Back to the Future

Installing hydronics and air-to-water heat pumps to get fossil fuels out of buildings

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The Twenty-Eighth Westford Symposium on Building Science

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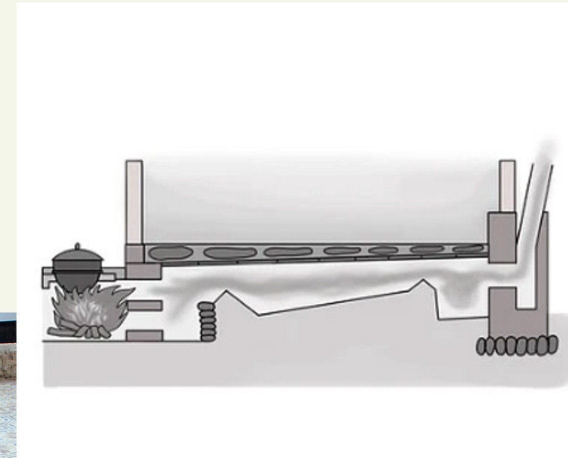
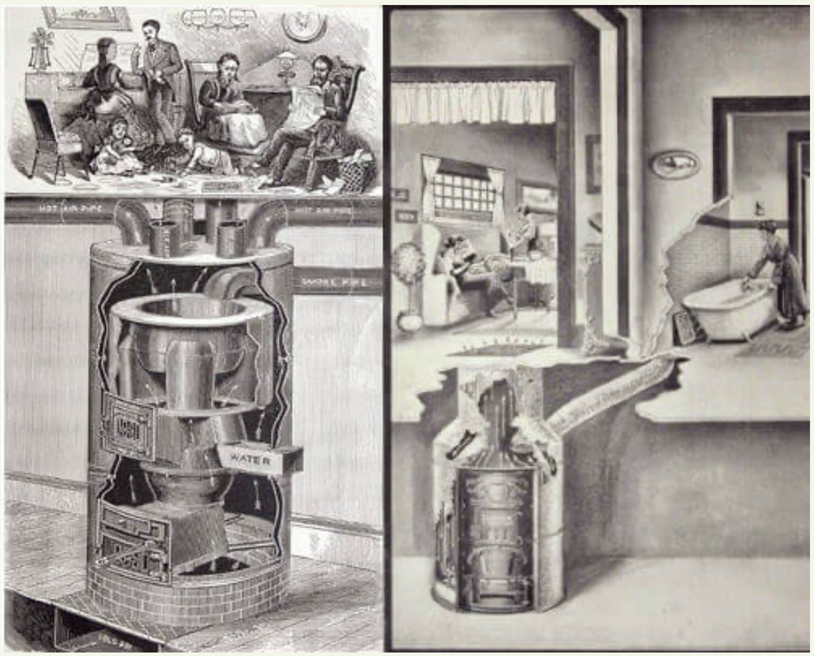
Fireplaces and Hot Air

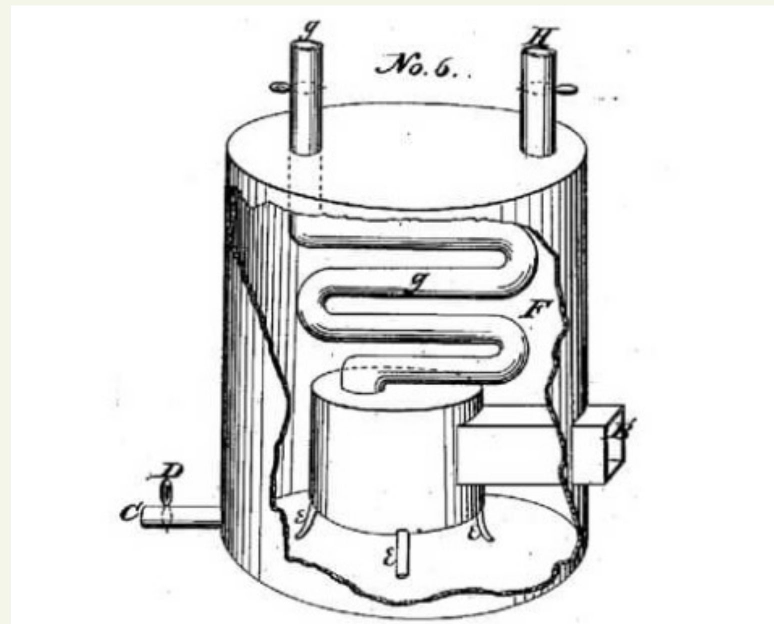
Roman Hypocaust System



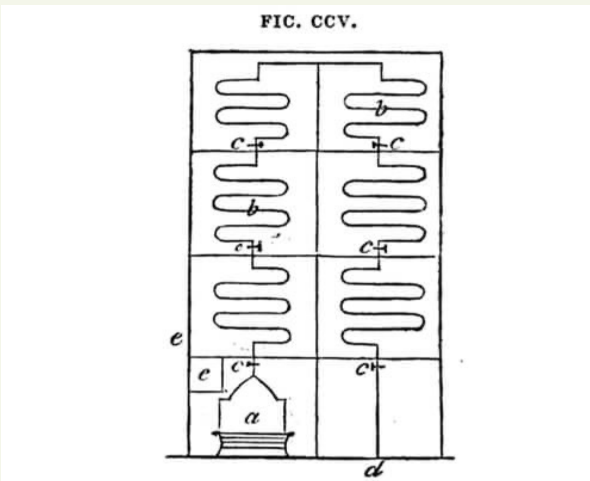
Moe Hot Air and Hot W

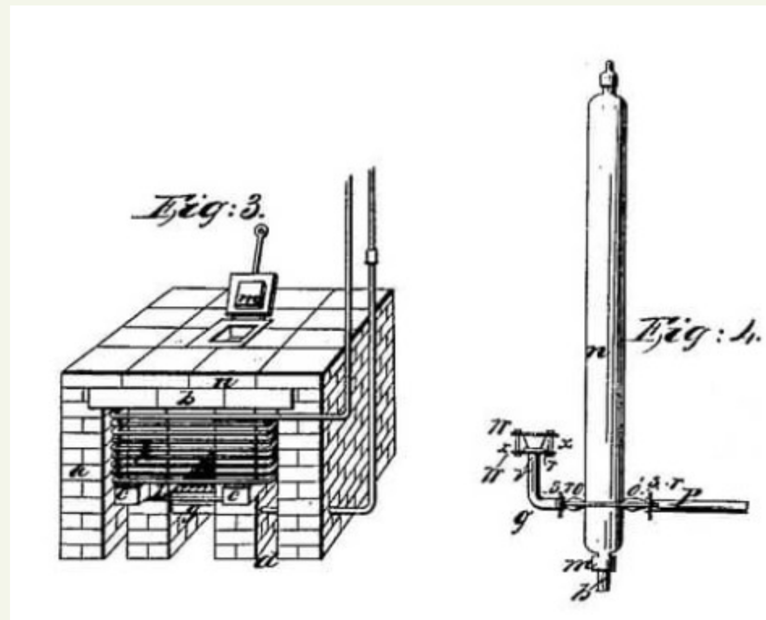
Early Warm Air Furnace Designs



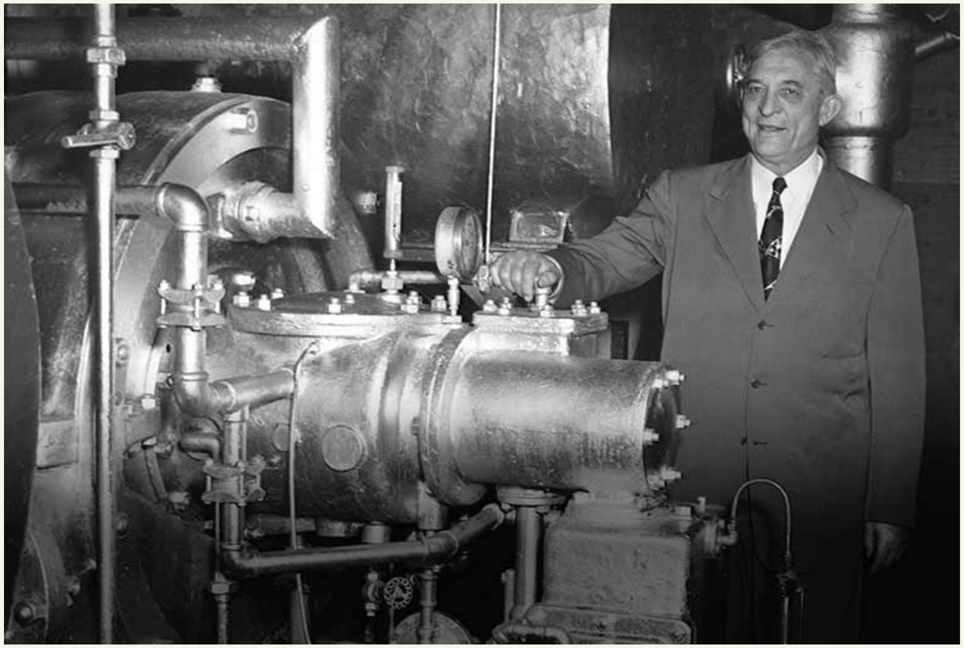


Industrial Revolution: Heating with Steam & HW





Mr. Carrier Invents the Chiller



Willis Carrier is shown in 1950, with the first centrifugal chiller built, then running for 27 years at the Onondaga Pottery Company in Syracuse, New York

Distribution

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Moving Heat with Air vs W vs Refrigerant

MATH

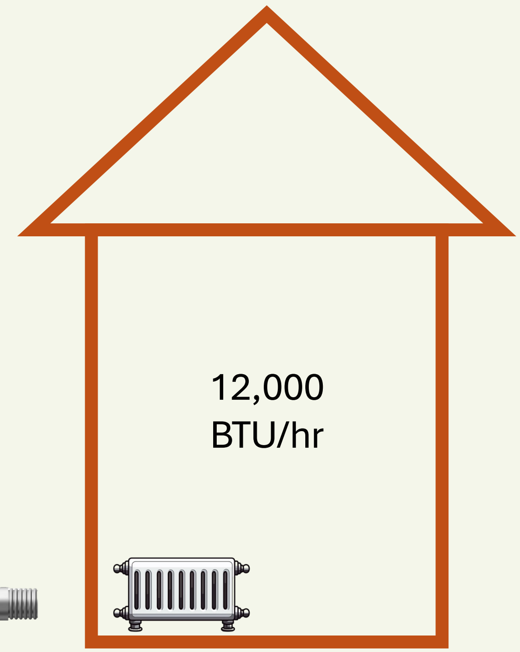
Q = m x CpDT = mass flow x heat capacity x temperature change

Assume DT = 20 F,   Cp = 1 BTU / lb F

M = mass flow in lb/hr = volume flow x density = q (gal/min) x 8.34 lb/gal x 60 min / hr

Q = 500 gpm DT

Flow (GPM) = Q / DT / 500 = 12000 / 20 / 500 = 1.2 gpm



Moving Heat with Air vs Water vs Refrigerant

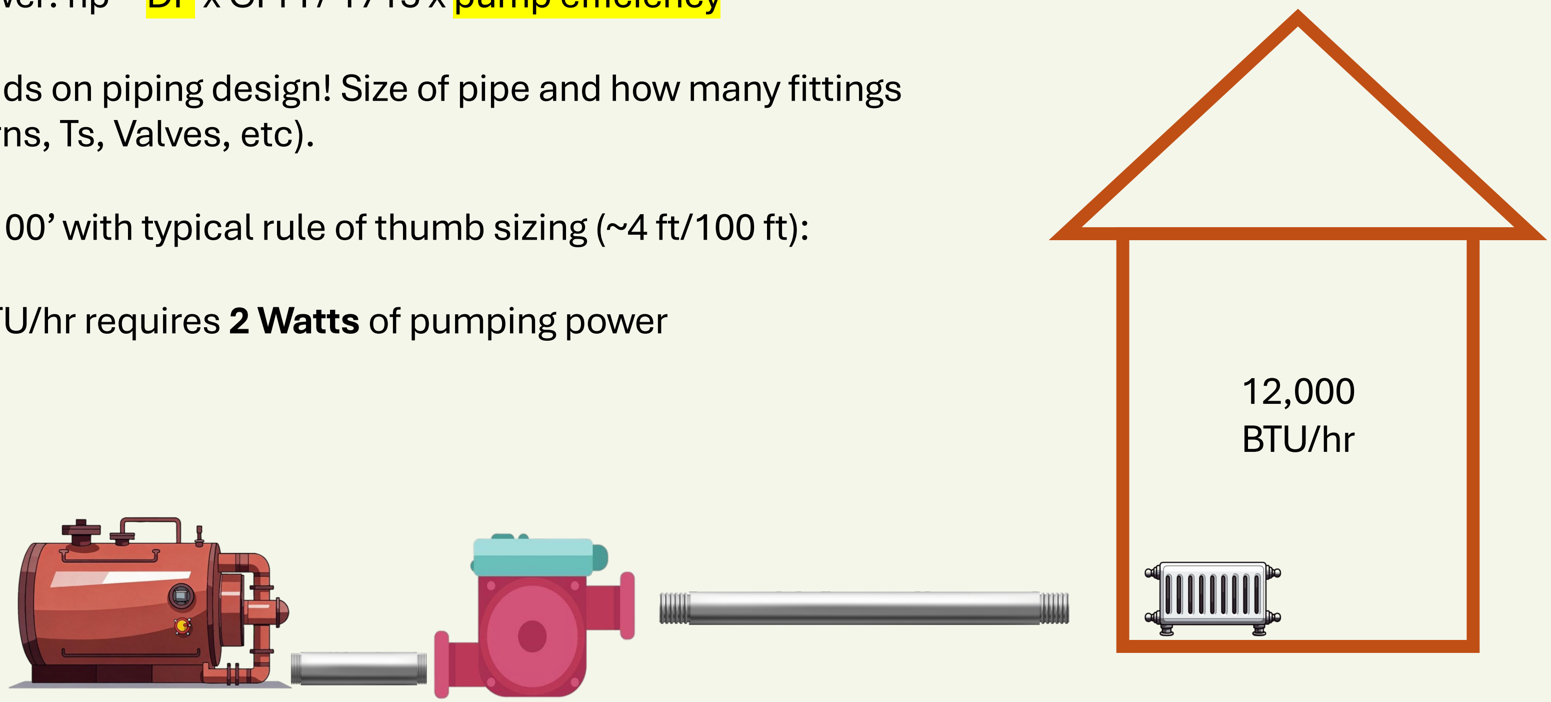
MATH

Pump Power: hp = DP x GPM / 1715 x pump efficiency

DP depends on piping design! Size of pipe and how many fittings (sharp turns, Ts, Valves, etc).

Assume 100’ with typical rule of thumb sizing (~4 ft/100 ft):

12,000 BTU/hr requires **2 Watts** of pumping power



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Moving Heat with Air vs Water vs Refrigerant

MATH

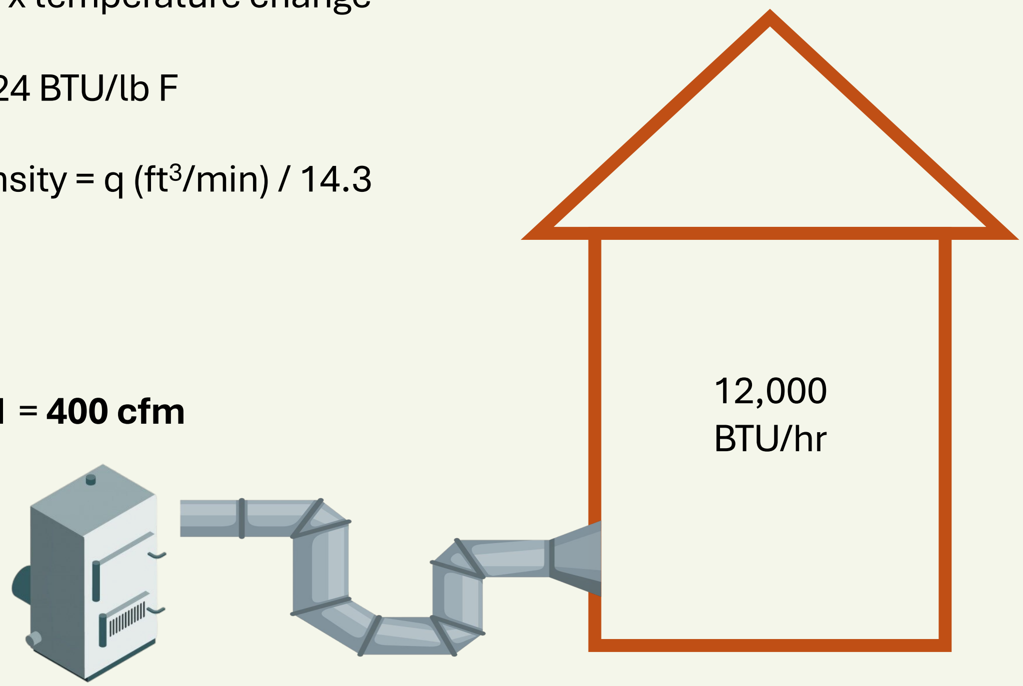
Q = m x CpDT = mass flow x heat capacity x temperature change

Assume DT = 30 F,   Cp = Air at 100 F = 0.24 BTU/lb F

M = mass flow in lb/hr = volume flow x density = q (ft^3/min) / 14.3 $ft^{3/lb}$ x 60 min / hr

Q = 1 x ft^3 / min x DT

Flow (ft^3 /min) = Q / DT / 1 = 12,000 / 30 / 1 = **400 cfm**



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Moving Heat with <u>Air</u> vs Water vs Refrigerant

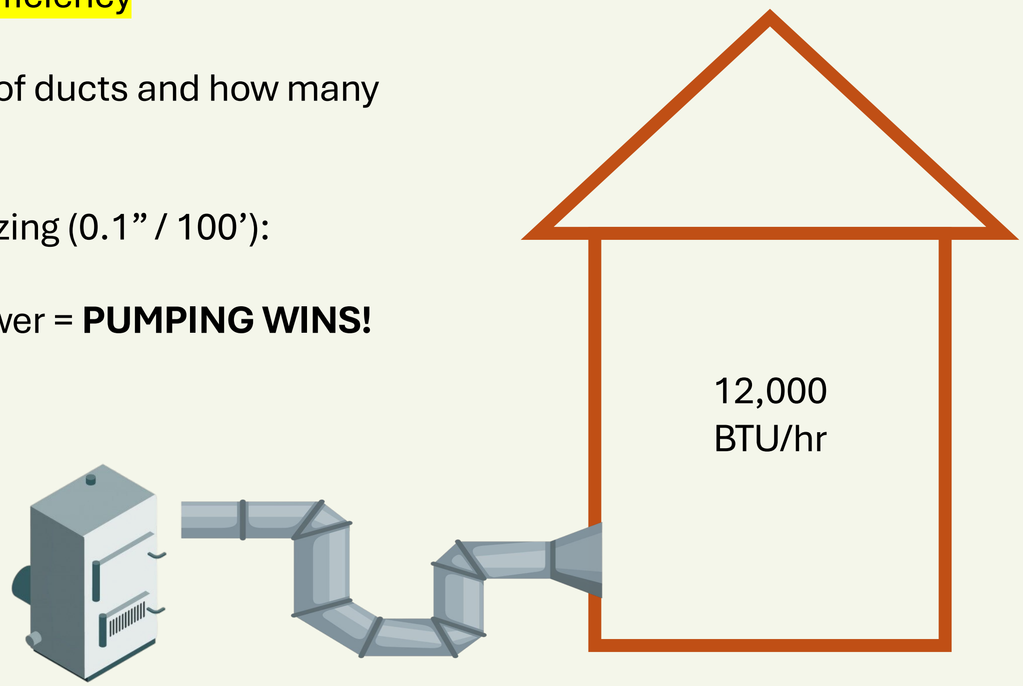
MATH

Fan Power: bhp = DP x CFM / 6356 x fan efficiency

DP depends on DUCTWORK design! Size of ducts and how many fittings (sharp turns, Ts, Dampers, etc).

Assume 100' with typical rule of thumb sizing (0.1" / 100'):

12,000 BTU/hr requires **8 Watts** of fan power = **PUMPING WINS!**



Moving Heat with Air vs Water vs Refrigerant

MATH

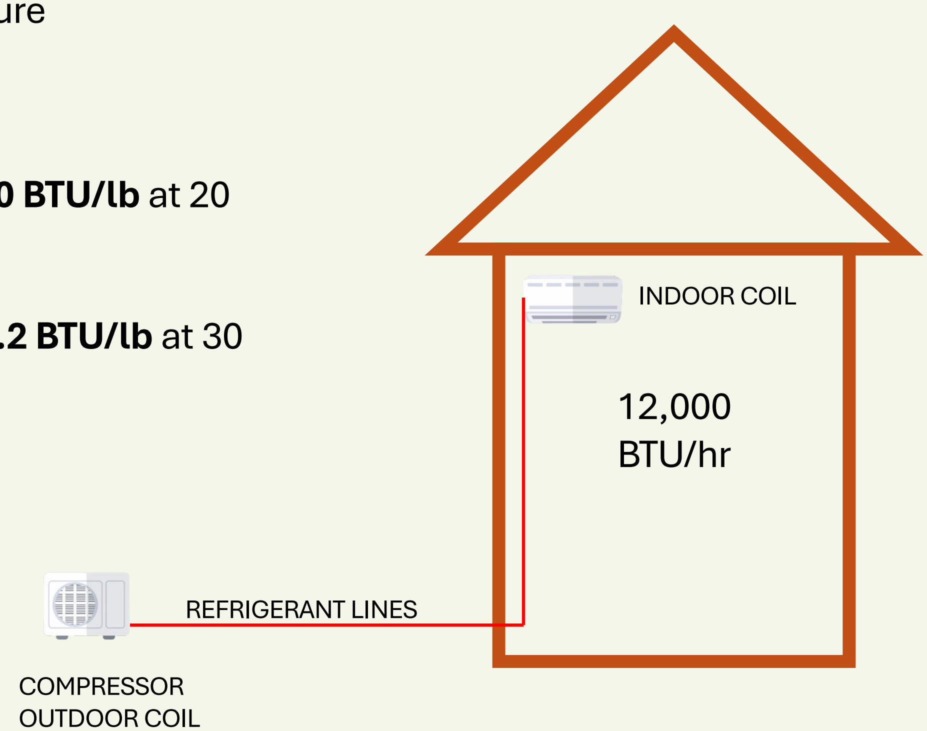
Refrigerant uses PHASE CHANGE at high pressure

Heat of Vaporization of R32: **168 BTU/lb**

Sensible heat capacity of water: 1 BTU/lb F or **20 BTU/lb** at 20 degree DT

Sensible heat capacity of air: 0.24 BTU/lb F or **7.2 BTU/lb** at 30 degree DT

ISSUES WITH REFRIGERANT:
- High Pressure
- Leaks
- GWP & ODP
- Cost



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Hydronic System Challenges

- Potential for water leaks
- Care must be taken to avoid condensation
- Cost of piping installation

Piping

Image courtesy of Viaga

Image courtesy of Mega-therm

Cescent Halls

Area	Nominal Pipe Size (in.)	Nominal Pipe Thickness (in.)	System (CHW or HHW)	Tested Pipe Thickness 11-01-19 (in.)	Percent Degrdation (%)
1	5"	0.258	CHW	0.249	3.49%
2	4"	0.237	CHW	0.224	5.49%
3	4"	0.237	HHW	0.249	**NONE**
4	4"	0.237	HHW	0.242	**NONE**
5	3/4"	0.0450	CHW	0.05	**NONE**
6	1/2"	0.0400	HHW	0.039	2.50%
7	3/4"	0.0450	HHW	0.044	2.22%
8	1 1/4"	0.0550	CHW	0.052	5.45%
9	3/4"	0.0450	HHW	0.048	**NONE**
10	1 1/4"	0.0550	CHW	0.047	14.55%
11	3/4"	0.0450	HHW	0.052	**NONE**
12	1 1/4"	0.0550	CHW	0.057	**NONE**
13	3/4"	0.0450	HHW	0.044	2.22%
14	1 1/4"	0.0550	CHW	0.051	7.27%
15	3/4"	0.0450	HHW	.055 / .055	**NONE**
16	3/4"	0.0450	HHW	.046 / .053	**NONE**
17	3/4"	0.0450	HHW	.045 /.047	**NONE**
18	3/4"	0.0450	CHW	0.044	2.22%
18	3/4"	0.0450	CHW	0.051	**NONE**
19	3/4"	0.0450	CHW	0.044	2.22%
19	3/4"	0.0450	CHW	0.044	2.22%
20	1"	0.0500	CHW	0.05	0.00%
20	3/4"	0.0450	CHW	0.047	**NONE**

Crescent Halls

- ASME Standard 16 - *Wrought Copper and Copper Alloy Solder-Joint Pressure Fittings*

- *Copper Development Association Soldering Procedure Specifications*

- *Requires no more than 30% void in the soldered joint*

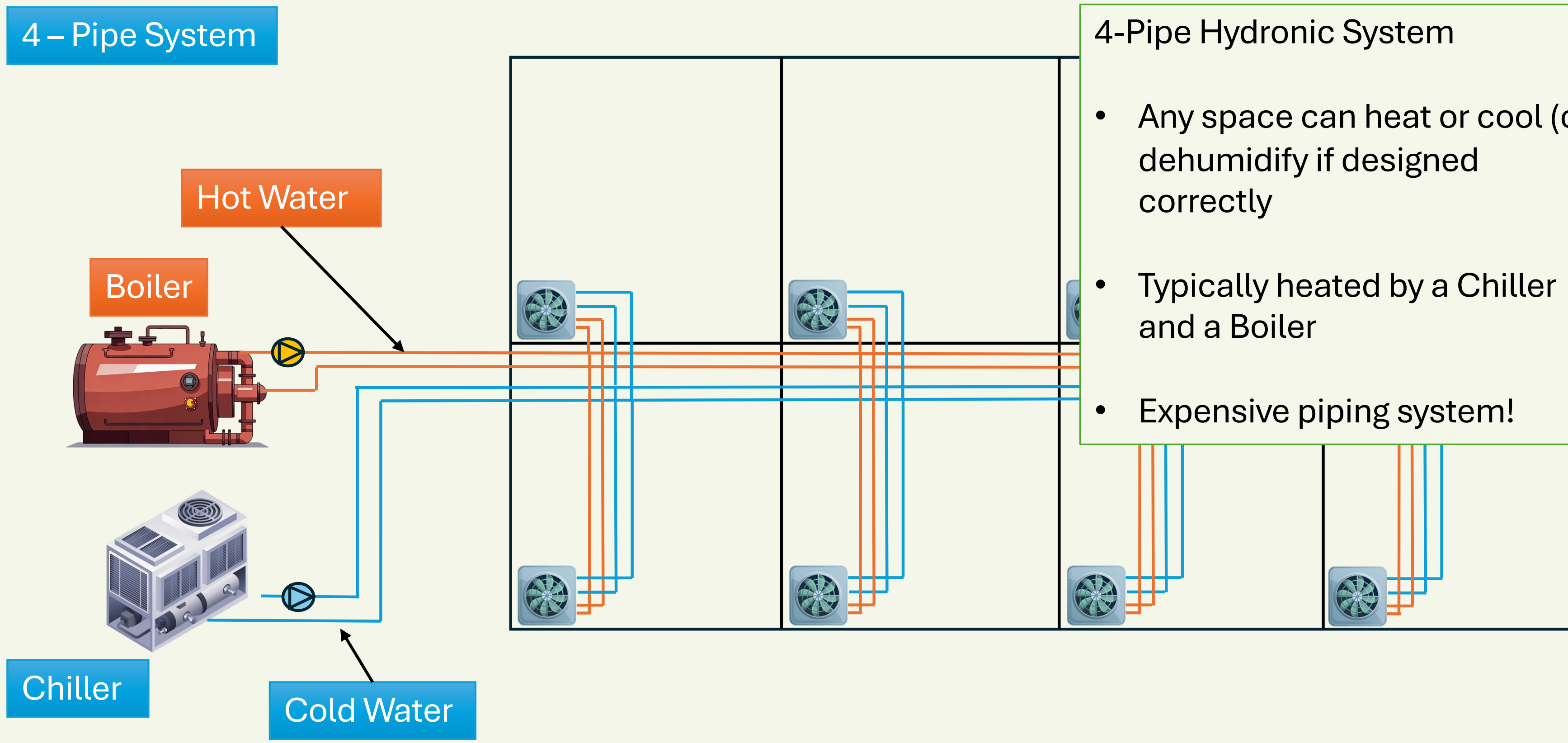
50/50 Tin-Lead solder (soft solder, now banned for potable water)

Tube size	100°F	150°F	200°F	250°F
1/4"–1"	200	150	100	85
1-1/4"–2"	175	125	90	70
2-1/2"–4"	150	100	75	50
5"–8"	135	90	70	45

95/5 Tin-Antimony solder (lead-free soft solder, current standard)

Tube size	100°F	150°F	200°F	250°F
1/4"–1"	500	400	300	200
1-1/4"–2"	400	350	275	175
2-1/2"–4"	300	250	200	150
5"–8"	270	150	100	70

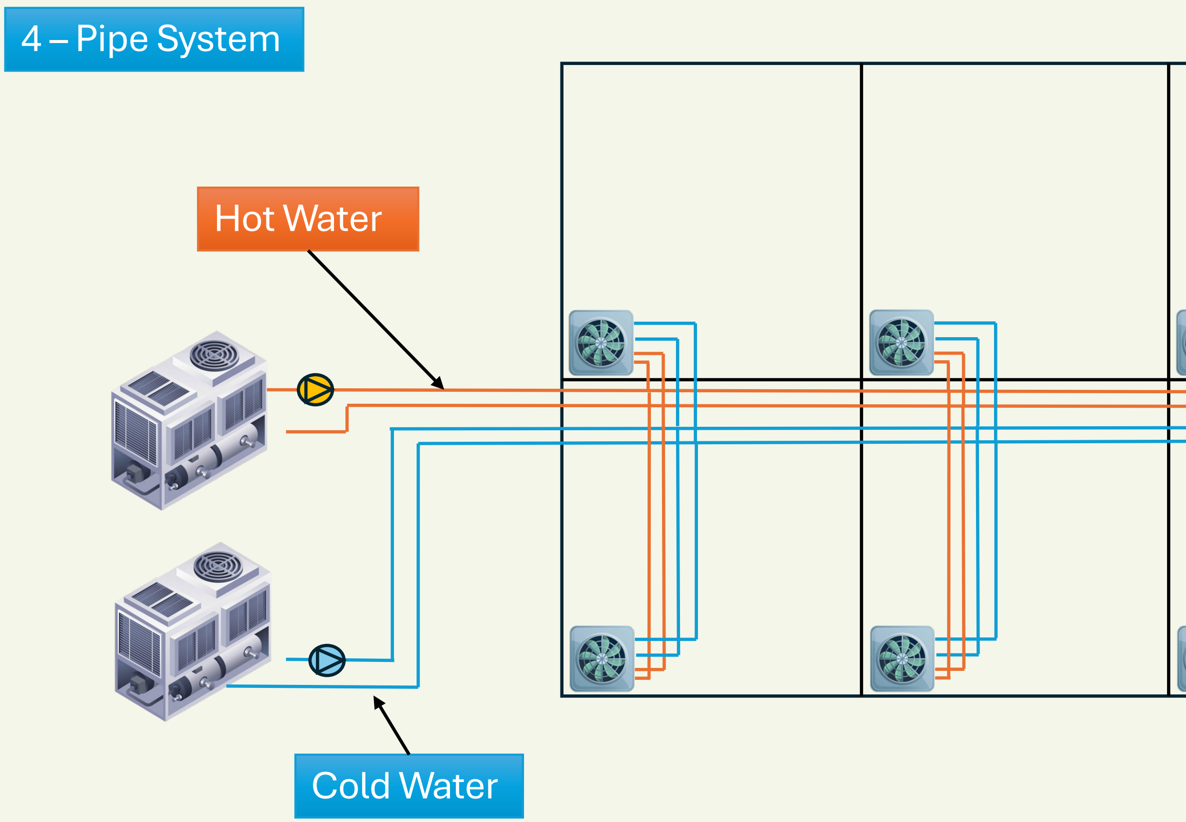
Hydronic Heating / Cooling Systems



4-Pipe Hydronic System

- Any space can heat or cool (or dehumidify if designed correctly
- Typically heated by a Chiller and a Boiler
- Expensive piping system!

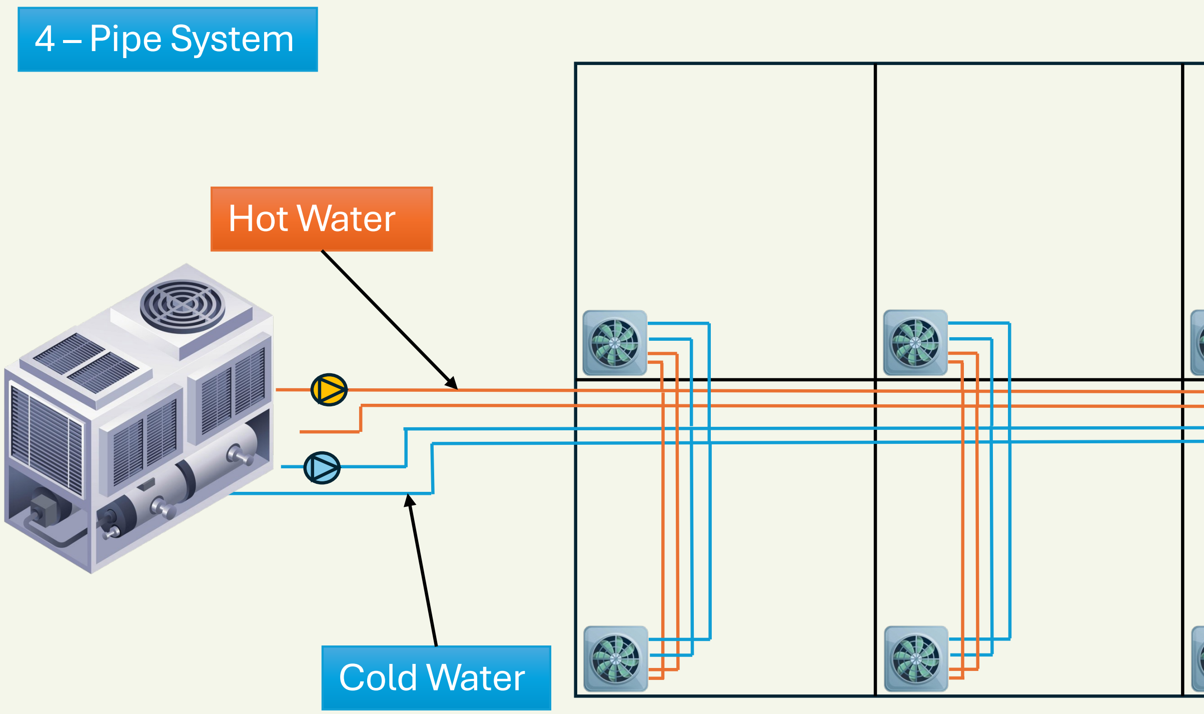
Hydronic Heating / Cooling Systems



4-Pipe Hydronic System – Heat Pump Heat

- Boiler systems are typically designed for high water temps – 160 – 200 F
- Need to re-size terminal units and maybe piping to accommodate lower water temperature
- Tightening up the envelope makes heat pump heating more feasible

Hydronic Heating / Cooling Systems



4-Pipe Hydronic System – 4-Pipe Heat Pump

- One heat pump makes hot and cold water at the same time
- Greater efficiency during periods where chilled water and hot water are used simultaneously
- Balance of heat is rejected/absorbed to/from the outside

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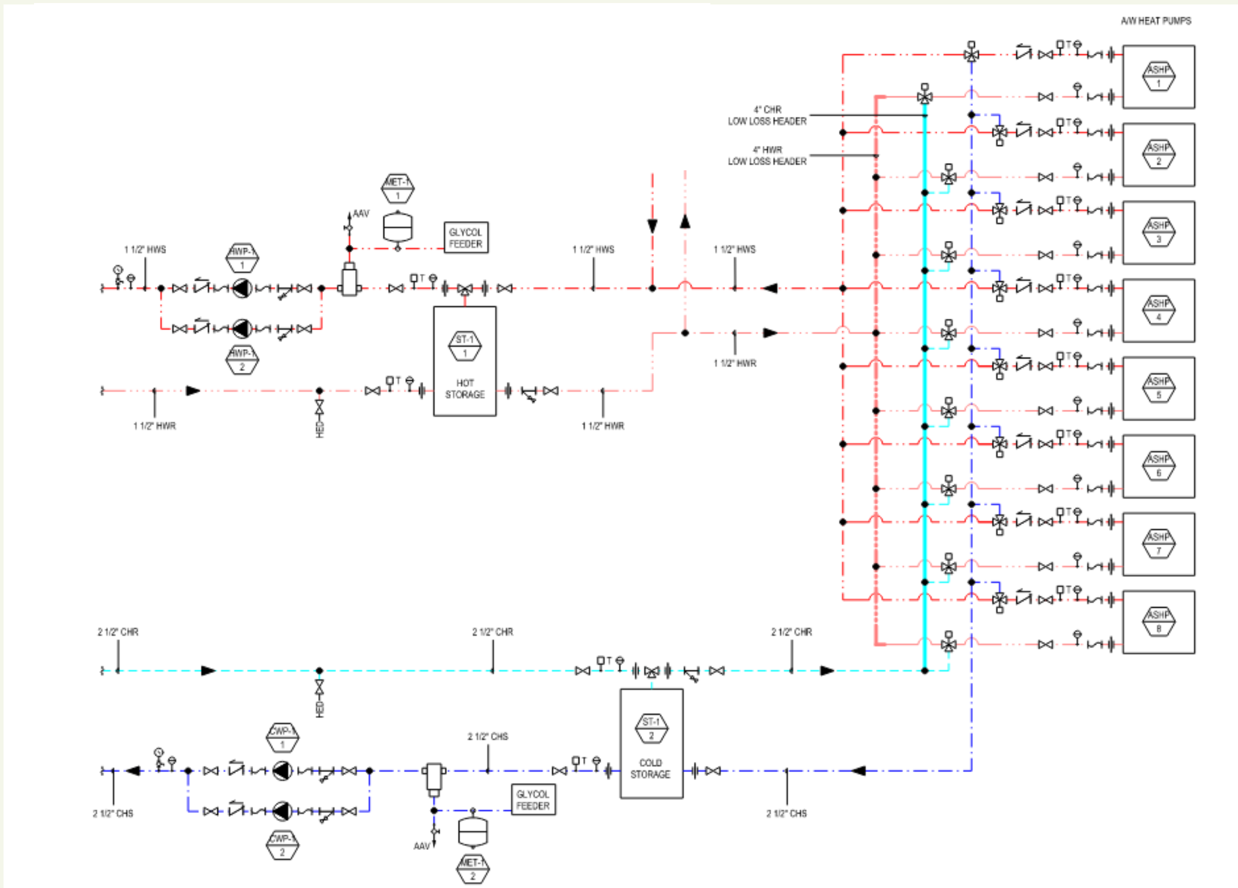
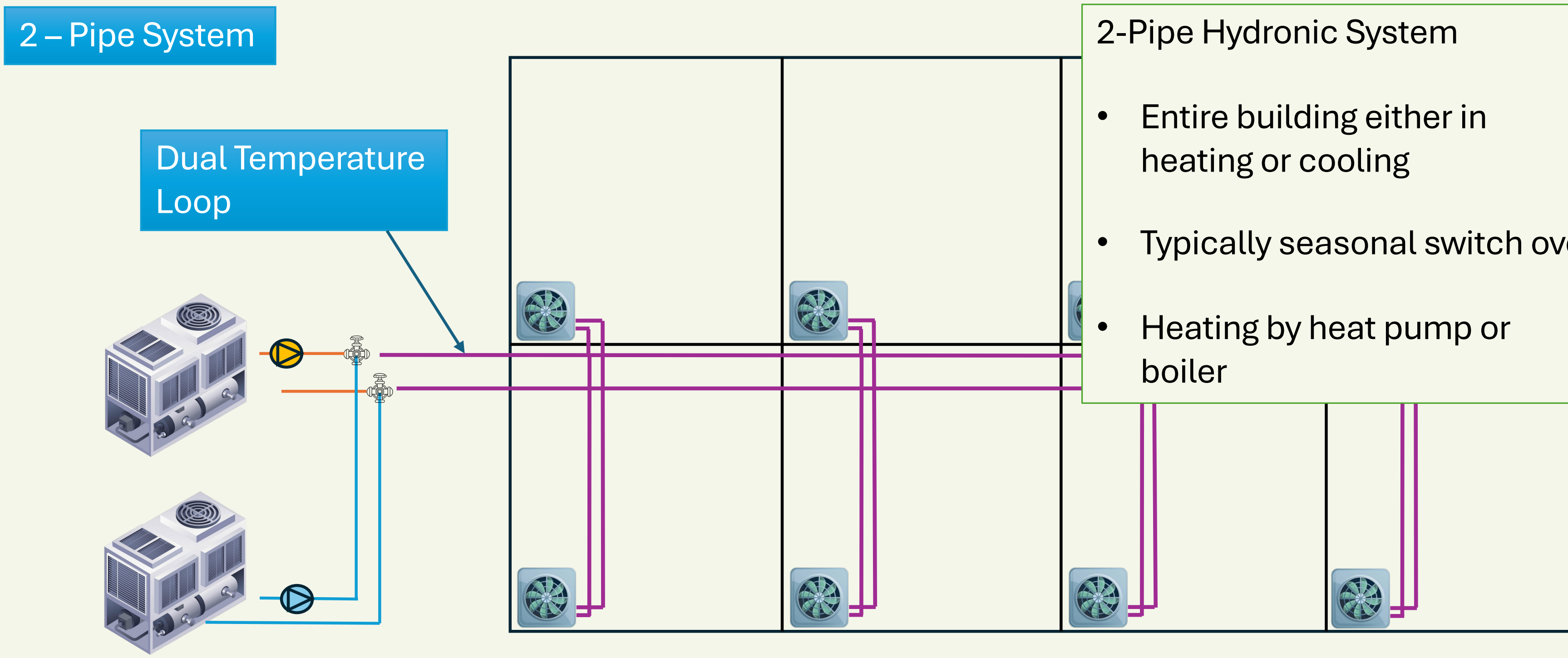
Hydronic Heating / Cooling Systems



Hydronic Heating / Cooling Systems

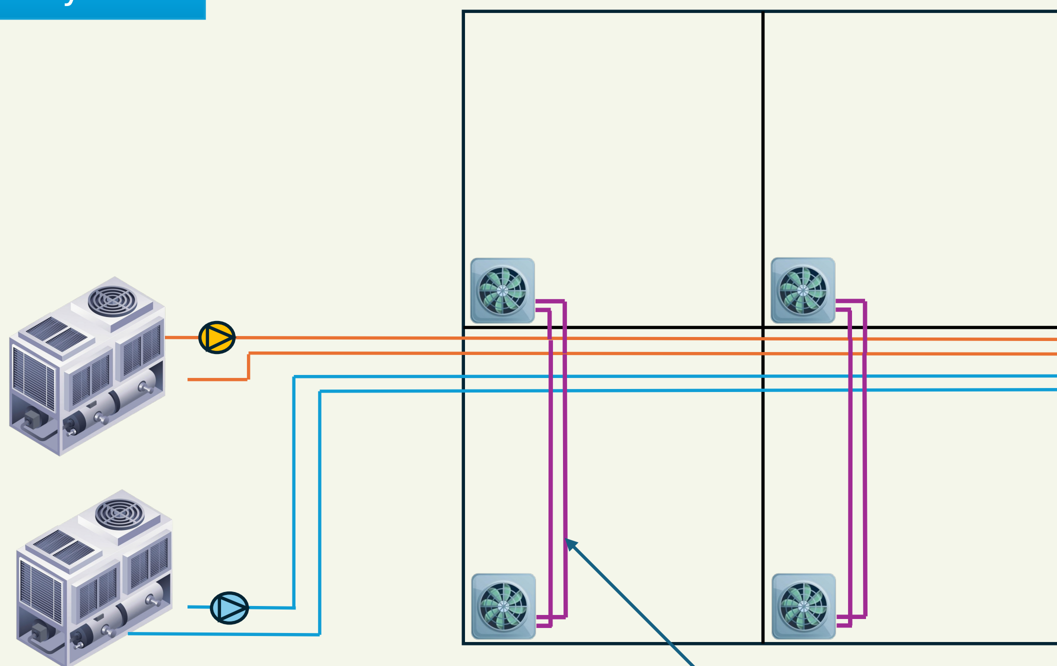


2-Pipe Hydronic System

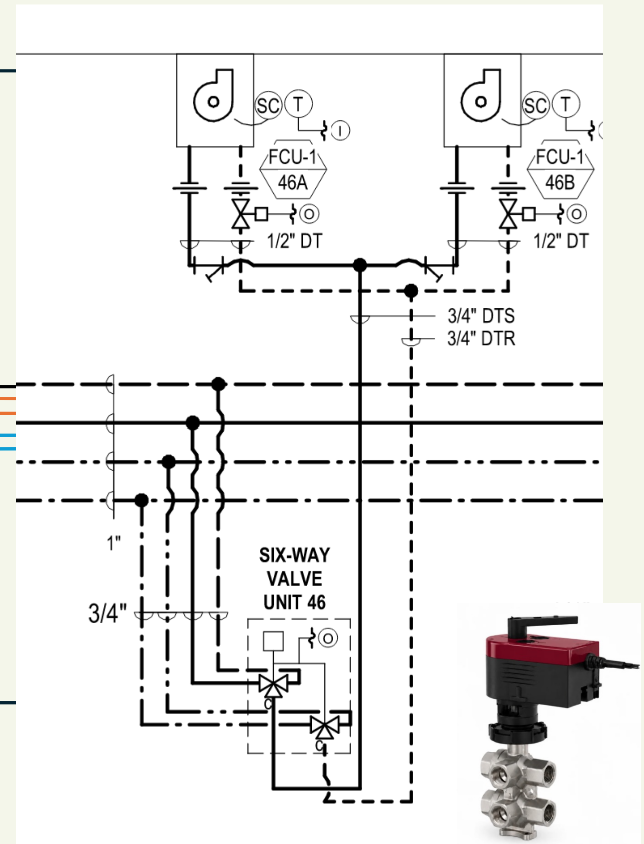
- Entire building either in heating or cooling
- Typically seasonal switch over
- Heating by heat pump or boiler

Hydronic Heating / Cooling Systems

Hybrid System



2-Pipe Home Run to Each Fan Coil



MB tek

Cycle House

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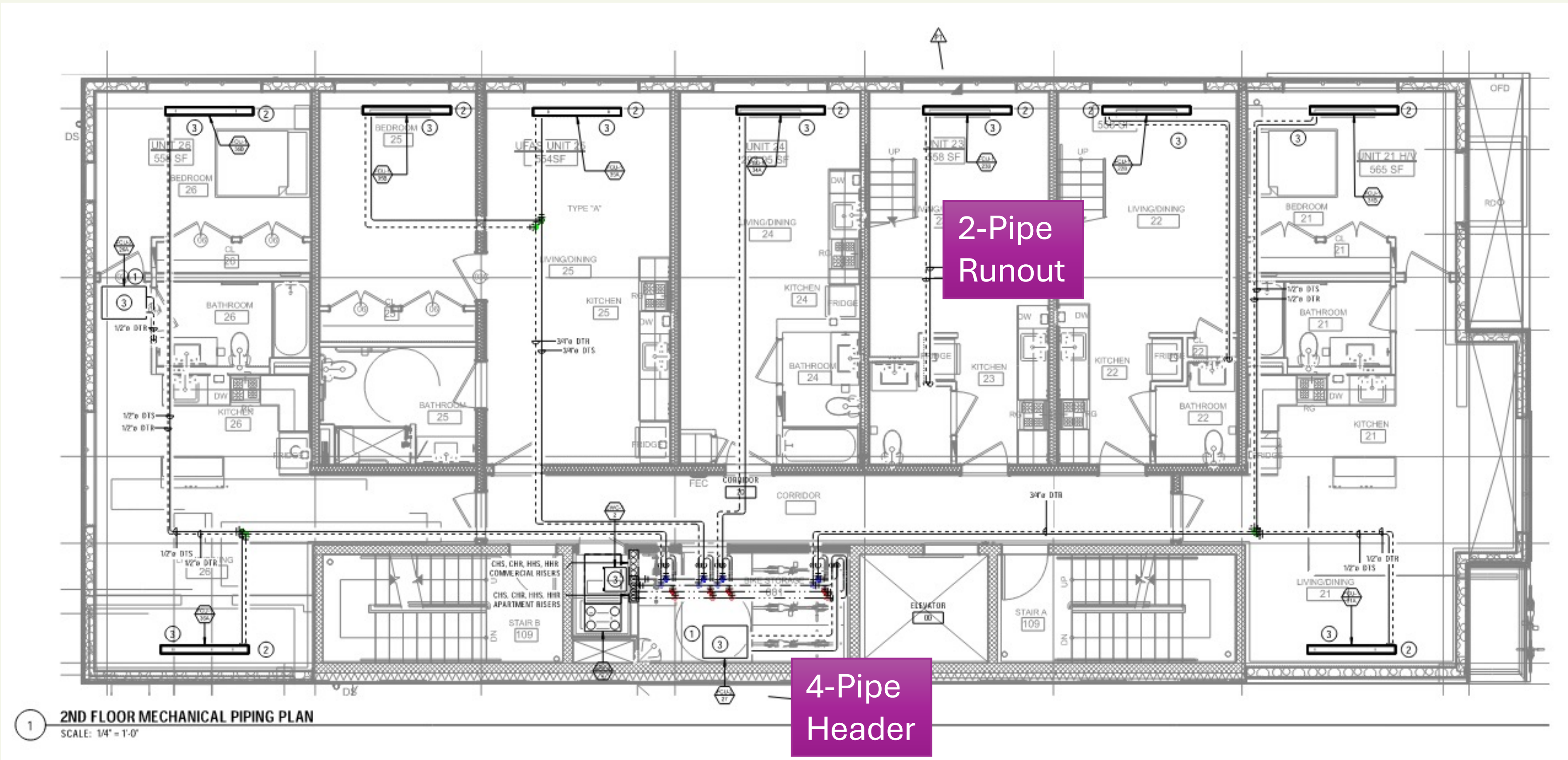
Cycle House

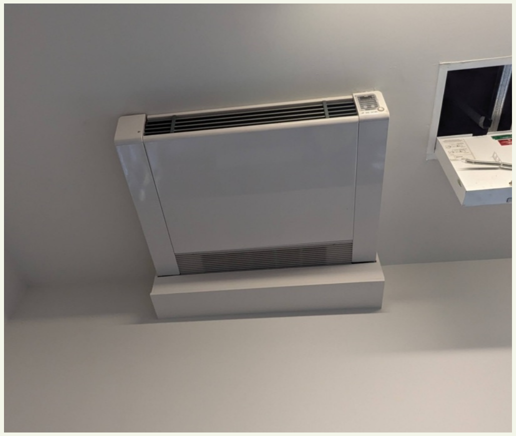

2-Pipe Runout
4-Pipe Header
2ND FLOOR MECHANICAL PIPING PLAN
SCALE: 1/4" = 1'-0"

Cycle House

6-way Valve Header

Modular Chilltrix
Heat Pumps

Cycle House



Lots of options for hydronic fan coils!

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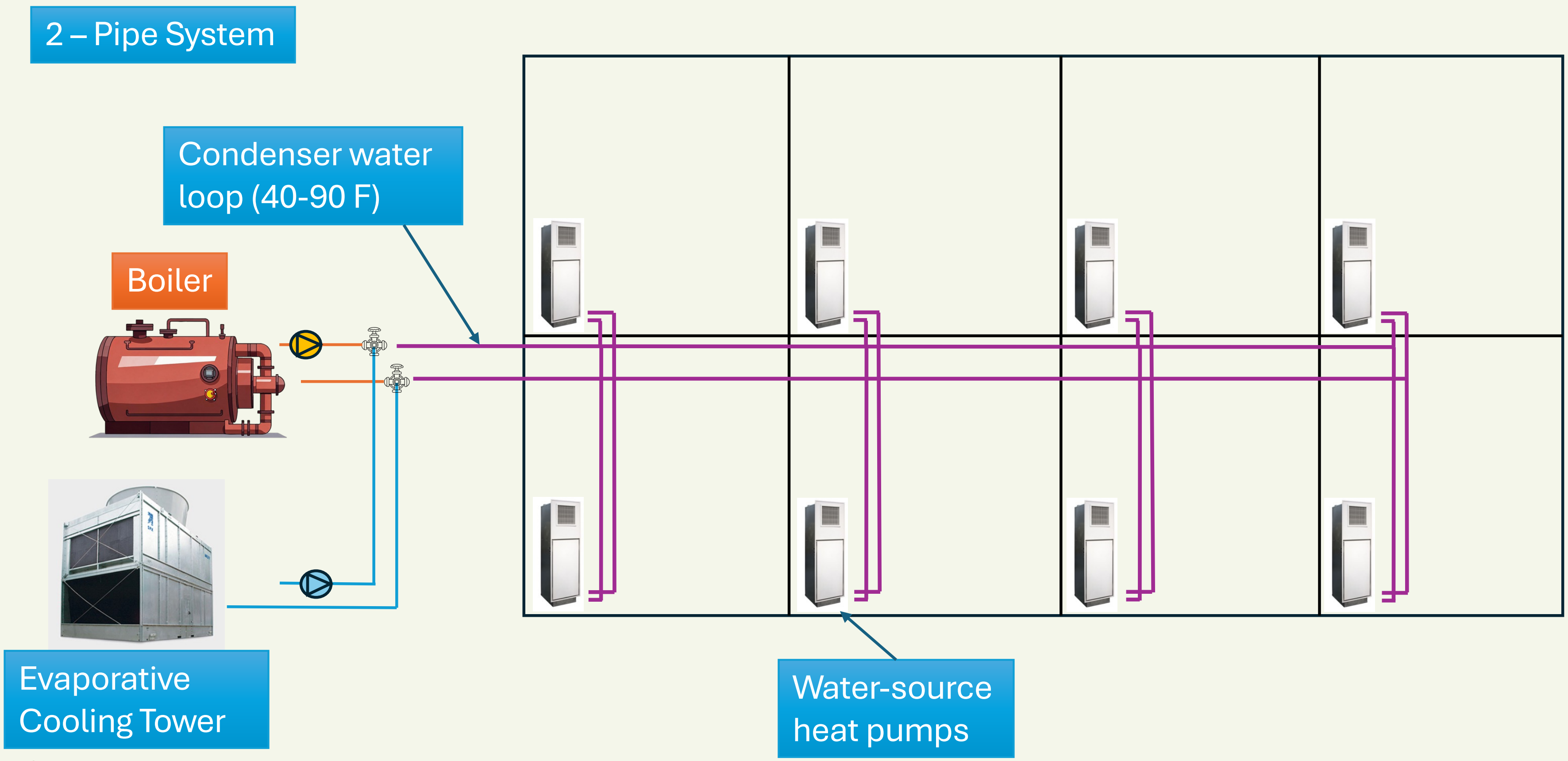
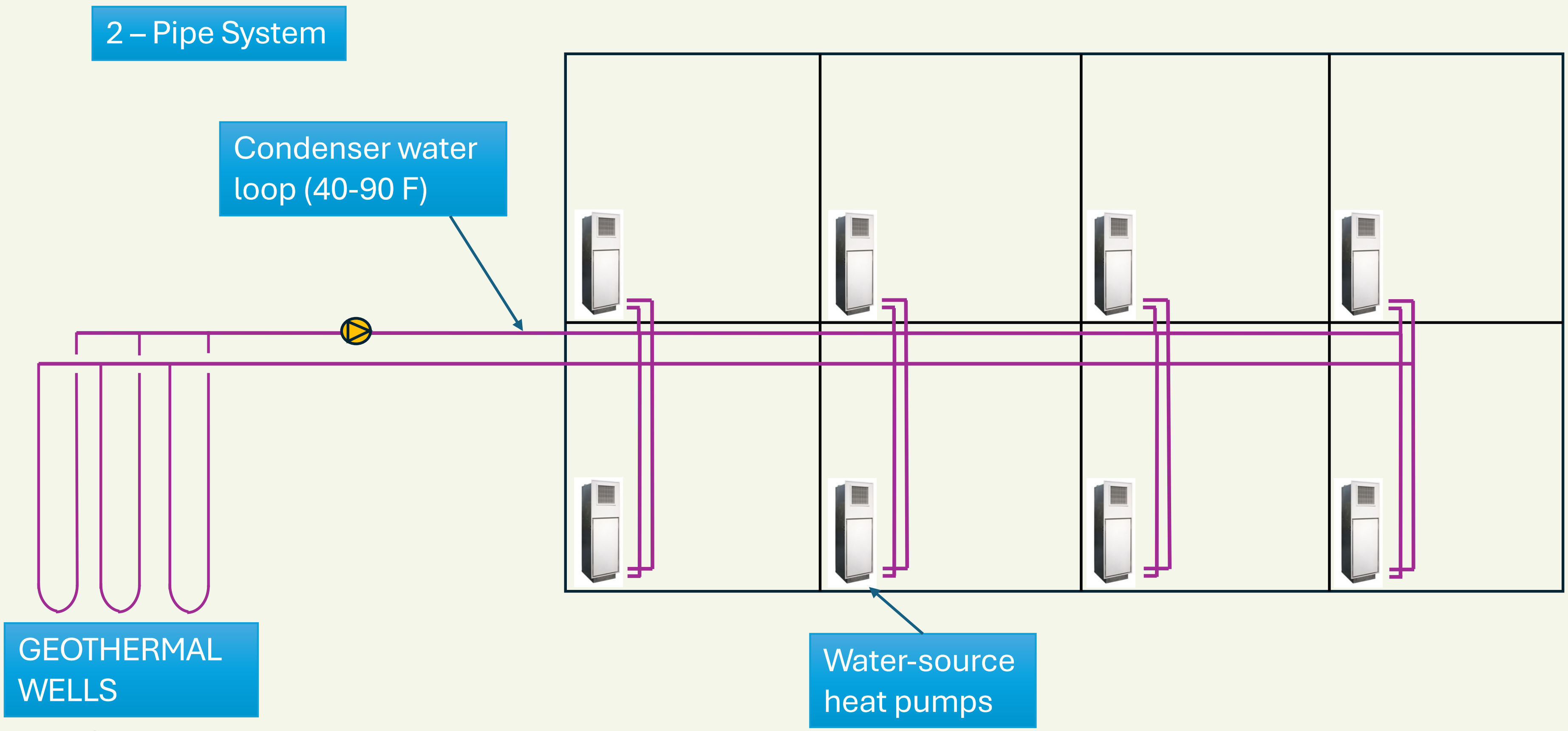
Cycle House

2-Pipe “line set” out to fan coil

Distributed Water-to-Air Heat Pumps



Distributed Water-to-Air Heat Pumps (Geothermal)



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Distributed Water-to-Air Heat Pumps (Pump Power)

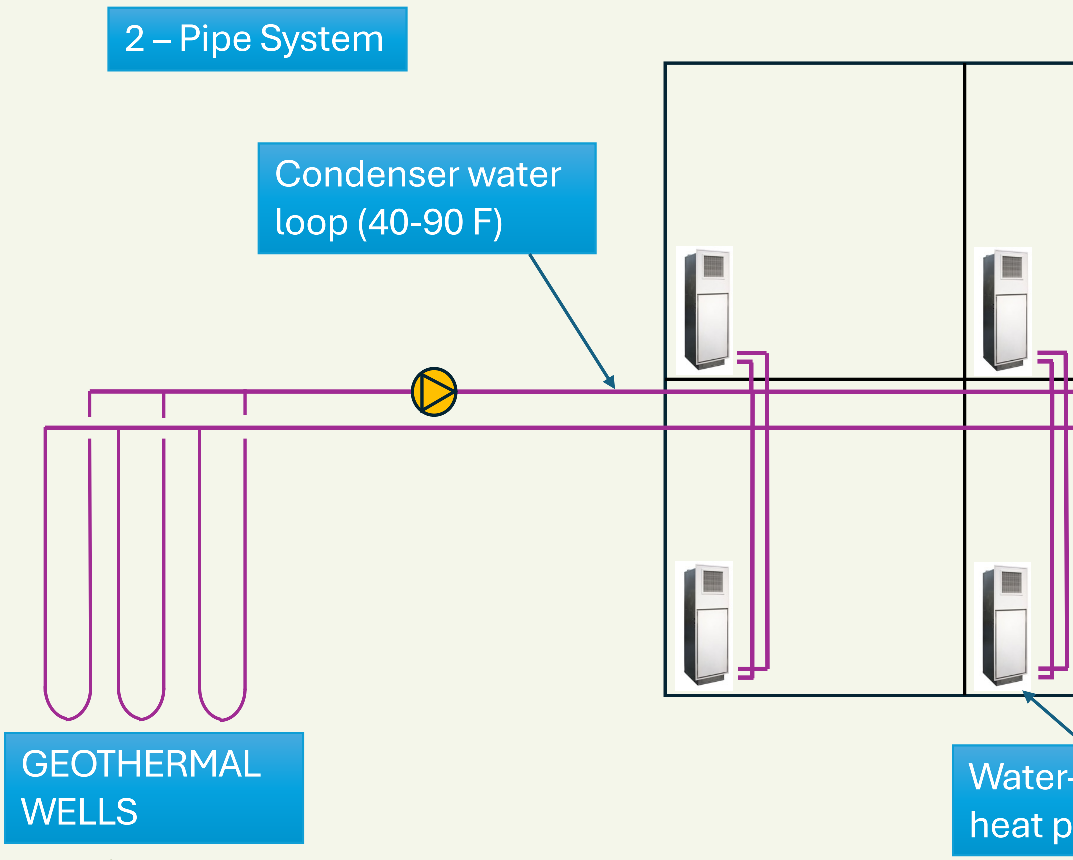

Table 5.1
Benchmarks for GCHP System Pumping Efficiency–
Required Pump Power to Cooling Capacity @ 2.5 to 3.0 gpm/ton

Pump Pwr./ Clg. Cap. Watts Input/ Ton	Pump Pwr./ Clg. Cap. Pump hp/100 Tons	Grade
50 or Less	5 or Less	A - Excellent
50 to 75	5 to 7½	B - Good
75 to 100	7½ to 10	C - Mediocre
100 to 150	10 to 15	D - Poor
Greater than 150	Greater than 15	F - Bad

"Ground-Source Heat Pumps" Subtitle: "Design of Geothermal Systems for Commercial and Institutional Buildings" by: Stephen P. Kavanaugh and Kevin Rafferty Published by: ASHRAE

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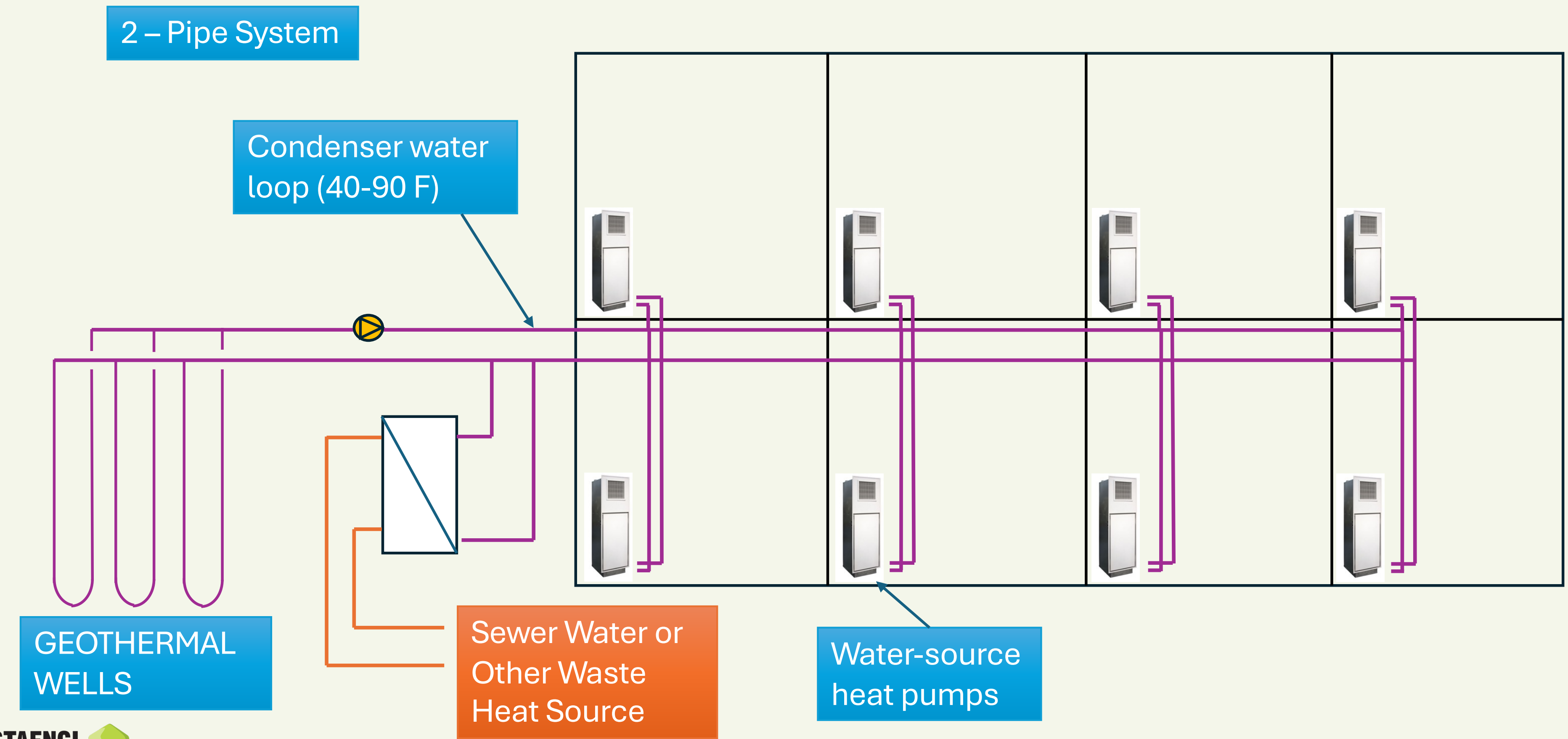
Distributed Water-to-Air Heat Pumps (Other Sources)



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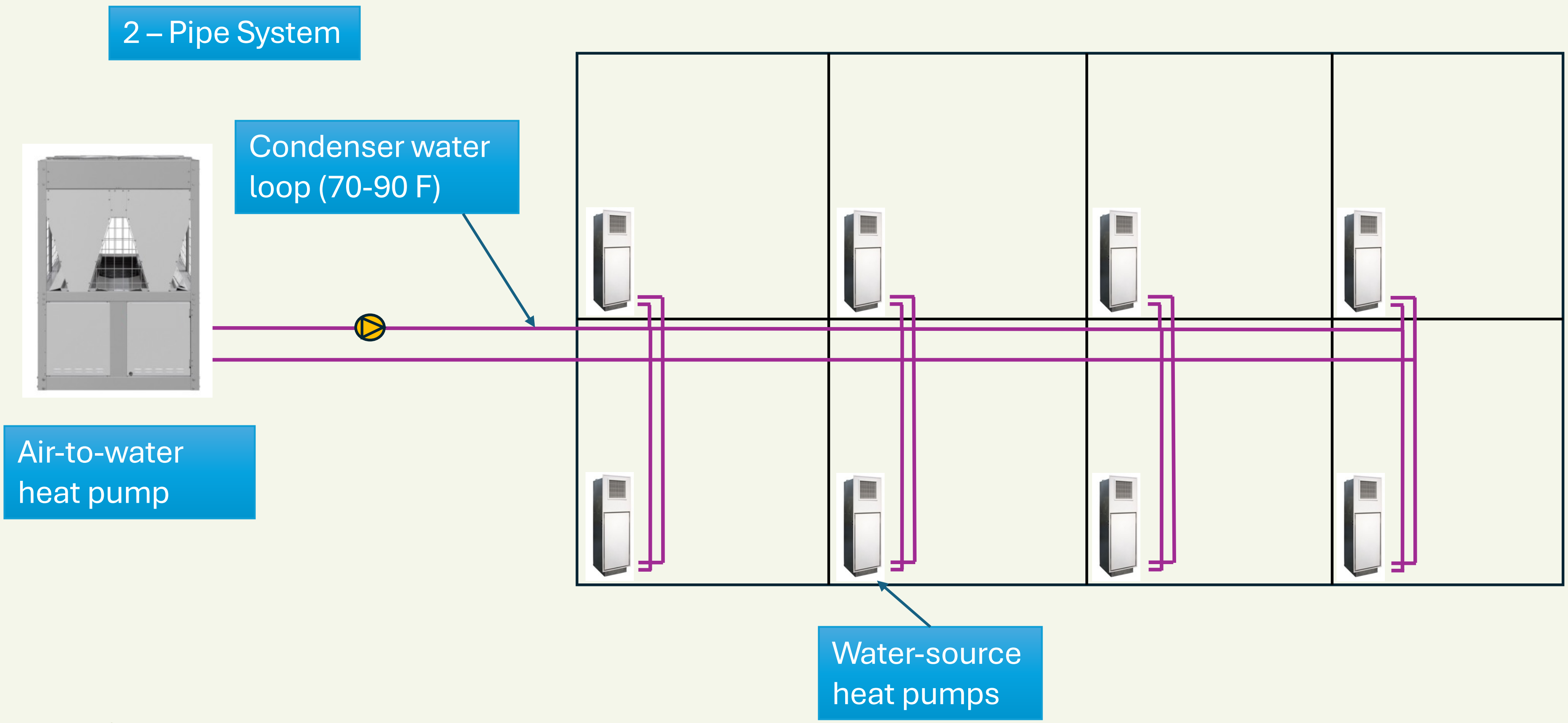
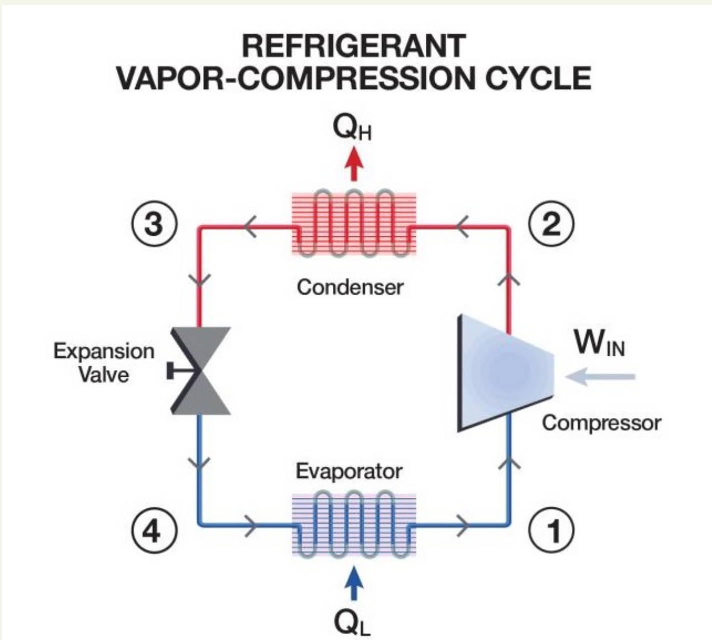
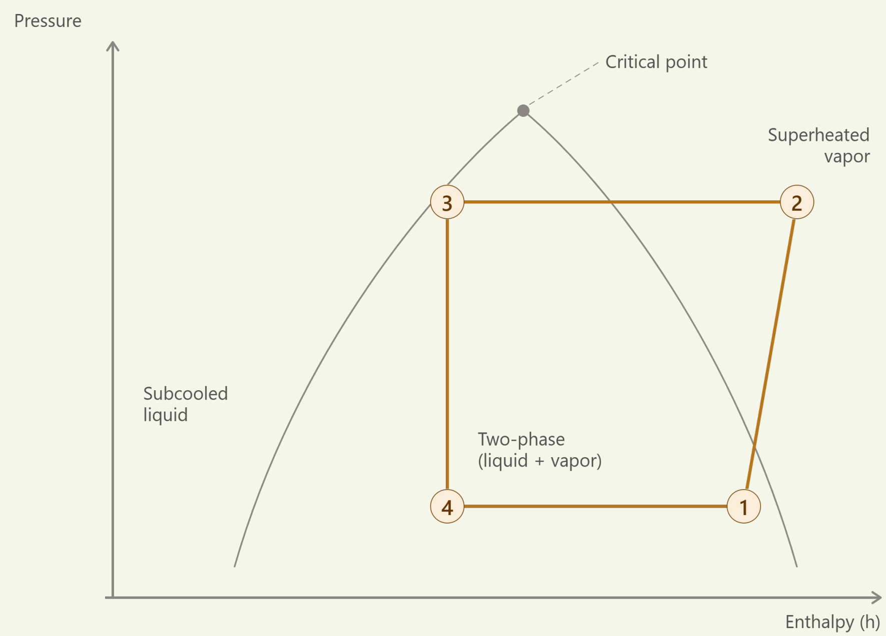
Distributed Water-to-Air Heat Pumps
(All Electric – Compressors in Series)



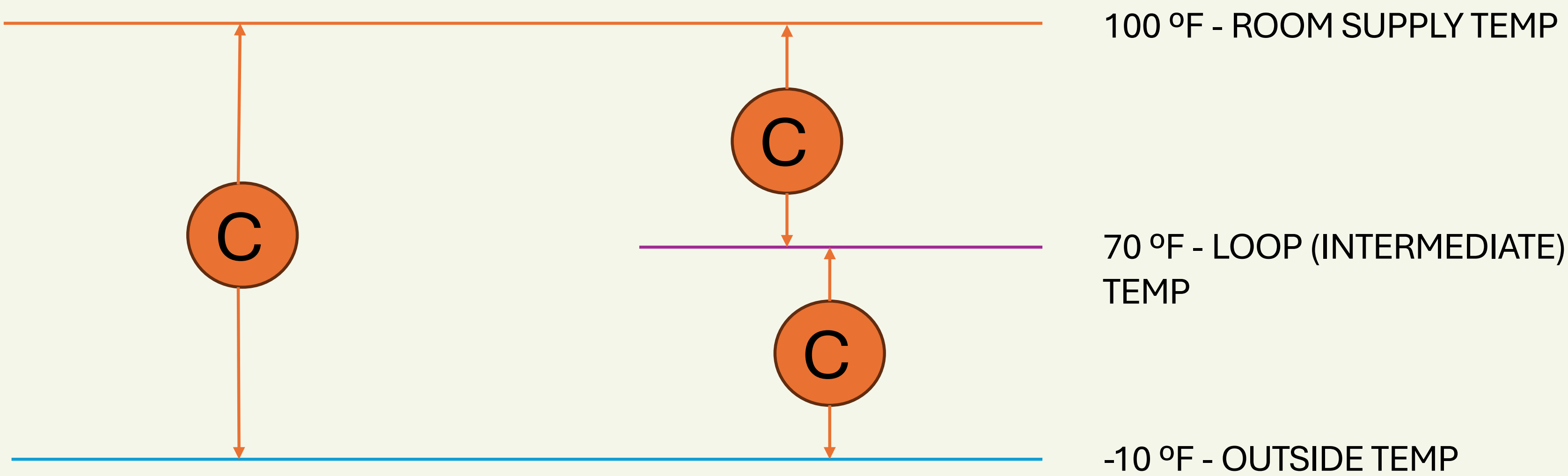
Heat Pump Refrigeration Cycle



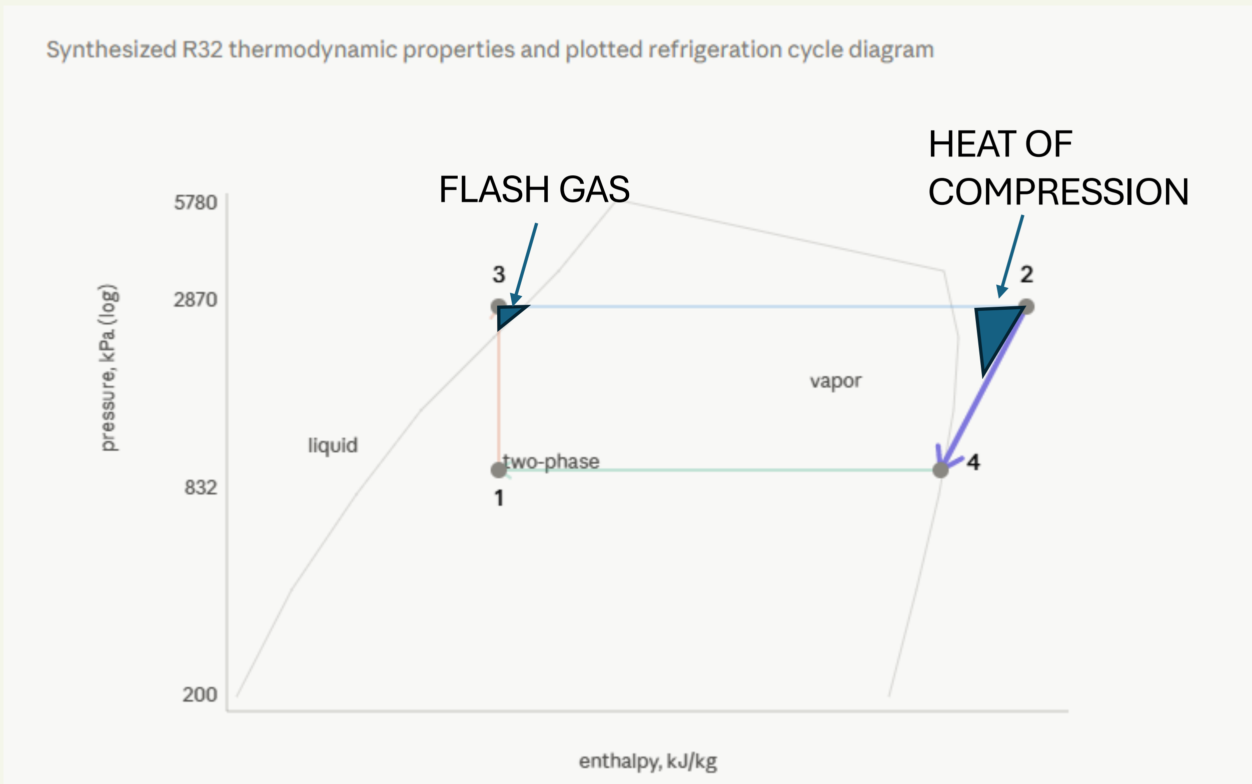


Compressors in Series

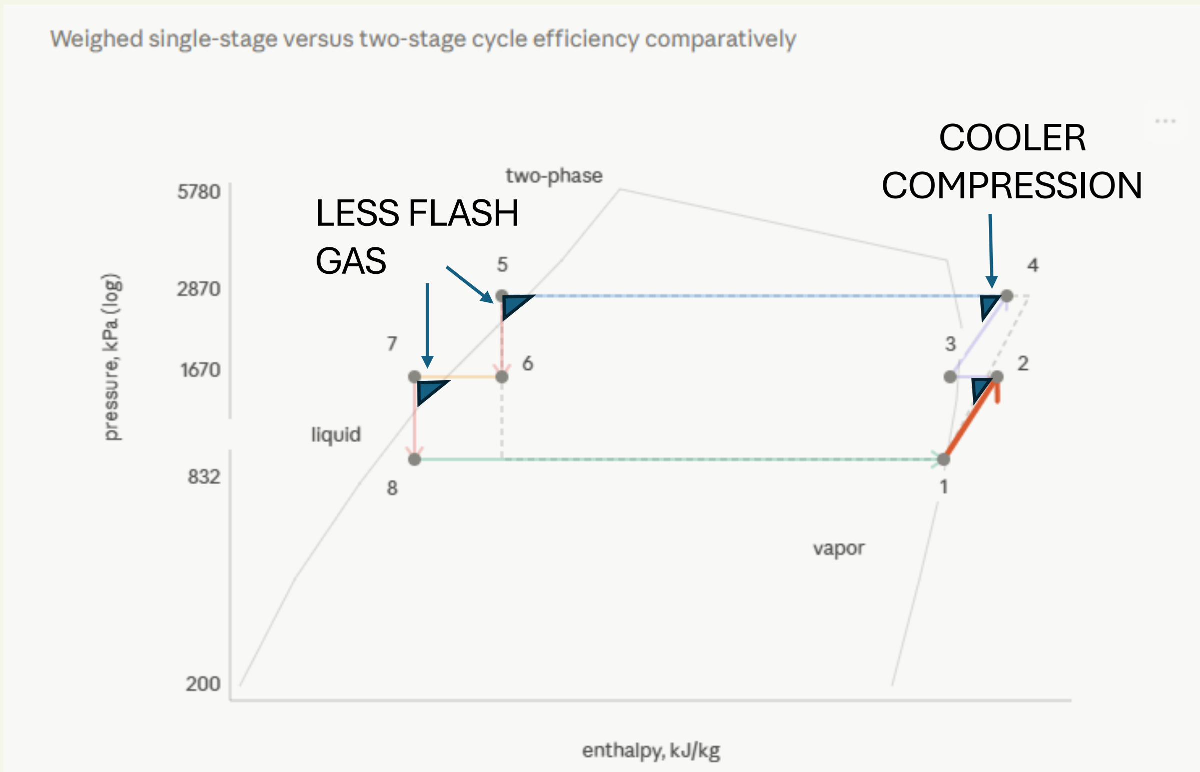
$$COP_{overall} = COP_1 \cdot COP_2 / (COP_1 + COP_2 - 1)$$



Compressors in Series



Compressors in Series – 2 STAGE



DEPENDS ON EQUIPMENT SPECIFICS, BUT COMPESSORS IN SERIES CAN THEORETICALLY BE 5-15% MORE EFFICIENT

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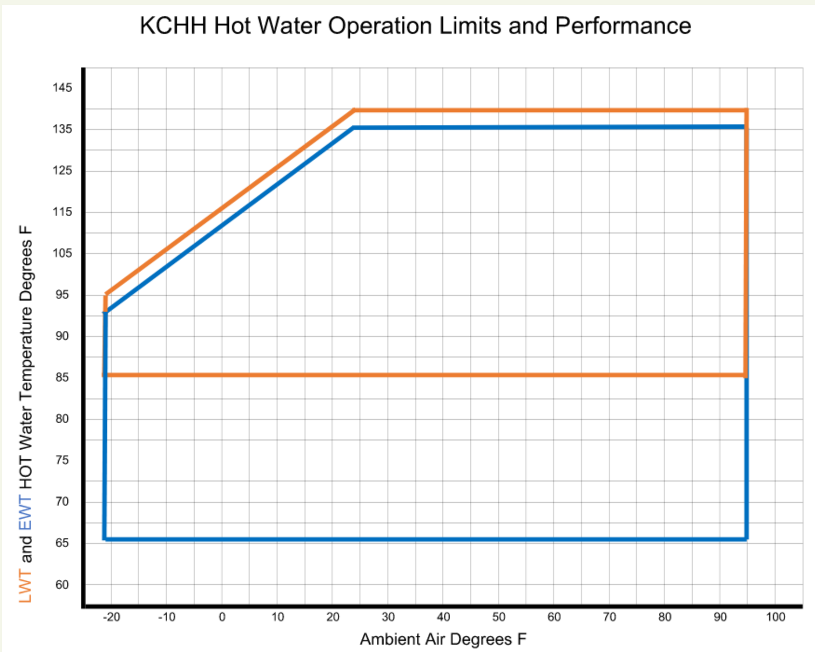
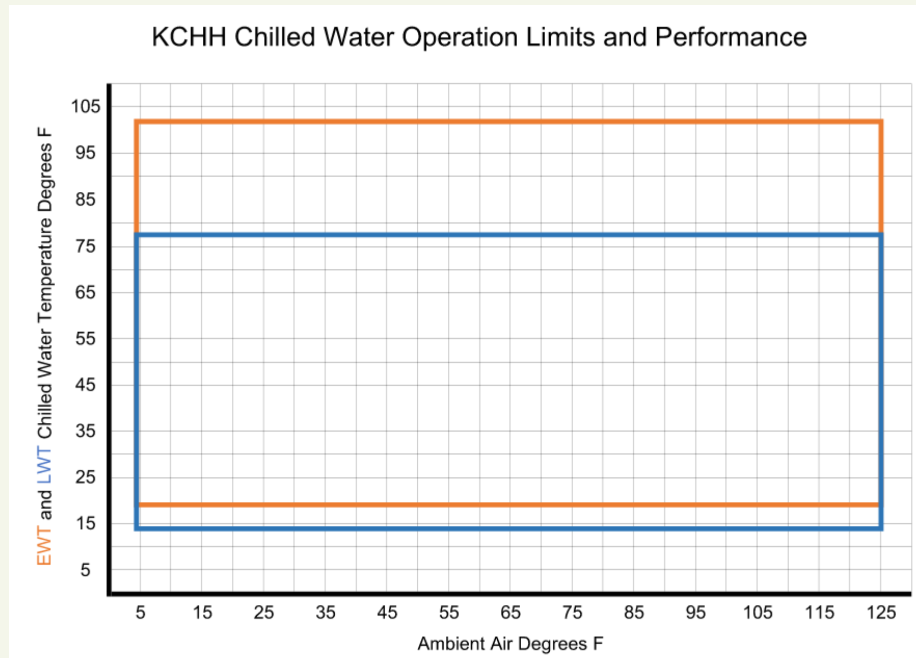
Air-to-Water Heat Pump - Performance

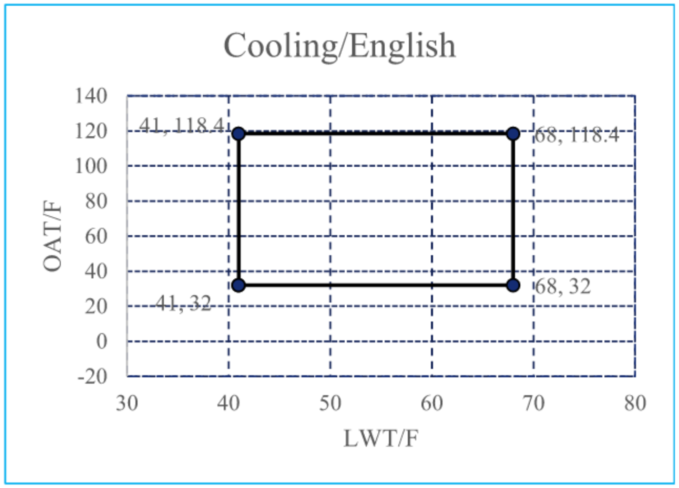




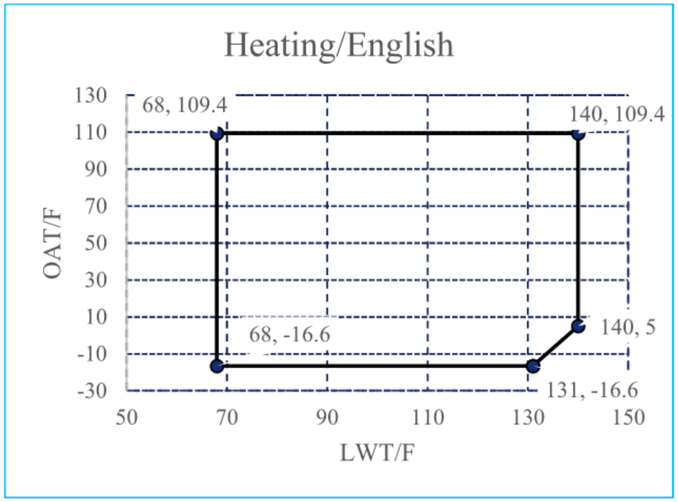
Images courtesy of LG

Air-to-W Heat Pump - Performance

30RQM020 Cooling Mode (English)



30RQM020 Heating Mode (English)



Images courtesy of Carrier

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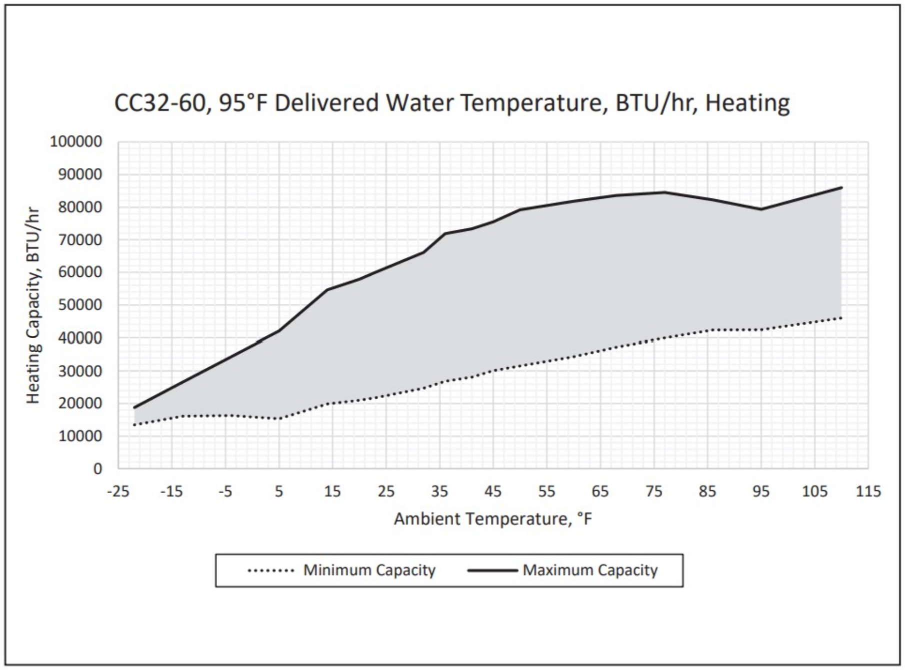
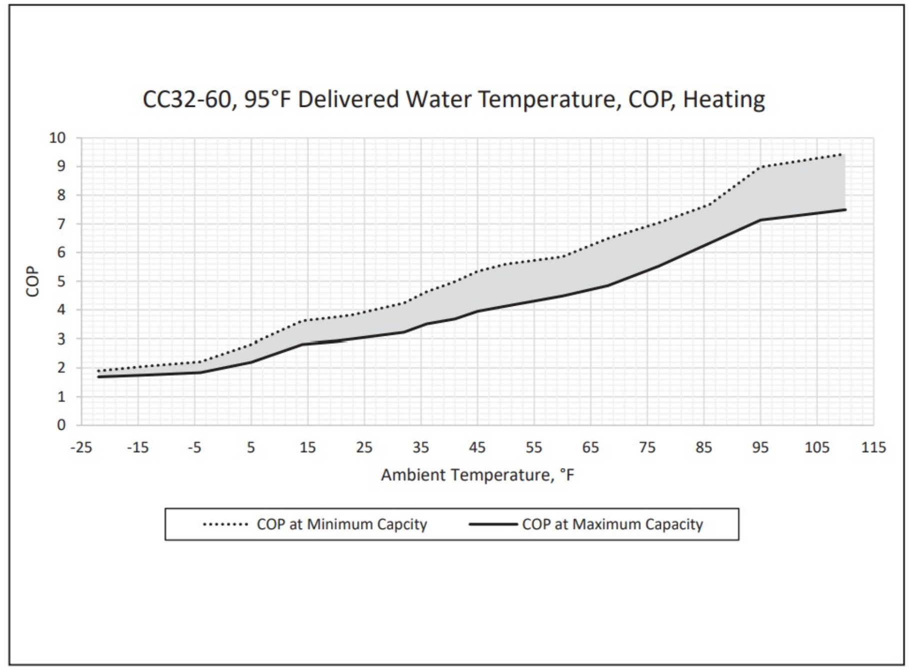
Air-to-W Heat Pump - Performance





Images courtesy of SpacePak

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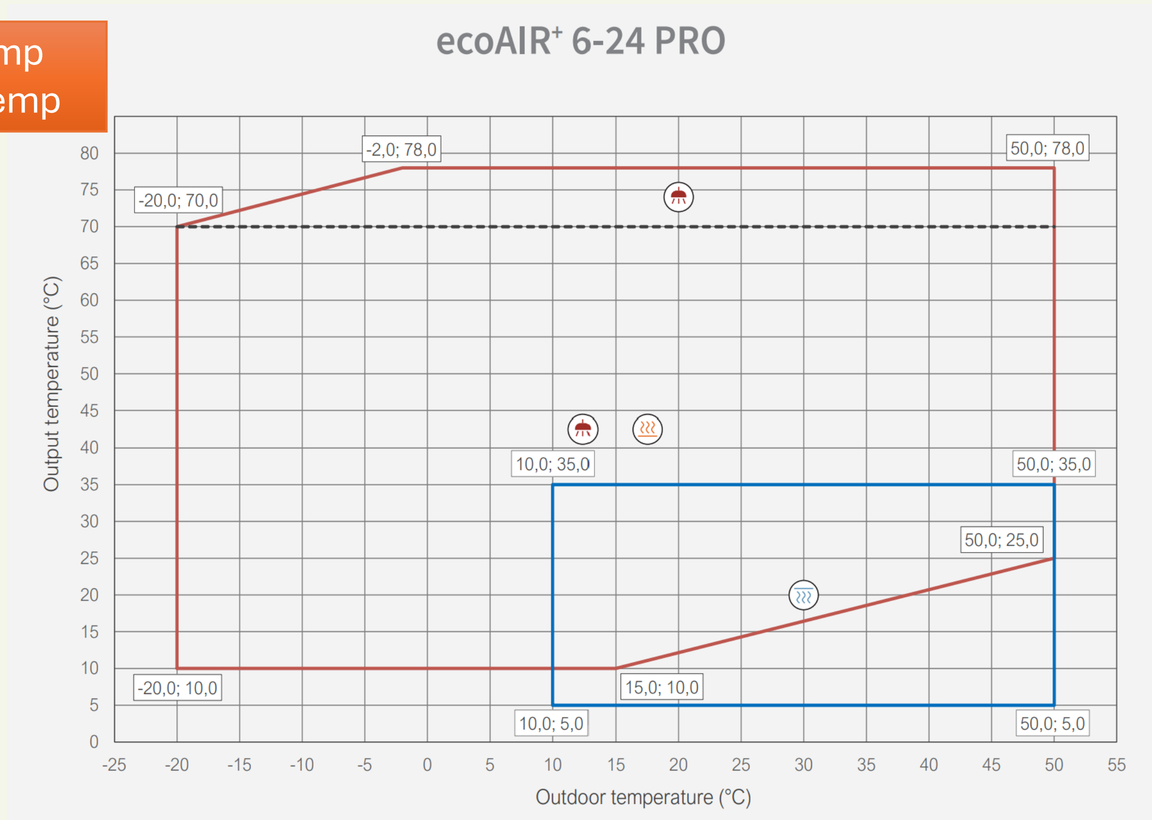
Air-to-W Heat Pump - Performance

-4 F OSA Temp
158 F HW Temp



122 F OSA Temp
41 F CHW Temp

Images courtesy of ECOForest

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Air-to-W Heat Pump - Efficiency

Ratings:

System	Test Conditions	Max Capacity @A95 °F kBtu/h	Seasonal COP	Seasonal EER
CX65	Cooling at W55.4 °F	54.43	8.77	29.92
CX65	Cooling at W44.6 °F	45.28	6.75	23.03
CX65	Heating W95 °F / A47 °F db / 43 °F wb	66.36	SCOP 5.36	*HSPF 18.28

Cooling performance certified under AHRI Standard 550/590 (I-P) and AHRI Standard 551/591 (SI). Heating COP and SCOP is certified by SGS under EN 14825.

Efficiency Ratings for Chilltrix CX65X

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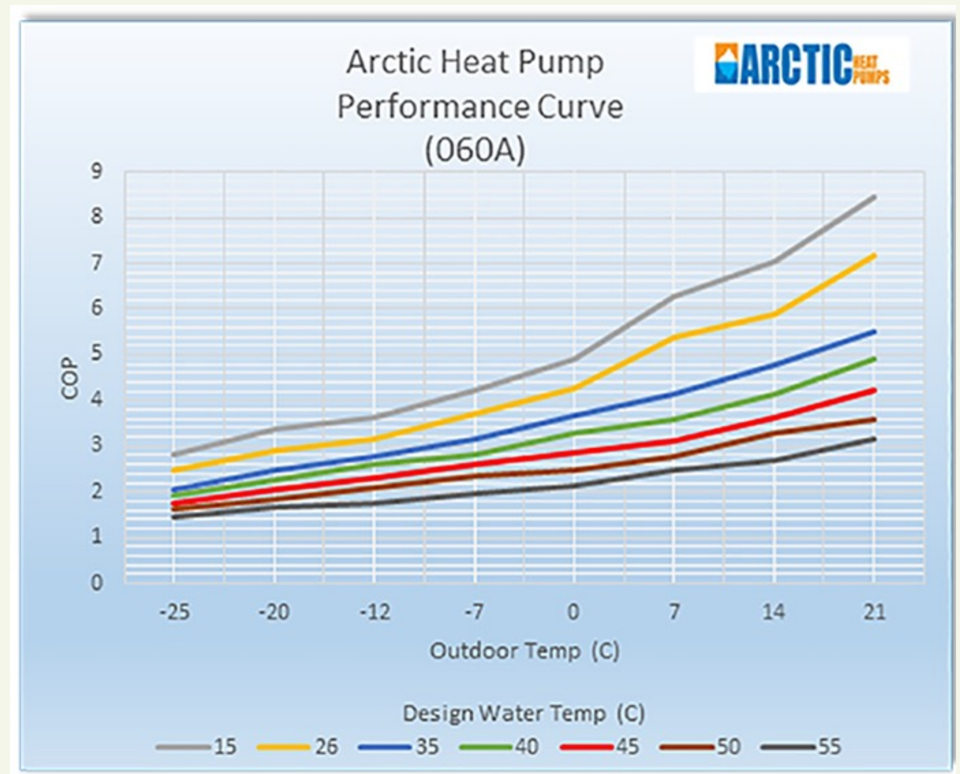
Air-to-W Heat Pump - Performance



Images courtesy of Arctic

Air-to-Water Heat Pumps

Small (<6 tons)	Notes
Arctic	Excellent capacity at very cold climates
Chilltrix	One of the highest efficiency small capacity units
Enertech	Newish company. Integrated product
Mitsubishi Ecodan	Integrated system / split refrigerant
Nordic	Split system to avoid freezing concerns (not monoblock)

Air-to-Water Heat Pumps

Med/Large	Notes
Aermec	2-pipe and 4-pipe configurations available
Carrier	2-pipe and 4-pipe with low temperature performance
LG NRP	Modular. Good efficiency. Low temperature performance
Multi-stack	Integrated system
Trane	Modular
EcoForest	High efficiency equipment from Spain. R290. Integrated controls

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THANK YOU

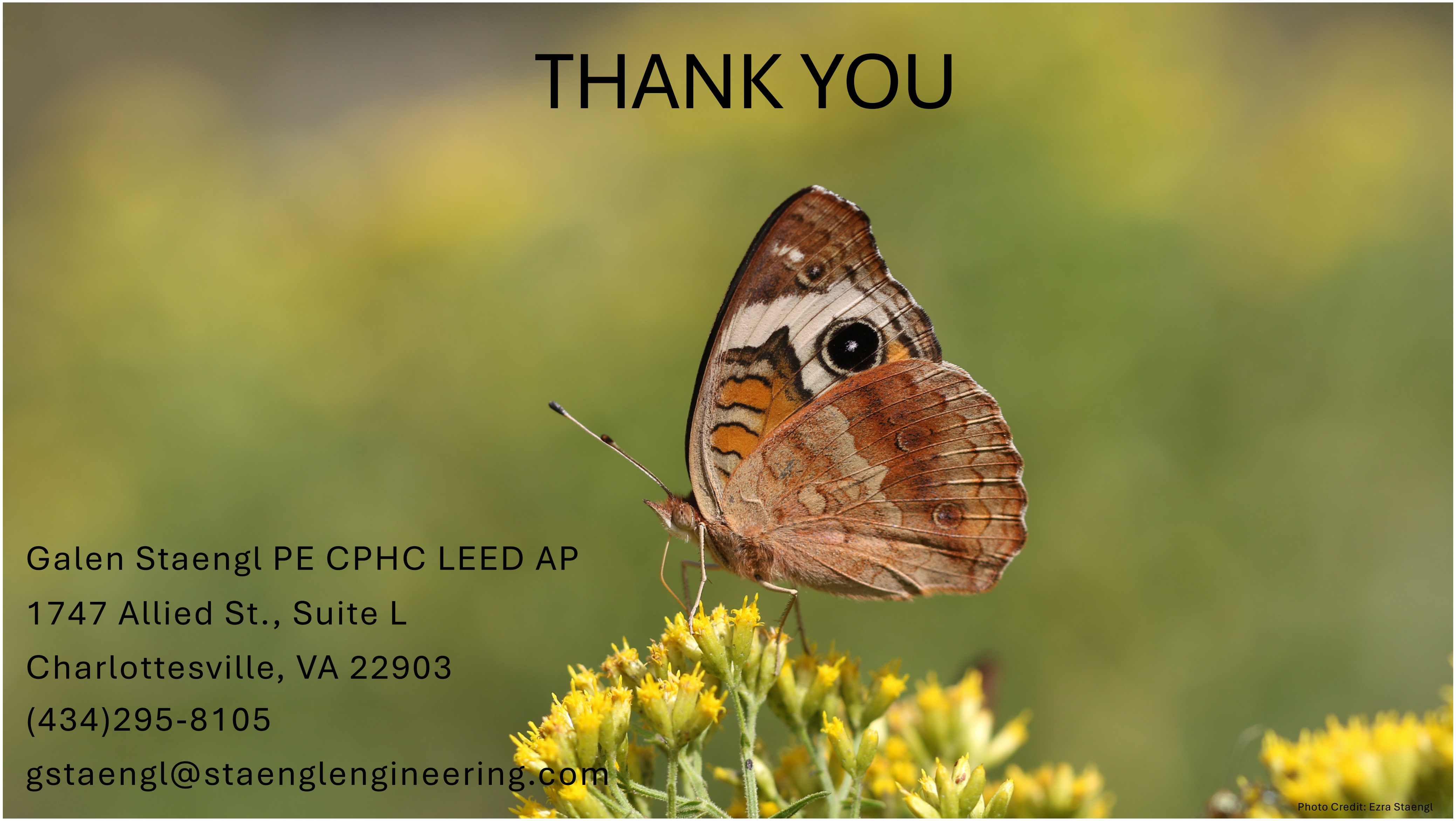

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Photo Credit: Ezra Staengl