CAE 464/517 HVAC Systems Design

Spring 2023

March 30, 2023

Hydronic systems: Intro to hydronic systems

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www.built-envi.com

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Illinois Institute of Technology
muh182@iit.edu

ANNOUNCEMENTS

Announcements

ASHRAE
Illinois Institute of Technology
Student Branch

JLL

SEES IIT
ENVIRONMENTAL ENGINEERING

Building Performance focusing on net zero design and energy modeling

SPEAKER
Senior Project Manager
Luis Lara

WHEN
March 30th, 2023
12:40 pm – 1:40 pm

WHERE
John T. Rettaliata Engineering Center, RE 104

TALK ABOUT
- ✓ Green building work
- ✓ Energy performance skill
- ✓ Sustainability consulting
- ✓ Energy conservation

For more information, feel free to contact ASHRAE and SEES official email
ashrae_iit@iit.edu
sees@iit.edu

Interested in Joining

Lunch will be provided!

Announcements

- Solution to Assignment 4 will be posted on Blackboard today at 11 am

Announcements

- Revit Training videos are posted on Blackboard

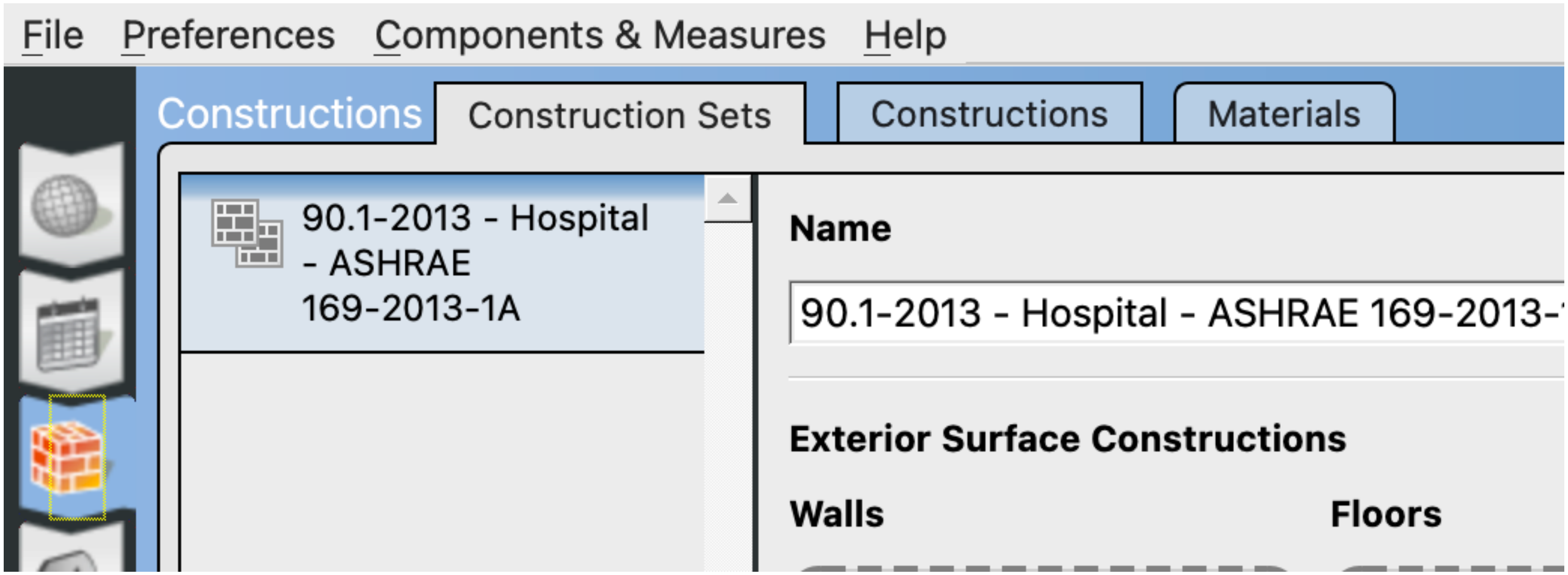
Announcements

- Midterm Exam 2
  - ❑ Exam will take place next Tuesday, 04/04/23 in class (all students are required to attend in person)
  - ❑ Open book / open notes (laptop/tablet is allowed)

PROJECT PART 1 FEEDBACK

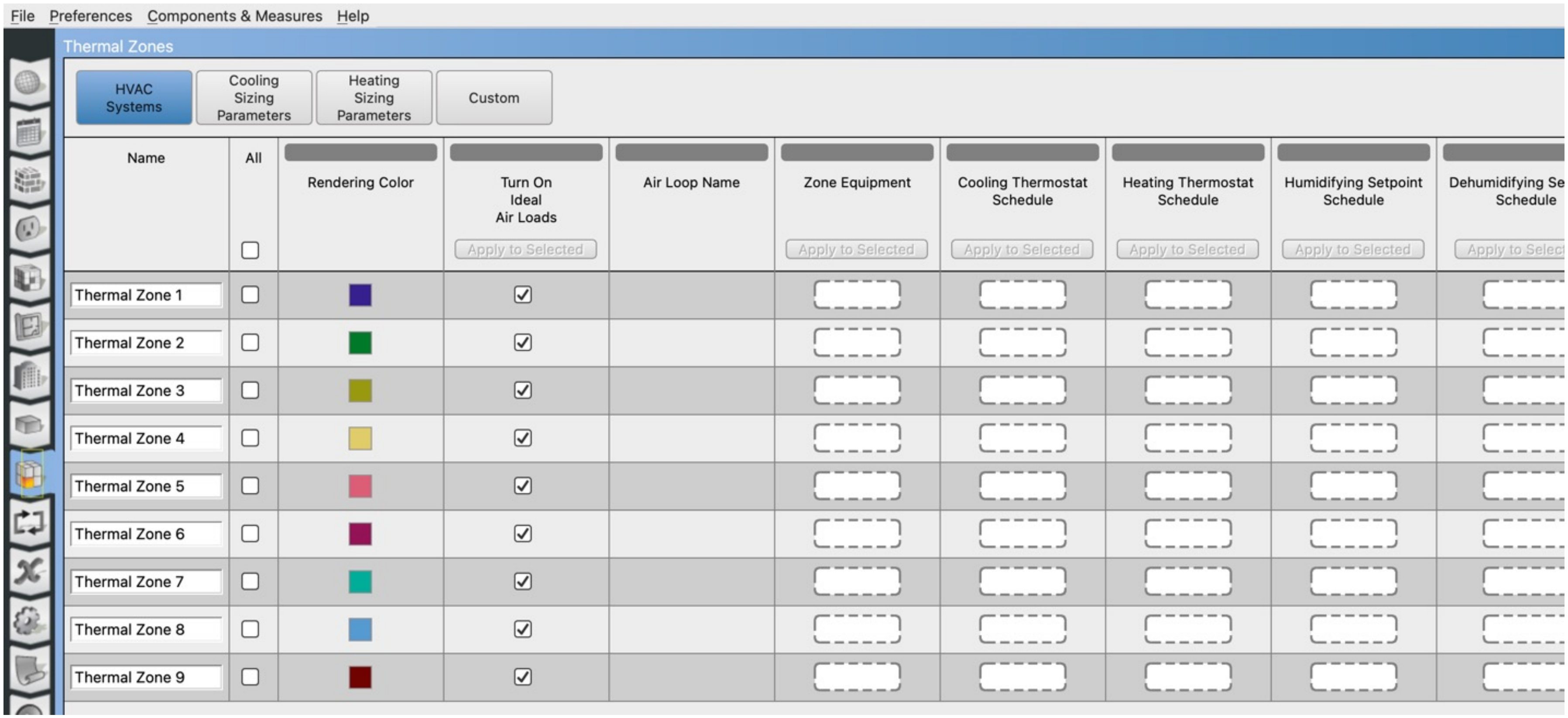
Project Part 1 Feedback

- Make sure to use the right construction set



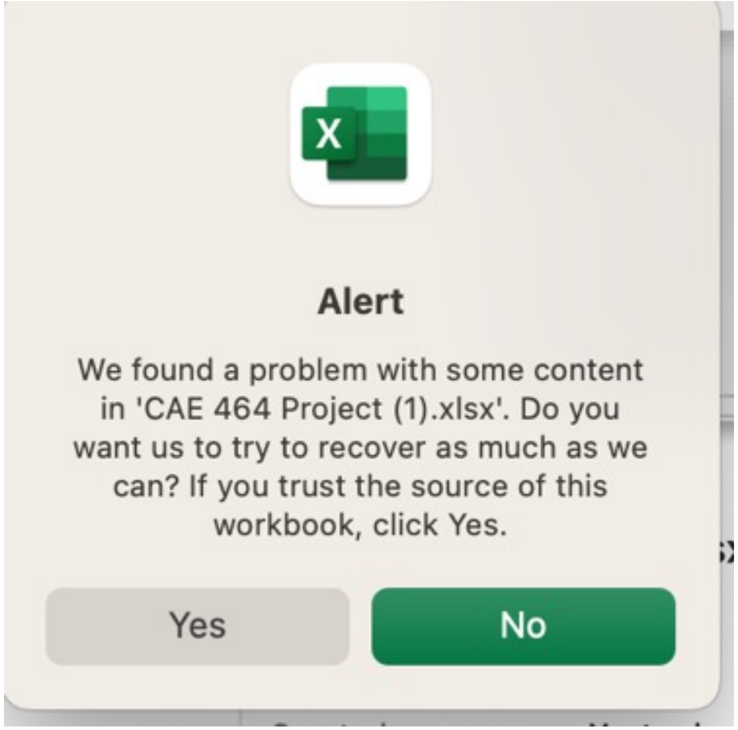
Project Part 1 Feedback

- Make sure to include heating and cooling setpoints



Project Part 1 Feedback

- Pay attention to converting from the Google Sheets to the offline version



Project Part 1 Feedback

- Make sure to use equations and features in Excel

	A	B	C	D	E	F	G
1	Room #	Room Name	Area (SF)	ACH	Volume (ft^3)	Volume flow rate (cfm)	Notes
2	100	Vestibule	46	0	414	=(D2*E2)/60	
3	101	O2 Room	111	0	1443	=(D3*E3)/60	
4	102	Provider	93		1216.75	10.58	Solved For CFM using Vbz equation
5	103	Med Asst.	102		918	11.12	Solved For CFM using Vbz equation
6	104	Telemed	153		1377	14.18	Solved For CFM using Vbz equation
7	105	Social Services	224		2016	23.44	Solved For CFM using Vbz equation
8	106	Corridor	379	2	3411	=(D8*E8)/60	
9	107	Corridor	587	2	5283	=(D9*E9)/60	
10	108A	Intake Room	162	4	1458	=(D10*E10)/60	
11	108B	Intake Room	174	4	1566	=(D11*E11)/60	
12	109	Soiled	78	6	702	=(D12*E12)/60	
13	110	Clean	85	4	765	=(D13*E13)/60	
14	111	Lab	85	6	765	=(D14*E14)/60	
15	112	Staff Toilet	47	0	423	=(D15*E15)/60	
16	113	Patient Toilet	48	0	432	=(D16*E16)/60	
17	114	Exam	119	4	1071	=(D17*E17)/60	
18	115	Exam	119	4	1071	=(D18*E18)/60	
19	116	Exam	118	4	1062	=(D19*E19)/60	
20	117	Corridor	191	2	1719	=(D20*E20)/60	
21	118	Exam	118	4	1062	=(D21*E21)/60	
22	119	Exam	118	4	1062	=(D22*E22)/60	
23	120	Exam	118	4	1062	=(D23*E23)/60	
24	121	Exam	118	4	1062	=(D24*E24)/60	
25	122	Exam	118	4	1062	=(D25*E25)/60	
26	123	Exam	118	4	1062	=(D26*E26)/60	
27	124	Corridor	429	2	3861	=(D27*E27)/60	
28	125	IT	69		948.75	='Room Schedule'!I28*(5)+'Room Schedule'!C28	Solved For CFM using Vbz equation
29	126	Elec.	75	0	1006.25	=(D29*E29)/60	
30	127	Exam	131	4	1179	=(D30*E30)/60	
31	128	Staff Toilet	51	0	408	=(D31*E31)/60	

Project Part 1 Feedback

- Include a summary of each thermal zone heating and cooling loads for both the OpenStudio and the spreadsheet

Thermal Zone	OpenStudio		Spreadsheet		Difference	
	Heating (kBtu/hr)	Cooling (Ton or kBtu/hr)	Heating (kBtu/hr)	Cooling (Ton or kBtu/hr)	Heating (kBtu/hr)	Cooling (Ton or kBtu/hr)
1						
2						
3						

Project Part 1 Feedback

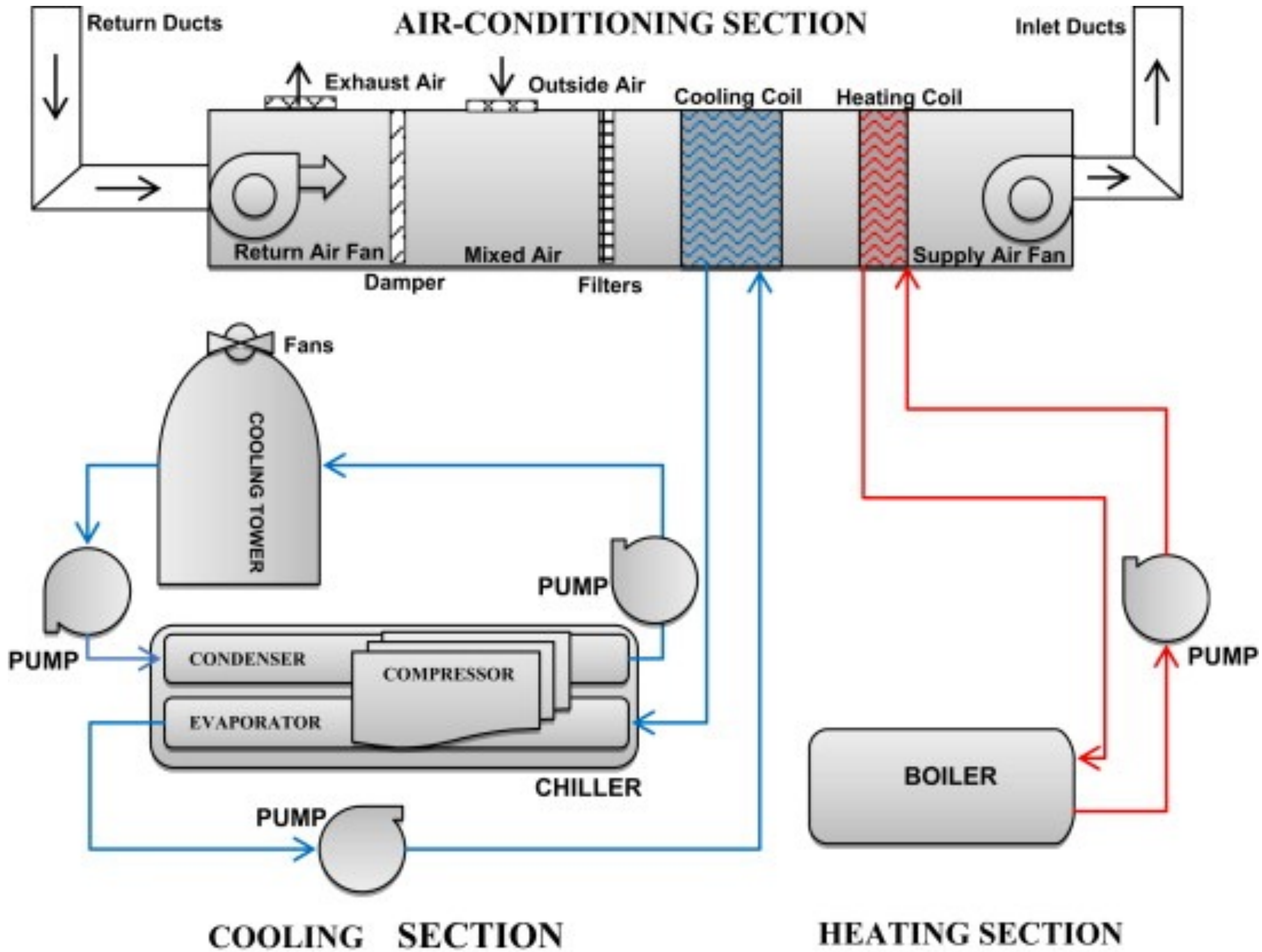
- Fix all the comments for the final submission of the project in May
- Do not forget about the contribution page

INTRODUCTION TO HYDRONIC SYSTEMS

Hydronic Systems

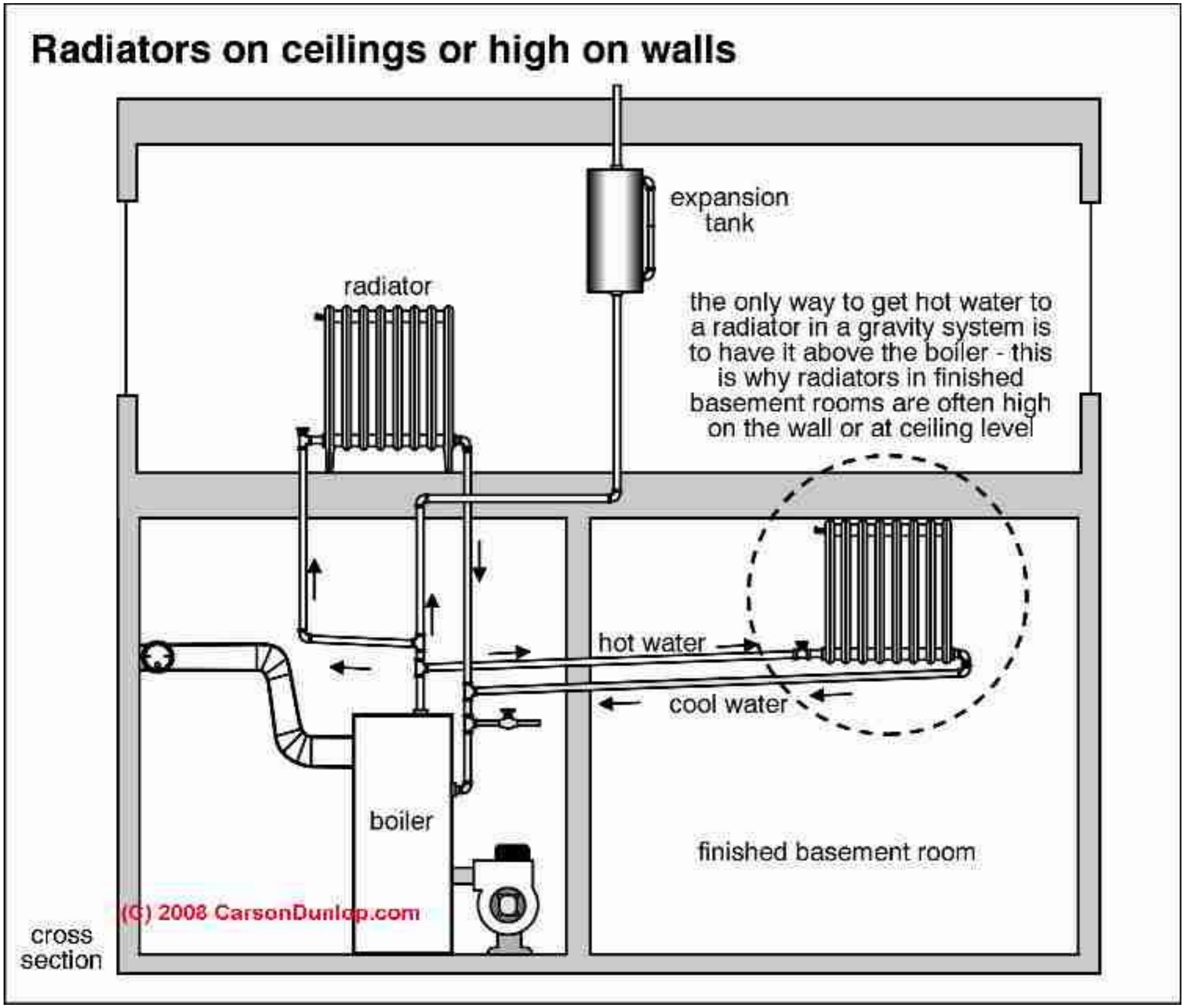
- A system that uses water as the heat transfer medium in heating and cooling applications
- A system in which the heat carrier is neither consumed nor rejected after use but is used repeatedly by recirculation
- Heat carriers are then circulated throughout a series of pipes or tubes to produce a desired room temperature

Hydronic Systems



Hydronic Systems

- Boilers



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

Hydronic Systems

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

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

Hydronic Systems

- Hot Water Storage Tanks

Residential
- Vertical (40 gallons)
- 34,000 – 40,000 Btu

Commercial
- Vertical (150 gallons to 4,000 gallons)
- Horizontal (250 gallons to 4,000 gallons)

https://www.homedepot.com/p/Rheem-Performance-40-Gal-Short-6-Year-38-000-BTU-Natural-Gas-Tank-Water-Heater-XG40S06HE38U0/204321639?cm_mmc=Shopping%7CG%7CVF%7CD26P%7C26-10_WATER_HEATERS%7CRheem%7CPLA%7c71700000033150354%7c58700003868932471%7c92700031086650195&gclid=Cj0KCQjwjpjkBRDRARIsAKv-0O0b0R1tJLZzrGIcr5jyyvf6j5q6-PsQ7HTNl7RaXcHrLSlFm8MtFRoaApx4EALw_wcB&gclsrc=aw.ds https://www.pvi.com/products/commercial-hot-water-storage-tanks.htm

Hydronic Systems

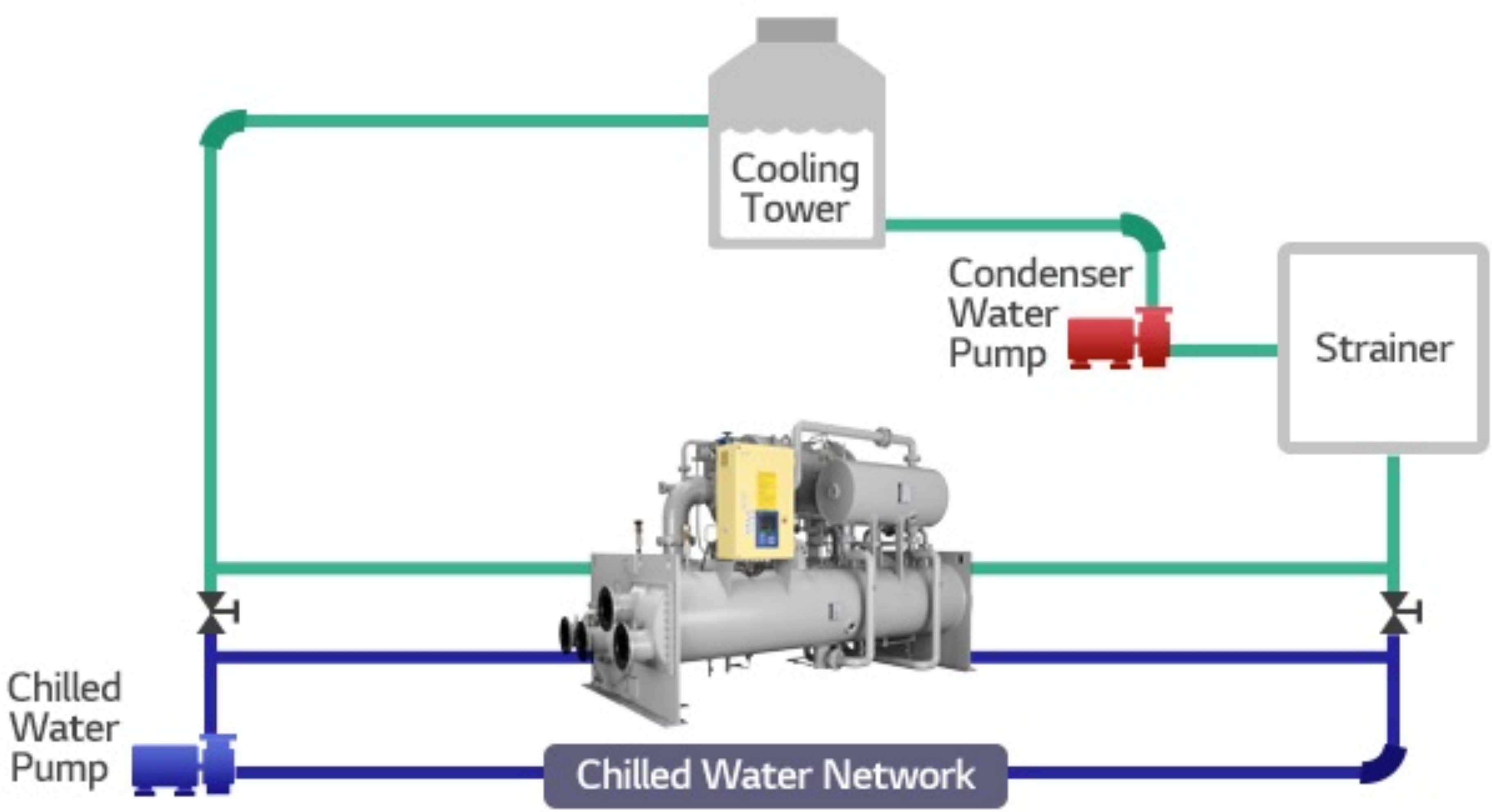
- Tankless water heater

Advantages and setbacks?

https://express.google.com/u/0/product/2600371301634687312_7920860133981164464_7472660?utm_source=google_shopping&utm_medium=tu_prop&utm_content=eid-lsjeuxoeqt&gtim=CNHuioe1w5C3-AEQscvZ7cHH4I8hGKDuz8YClgNVU0Qo8OjF5AUwlIzIAw&utm_campaign=7472660&gclid=Cj0K

Hydronic Systems

- Chilled water



https://www.lghvacstory.com/chillers/

Hydronic Systems

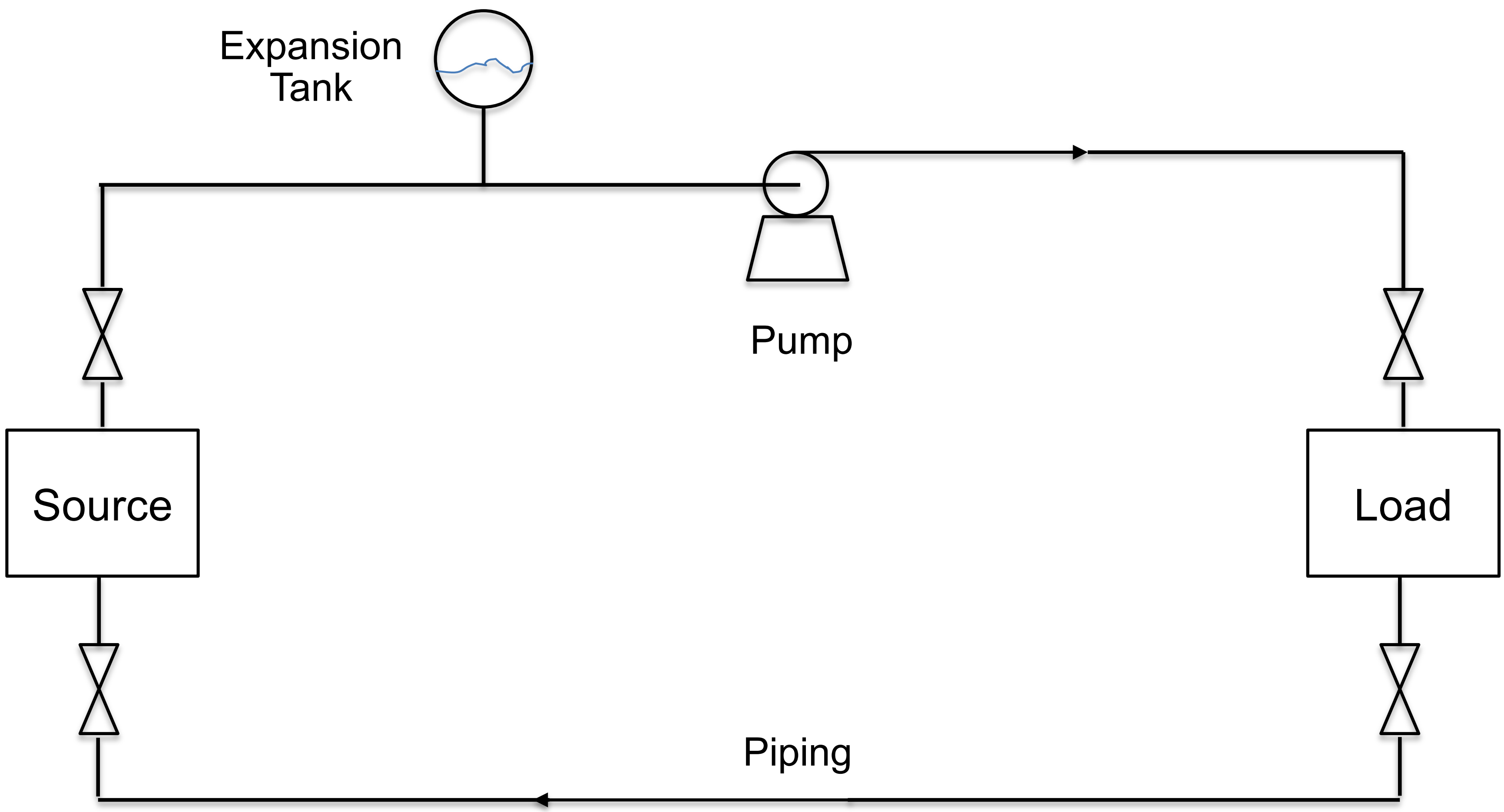
- We used a few of chapters of ASHRAE Systems Handbook:
  - Chapter 13: Hydronic Heating and Cooling
  - Chapter 32: Boiler
  - Chapter 36: Radiators

BASIC OF HYDRONIC SYSTEMS

Basic of Hydronic Systems

- There are two main component types:
  - Thermal components:
    - Heat source(s)
    - Heat load(s)
    - Expansion tank
  - Hydraulic components
    - Piping
    - Pump
    - Expansion tank

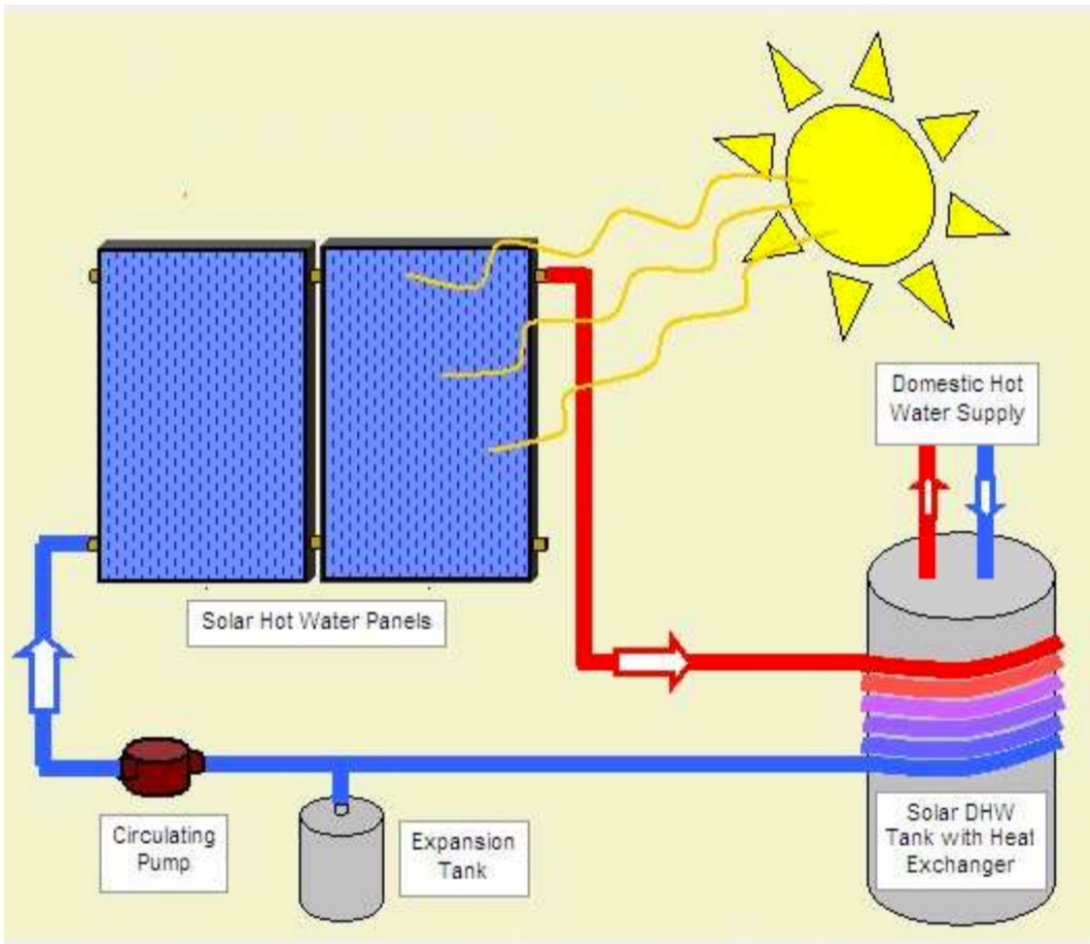
Basic of Hydronic Systems



Is this an open or closed loop system?

Basic of Hydronic Systems

- An example is a closed-loop system is a solar hot water system



Basic of Hydronic Systems

- There are different temperature ranges:
  - ❑ Chilled Water (CHW):
    - Temperature range: 39 ºF to 50 ºF
  - ❑ Condenser Water (CW):
    - Temperature range: 55 ºF to 100 ºF
  - ❑ Hot Water (HW):
    - Temperature range: 100 ºF to 210 ºF
  - ❑ High Temperature Water (HTW):
    - Temperature range: 212 ºF to 455 ºF

Basic of Hydronic Systems

- Another important considerations for selecting hydronic systems are:
  - ❑ Amps / voltage / power (kW)
  - ❑ Water temperature range
  - ❑ Capacity (MBH, Ton, …)
  - ❑ Fuel type
  - ❑ Application (residential, commercial, …)

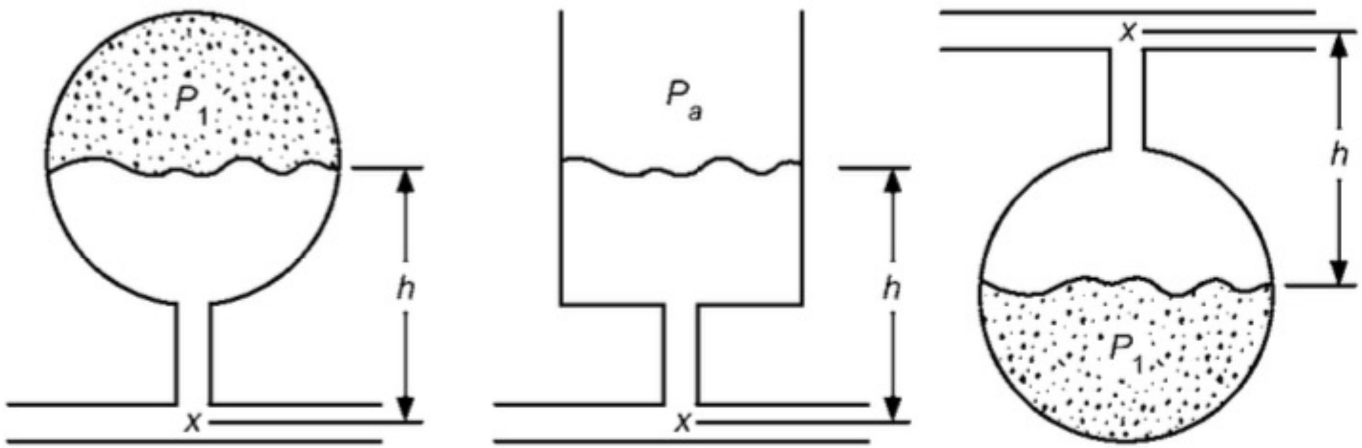
Basic of Hydronic Systems

- Water expand as it is heated, meaning the pressure in the system changes
- In the installation, we use expansion tank or expansion chamber vessel to accommodate the increase in the pressure of the system:
  - ❑ Look similar to a mini tank or boiler
  - ❑ Located typically on top of or next to the water heater
  - ❑ Sized based on the water pressure in the system
  - ❑ Avoid failure or bursting

https://westank.com/expansion-tanks/

Basic of Hydronic Systems

- Three common expansion tank types are:
  - ❑ Closed tank
  - ❑ Open tank
  - ❑ Diaphragm tank



$P_x = P_1 + \rho_w h$ A. CLOSED TANK AIR/ WATER INTERFACE

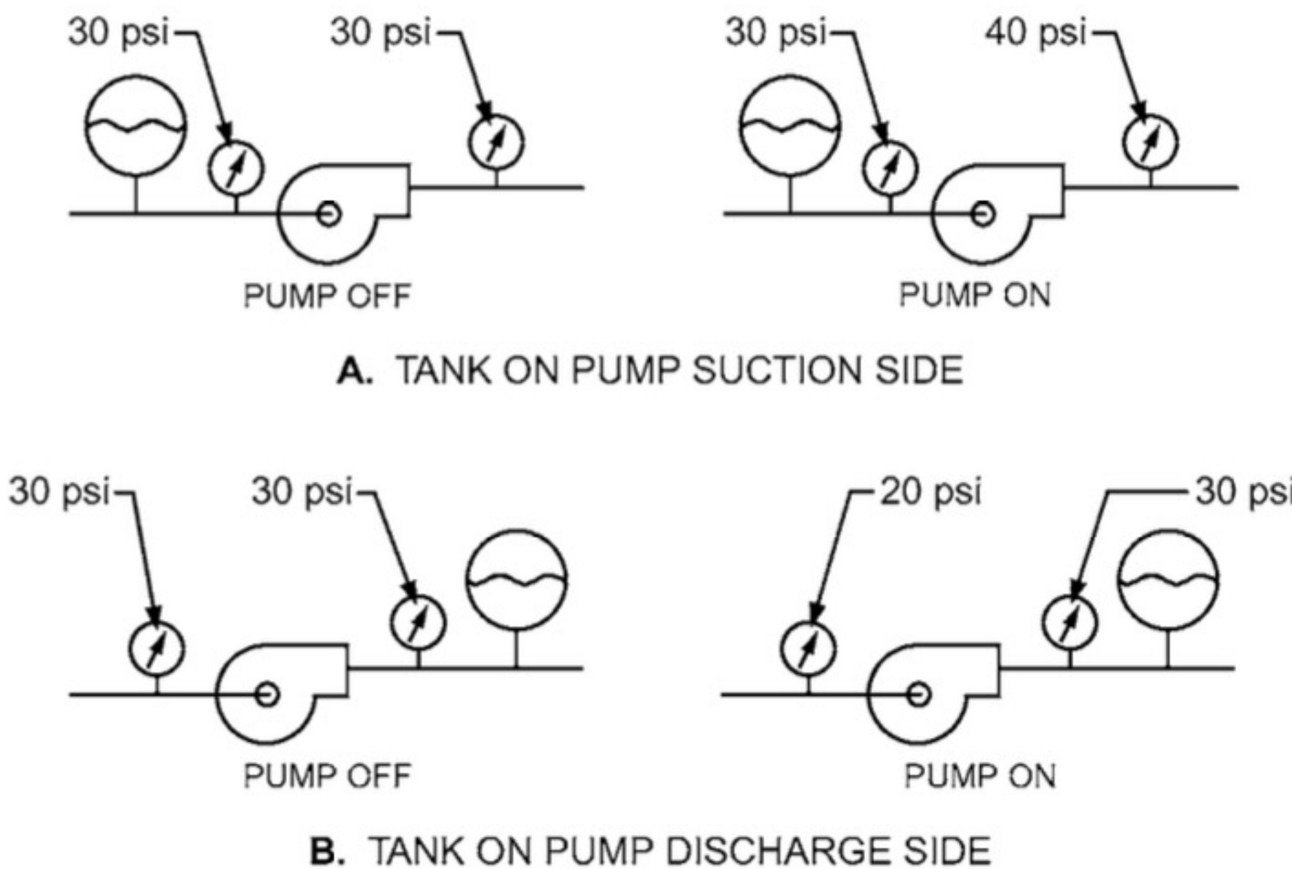
$P_x = P_a + \rho_w h$ B. OPEN TANK

$P_x = P_1 - \rho_w h$ C. DIAPHRAGM TANK

ASHRAE Systems, Chapter 13

Basic of Hydronic Systems

- An example of installing expansion tanks in a hydronic systems:



ASHRAE Systems, Chapter 13

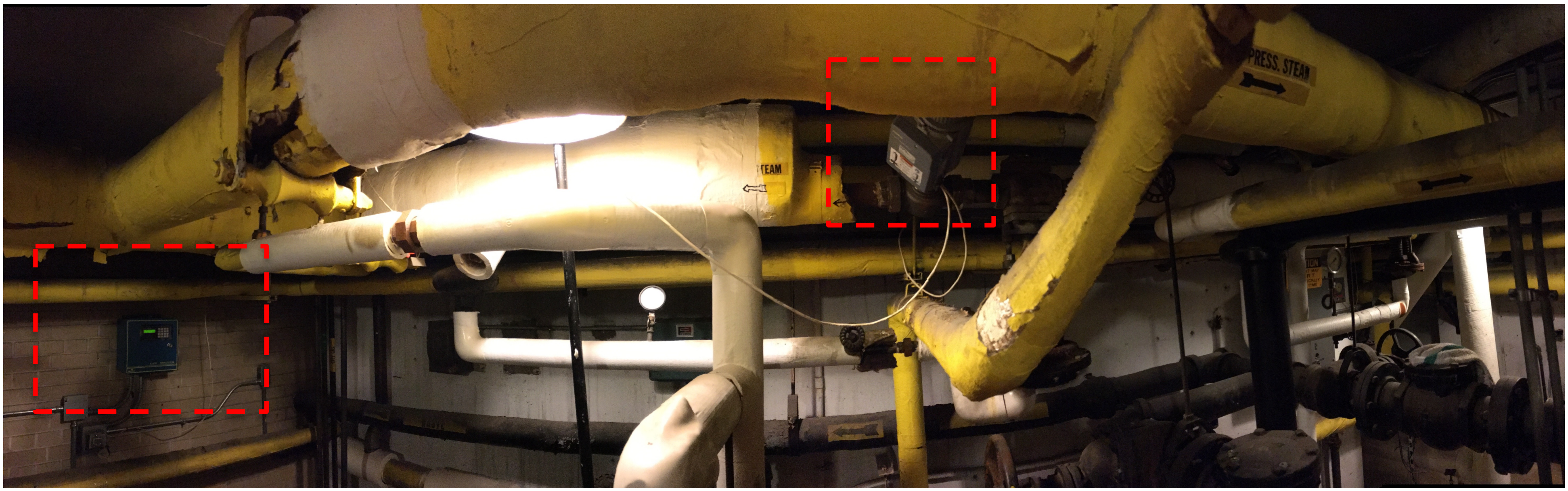
IIT HYDRONIC SYSTEMS

IIT Hydronic Systems

- Alumni Hall and Herman Hall buildings steam system

IIT Hydronic Systems

- Alumni Hall and Herman Hall buildings steam system



HYDRONIC HEATING SYSTEMS

Hydronic Heating Systems

- Common temperature range of hydronic hot water systems are:
  - ❑ Low temperature hot water systems (LTHW)
  - ❑ Medium temperature hot water systems (MTHW)
  - ❑ High temperature hot water systems (HTHW)

Hydronic Heating Systems

- Low temperature hot water systems (LTHW):
  - Most widely used for residential and smaller commercial/institutional buildings (Loads less than 1.5 MW or 5×10^6 Btu/h or 5,000 MBH)
  - Used for space heating loads and domestic hot water
  - Maximum temperature < 120 ºC (250 ºF)
  - Maximum pressure < 1,100 kPa (160 psia)
  - Steam-to-water or water-to-water heat exchanger often used
  - System temperature drop (supply to return) is usually 6 ºC to 24 ºC (10 ºF to 40 ºF)

Hydronic Heating Systems

- Medium temperature hot water systems (MTHW):
  - Commonly used for space heating in commercial/institutional buildings and in industrial applications (Loads range from 1.45 to 1.75 MW or $5x10^6$ to $6x10^6$ Btu/h)
  - Design supply temperatures: 120 ºC to 175 ºC (250 ºF to 350 ºF)
  - Pressure ratings for boilers/ piping: about 1,030 kPa (150 psia)

Hydronic Heating Systems

- High temperature hot water systems (HTHW):
  - Generally limited to campus-type district heating applications
  - Supply temperatures in the range of 175 ºC to 230 ºC (350 ºF to 400 ºF)
  - System temperature drop can be up to 55 ºC (100 ºF)
  - Pressure rating is about 300-350 psia

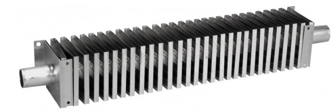
Hydronic Heating Systems

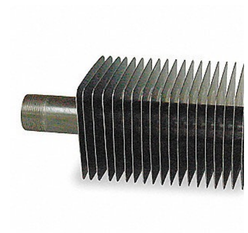
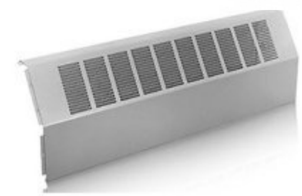
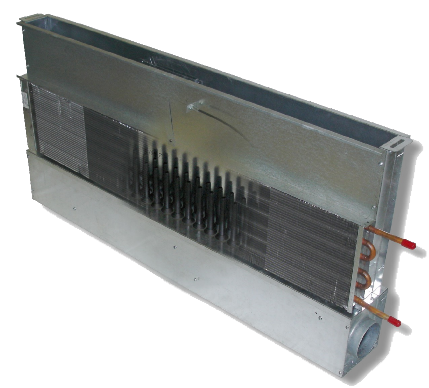
- Hydronic heating source devices are:
  - ❑ Hot water generator or boiler
  - ❑ Steam-to-water heat exchanger
  - ❑ Water-to-water heat exchanger
  - ❑ Solar heating panels
  - ❑ Heat recovery or salvage heat device
  - ❑ Exhaust gas heat exchanger
  - ❑ Incinerator heat exchanger
  - ❑ Heat pump condenser
  - ❑ Air-to-water heat exchanger (heat recovery coil)

https://www.wandaboiler.com/industrial-gas-fired-boilers-oil-fired-boilers/

Hydronic Heating Systems

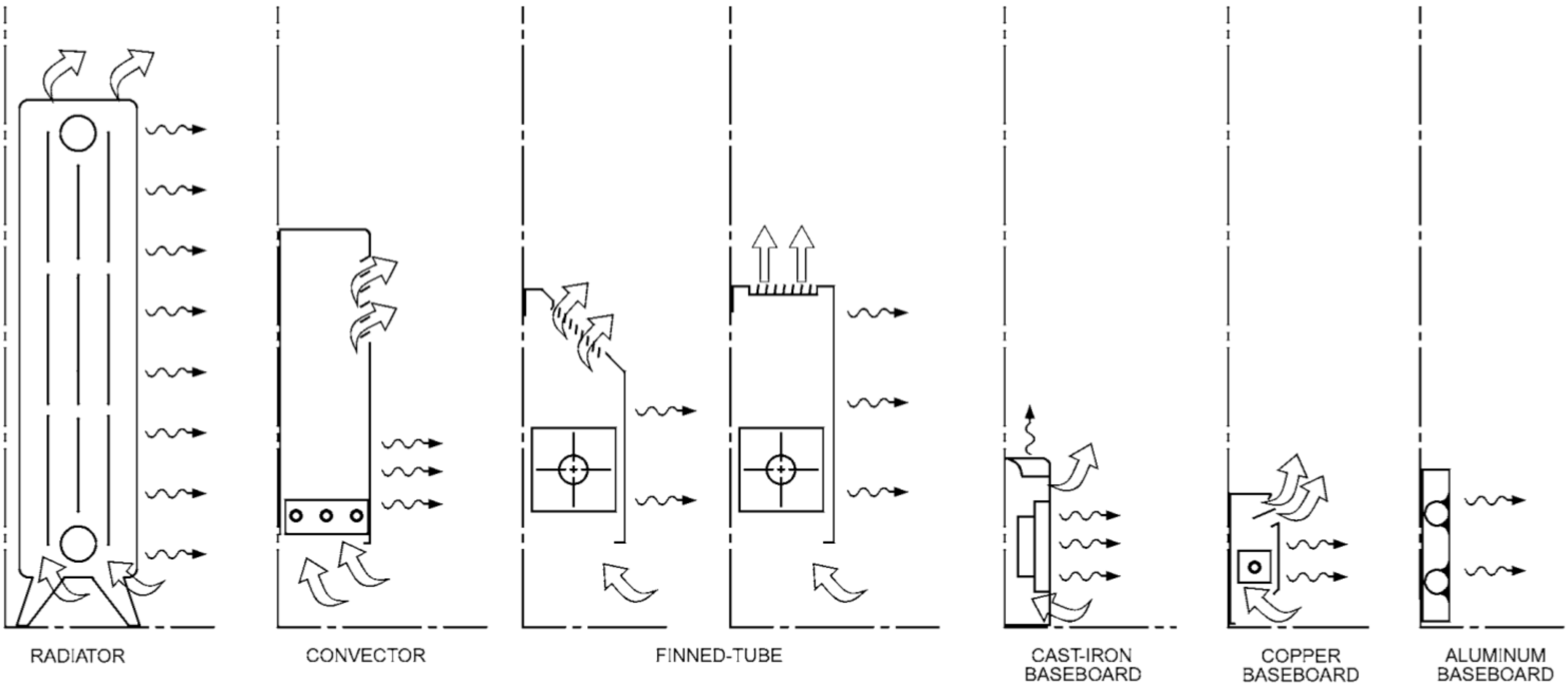
- Hydronic heating load devices are:
  - ❑ Preheat coils in central units
  - ❑ Convectors
  - ❑ Heating coils in central units
  - ❑ Unit heaters
  - ❑ Zone or central unit reheat coils
  - ❑ Fan-coil units
  - ❑ Induction unit and chilled beam coils
  - ❑ Finned-tube radiation
  - ❑ Baseboard radiation
  - ❑ Water-to-Water heat exchangers
  - ❑ Radiant heating panels

https://www.grainger.com/product/5E307?gclid=Cj0KCQjAn4PkBRCDARIsAGHmH3d3NEOg6gMpb4OY9bsiK3EYG0AXZTTJvzxhmUd1LmgZX_mbJXhaI4oaAplSEALw_wcB&cm_mmc=PPC:+Google+PLA&ef_id=Cj0KCQjAn4PkBRCDARIsAGHmH3d3NEOg6gMpb4OY9bsiK3EYG0AXZTTJvzxhmUd1LmgZX_mbJXhaI4oaAplSEALw_
https://www.grainger.com/category/hvac-and-refrigeration/heaters/hot-water-heating-and-supplies/hydronic-unit-heaters
https://www.alde.us/our-products/convectors/ & http://usacoil.com/tag/preheat-coils/

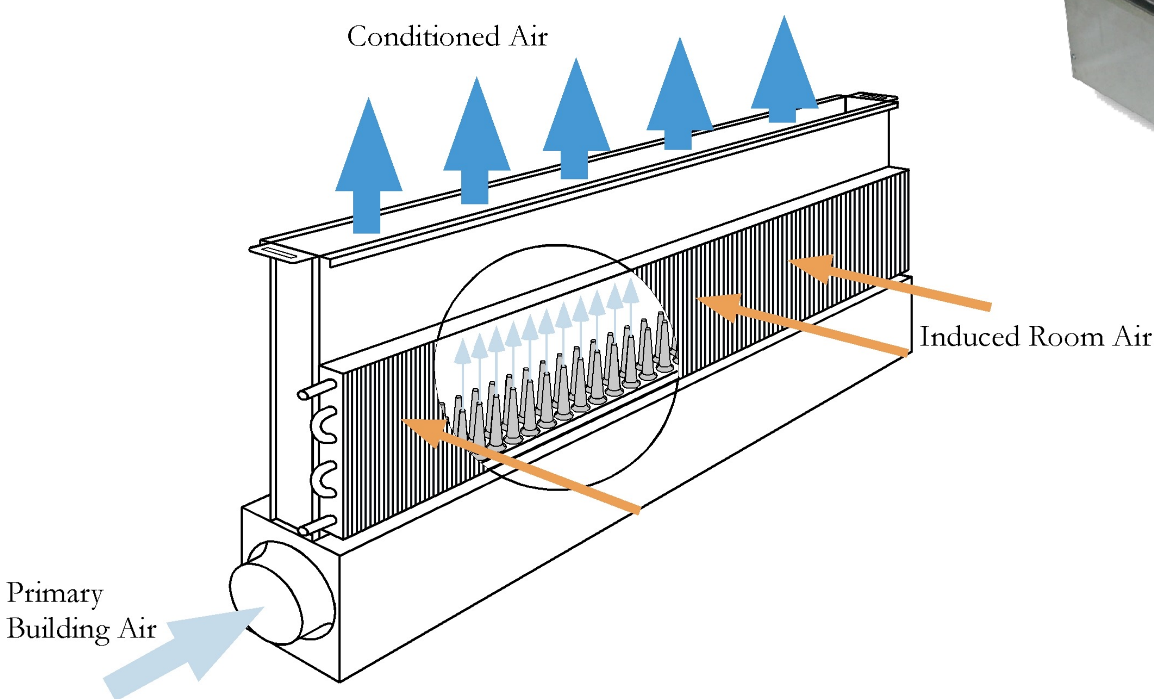
Hydronic Heating Systems



ASHRAE Systems Handbook, Chapter 36

Hydronic Heating Systems

- For example, induction units:



https://www.canyonairproducts.com/info-and-specifications/

Hydronic Heating Systems

- For example, finned tube

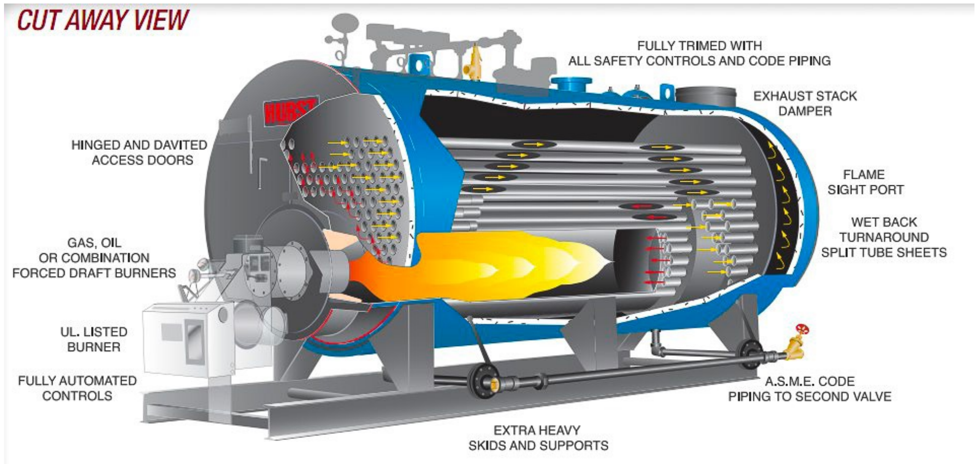
Hydronic Heating Systems

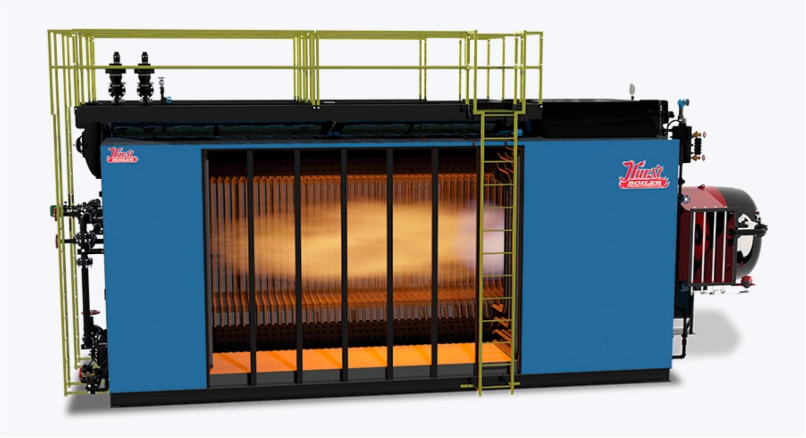
- For example, unit heaters:
  - ❑ Able to provide a high heating capacity in a compact casting
  - ❑ The ability to project air in a controlled manner to a far distance
  - ❑ Inexpensive compared to the output

https://www.contractingbusiness.com/commercial-hvac/article/20869989/products-up-close-unit-heaters

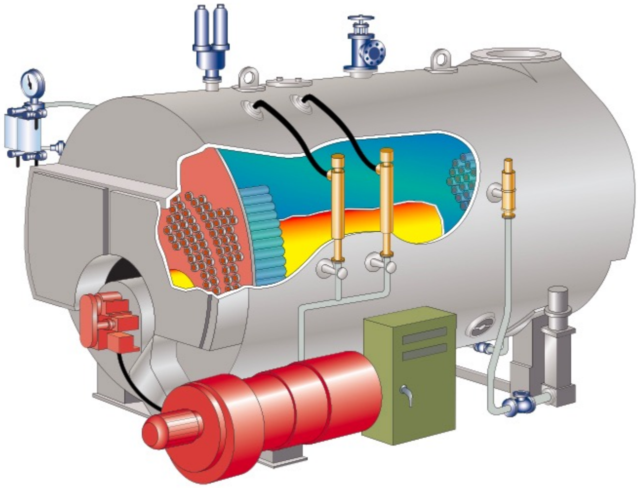
Hydronic Heating Systems

- Three common boiler types are:
  - ❑ Water tube boilers
  - ❑ Fire tube boiler
  - ❑ Cast iron boilers





Water tube boilers

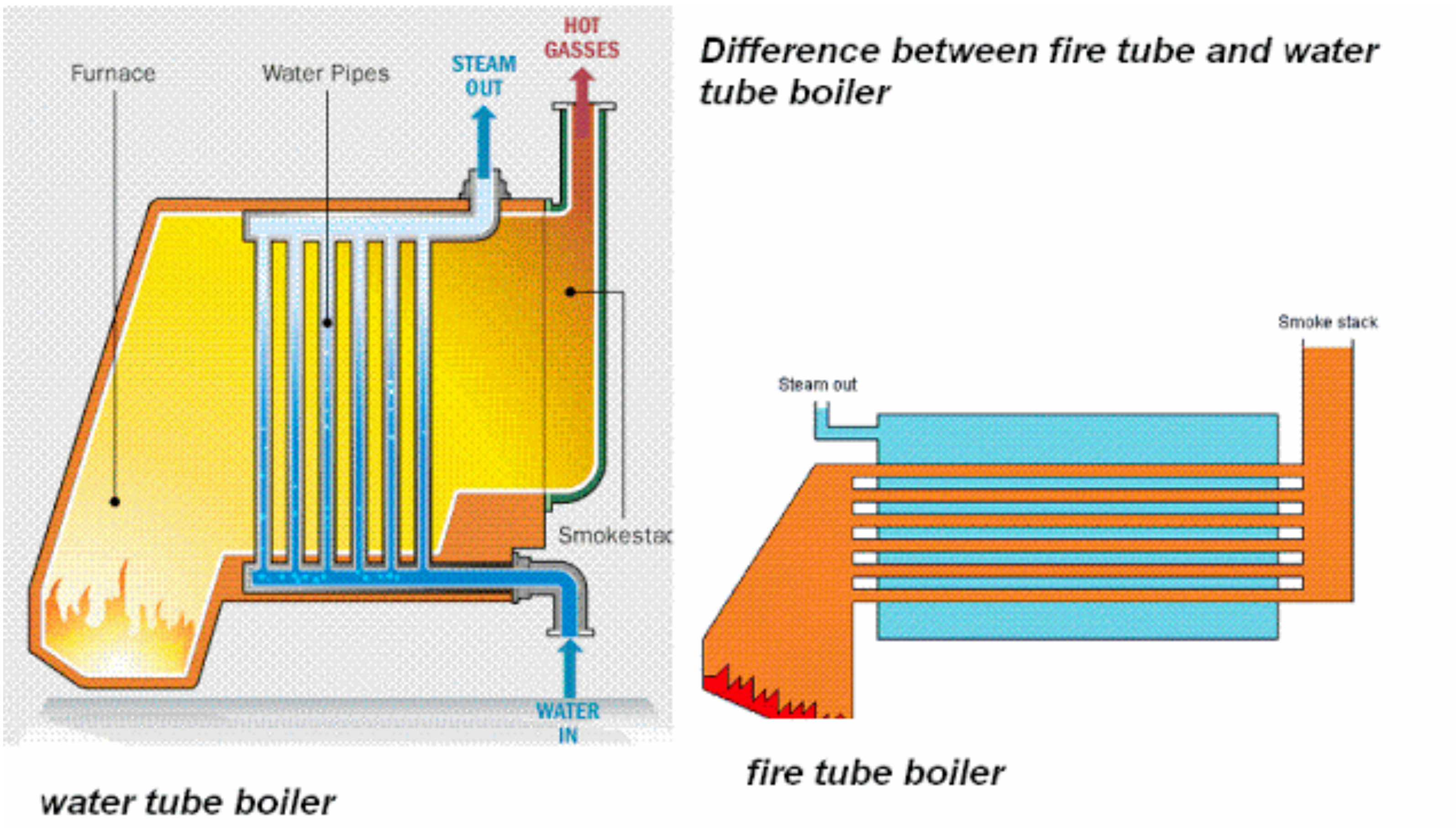


Fire tube boilers

https://s3.amazonaws.com/hurstboiler/documents/HBC-09546-SERIES-600-A-2019.pdf. & https://www.hurstboiler.com/boilers/scotch_marine/series_400#group-4
https://www.spiraxsarco.com/learn-about-steam/the-boiler-house/shell-boilers

Hydronic Heating Systems

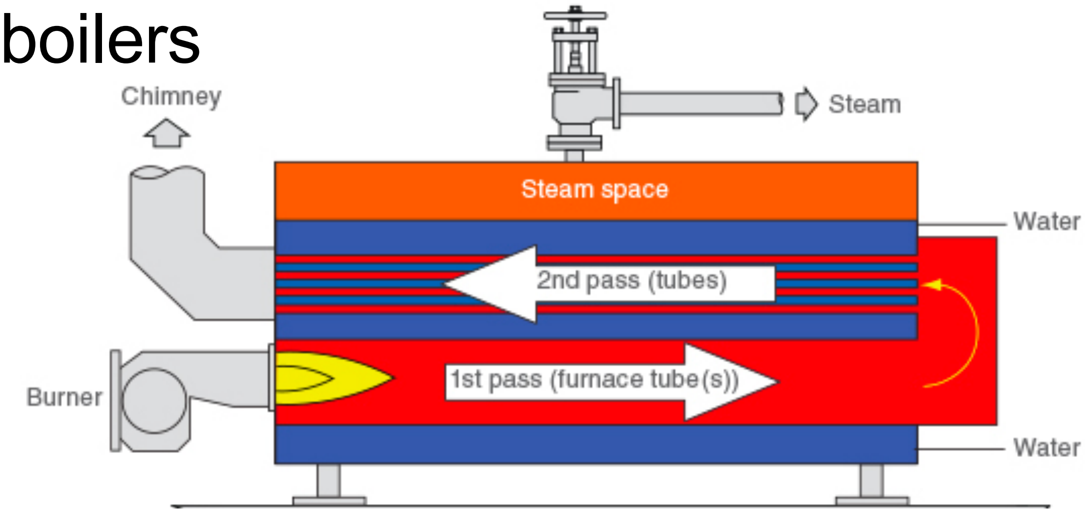
- Water tube boiler vs fire tube boilers

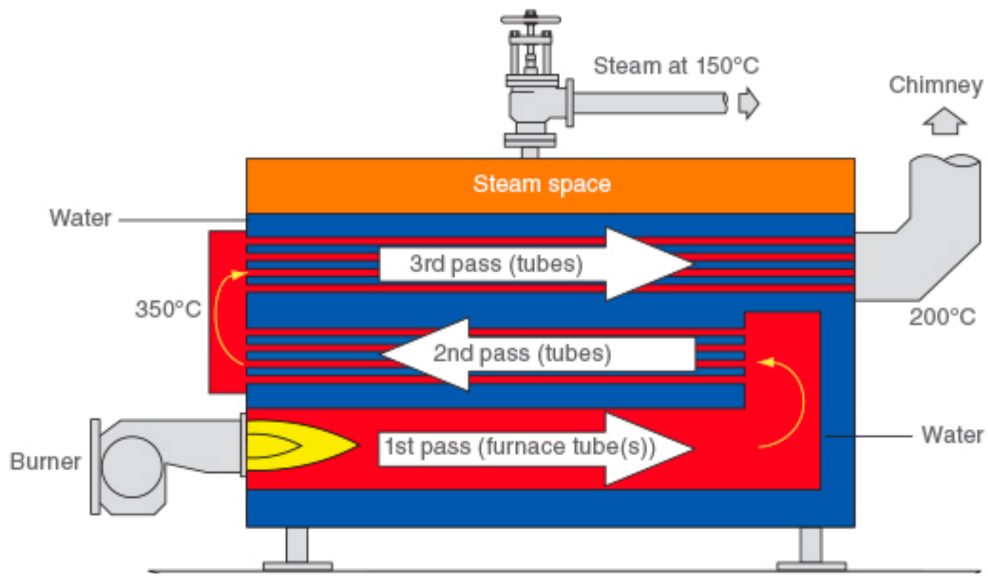


https://www.green-mechanic.com/2014/08/difference-between-fire-tube-boiler-and.html

Hydronic Heating Systems

- Fire tube boilers





Fire tube boilers

https://www.spiraxsarco.com/learn-about-steam/the-boiler-house/shell-boilers

Hydronic Heating Systems

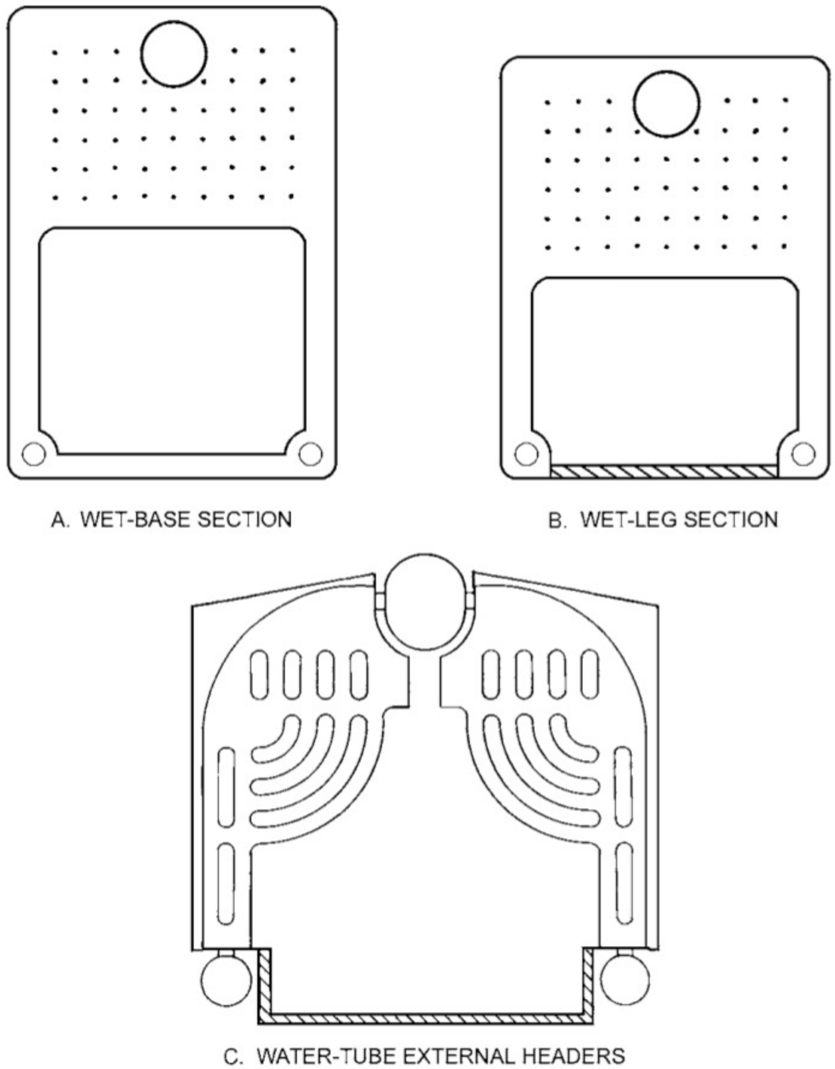
- Cast iron boilers

Cast iron boiler

https://industrialburnerservice.weebly.com/case-study---burrillville-middle-school.html

Hydronic Heating Systems

- Cast iron boilers



Cast iron boiler

ASHRAE Systems Handbook, Chapter 32

Hydronic Heating Systems

- A completely hydronic heating system
  - Used to be installed in commercial buildings
  - Is well-suited for perimeter spaces with seasonal needs
  - Because of their limited space requirements, it used to suitable for retrofit applications:
    - Take up little to no space in the central machine room
    - Do not need ducts
  - They can provide individual room control, and can be coupled with heat recovery and solar heating systems

Hydronic Heating Systems

- A completely hydronic heating system
  - ❑ Not suited for interior spaces and for spaces requiring
    - Close control of humidity
    - Requiring proper ventilation air
  - ❑ High maintenance
  - ❑ Repair needs to be done in occupied spaces

Can these systems be connected to an AHU?

HYDRONIC COOLING SYSTEMS

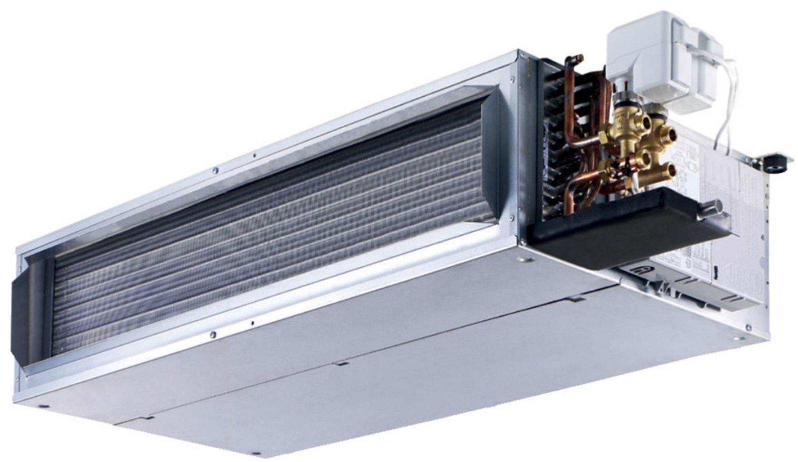
Hydronic Cooling Systems

- Hydronic cooling source devices are:
  - ❑ Electric compression chiller
  - ❑ Thermal absorption chiller
  - ❑ Heat pump evaporator
  - ❑ Air-to-water heat exchanger (heat recovery coil)
  - ❑ Water-to-water heat exchanger

https://instrumentationtools.com/difference-between-hvac-absorption-chillers-and-electric-chillers/

Hydronic Cooling Systems

- Hydronic cooling load devices are:
  - ❑ Coils in central units
  - ❑ Fan-coil units
  - ❑ Induction unit and chilled beam coils
  - ❑ Radiant cooling panels
  - ❑ Water-to-water heat exchangers



https://www.ahi-carrier.gr/en/product/42nl-42nh-idrofan-hydronic-ducted-fan-coil-units/
http://www.york.com/for-your-workplace/air-systems/fan-and-blower-coil-units/floor-mounted-vertical-fan-coil-units

HYDRONIC SYSTEM DISTRIBUTION CIRCUITS

Hydronic System Distribution Circuits

- The system between the source (boiler or chiller) and the terminal units (or devices) in rooms/zones can have the following configurations:
  - ❑ Series
  - ❑ One pipe main
  - ❑ Two pipe (Direct or reverse return)
  - ❑ Three pipe
  - ❑ Four pipe

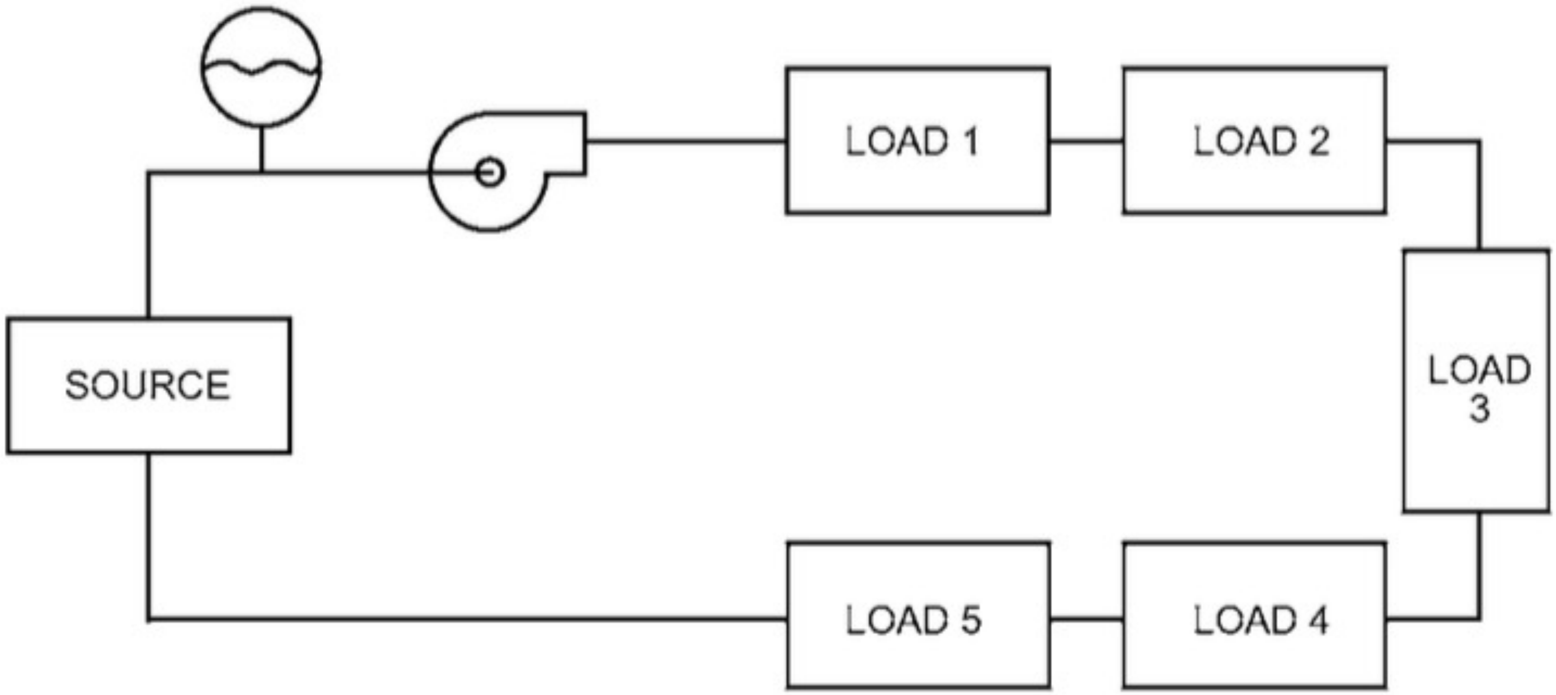
https://heatinghelp.com/systems-help-center/a-steam-heating-primer/

Hydronic System Distribution Circuits

- There are many piping arrangements, particularly for hot water systems
- Closed-loop systems are commonly classified as two-or four-pipe

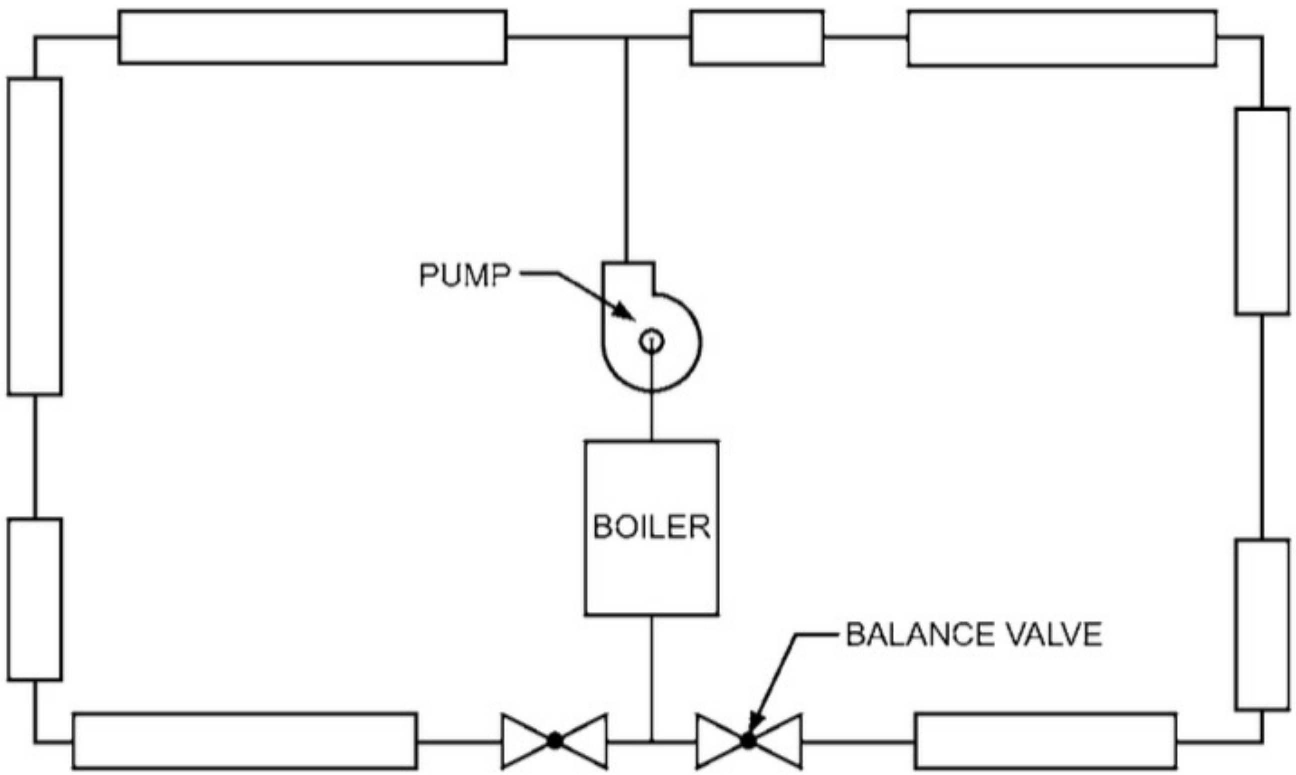
Hydronic System Distribution Circuits

- Simple series circuit is one approach:



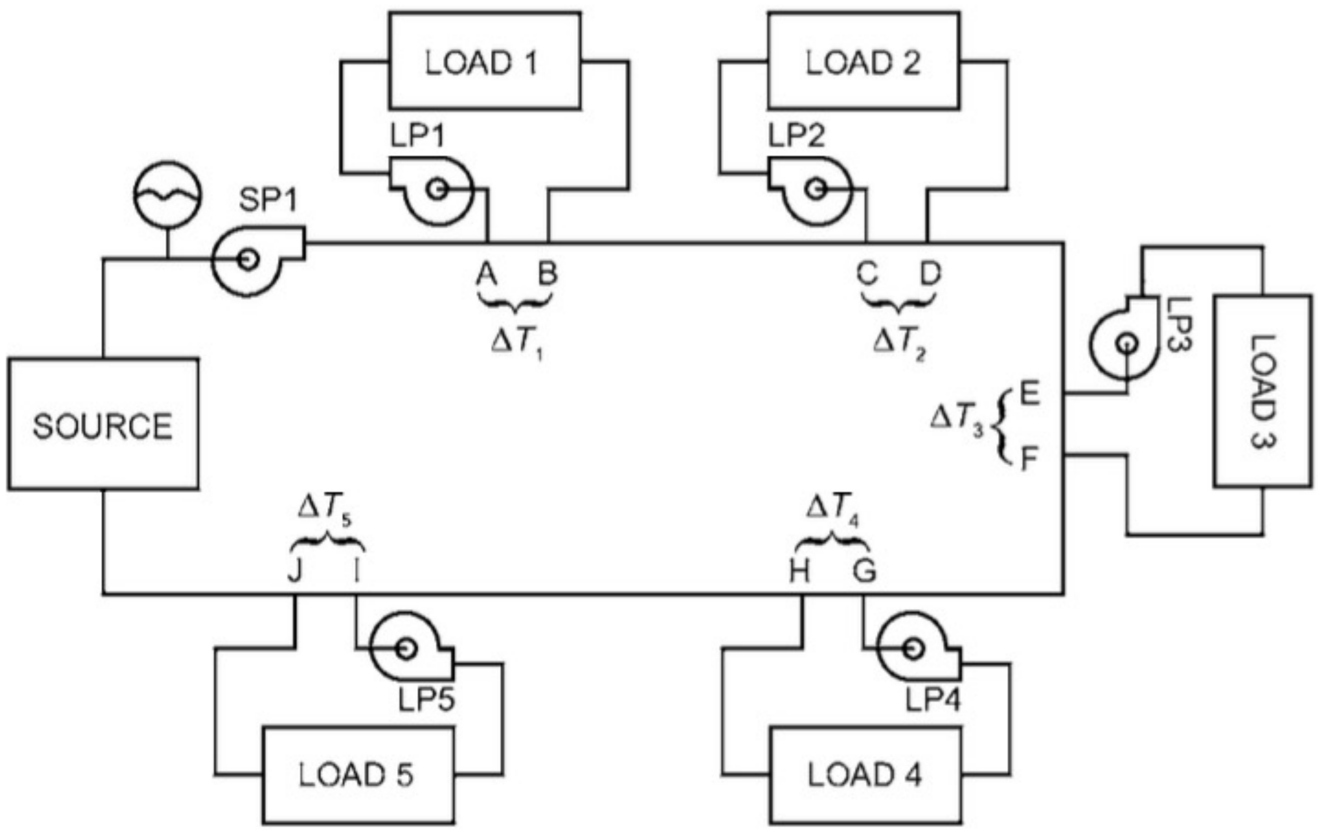
Basic of Hydronic Systems

- Another approach is to use a pump in this configuration:



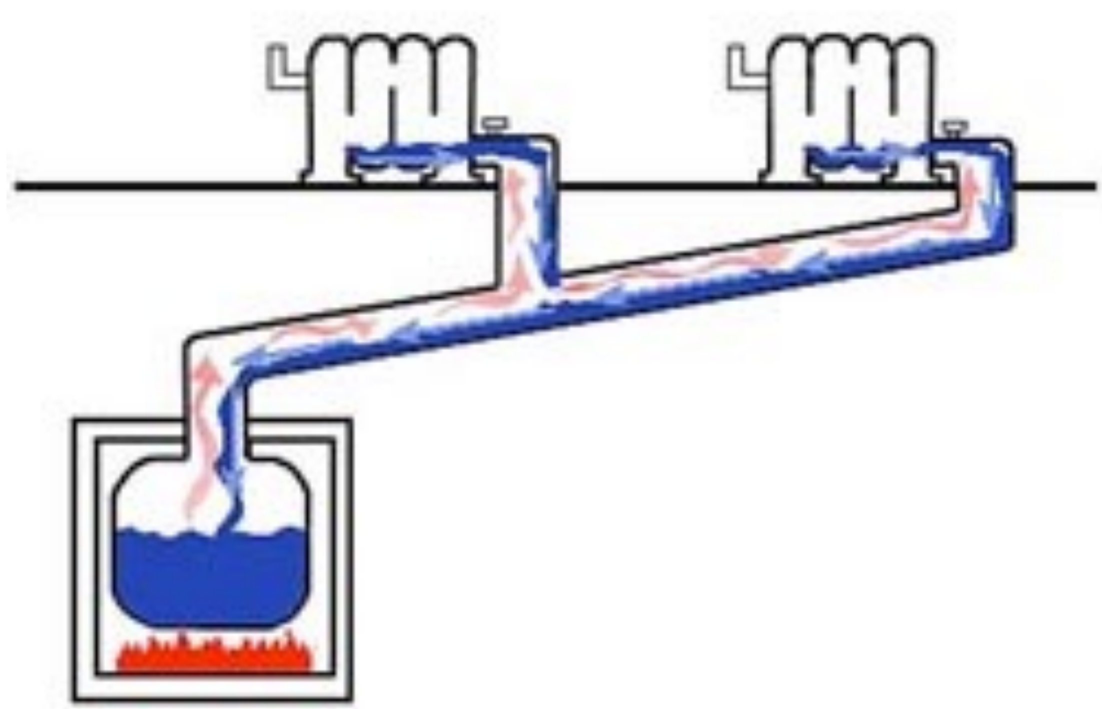
Hydronic System Distribution Circuits

- Another approach is the series circuit with distributed load pumps:



Hydronic System Distribution Circuits

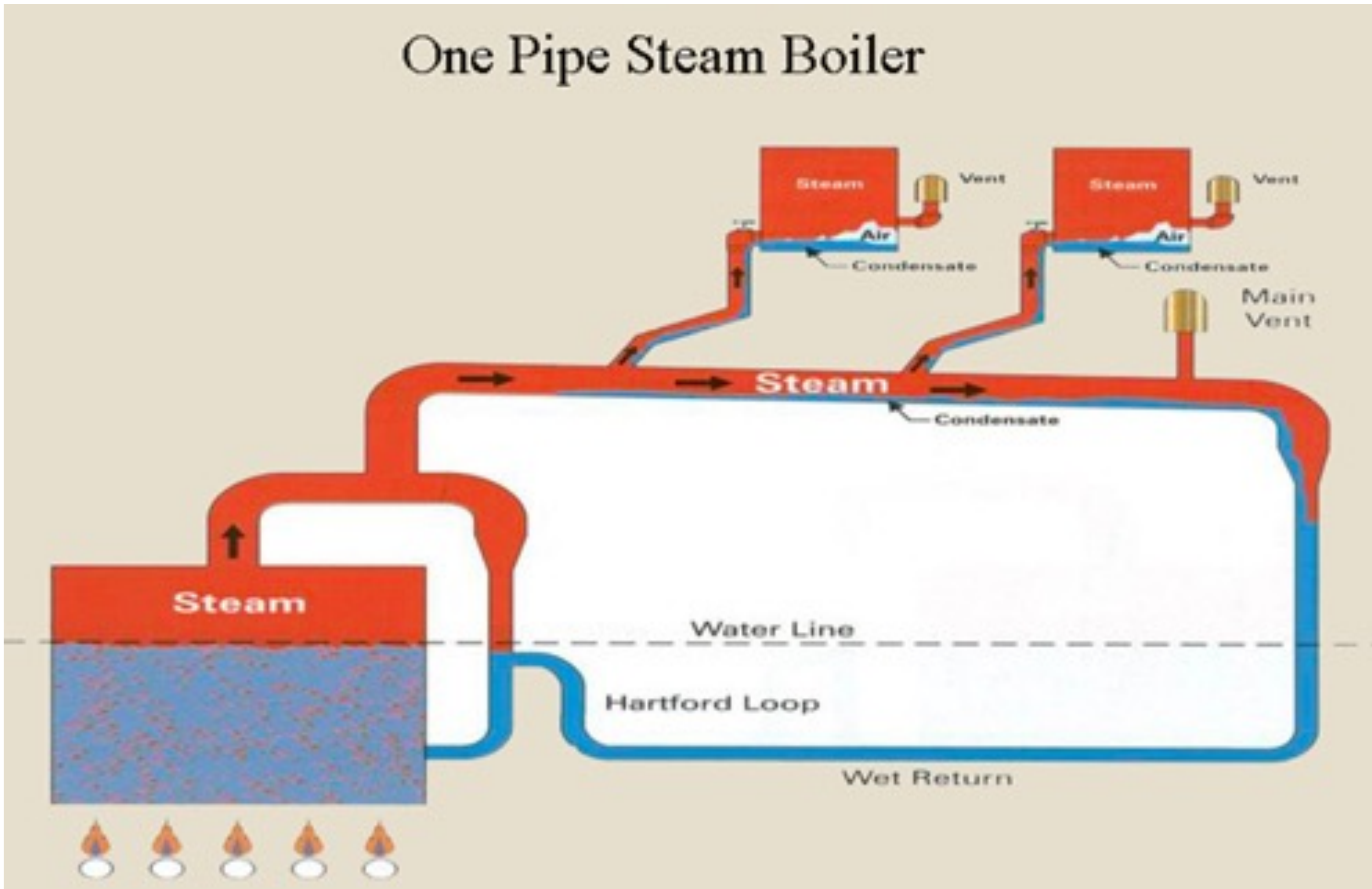
- One-pipe hydronic systems:
  - ❑ Have a single pipe that acts as the supply pipe and return pipe for the flow loop
  - ❑ Connects one terminal unit to the next terminal unit



http://c03.apogee.net/contentplayer/?coursetype=res&utilityid=mp&id=2379

Hydronic System Distribution Circuits

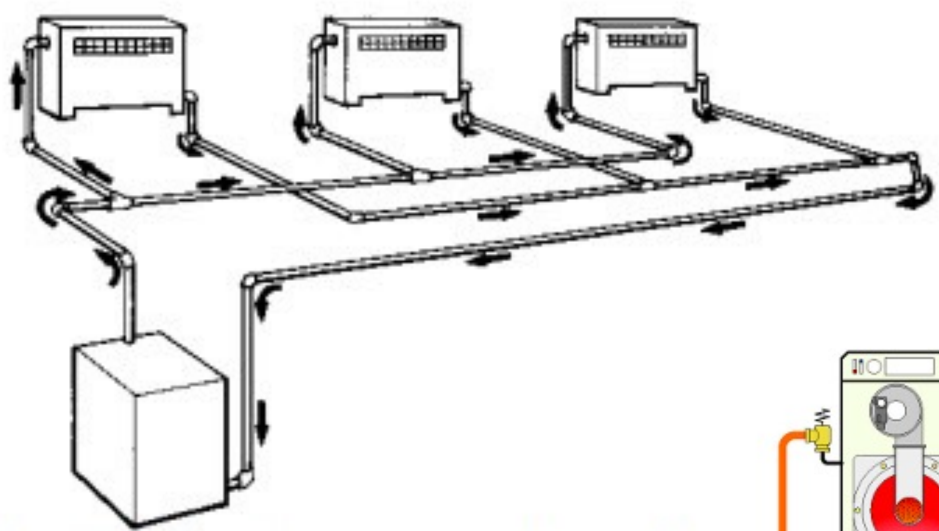
- One-pipe hydronic systems:

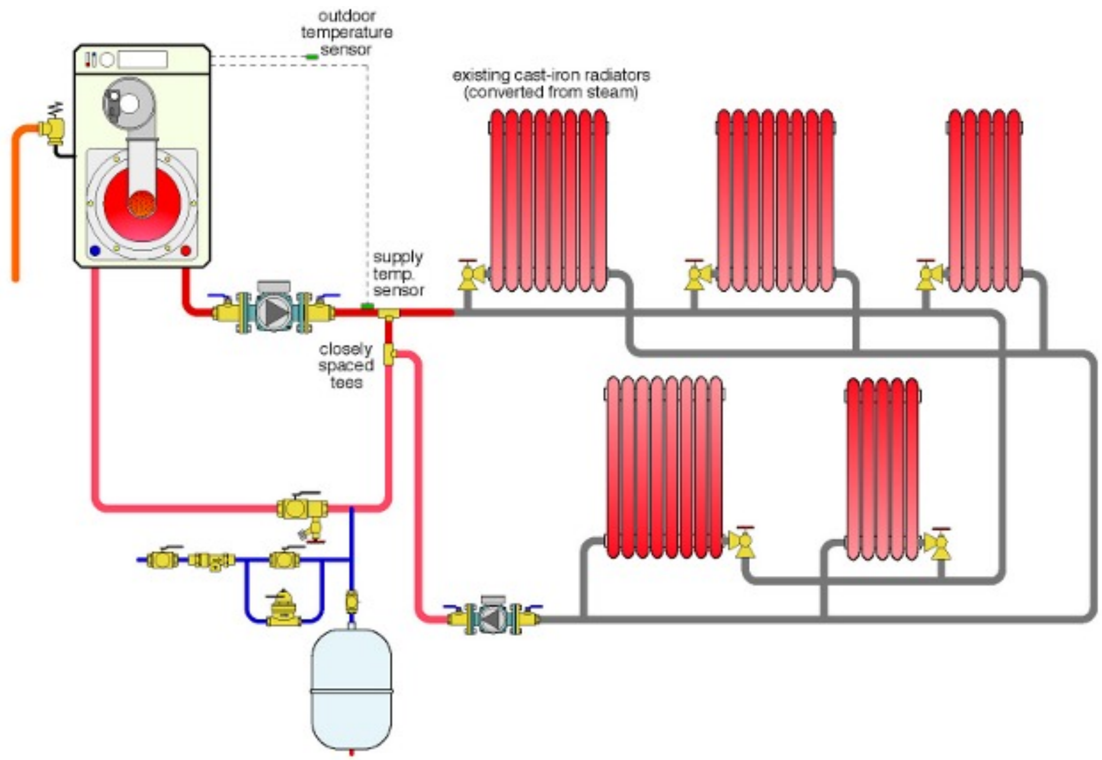


https://degraceplumbing.com/steam-boilers-in-nj/

Hydronic System Distribution Circuits

- Two-pipe hydronic systems:
  - ❑ Have a separate supply pipe and return pipe at each terminal unit

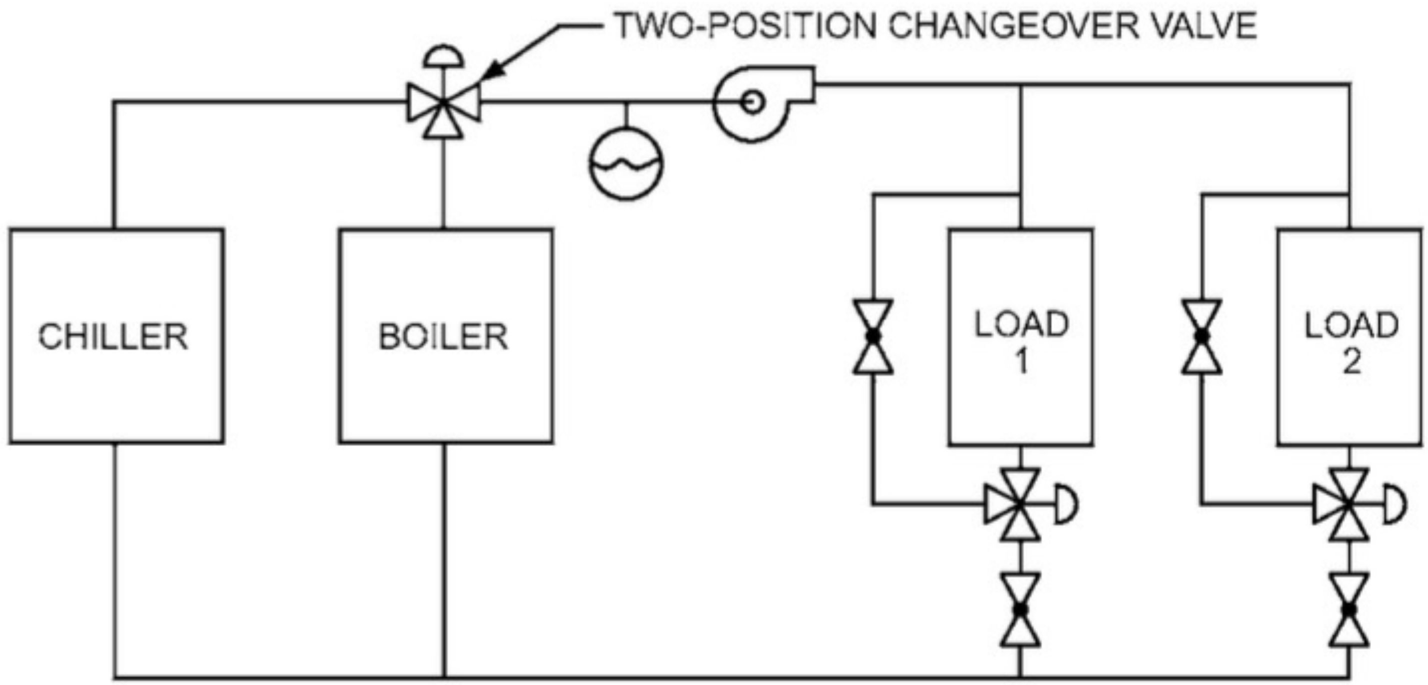




https://www.pmmag.com/articles/99627-iron-meets-microprocessor

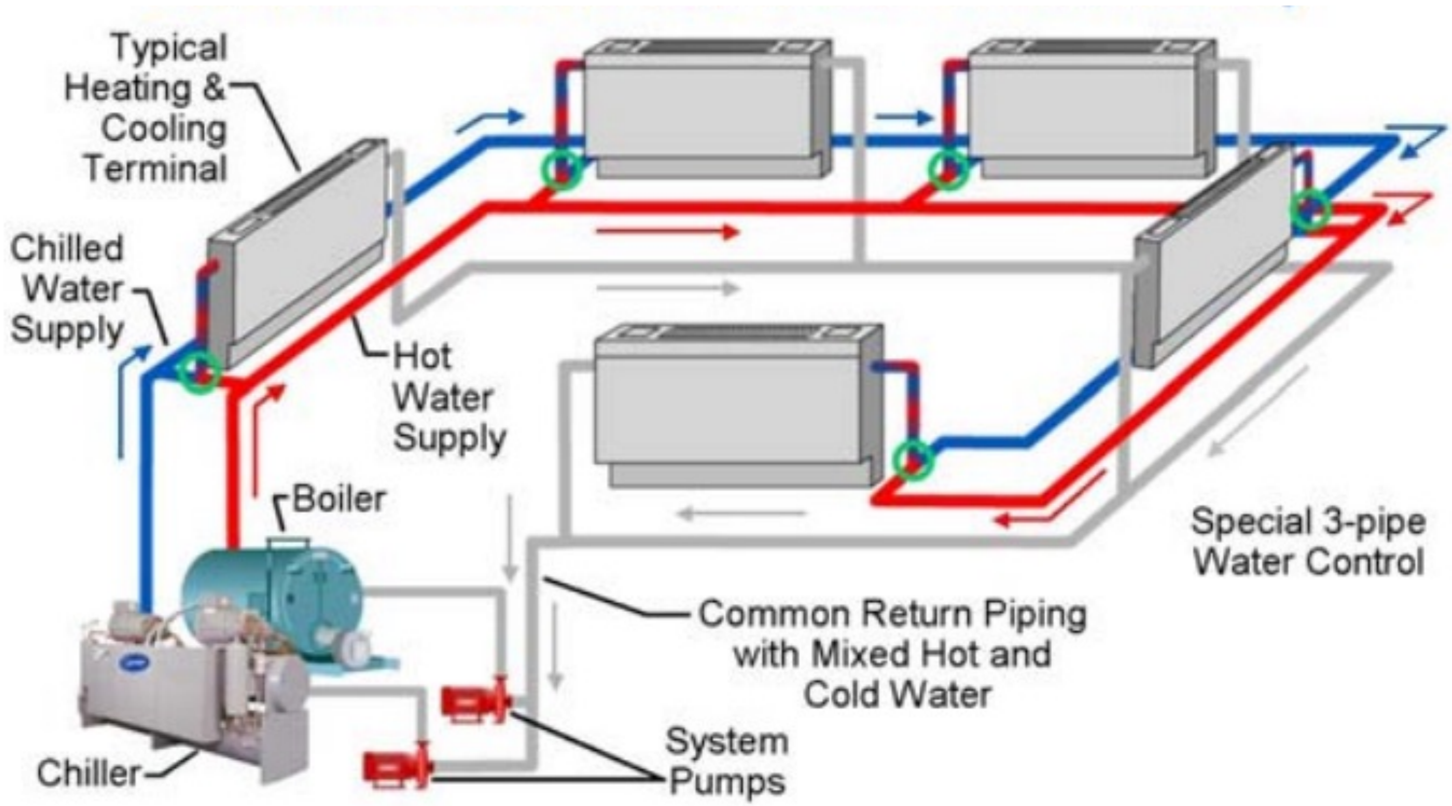
Hydronic System Distribution Circuits

- Two-pipe hydronic systems:



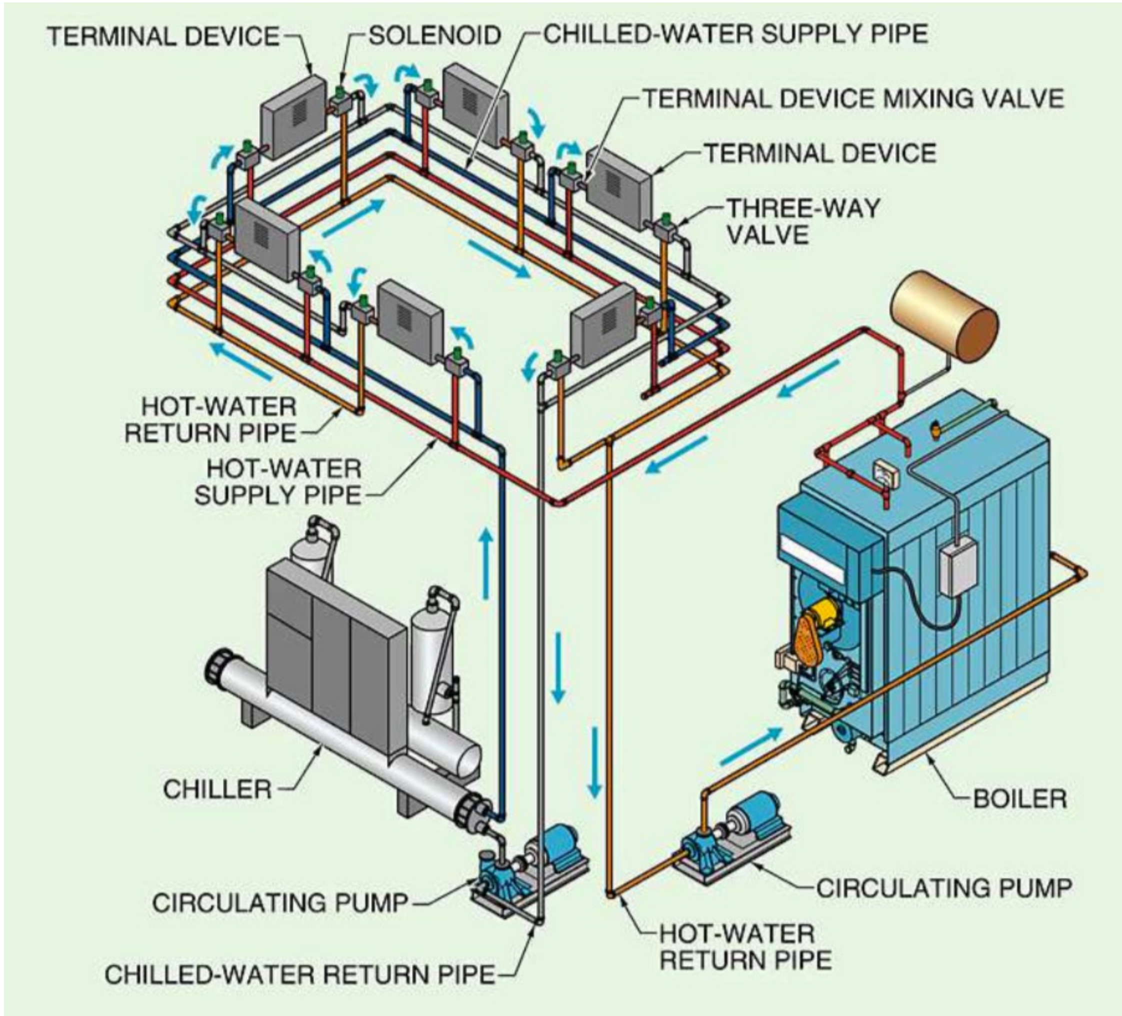
Hydronic System Distribution Circuits

- Three-pipe hydronic systems:
  - ❑ Have a hot-water loop and a cold-water loop so that hot or cold water can be introduced to any terminal unit at any time



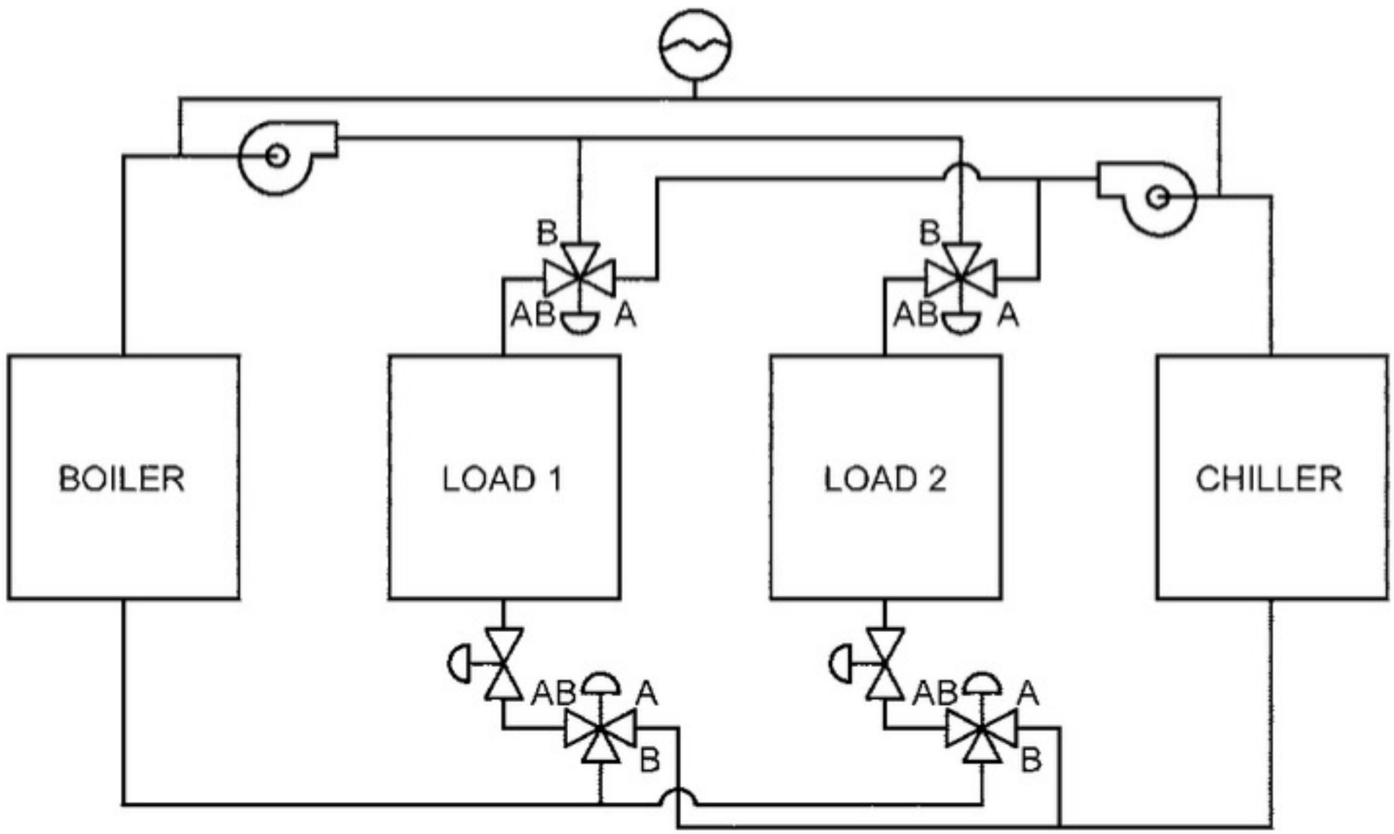
Hydronic System Distribution Circuits

- Four-pipe hydronic system:
  - ❑ Uses supply and return heating piping and supply and return cooling piping



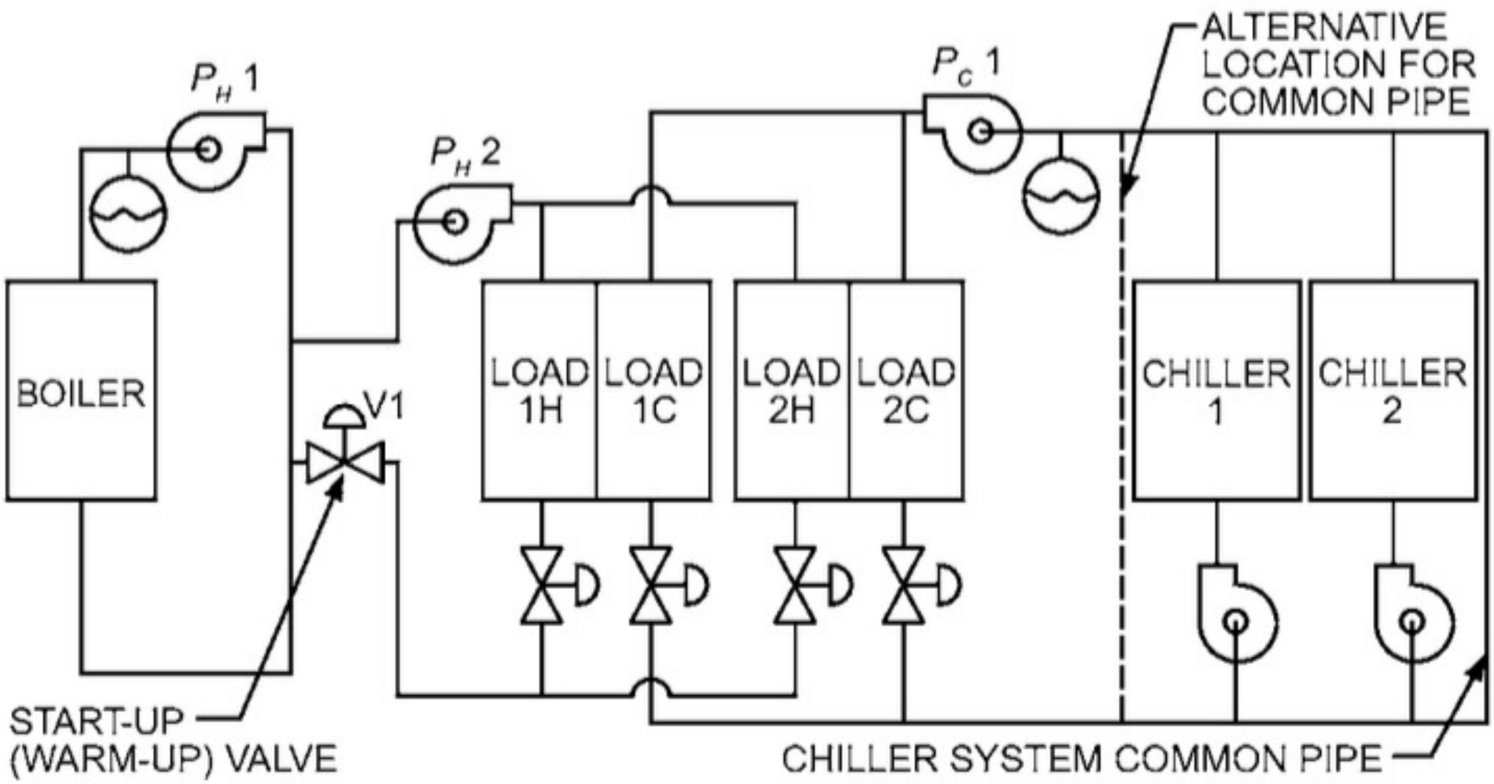
Hydronic System Distribution Circuits

- Four-pipe hydronic system (common loads):

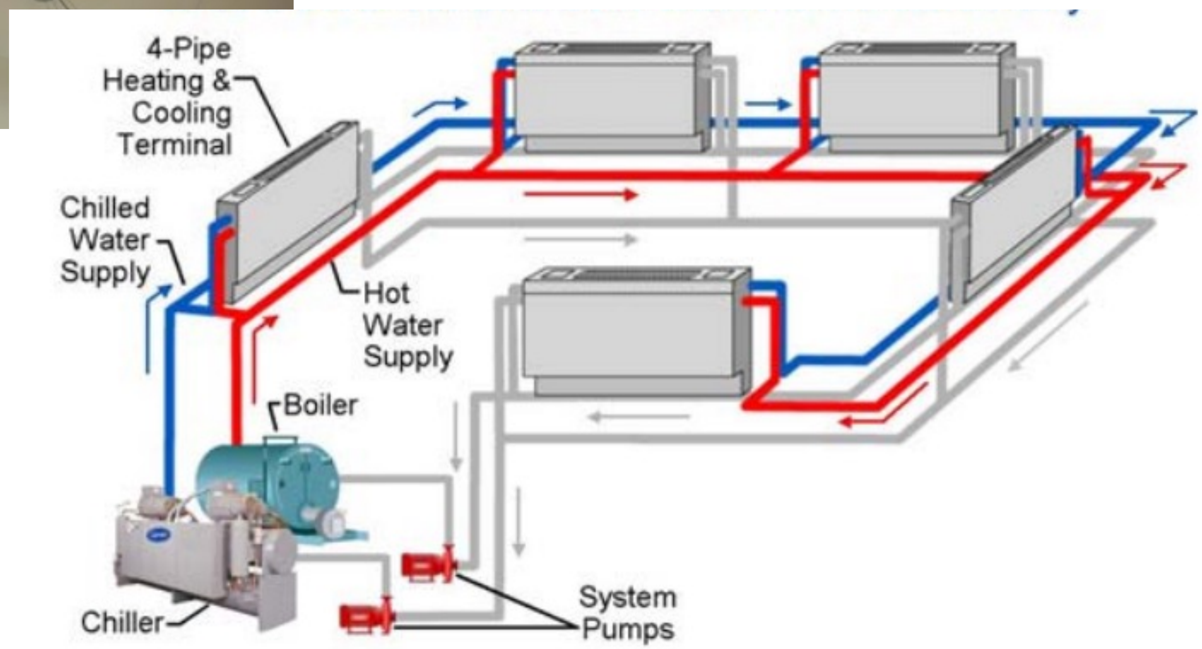


Hydronic System Distribution Circuits

- Four-pipe hydronic system (independent loads):



Hydronic System Distribution Circuits

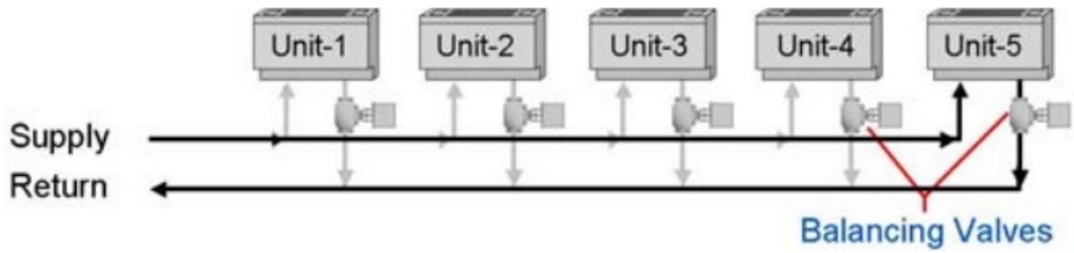


Hydronic System Distribution Circuits

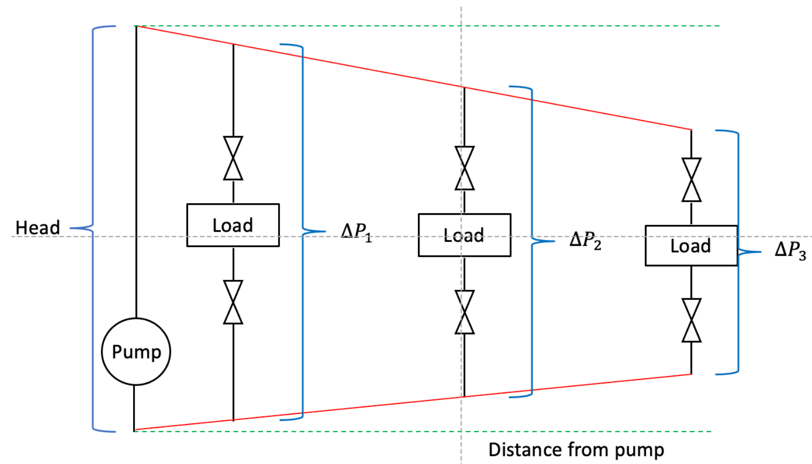
- Four-pipe hydronic system:
  - Respond quickly to load changes
  - Simultaneously operation of heating and cooling system
  - Higher efficiency
  - Lower operating cost but higher initial cost

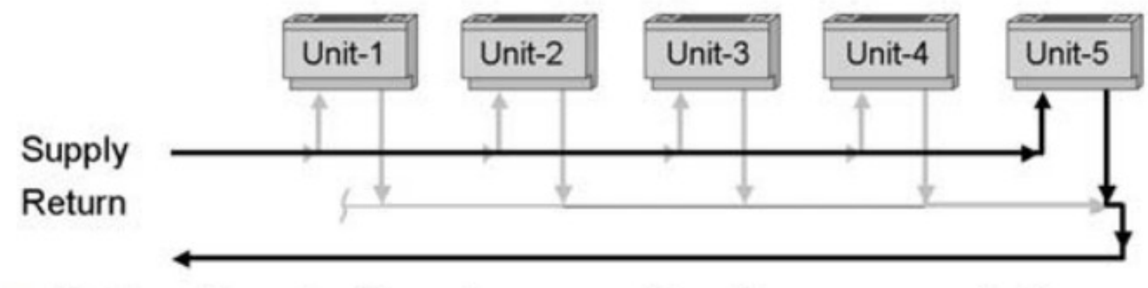
RETURN TYPES (REVERSE VS DIRECT)

Return Types

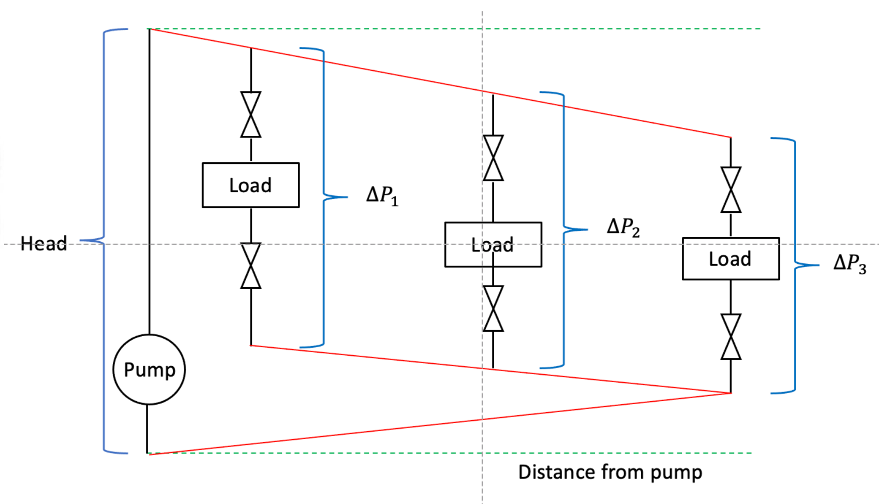


Direct





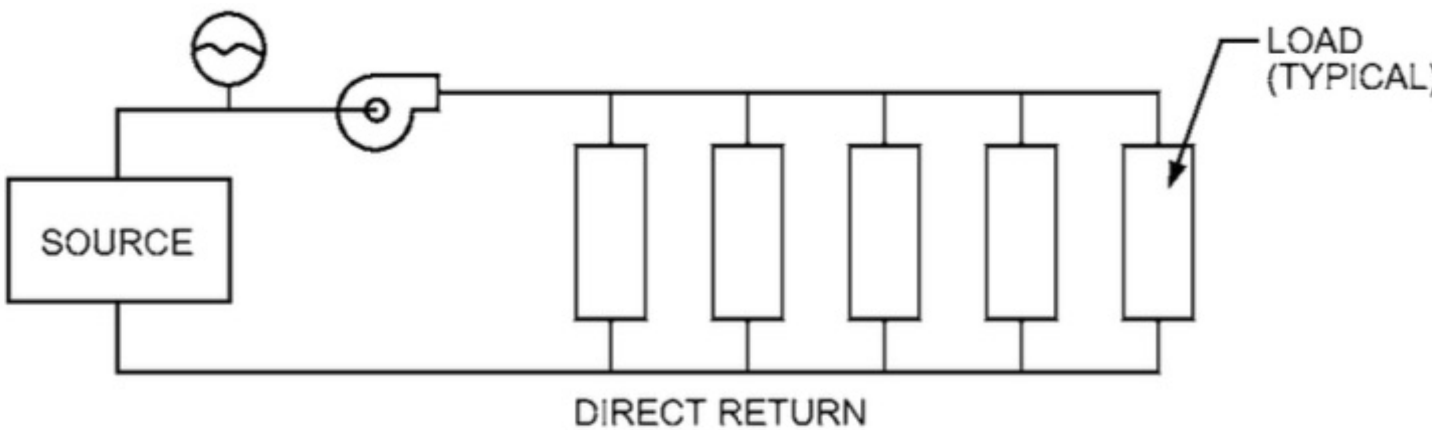
Reverse



http://siglercommercial.com/wp-content/uploads/2017/10/02-Chilled-Water-Piping-Pumps.pdf

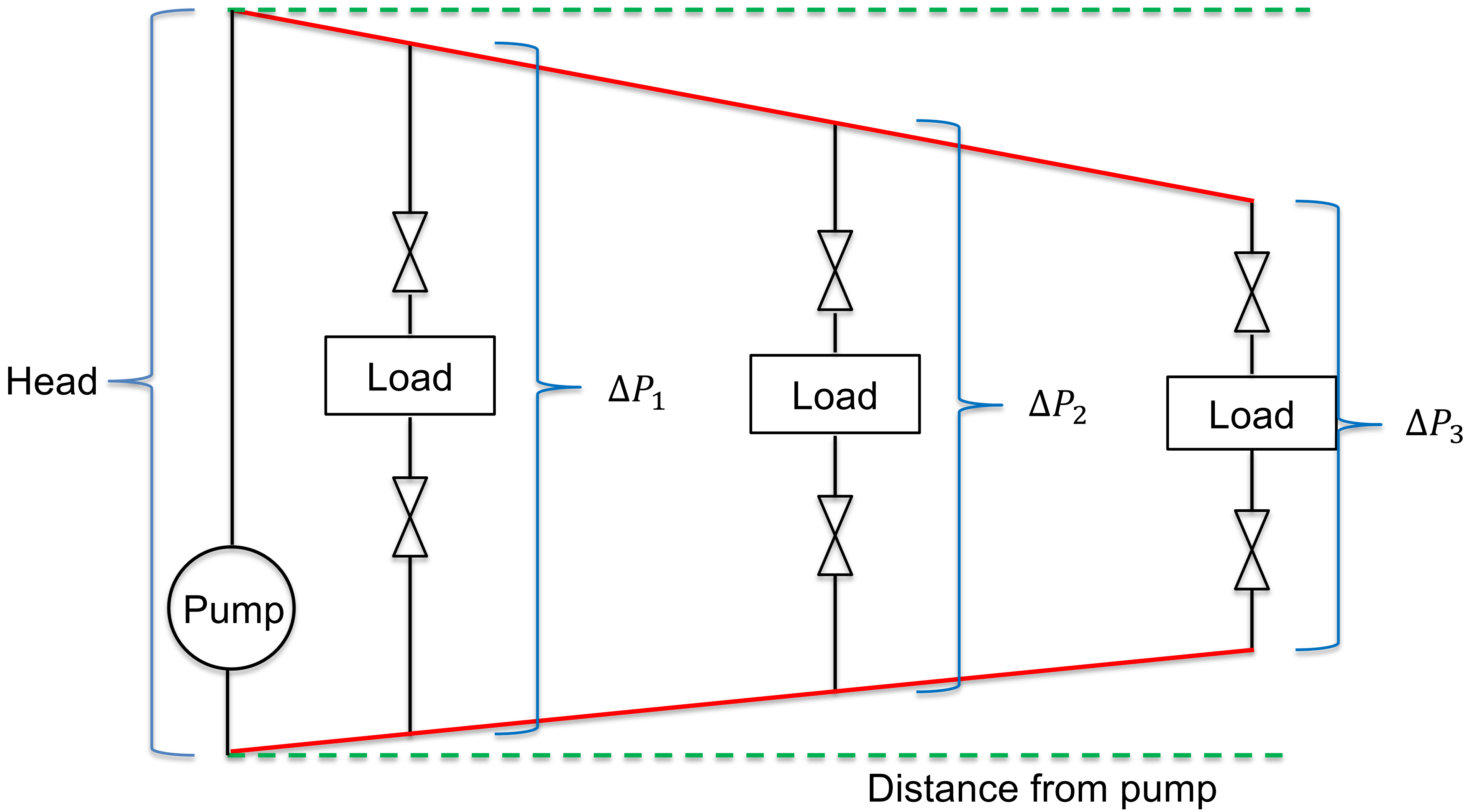
Return Types

- Direct return:
  - ❑ Water enters the first unit from supply
  - ❑ Water leaves the first unit and returns directly to the source
  - ❑ Unequal pressure drop
  - ❑ The first unit supplied is the first unit returned
  - ❑ Balancing vales are required



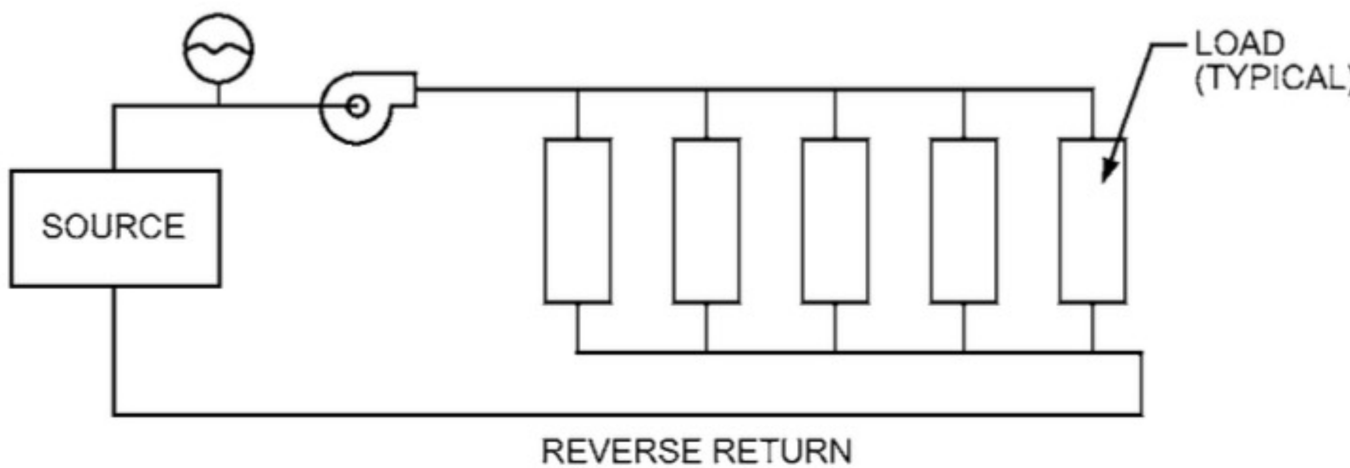
Return Types

- Direct return:



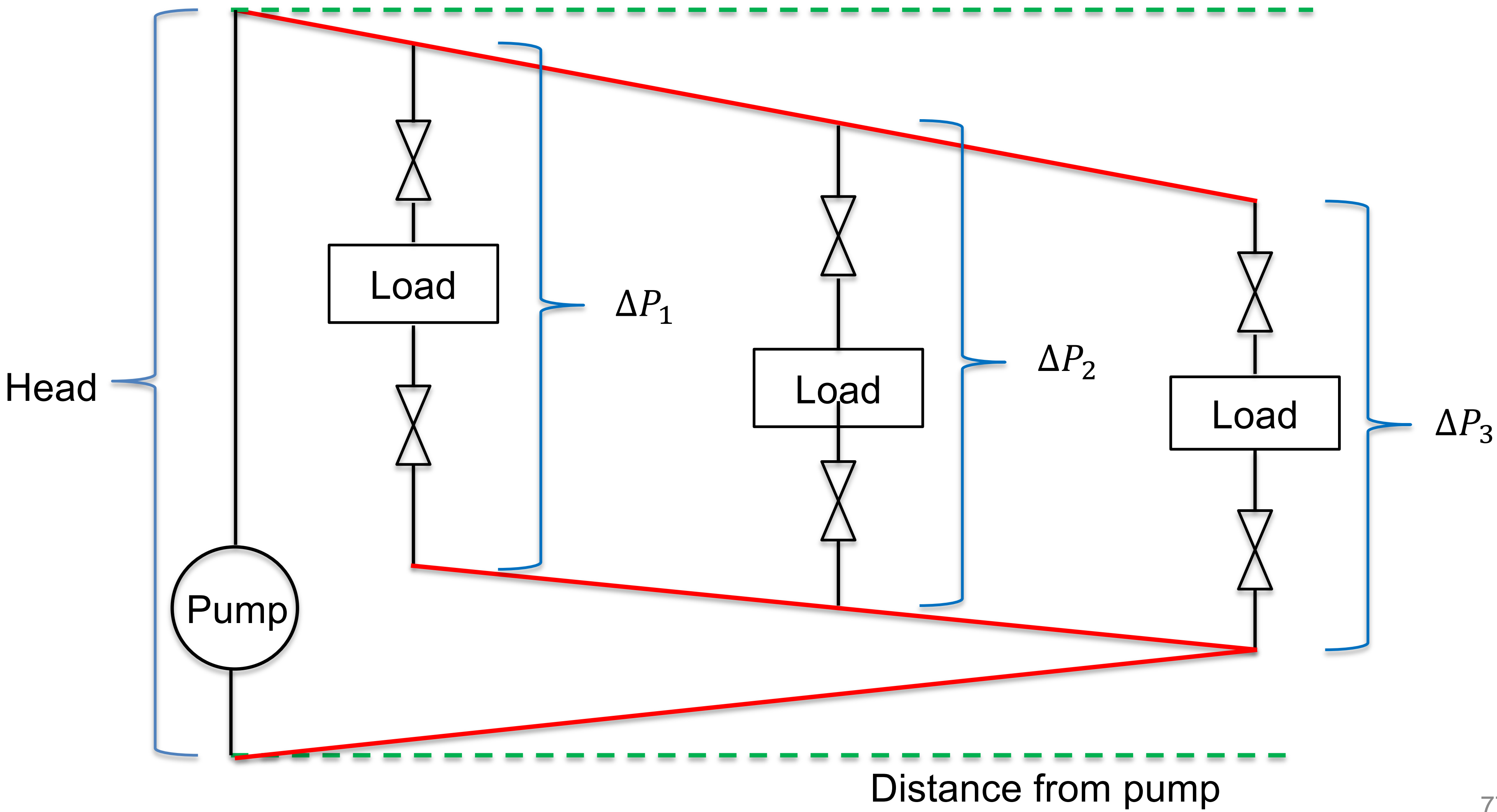
Return Types

- Reverse return:
  - ❑ Return direction is the same direction as the supply flow
  - ❑ Water leaves the first unit and goes all the way around in returning to the source
  - ❑ Equal pressure drop
  - ❑ The first unit supplied is the last unit returned
  - ❑ Balancing vales may be eliminated



Reverse Return

- Reverse return:



INTRO TO PIPE DESIGN

Intro to Pipe Design

- Similar to the duct design, we rely on the ASHRAE Handbook

CHAPTER 22

PIPE DESIGN

Intro to Pipe Design

- In hydronic systems pressure drop is calculated at feet per 100 feet of pipe at a given velocity

Pipe Size	Velocity (fps)
Large ($\geq 12''$)	6-8
Medium (Between 2" and $12''$)	3-4
Small ($\leq 12''$)	2

Intro to Pipe Design

- Similar to the duct design, we have similar head loss figures: