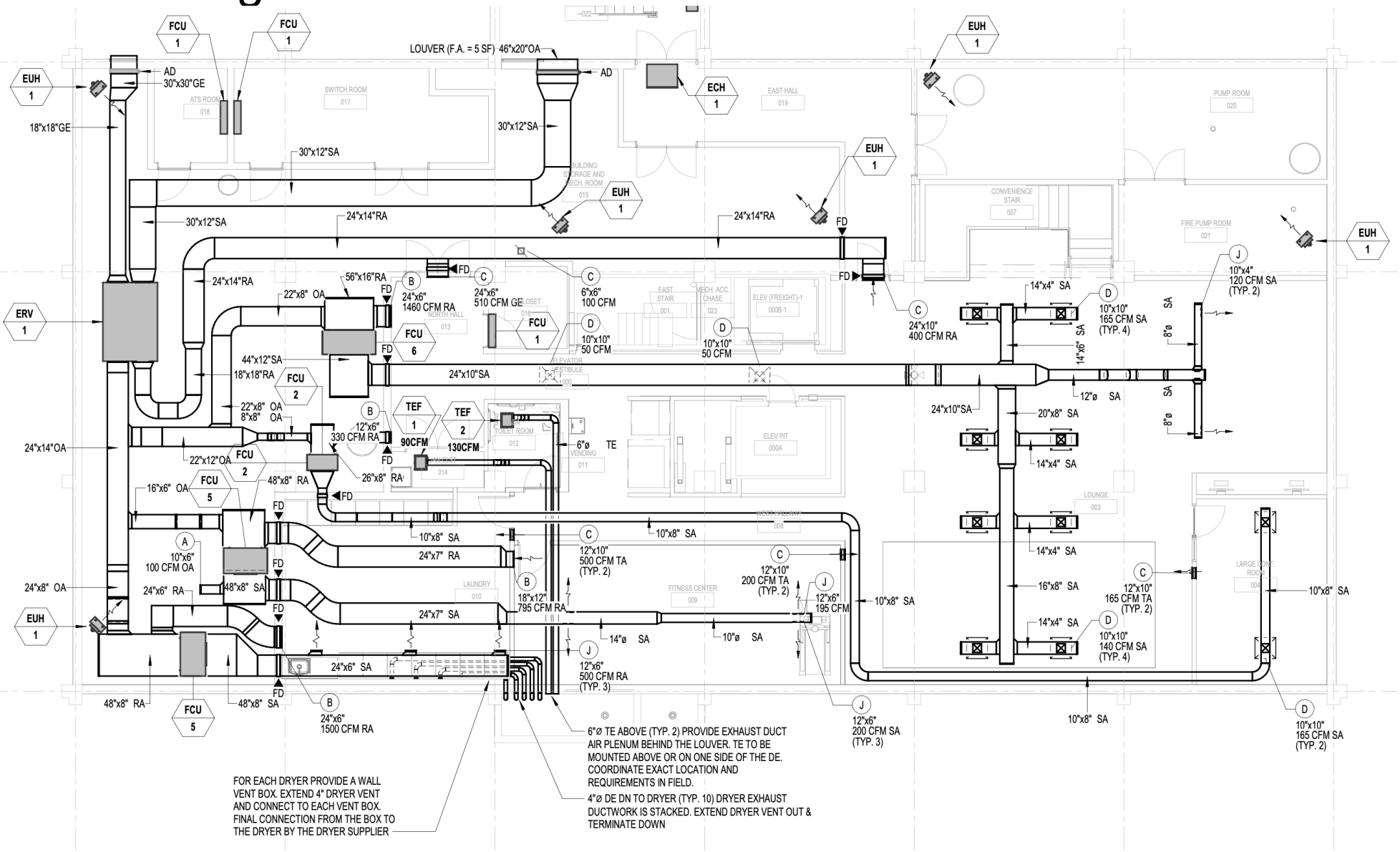
HVAC System Drawings

- Cunningham Hall



ANNOUNCEMENTS

Announcement

- ASHRAE IL Chapter Scholarship
  - ❑ Application Link: https://illinoisashrae.org/Scholarship

Apply for Chapter Engineering Scholarships by January 31st

The deadline for annual Illinois Chapter ASHRAE Scholarships in 2023 is January 31st. The Chapter plans to award **up to four $1,500 scholarships** to deserving college students interested in pursuing studies in engineering, science or mathematics that are fundamental for a career in the HVAC field. **It's quick and simple to apply** for one of these scholarships. Applicants do not need to belong to an ASHRAE student chapter.

Don't let this opportunity to lower the educational expenses of the college student (and future engineer) in your life pass you by. **For additional information and application form, click here**.

Please submit your application by January 31, 2023. The Chapter plans to announce scholarship winners in the spring of 2022.