CAE 464/517 HVAC Systems Design

Spring 2023

April 18, 2023

Hydronic systems: Boiler and chiller selection and additional examples

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ANNOUNCEMENTS

Announcements

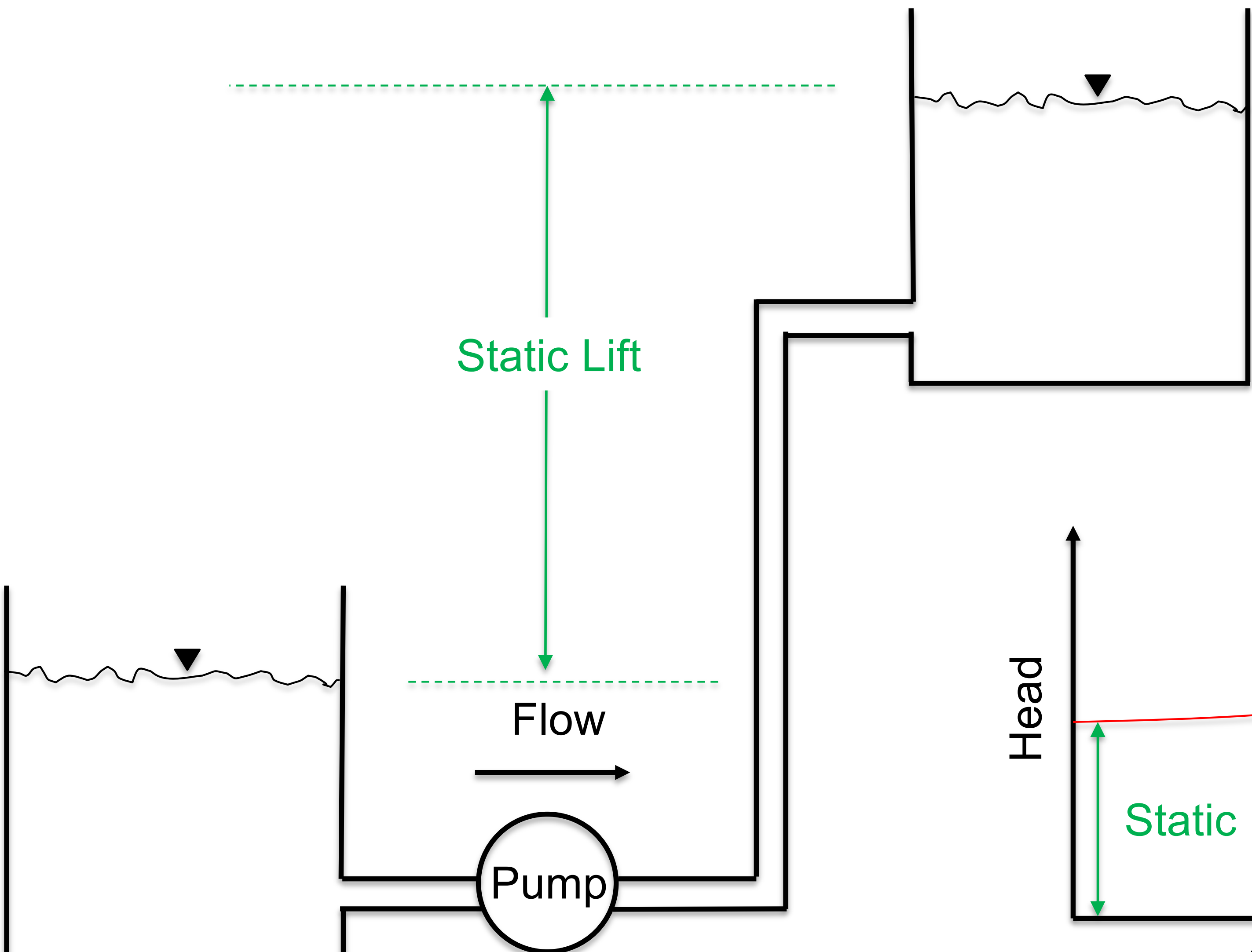
- Assignment 5 is due tonight (optional) – solution will be posted immediately

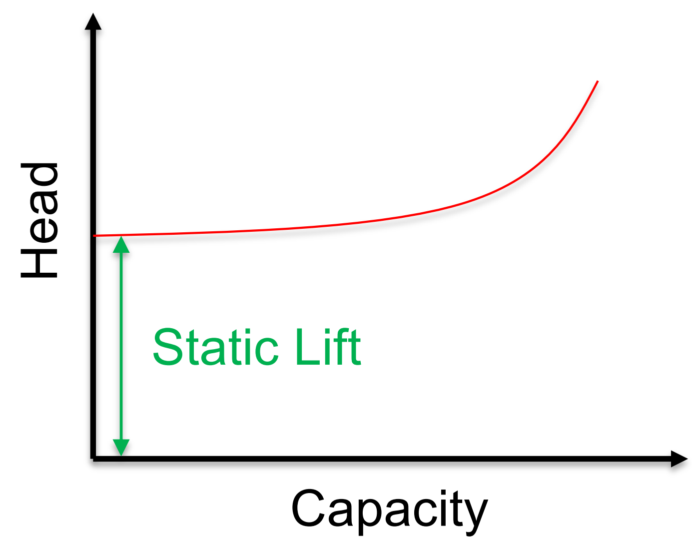
- If you forget about your contribution page for Project Part 2, you should email it to me immediately. Otherwise, your project will not be graded.

RECAP

Recap

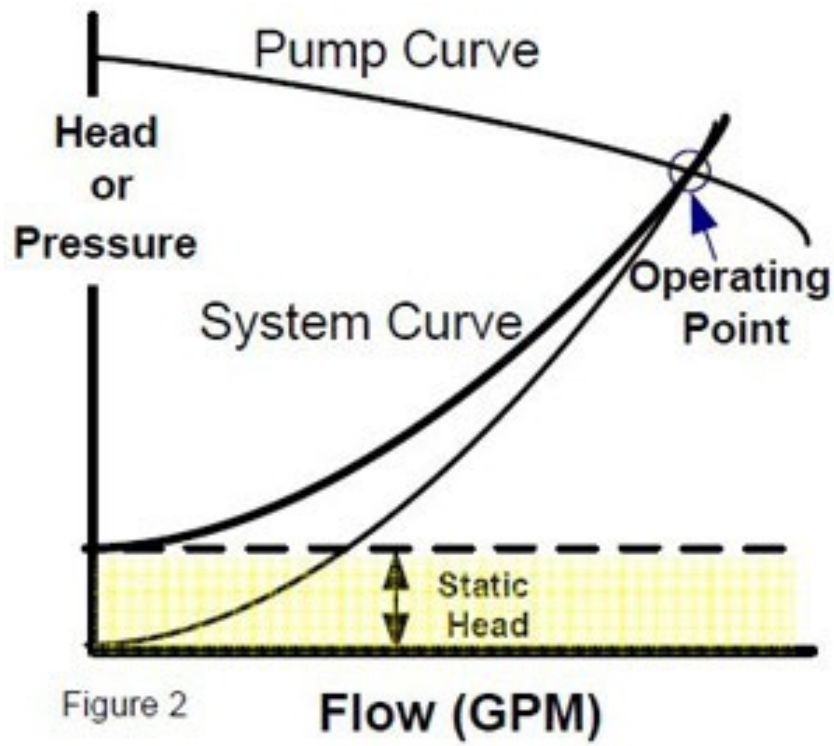
- How is the system curve for this one?

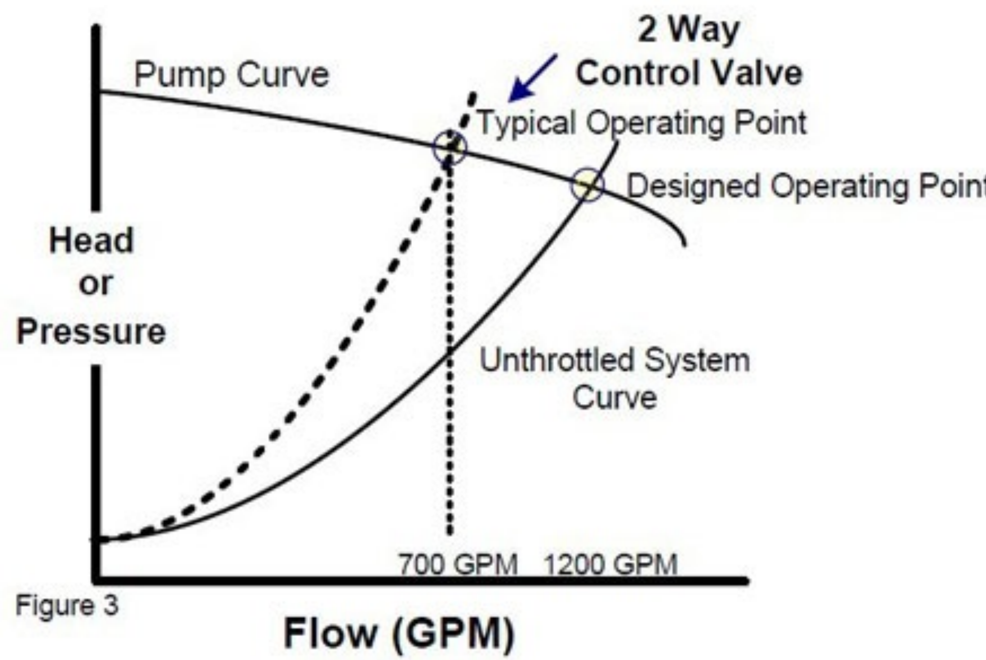




Recap

- System curve can change over time

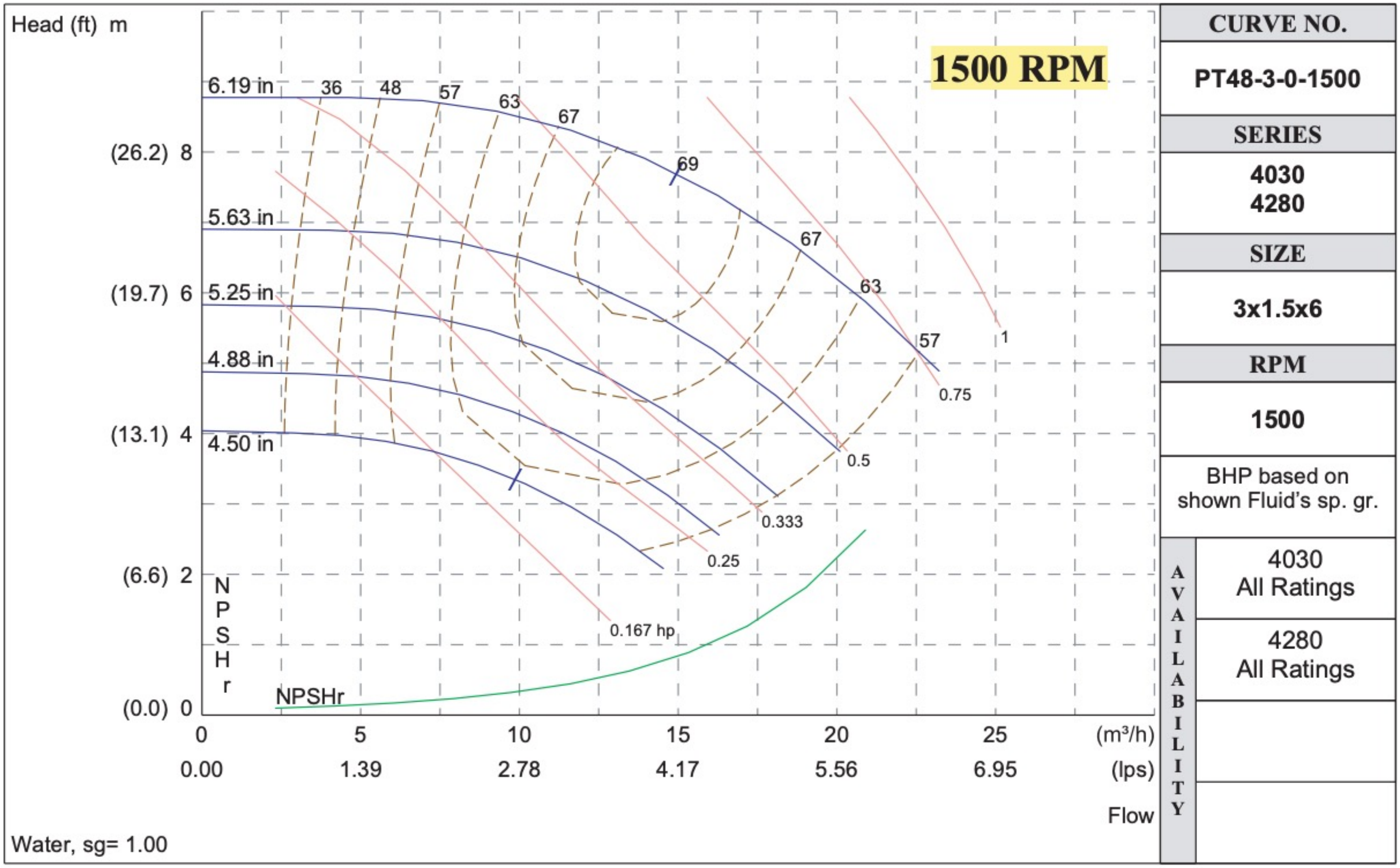




http://www.frequencyinverters.org/frequency-converter-for-pumps-278604.html

Recap

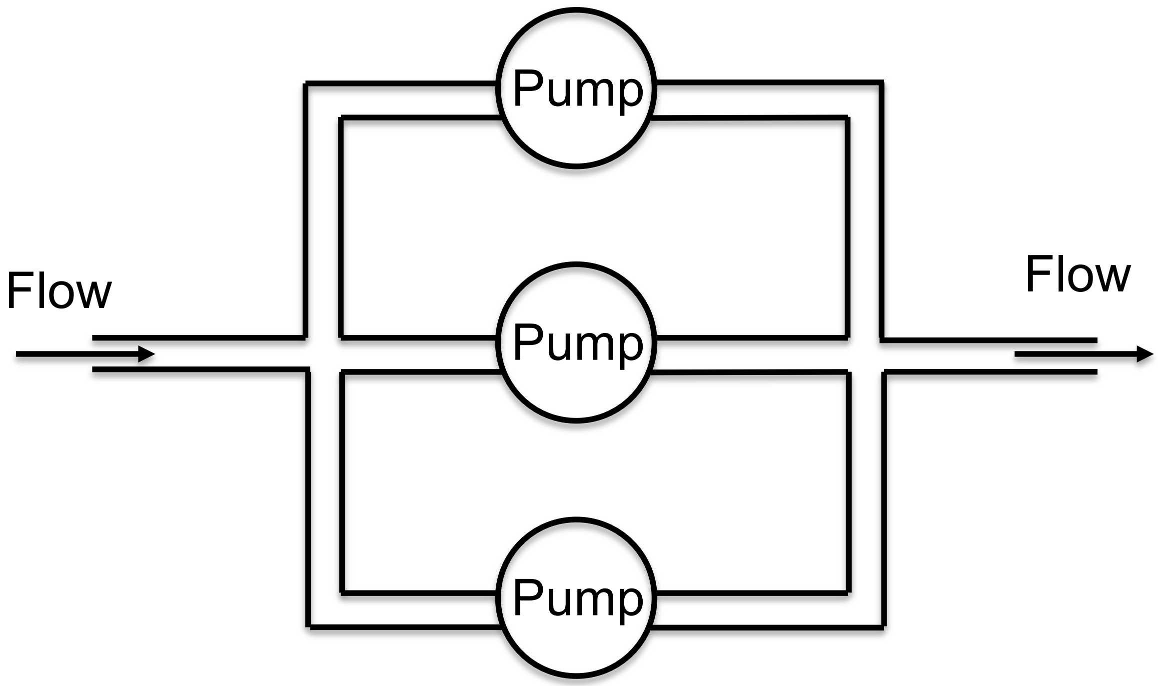
- Manufacture 1:



https://armstrongfluidtechnology.com/~/media/documents/specifications/submittal-data/4030-base-mounted-pumps/4030-50hz/40-51l_4030_3x1-5x6.pdf?la=en&display=1

Recap

- Pumps in parallel:
  - ❑ Operate at the same head
  - ❑ The total flow rate in the system is the sum of each pump flow rate



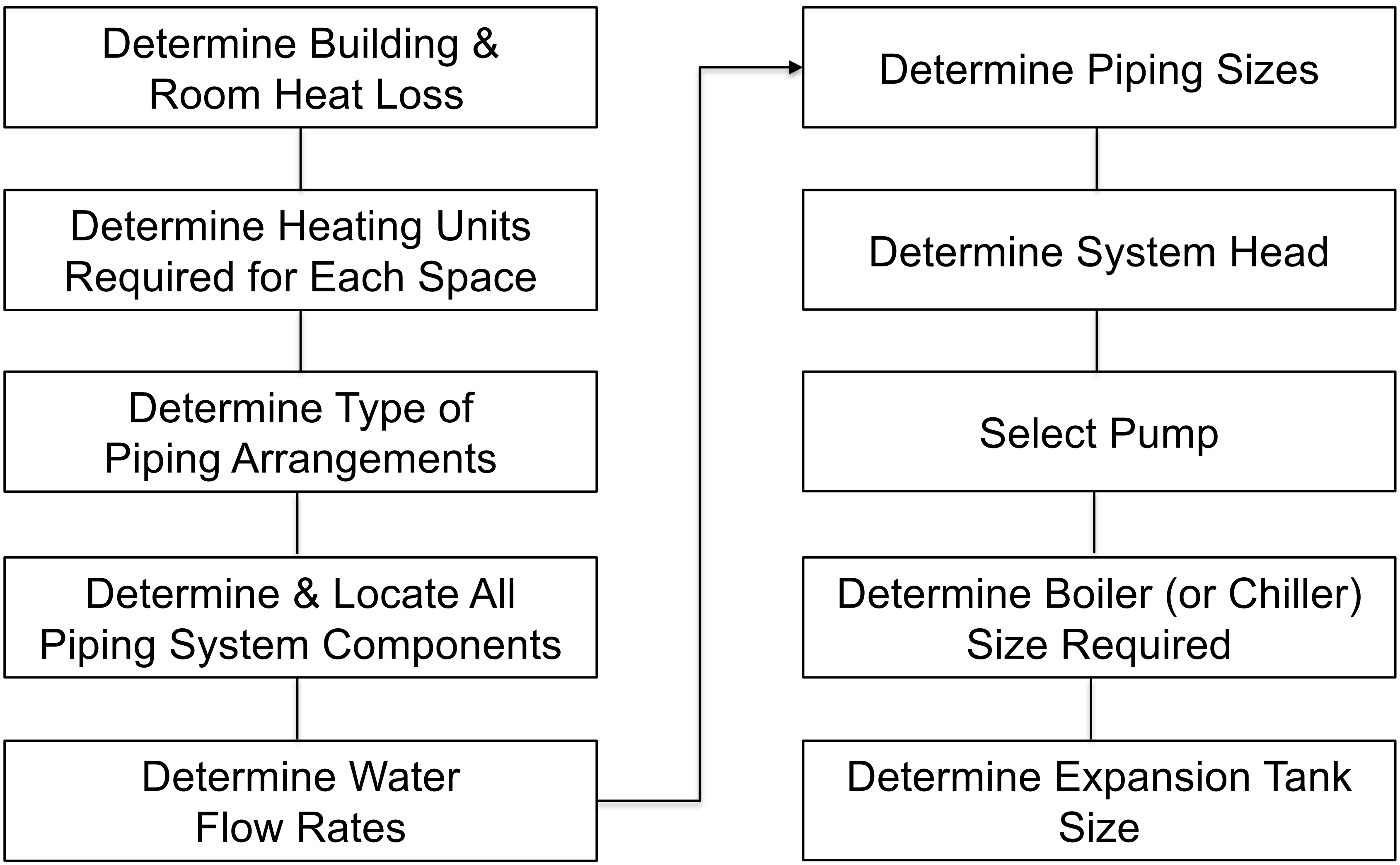
$$H = H_1 = H_2 = H_3$$

$$Q_{total} = Q_1 + Q_2 + Q_3$$

DESIGN PROCEDURE

Design Procedure

- Overall design procedure:



Design Procedure

- Pump design procedure:

1. Determine Load (Btu/hr)
2. Select (ΔT)
3. Determine Flow Rate (GPM)
4. Consider Piping Layout / Pip Sizes
5. Determine System Head (Pressure Drop ft)
6. Form System Curve
7. Select Pump (Manufacturers Datasheet)
8. Determine Boiler (or Chiller) Size Required

Find the greatest head loss

Recommend balancing valve if needed

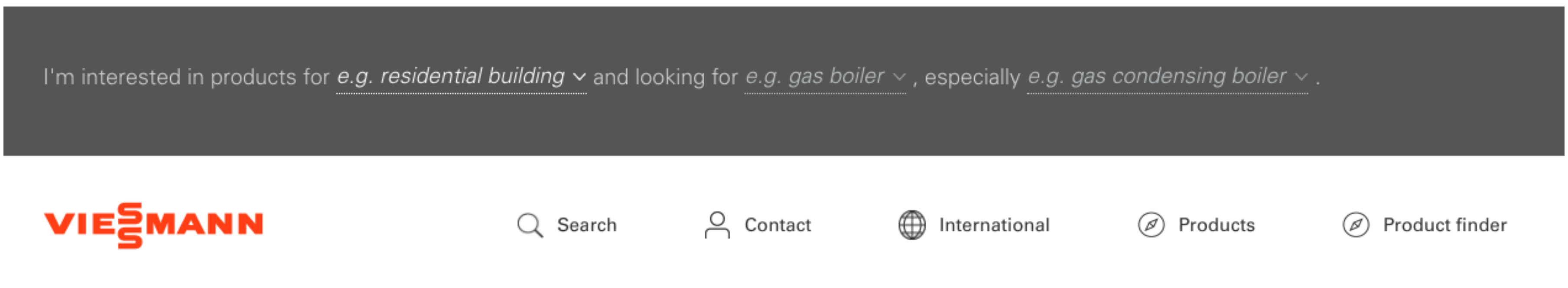
BOILER SELECTION AND HEAD LOSSES

Boiler Selection and Head Losses

- An example from the campus

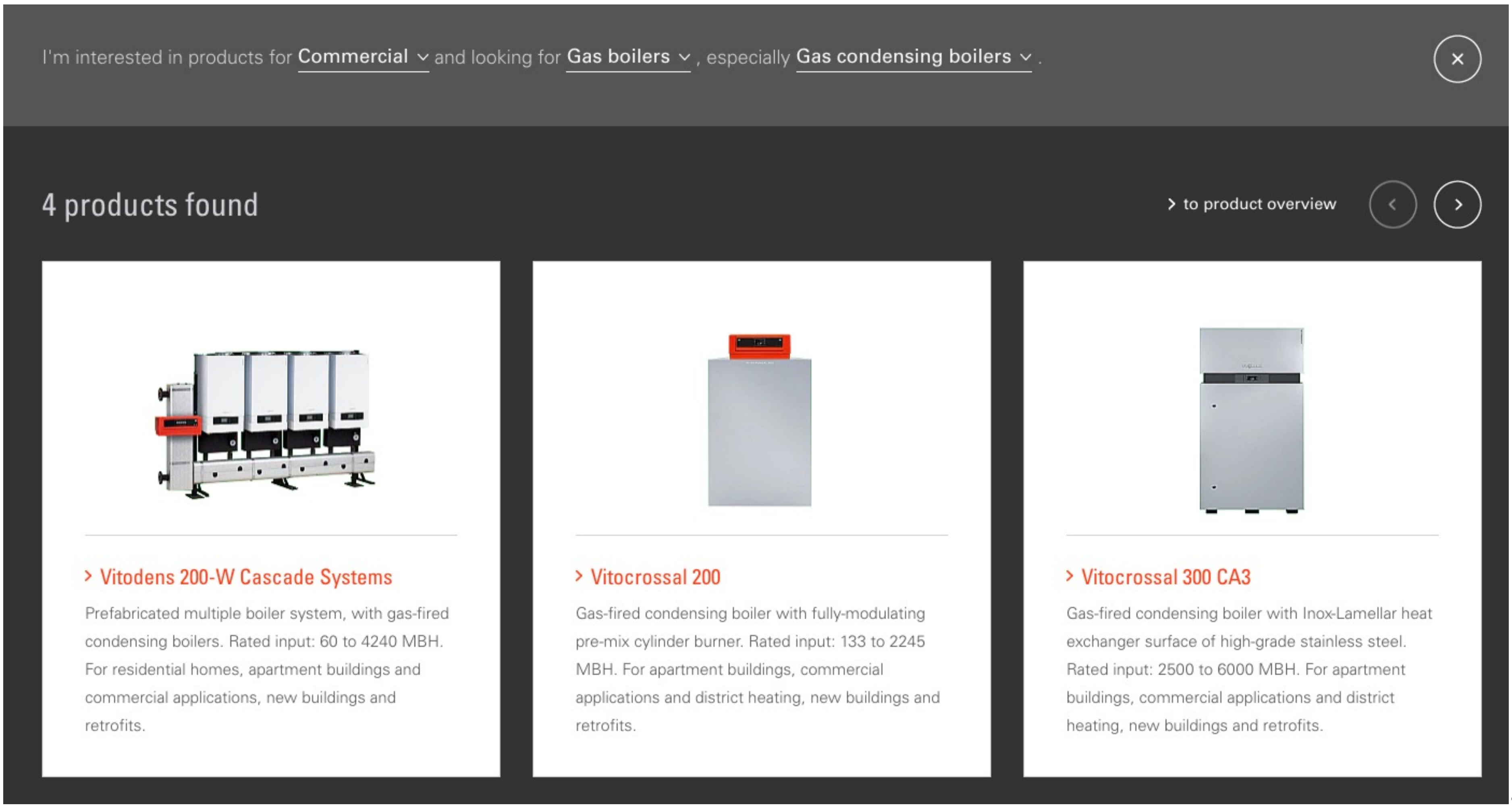
Boiler Selection and Head Losses

- Manufacture 1 (VIESMANN):
  - ❑ Website Link: https://www.viessmann-us.com/
  - ❑ Click on the “Product Finder” to select your product:



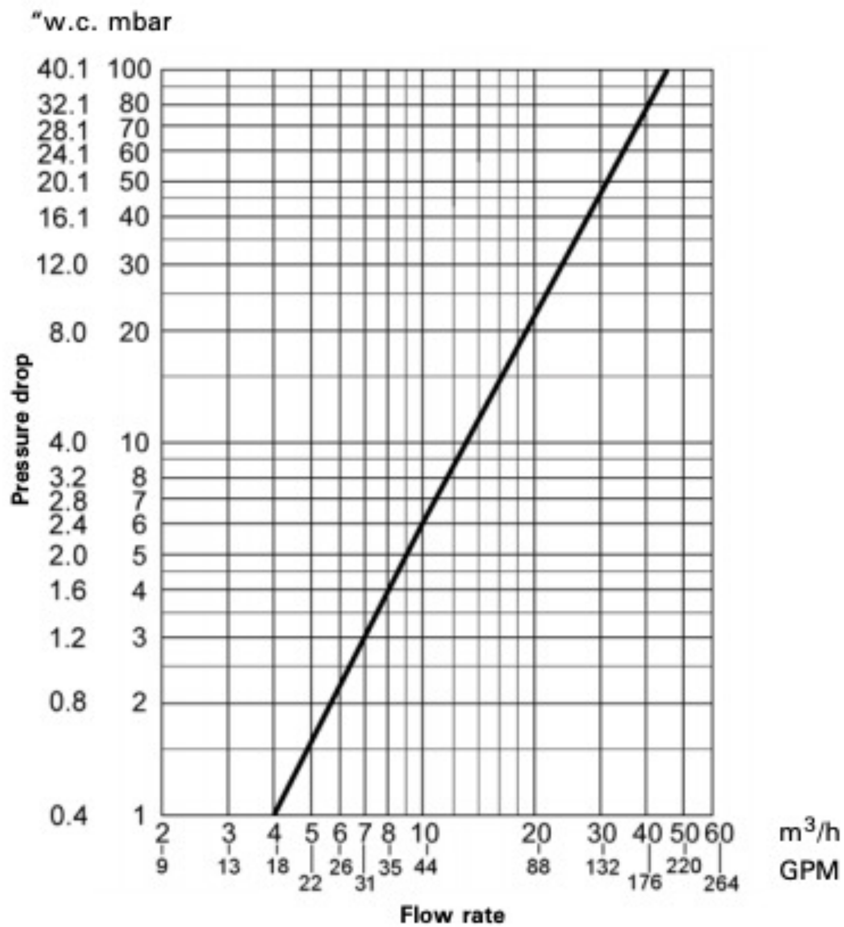
Boiler Selection and Head Losses

- Manufacture 1 (VIESMANN):
  - ❑ Review the capacity first range first



Boiler Selection and Head Losses

- Manufacture 1 (VIESMANN):
  - ❑ Click on Downloads (e.g., technical data, CAD file, ...)
  - ❑ Pay attention to specs (e.g., pressure drop, efficiency, capacity, …)



Boiler Selection and Head Losses

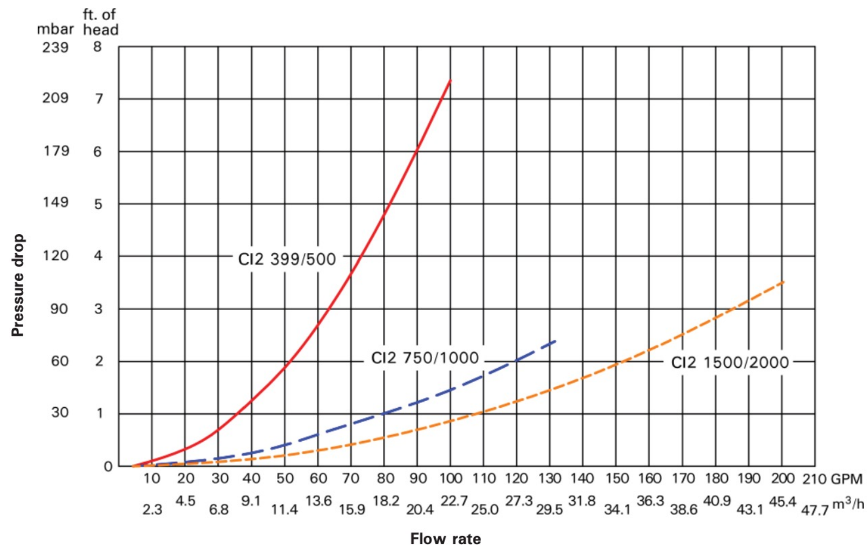
- Manufacture 1 (VIESMANN):
  - ❑ Pay attention to specs (e.g., pressure drop, efficiency, capacity, …)

Vitocrossal 200, CI2 Series Technical Data | Specifications

Flow Rate

Pressure drop (primary circuit)

The Vitocrossal 200, CI2 is only suitable for fully pumped hot water heating systems.



Recommended Flow Rates CI2

CI2 model		399	500	750	1000	1500	2000
20°F △t	GPM	39	48	73	97	146	194
40°F △t	GPM	19	24	36	49	73	97
100°F △t	GPM	8	10	15	19.5	29	39
11°C △t	m^3/h	8.9	10.9	16.6	22.0	33.2	44.1
22°C △t	m^3/h	4.3	5.5	8.2	11.1	16.6	22.0
56°C △t	m^3/h	1.8	2.3	3.4	4.4	6.6	8.9

△t = temperature difference
This boiler does not require a flow switch.

Minimum flow rate based on: 100°F △t (56°C △t)
Maximum flow rate based on: 20°F △t (11°C △t)

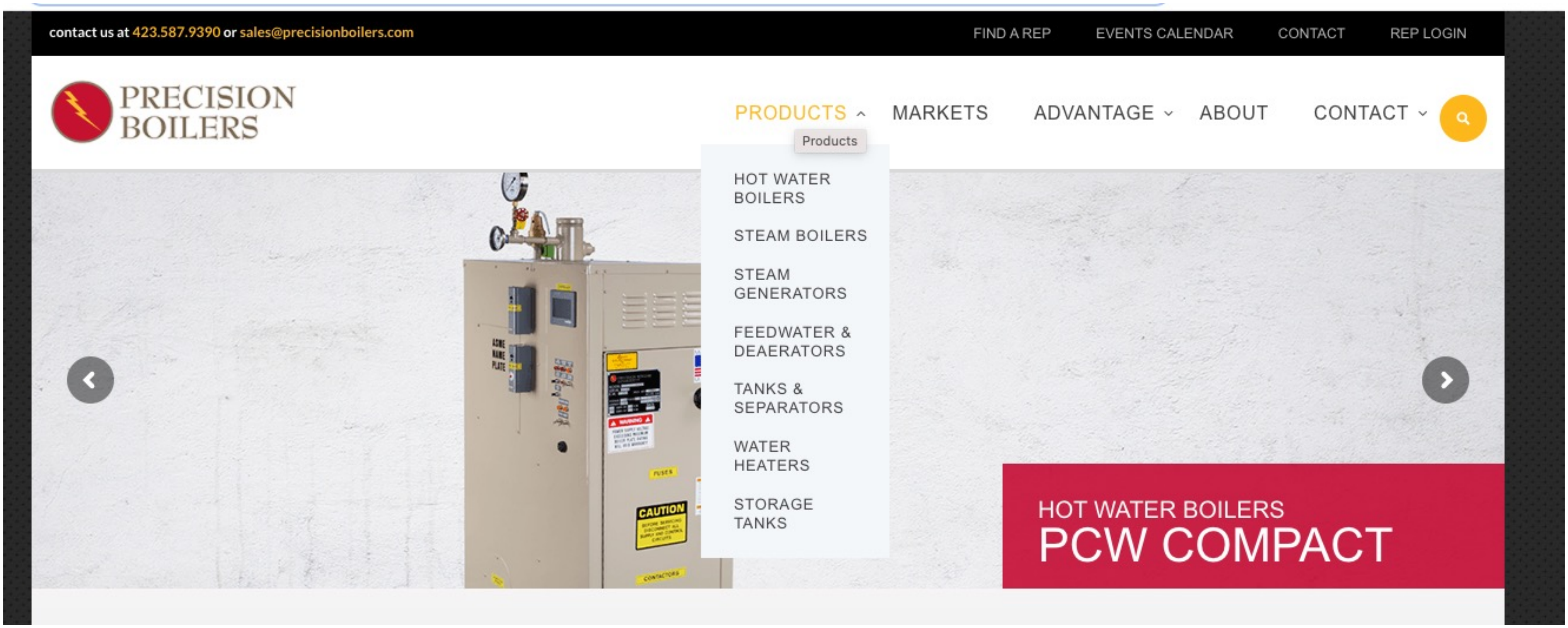
https://www.viessmann-us.com/content/dam/public-brands/us/pdf/technical-data-manuals/vitocrossal_200_ci2_tdm.pdf/_jcr_content/renditions/original./vitocrossal_200_ci2_tdm.pdf

Boiler Selection and Head Losses

- Manufacture 1 (VIESMANN):
  - ❑ Some of the links for the CAD drawings and Revit models exist here:
  - ❑ https://www.viessmann-us.com/en/services/downloads/cad.html
  - ❑ https://www.vitoteam.com/Pages/eng/cad/drawings.php?b1=CU3A-26&b2=CU3A-35&b3=CU3A-45&b4=CU3A-57&clean=Y&title=Vitocrossal+300

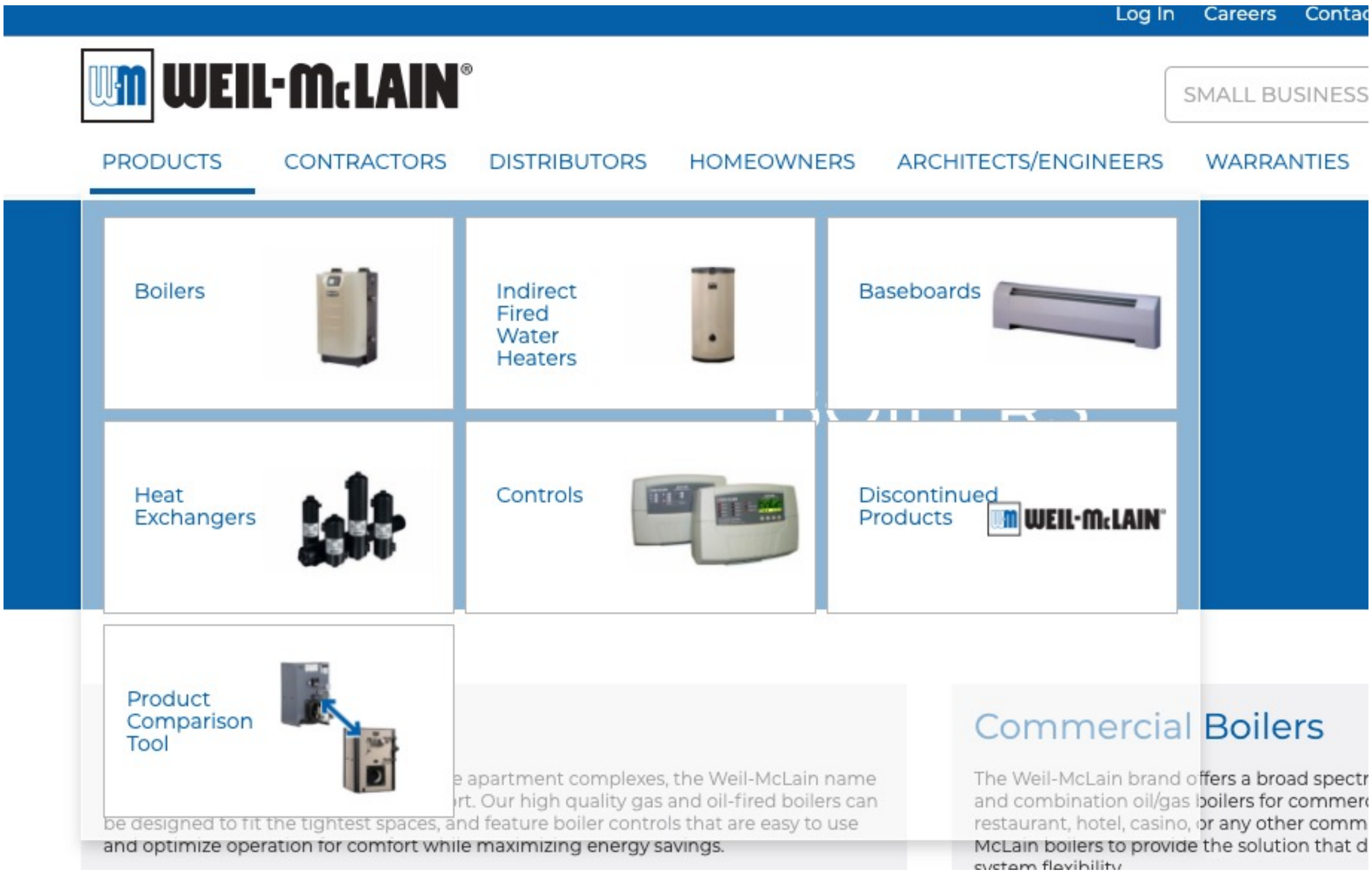
Boiler Selection and Head Losses

- Manufacture 2 (Precision Boilers):
  - ❑ Website Link: https://precisionboilers.com/
  - ❑ Click on the "Products" to select your product:



Boiler Selection and Head Losses

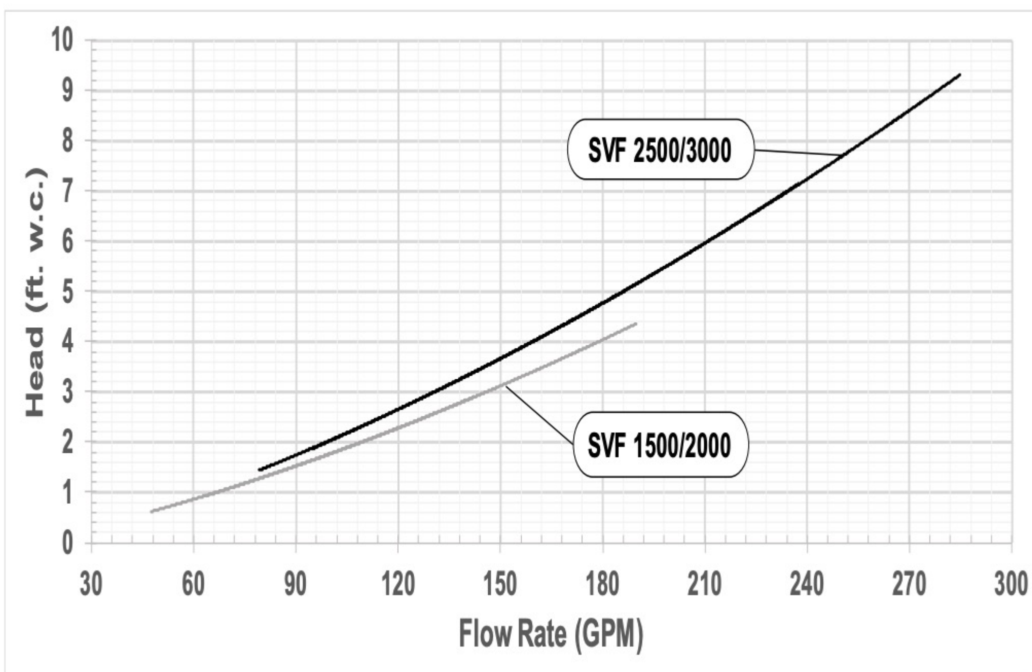
- Manufacture 3 (Weil-McLain):
  - ❑ Website Link: https://www.weil-mclain.com/products/boilers
  - ❑ Click on the "Products" to select your product:



Boiler Selection and Head Losses

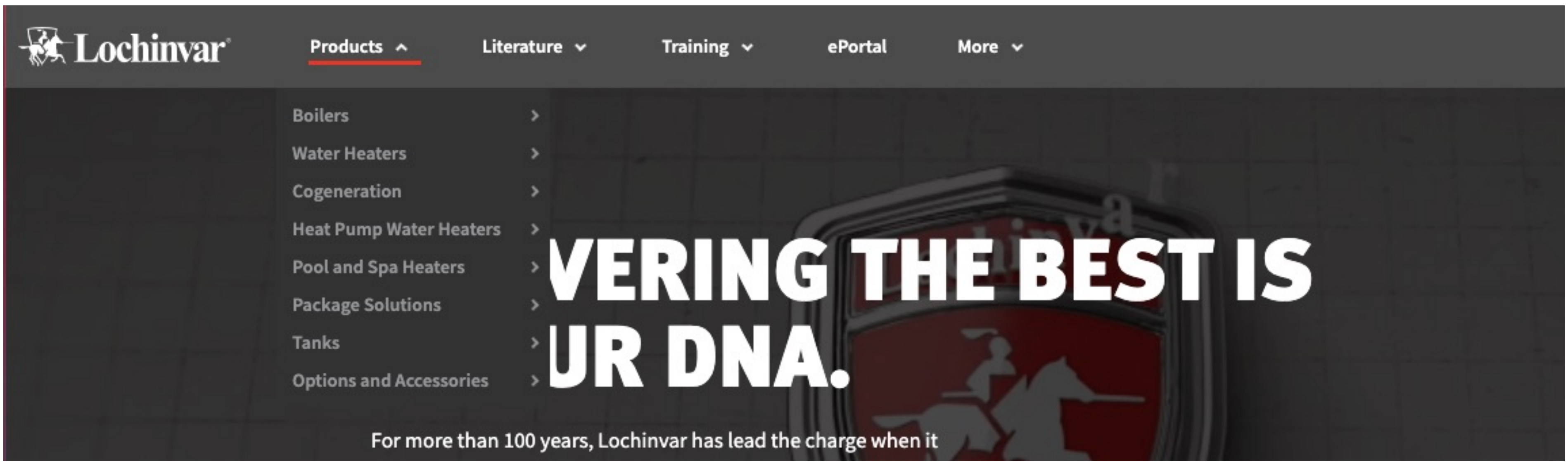
- Manufacture 3 (Weil-McLain):
  - ❑ For a specific boiler: https://www.weil-mclain.com/products/svf-1500-3000
  - ❑ Look at the datasheet: https://www.weil-mclain.com/sites/default/files/field-file/Weil-McLain_SVF-1500-3000-TechDataSheet_WM2002-web.pdf

Figure 4 Boiler head loss vs flow rate for ***SVF***™ boilers



Boiler Selection and Head Losses

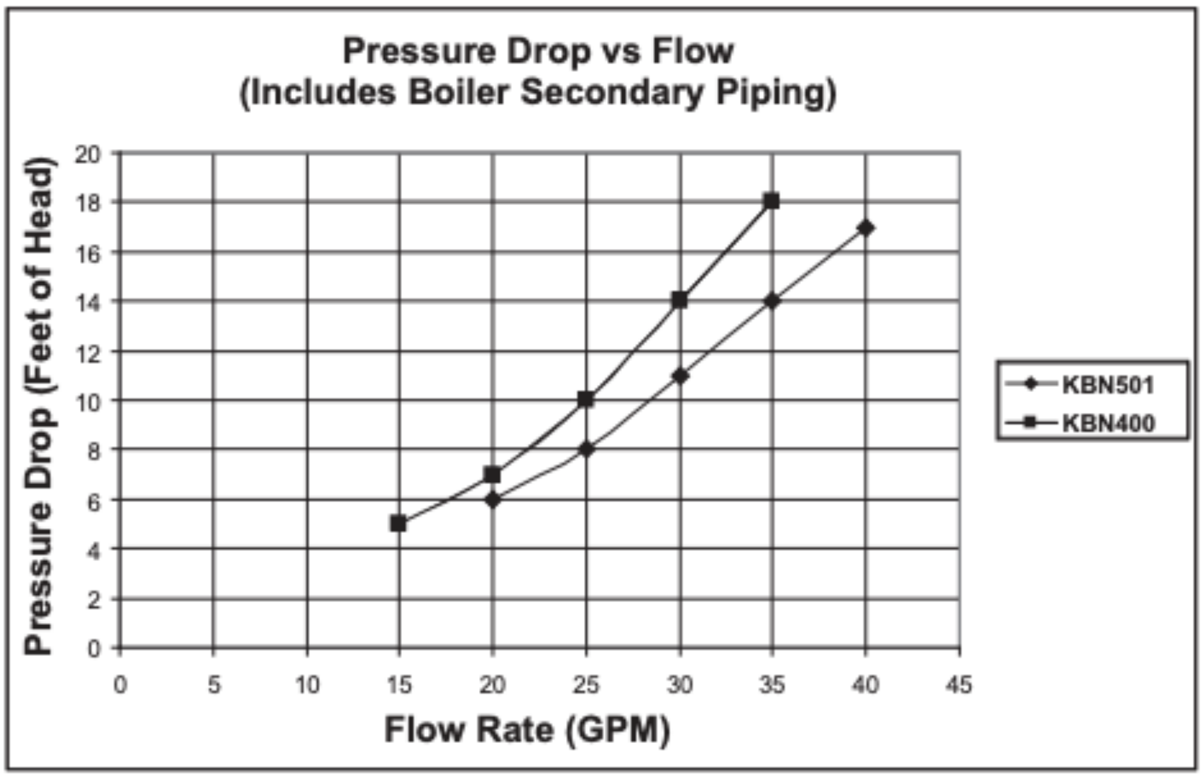
- Manufacture 4 (Lochinvar):
  - ❑ Webpage Link: https://www.lochinvar.com/
  - ❑ Click on "Products"



Boiler Selection and Head Losses

- Manufacture 4 (Lochinvar):
  - ❑ For example, looking into the pressure drop: https://www.lochinvar.com/lit/455215KBXII-I-O_Rev%20AB_100161488_2000013409%20(34739).pdf

Figure 6-5 *Pressure Drop vs. Flow - Models 400 and 501*



CLASS ACTIVITY

Class Activity

- Select one boiler and identify
  - ❑ Max capacity
  - ❑ GPM
  - ❑ Temperature difference
  - ❑ Pressure drop
  - ❑ BIM files

CHILLER SELECTION

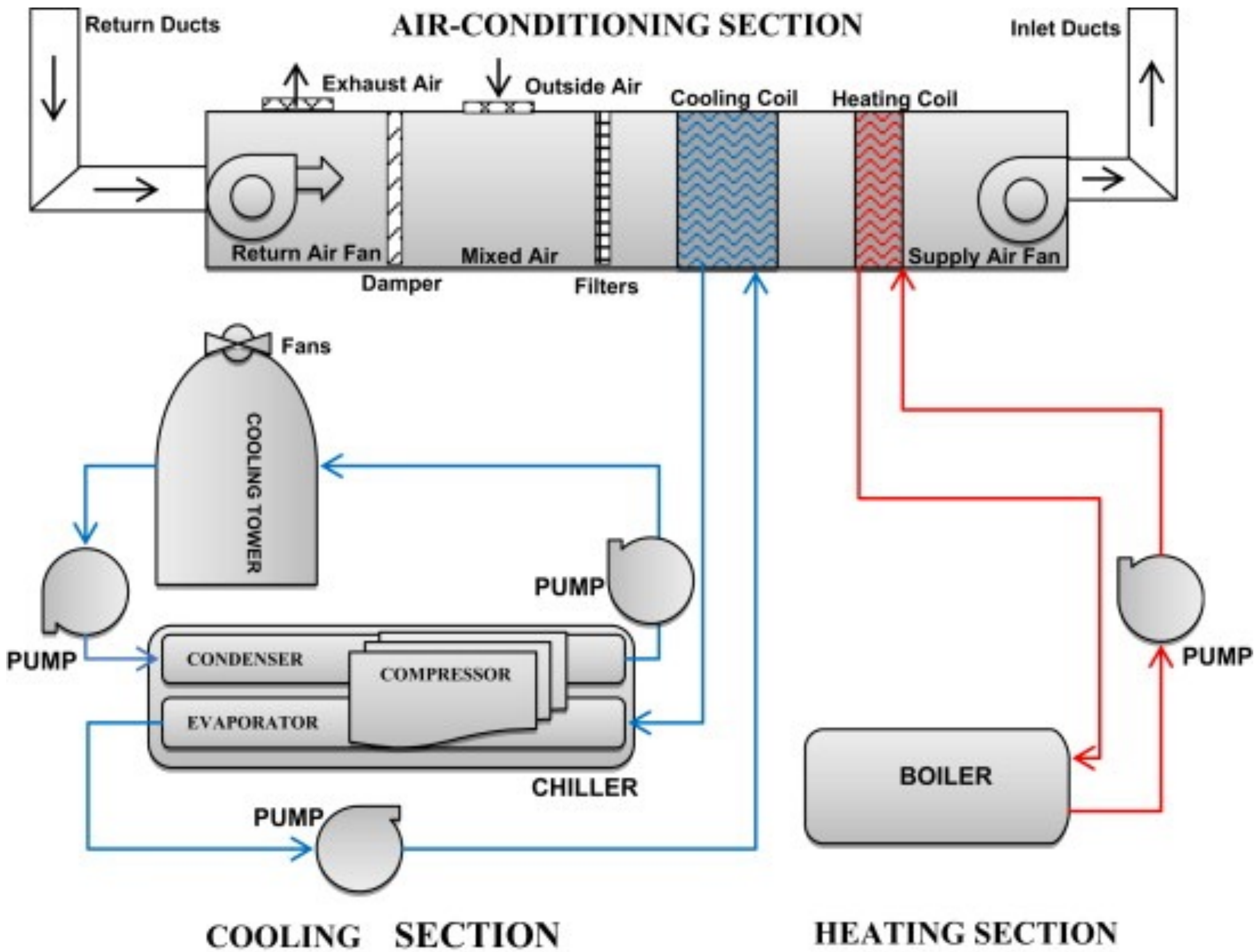
Chiller Selection

- Cycle
  - ❑ Vapor compression
  - ❑ Absorption

- Heat rejection
  - ❑ Sensible to air
  - ❑ Evaporative to air
  - ❑ Water or ground

Chiller Selection

- How many HVAC loops do you see here?



Assessing the energy efficiency improvement potentials of HVAC systems considering economic and environmental aspects at the hospitals

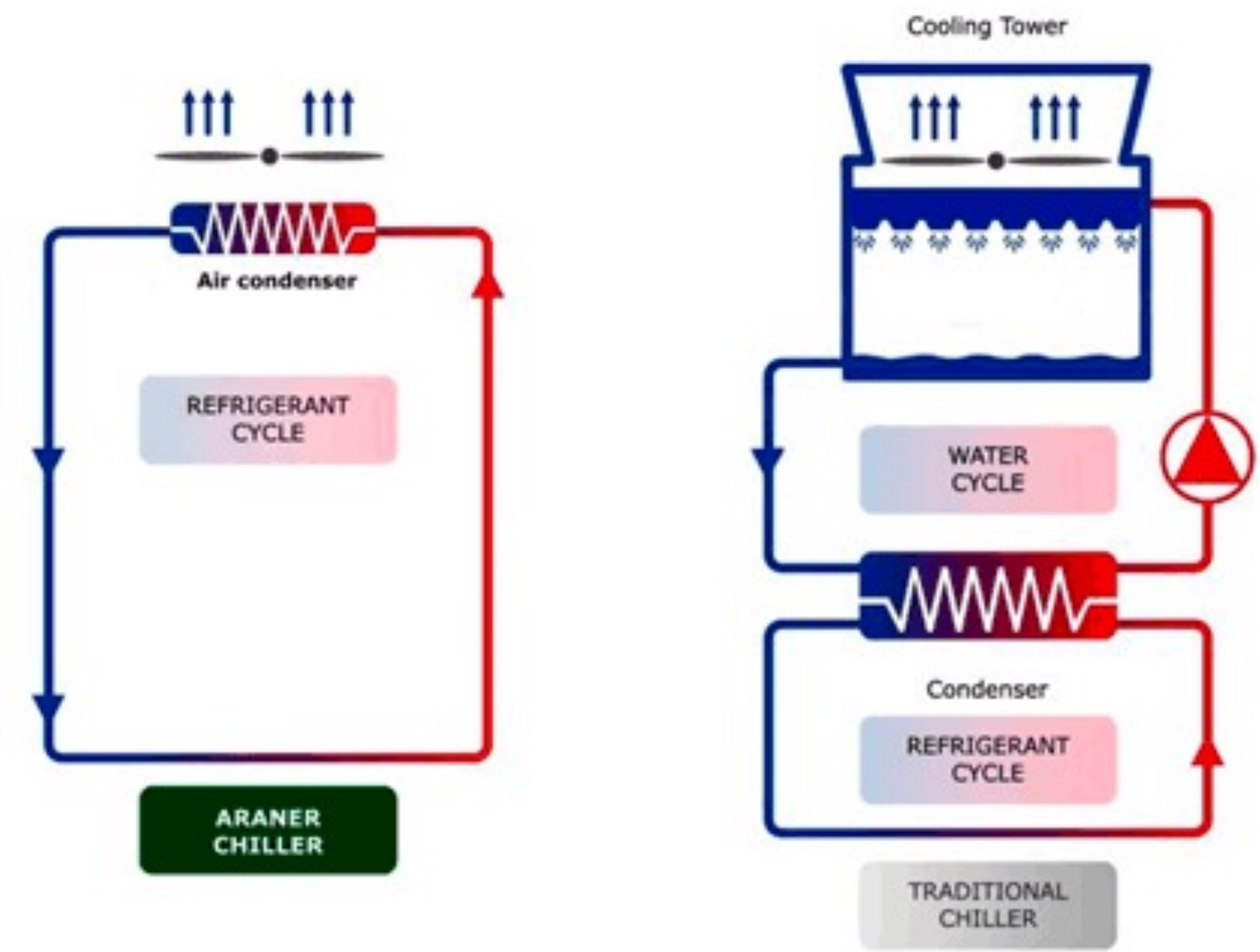
Chiller Selection

- The cooling is the most complex one to determine the number of loops:
  - ❑ Do we have a chilled water loop or not?
  - ❑ If it is a chilled water loop, do we have an air cooled or a water cooled chiller?

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

Chiller Selection

- Water cooled vs air cooled chillers



https://www.araner.com/blog/difference-between-air-cooled-and-water-cooled-chiller/

Chiller Selection Considerations

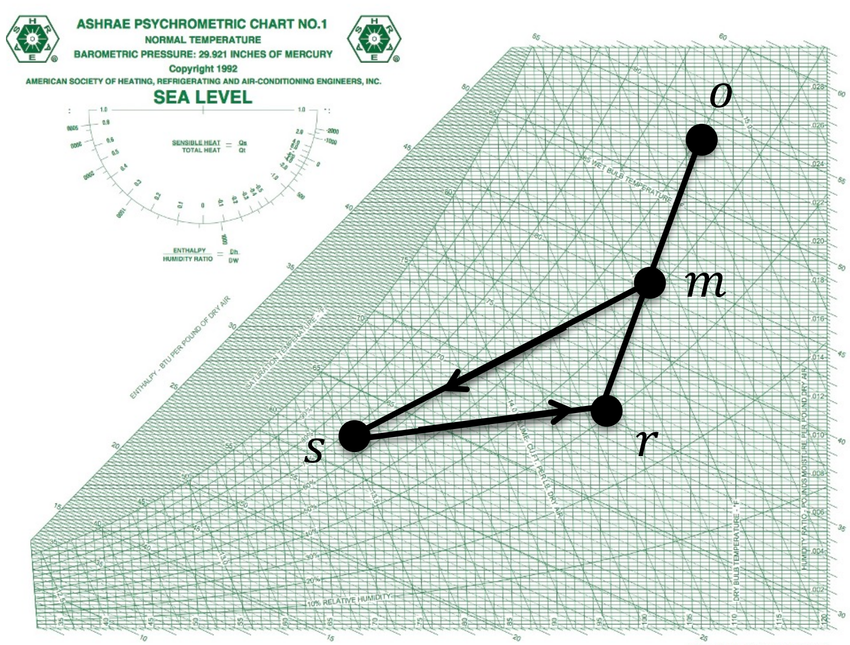
- Peak load
  - ❑ Size ranges covered by different types vary
- Load characteristics
  - ❑ Operating temperatures
  - ❑ Load variation
- Energy availability/cost
  - ❑ Maintenance and reliability
  - ❑ Compatibility (retrofit)

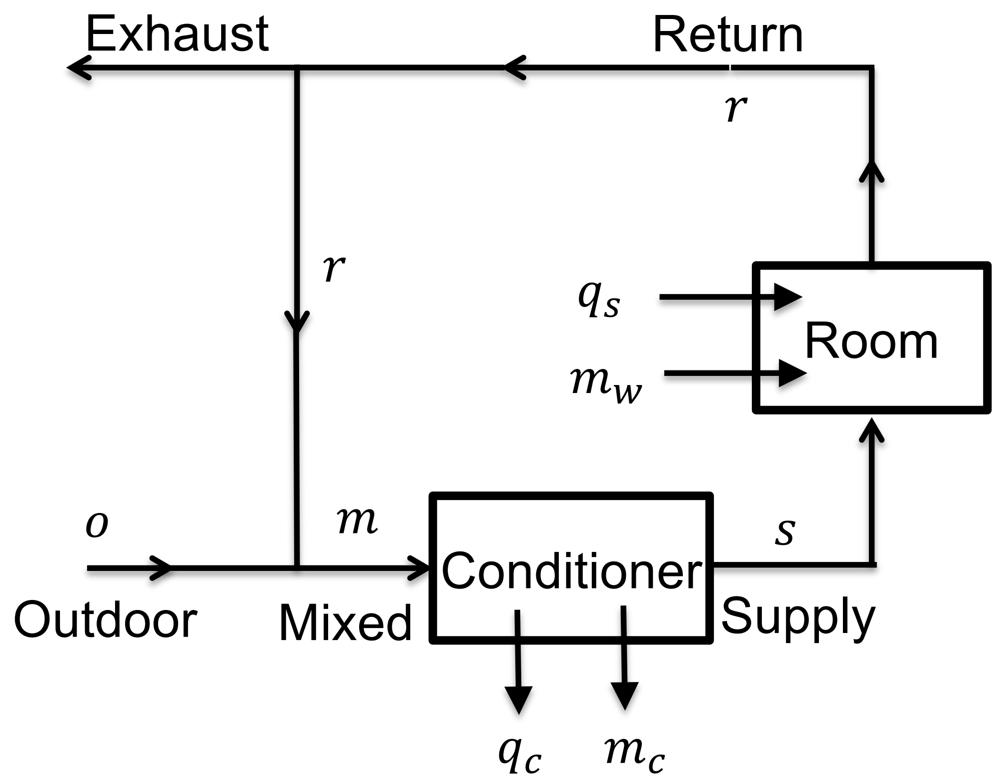
Chiller Selection

- The chiller selection process entails the following steps:
  1. Determine the cooling load
  2. Consider the outdoor condition
  3. Determine the coolant type (e.g., chilled water with glycol), temperature, and flow rate
  4. Review the chiller specifications and datasheets
  5. Review the performance of the chiller under the selected outdoor condition (i.e., capacity (Ton or kW), water flow rate)
  6. Calculate the temperature difference between the leaving water of the chiller and the return water of the chiller
  7. Consider the capacity correction factor in your calculations (i.e., anti-freeze factor, power factor, defrosting factor, quiet factor, altitude factor)

Chiller Selection

- How do we account for the outdoor air/return fractions





Can you write the equations?

Chiller Selection

- For example, consider this Samsung chiller:

https://www.samsunghvac.com/DVM-Chiller/DVM-Chiller

Chiller Selection

- Determine the cooling load:
  - ❑ Utilize the cooling load calculation
  - ❑ System schematic and space conditioning processes

Chiller Selection

- Determine the chiller size, coolant type (e.g., chilled water with glycol), temperature, and flow rate

$$\Delta T = LWT - EWT$$

$$\frac{Btu}{hr} = GPM \times 8.33 \Delta T(°\mathrm{F})$$

$$Ton = \frac{\Delta T(°\mathrm{F}) \times GPM}{24}$$

$$ton = \frac{\frac{Btu}{hr}}{12{,}000}$$

$$\Delta T(°\mathrm{F}) = \frac{12{,}000 \times Ton}{500 \times GPM}$$

Chiller Selection

- Look at the nomenclature:

) Nomenclature

Model Name

AG	015	K	S	V	A	F	H	/	AA
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)		Buyer

(1) Classification

AG	Chiller
AM	DVM

(2) Capacity

USRT (3 digits)

(3) Version

F	2013
H	2014
J	2015
K	2016

(4) Product Type

S	Set
X	Outdoor Unit
N	Indoor Unit

(5) Feature1

V	Inverter

(6) Feature2

A	Standard + General Temp.+ Module

(7) Rating Voltage

F	3Ø, 208~230V, 60Hz
H	3Ø, 380V, 60Hz
J	3Ø, 460V, 60Hz

(8) Mode

H	Heat Pump

Chiller Selection

- Understand the performance and power requirements:

DVM Chiller

Type						DVM Chiller	DVM Chiller	DVM Chiller	DVM Chiller
Model Name						AG010KSVAFH/AA	AG015KSVAFH/AA	AG010KSVAJH/AA	AG015KSVAJH/AA
Power Supply					Φ, #, V, Hz	3,3,208~230,60	3,3,208~230,60	3,3,460,60	3,3,460,60
Mode					-	HEAT PUMP	HEAT PUMP	HEAT PUMP	HEAT PUMP
Performance	Ton				usRT	10	15	10	15
	HP				HP	12	18	12	18
	Capacity (Rated)	Cooling	Amb. 95°F, Entering/Leaving Temp 55/44°F		kBtu/h	120.0	168.0	120.0	168.0
		Heating	Dry/Wet Bulb 47/43°F	Leaving Temp. 105°F	kBtu/h	128.0	182.0	128.0	182.0
				Leaving Temp. 120°F	kBtu/h	120.0	171.0	120.0	171.0
			Dry/Wet Bulb 17/15°F	Leaving Temp. 105°F	kBtu/h	84.0	90.0	84.0	90.0
				Leaving Temp. 120°F	kBtu/h	80.0	85.0	80.0	85.0
Power	Power Input	Cooling	Amb. 95°F, Entering/Leaving Temp 55/44°F		kW	10.71	16.63	10.71	16.63
		Heating	Dry/Wet Bulb 47/43°F	Leaving Temp. 105°F	kW	9.77	15.17	9.77	15.17
				Leaving Temp. 120°F	kW	11.54	17.45	11.54	17.45
			Dry/Wet Bulb 17/15°F	Leaving Temp. 105°F	kW	11.20	12.00	11.20	12.00
				Leaving Temp. 120°F	kW	12.70	13.08	12.70	13.08
	Current Input	Cooling	Amb. 95°F, Entering/Leaving Temp 55/44°F		A	29.59	47.24	15.81	25.25
		Heating	Dry/Wet Bulb 47/43°F	Leaving Temp. 105°F	A	26.99	41.91	14.43	22.40
				Leaving Temp. 120°F	A	31.88	48.20	17.04	25.77
			Dry/Wet Bulb 17/15°F	Leaving Temp. 105°F	A	30.94	33.15	16.54	17.72
				Leaving Temp. 120°F	A	35.08	36.13	18.75	19.31

Chiller Selection

- Review the temperature difference and impact of outdoor air temperature on the performance:

Cooling (ΔT = 10℉)

AG010KSV***

LWT	Outdoor Air Temperature (°F, DB)																							
	55			65			75			85			95			105			115			118.4		
	TC	PI	Water flow	TC	PI	Water flow	TC	PI	Water flow	TC	PI	Water flow	TC	PI	Water flow	TC	PI	Water flow	TC	PI	Water flow	TC	PI	Water flow
	Ton	kW	GPM	Ton	kW	GPM	Ton	kW	GPM	Ton	kW	GPM	Ton	kW	GPM	Ton	kW	GPM	Ton	kW	GPM	Ton	kW	GPM
14[2)]	7.671	5.763	18.410	7.499	7.002	17.995	7.251	7.814	17.401	6.575	8.425	15.800	5.930	9.488	15.800[3)]	5.258	10.745	15.800[3)]	4.004	10.629	15.800[3)]	3.583	9.781	15.800[3)]
23[2)]	9.853	6.179	23.646	9.844	7.431	23.624	9.738	8.213	23.369	9.293	8.845	22.302	8.844	9.977	21.224	7.793	11.179	18.701	6.340	11.531	15.800[3)]	5.673	11.091	15.800[3)]
32[2)]	9.954	6.257	23.887	9.946	7.624	23.867	9.839	8.530	23.611	9.394	9.160	22.544	8.945	10.299	21.466	7.914	11.567	18.992	6.795	11.881	16.308	6.081	11.521	15.800[3)]
41	10.859	6.421	26.059	10.857	7.819	26.054	10.748	8.742	25.792	10.299	9.463	24.715	9.749	10.621	23.395	8.660	11.886	20.783	7.274	12.268	17.456	6.550	11.988	15.800[3)]
44	11.110	6.490	26.653	11.108	7.904	26.653	11.004	8.828	26.412	10.550	9.550	25.314	10.000	10.710	24.000	8.860	11.977	21.272	7.430	12.273	17.820	6.646	11.909	15.949
48	11.820	6.607	28.368	11.820	8.027	28.368	11.670	8.950	28.013	11.250	9.780	27.003	10.620	10.920	25.487	9.410	11.900	22.577	7.890	12.090	18.936	7.095	11.697	17.026
52	12.390	6.722	29.733	12.390	8.150	29.733	12.240	9.070	29.371	11.730	9.870	28.153	11.178	11.130	26.826	9.887	11.824	23.724	8.310	11.870	19.941	7.370	11.393	17.686
56	12.947	6.843	31.072	12.950	8.280	31.072	12.797	9.193	30.710	12.290	9.830	29.492	11.642	10.910	27.936	10.330	11.550	24.799	8.690	11.582	20.858	7.750	11.083	18.599
60	13.500	6.967	32.394	13.500	8.403	32.394	13.350	9.320	32.032	12.820	9.860	30.774	12.172	10.900	29.213	10.760	11.280	25.830	9.060	11.310	21.735	8.106	10.847	19.453
64.4	14.073	7.038	33.773	14.078	8.480	33.785	13.927	9.406	33.422	13.320	10.019	31.966	12.663	11.070	30.389	11.195	11.447	26.865	9.400	11.424	22.558	8.387	10.979	20.127

Chiller Selection

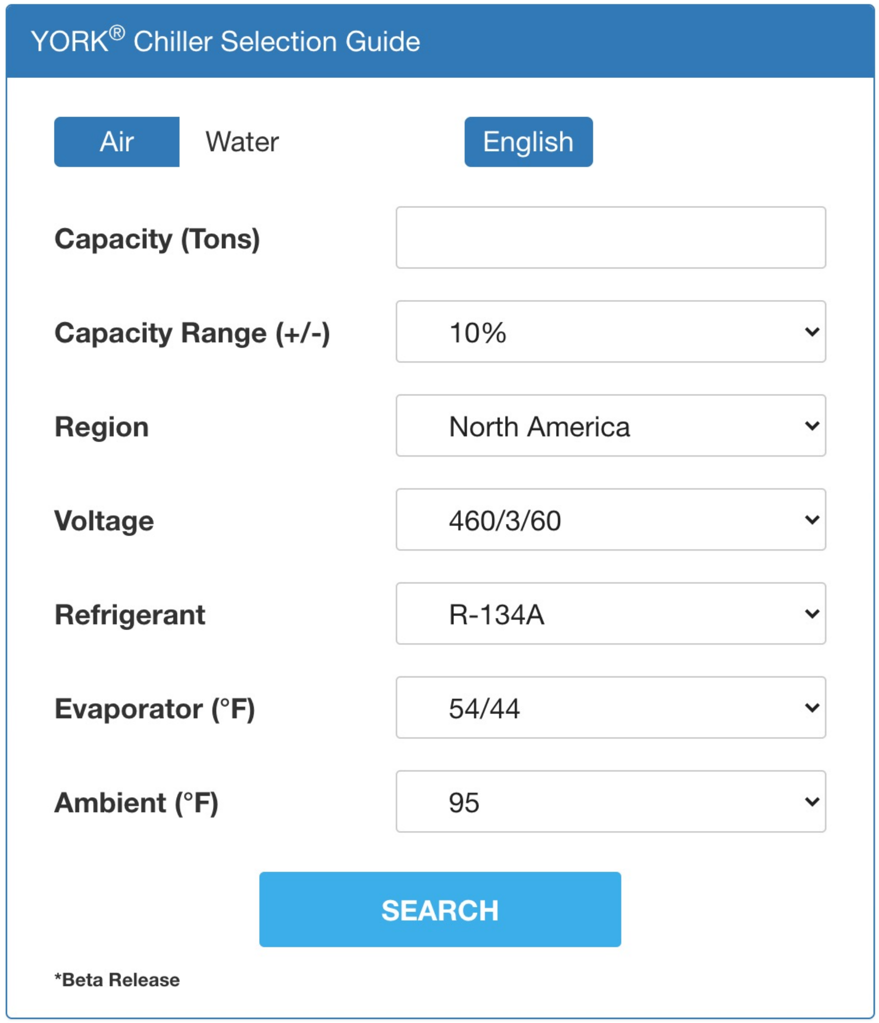
- Include the impact of correction factors:

1) Correction factor by % glycol

Anti-freeze	Ethylene glycol					Propylene glycol				
%wt	Freezing point (°F)	Min. LWT (°F)	Correction factor			Freezing point (°F)	Min. LWT (°F)	Correction factor		
			Capacity	Power Input	Pressure drop			Capacity	Power Input	Pressure drop
0%	32.0	41.0	1.000	1.000	1.000	32.0	41.0	1.000	1.000	1.000
10%	24.8	33.8	0.989	0.995	1.010	26.6	35.6	0.988	0.994	1.029
20%	15.8	24.8	0.975	0.990	1.023	19.4	28.4	0.973	0.988	1.061
30%	3.2	14.0	0.960	0.985	1.041	8.6	17.6	0.955	0.982	1.098
40%	-9.4	14.0	0.943	0.980	1.064	-7.6	14.0	0.933	0.976	1.142
50%	-34.6	14.0	0.924	0.975	1.082	-31.0	14.0	0.910	0.970	1.193

Chiller Selection

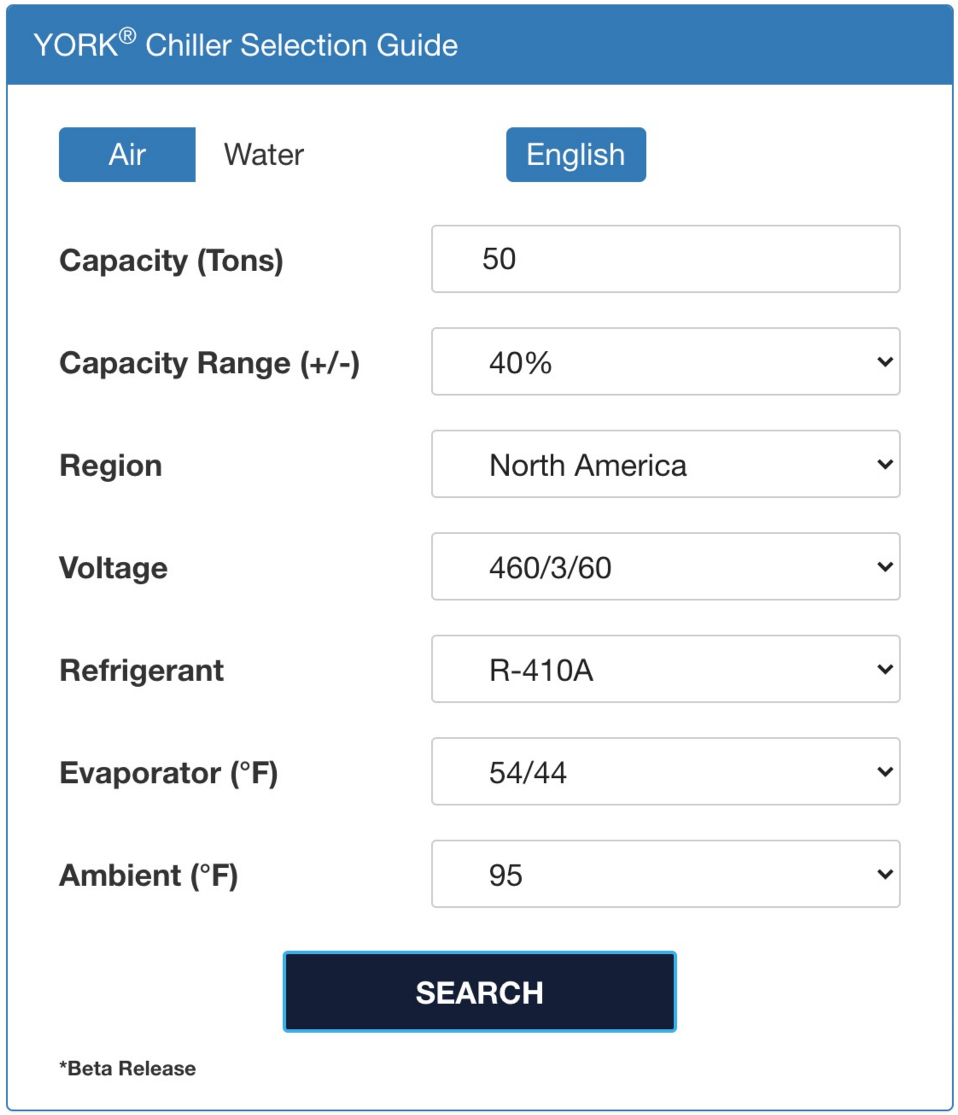
- Let's look at another manufacturer:



https://chillerapps.york.com/chiller-selection-guide

Chiller Selection

- Add the chiller capacity:



Chiller Selection

- Review the suggested chillers:

< BACK YORK® Chiller Selection Results

YCAL0043EE
37.2 Capacity (Tons)
Standard Fans, Standard Compressor — **14.45 IPLV, 10.11 EER**

YCAL0046EE
39.4 Capacity (Tons)
Standard Fans, Standard Compressor — **14.66 IPLV, 10.16 EER**

YLAA0041HE — **In Stock (NA)**
39.6 Capacity (Tons)
VSD Fans, Standard Compressor — **17.78 IPLV, 11.63 EER**

YCAL0052EE
46.2 Capacity (Tons)
Standard Fans, Standard Compressor — **15.05 IPLV, 10.16 EER**

Description: YORK 45 TON AIR COOLED CHILLER 460V

Availability: 0
Configuration: Standard Fans, Standard Compressor

Details: YCAL0052EE

Drawing: YCAL0052EE

BIM: YCAL0052EE

Smart Spec: YCAL0052EE

YORK® Chillers Brochure

Chiller Selection

- Review the performance data:

Unit Tag	Qty	Model No	Net Cooling Capacity (ton.R)	Nominal Voltage	Refrigerant Type
CH-1	1	YCAL0052EE46XEBSDTX	46.23	460-3-60.0	R410A

PIN:								
YCAL0052EE	46XEBSDTXA	XXRLXXXX44	XX1XXXXXXX	SXXXPXX7XX	BXXNXXXXXX			
....5...10	....5...20	....5...30	....5...40	....5...50	....5...60	....5...70	....5...80	....5...90

Evaporator Data		Evaporator Data (Cont.)		Performance Data	
EWT (°F)	54.00	Min. Flow Rate (USGPM)	59.99	EER (Btu/W·h)	10.16
LWT (°F)	44.00	Max. Flow Rate (USGPM)	300.0	IPLV.IP (Btu/W·h)	15.05
Design Flow Rate (USGPM)	110.6	**Condenser Data**			
Pressure Drop (ft H2O)	9.22	Ambient Temp. Design (°F)	95.0	**Physical Data**	
Fluid	Water	Altitude (ft)	0.000	Rigging Wt. (lb)	3170
Fouling Factor (h.ft².F/Btu)	0.000100	Compressor Type	Scroll - Hermetic	Operating Wt. (lb)	3208
Fluid Volume (USGAL)	3.500				

Electrical Data				
Circuit	1	2	3	4
Compressor RLA	23 / 23	23 / 23		
Fan QTY/FLA (each)	2 / 3.4	2 / 3.4		
High LRA Current	150 / 150	150 / 150		

Single Point				
Min. Circuit Ampacity	113			
Recommended Fuse/CB Rating	125			
Max. Inverse Time CB Rating	125			
Max. Dual Element Fuse Size (A)	125			
Unit Short Circuit Withstand (STD)	5 [kA]		**Operating Condition Electrical Data**	
Wires Per Phase	1		Compressor kW	47.90
Wire Range (Lug Size)	4 AWG - 300 kcmil		Total Fan kW	6.720
Starter Type	Across The Line		Total kW	54.62

Chiller Selection

- Look at another manufacturer:

TRANE

Selection Procedure

The chiller capacity tables presented in the "Performance Data" section cover the most frequently encountered leaving water temperatures. The tables reflect a 10°F temperature drop through the evaporator. For temperature drops other than 10°F, fouling factors other than 0.0001 (in accordance with ARI Standard 550/590) and for units operating at altitudes that are significantly greater than sea level, refer to the "Performance Adjustment Factors" section and apply the appropriate adjustment factors. For chilled brine selections, refer to the "Performance Adjustment Factors" section for ethylene glycol adjustment factors.

To select a Trane air-cooled chiller, the following information is required:

1

Design system load (in tons of refrigeration).

2

Design leaving chilled water temperature.

3

Design chilled water temperature drop.

4

Design ambient temperature.

5

Evaporator fouling factor.

An approximate evaporator chilled water flow rate can be determined by using the following formula:

$$\text{GPM} = \frac{\text{Tons x 24}}{\text{Temperature Drop (Degrees F)}}$$

NOTE: Flow rate must fall within the limits specified in the "General Data" section of this catalog.

SELECTION EXAMPLE

Given:

1

To calculate the approximate chilled waterflow rate we use the formula:

$$\text{GPM} = \frac{\text{Tons x 24}}{\Delta T}$$

From the 60 ton unit table in the "Performance Data" section of this catalog, a CGAF-C60 at the given conditions will produce 56.6 tons with a system power input of 69.0 kw and a unit EER of 9.8

$$\text{GPM} = \frac{\text{56.6 Tons x 24}}{10°\text{F}} = 135.8$$

2

To determine the evaporator water pressure drop we use the flow rate (gpm) and the evaporator water pressure drop curves found in the "Performance Adjustment Factors" section of this catalog. Entering the curve at 135.8 gpm, the estimated pressure drop for a nominal 60 ton evaporator is 6.0 feet.

3

For selection of chilled brine units or applications where the altitude is significantly greater than sea level or the temperature drop is different than 10°F, the performance adjustment factors should be applied at this point.

For example:

Corrected Capacity = Capacity (unadjusted) x Appropriate Adjustment Factor

Corrected Flow Rate = Flow Rate (unadjusted) x Appropriate Adjustment Factor

Corrected KW Input = KW Input (unadjusted) x Appropriate Adjustment Factor

4

Verify that the selection is within design guidelines. The final unit selection is:

Quantity (1) CGAF-C60

System Power Input = 69.0 KW

Unit EER = 9.8

MINIMUM LEAVING CHILLED WATER TEMPERATURE SET POINTS

The minimum leaving chilled water temperature set point for water is listed in the following table:

Table SP-1 — Minimum Leaving Chilled Water Temperature Set points for Water[1]

Evaporator Temperature Difference (Degrees F)	Minimum Leaving Chilled Water Temperature Set point (°F) CGAF-C20,C25,C30	CGAF-C40,C50,C60
6	40	39
8	41	39
10	42	40
12	43	40
14	44	41
16	45	41
18	46	42

[1]These are for units without HGBP, for units with HGBP, add 2°F to each minimum temperature in the table.

For those applications requiring lower set points, a glycol solution must be used. The minimum leaving chilled water set point for a glycol solution can be calculated using the following equation:

$$\text{LCWS (Minimum) (Evap)} = \text{GFT} + \frac{5 + \Delta T}{\text{\# of stages of capacity.}}$$

LCWS = Leaving Chilled Water Set point (F)

GFT = Glycol Freezing Temperature (F)

ΔT = Delta T (the difference between the temperature of the water entering and leaving the evaporator)

Solution freezing point temperatures can be found in the Performance Data section and the number of stages of capacity in the General Data section. For selection assistance, refer to the CGA Chiller Selection program.

https://www.trane.com/Commercial/Uploads/Pdf/1062/cg-prc007-en_0606.pdf

CLASS ACTIVITY

Class Activity

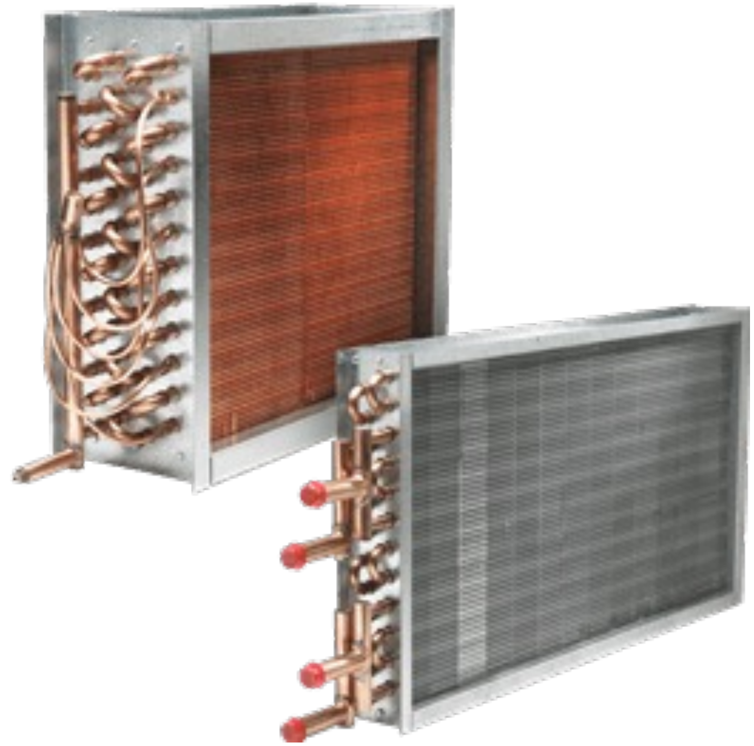
- Select one chiller and identify
  - ❑ Max capacity
  - ❑ GPM
  - ❑ Temperature difference
  - ❑ Pressure drop
  - ❑ Documents for using glycol
  - ❑ BIM files

COIL SELECTION

Coil Selection

- Example of coils

Chilled/Hot Water Coil

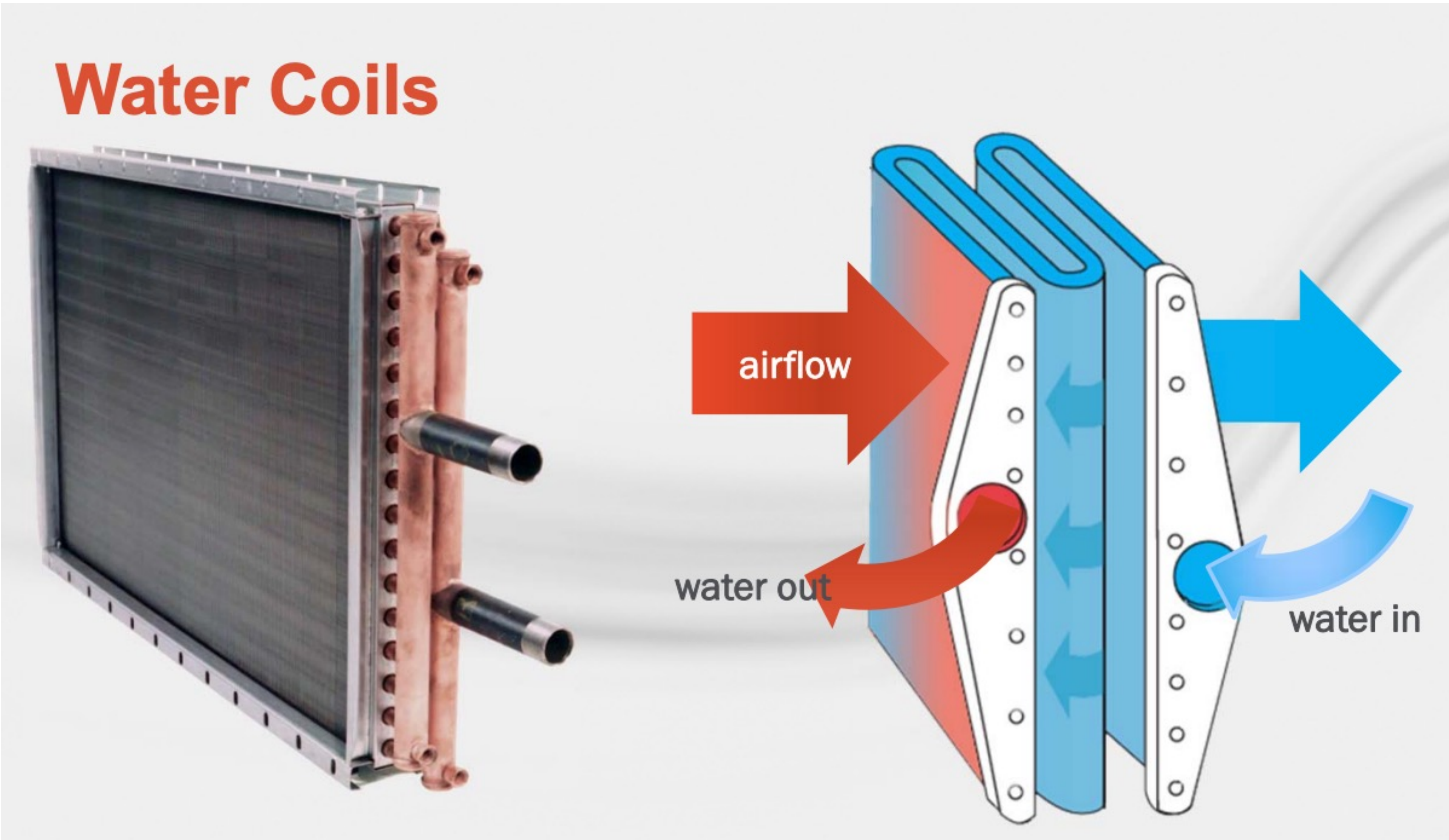


DX coils

https://www.greenheck.com/products/air-conditioning/hvac-coils

Coil Selection

- Example of coils



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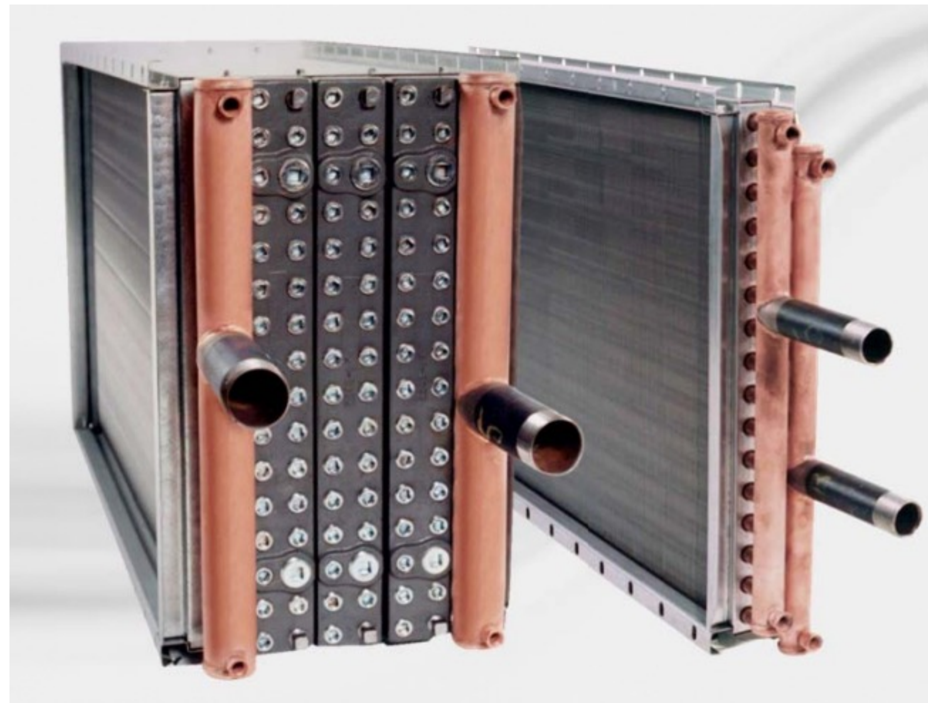
Coil Selection

- What are important variables?
  - ❑ Coil face area
  - ❑ Number of rows of tubes
  - ❑ Tube diameter
  - ❑ Number of fins
  - ❑ Fin surface design
  - ❑ Coil circuiting
  - ❑ Turbulators



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Coil Selection

- ASHRAE Chapter 23: Systems and Equipment

CHAPTER 23

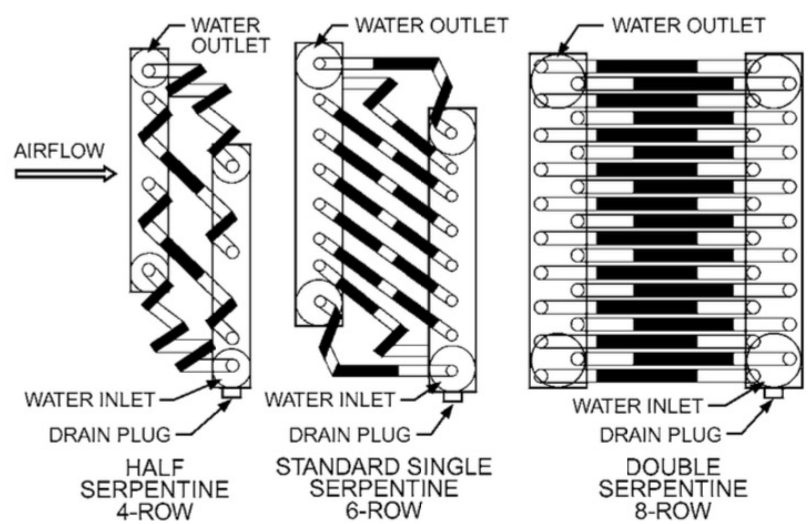
AIR-COOLING AND DEHUMIDIFYING COILS

Uses for Coils 23.1
Coil Construction and Arrangement 23.1
Coil Selection 23.5
Airflow Resistance 23.6
Heat Transfer 23.6
Performance of Sensible Cooling Coils 23.7
Performance of Dehumidifying Coils 23.9
Determining Refrigeration Load 23.14
Maintenance 23.15
Symbols 23.16

MOST equipment used today for cooling and dehumidifying an airstream under forced convection incorporates a coil section that contains one or more cooling coils assembled in a coil bank arrangement. Such coil sections are used extensively as components in room terminal units; larger factory-assembled, self-contained air conditioners; central station air handlers; and field built-up systems. Applications of each coil type are limited to the field within which the coil is rated. Other limitations are imposed by code requirements, proper choice of materials for the fluids used, the configuration of the air handler, and economic analysis of the possible alternatives for each installation.

1. USES FOR COILS

Coils are used for air cooling with or without accompanying dehumidification. Examples of cooling applications without dehumidifi-



Coil Selection

- There are too many coil sizing tools:
  - ❑ GreenHeck: https://www.greenheck.com/resources/software/coil-software-selection-program
  - ❑ CoilCalc: http://www.coilcalc.com/

Coil Selection

- For GreenHeck:

GREENHECK
Building Value in Air.

JOB SUMMARY

, USA

888-921-COIL (2645)
200 Morgan Street
Brownsville, TN 38012

Selection Summary

Tag	Comment	Model	Quantity
C-1		HW58S01B14-54x36-RH	12

Coil Selection

- For GreenHeck:

GREENHECK
Building Value in Air.

SUBMITTAL DATA

Greenheck Coil C-1

888-921-COIL (2645)
200 Morgan Street
Brownsville, TN 38012

Hot Water Coil

Tag	Qty	Model	Footnotes	Comment
C-1	12	HW58S01B14-54x36-RH	a,b	

Construction and Performance Details

Tag	C-1
Air flow (SCFM)	67335
Altitude (ft)	0
Total capacity (MBH)	2489.5
Entering dry bulb (°F)	55.0
Leaving dry bulb (°F)	89.1
Face velocity (ft/min)	416
Air pressure drop (in of water)	0.12
Air fouling factor (h·ft²·°F/Btu)	0.00000
Fluid	W
Entering fluid temp. (°F)	180.0
Leaving fluid temp. (°F)	95.7
Fluid flow rate (GPM)	60.0
Fluid velocity (ft/s)	2.73
Fluid pressure drop (ft of water)	5.8
Fluid fouling factor (h·ft²·°F/Btu)	0.00000
Fluid freezing temp. (°F)	32.0
Min. tube wall temp. (°F)	83.3
Coils per bank	12
Coil type	5/8
Fin height (in)	54.0
Fin length (in)	36.0
Face area (ft²)	162.00
Rows	1
Fin spacing (fins/in)	14
Fin material	Al
Fin type	Sine
Fin thickness (in)	0.006
Tube wall thickness (in)	0.020
Turbulators	No
Number of feeds	2
Supply conn. size (in)	0.750
Return conn. size (in)	0.750
Weight (lb)	69
Est. operating wt. (lb)	82
Est. internal volume (ft³)	0.25

Footnotes

(a) Certified in accordance with the AHRI Forced-Circulation Air-Cooling and Air-Heating Coils Certification Program which is based on AHRI Standard-410 within the Range of Standard Rating Conditions listed in Table 1 of the Standard. Certified units may be found in the AHRI Directory at www.ahridirectory.com.

Coil Selection

- Let's look at some simple strategy
- Sensible heat transfer from any fluid can be written as:

$$\dot{Q} = \dot{m} c_p \Delta T$$

- For air, we can write:

$$SCFM = (ACFM) \times (Density\ of\ measured\ air \left[\frac{lb}{ft^3}\right] / 0.075 \left[\frac{lb}{ft^3}\right])$$

$$\dot{Q}_{air} = (SCFM)(1.08)(\mathrm{L}AT - EAT)$$

Coil Selection

- Let's look at some simple strategy
- Sensible heat transfer from any fluid can be written as:

$$\dot{Q} = \dot{m} c_p \Delta T$$

- For water, we can write:

$$\dot{Q}_{water} = (500)(GPM)(\mathrm{L}WT - EWT)$$

Coil Selection

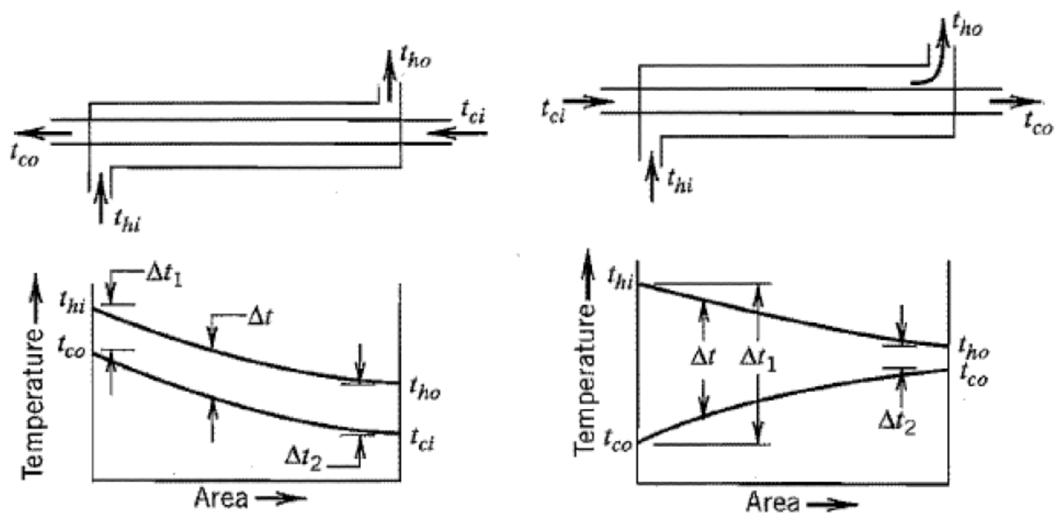
- Consider a little bit more complicated approach (e.g., Log Mean Temperature Difference (LMTD)):

$$\dot{Q}_{water} = U_{Overall} \times A \times \Delta T_{LMTD}$$

$$\Delta T_{LMTD} = \frac{\Delta T_o - \Delta T_i}{\ln\left(\frac{\Delta T_o}{\Delta T_i}\right)}$$

$$\frac{1}{U_{overall}} = \frac{1}{h_{cov,air} + h_{coil,air}} + \frac{1}{h_{water}} + \frac{t_{coil}}{k_{coil}}$$

Not Needed!



(a) Counterflow.

(b) Parallel flow.

Coil Selection

- Common numbers for the pressure drops are fine:

	Coil Type (Style)							
	Custom						Booster	
	Chilled Water	Hot Water	Direct Expansion	Condenser	Standard Steam	Steam Distributing	Hot Water	Standard Steam
Tube Diameter (inches)								
5/16			✓	✓				
3/8	✓	✓	✓	✓				
1/2	✓	✓	✓	✓				
5/8	✓	✓	✓	✓	✓	✓	✓	✓
1					✓	✓		
Rows								
Min Rows	1	1	1	1	1	1	1	1
Max Rows	12	12	12	12	2*	2*	2	2
Fin Height (inches)								
Min	*Fin height is dependent on tube diameter (see Tube Diameter chart)*						6	6
Max							24	24
Increments of							3	3
Fin Length (inches)								
Min	*Minimum fin length is 1 inch*						6	6
Max	*Max fin length is 200 inches (144 inches for steam) with center supports every 50 inches*						48**	48**
Increments of	*No restriction on fin length increments*						1	1
Recommended Face Velocity (FPM)								
Min	400	500	400	600	500	500	500	500
Max	550	800	550	750	850	850	800	850
Recommended Fluid Velocity (FPS - for water coils)								
Min	1.5	1.5	NA	NA	NA	NA	1.5	NA
Max	4.0	4.0	NA	NA	NA	NA	4.0	NA
Recommended Pressure Drop (ft. of H_2O or psi)								
Min	1	1	NA	NA	1	1	1	1
Max	20	10	NA	NA	125***	125***	10	125***

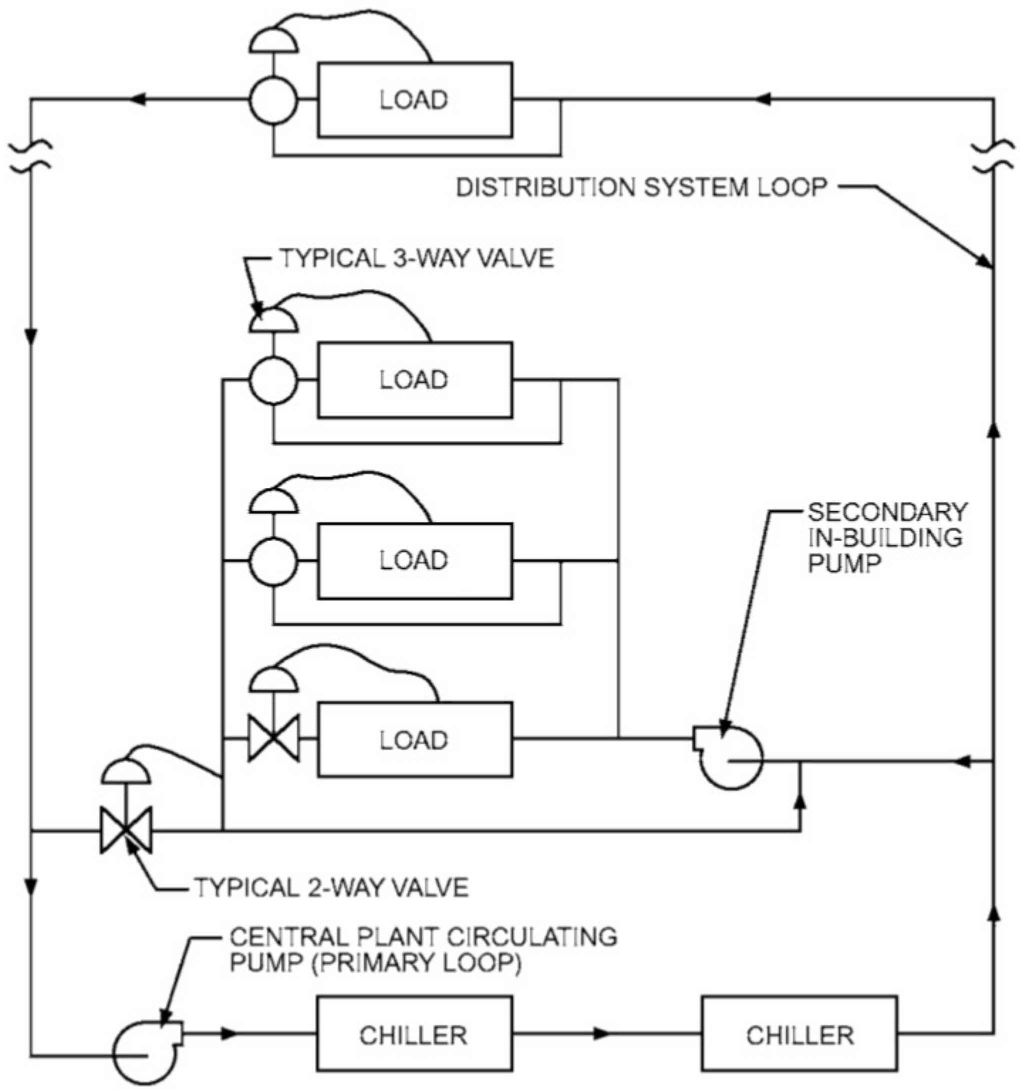
** Maximum Row of one for 1 inch tube diameter.*
*** Booster coil fin lengths are dependent on fin height.*
**** Higher steam pressures will require heavier tube wall thicknesses.*

https://content.greenheck.com/public/DAMProd/Original/10006/GreenheckCoils_catalog.pdf

PRIMARY AND SECONDARY SYSTEMS

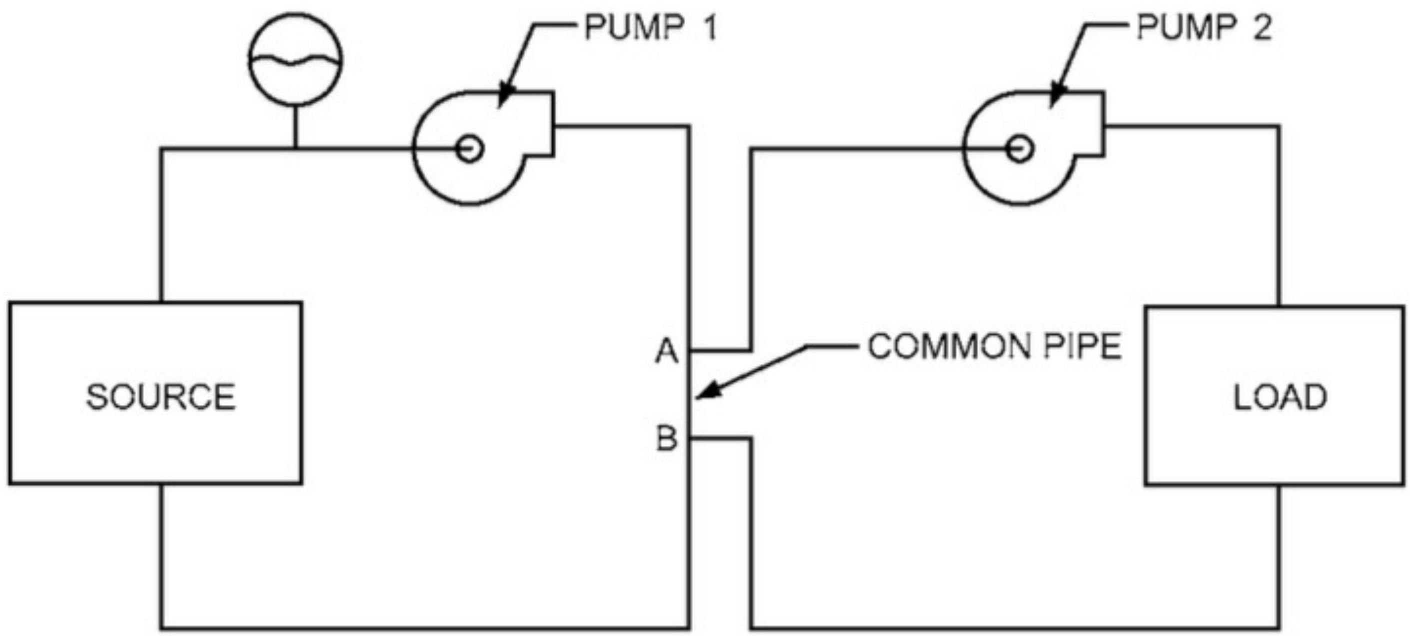
Primary and Secondary Systems

- Constant-flow primary distribution with secondary pumping:



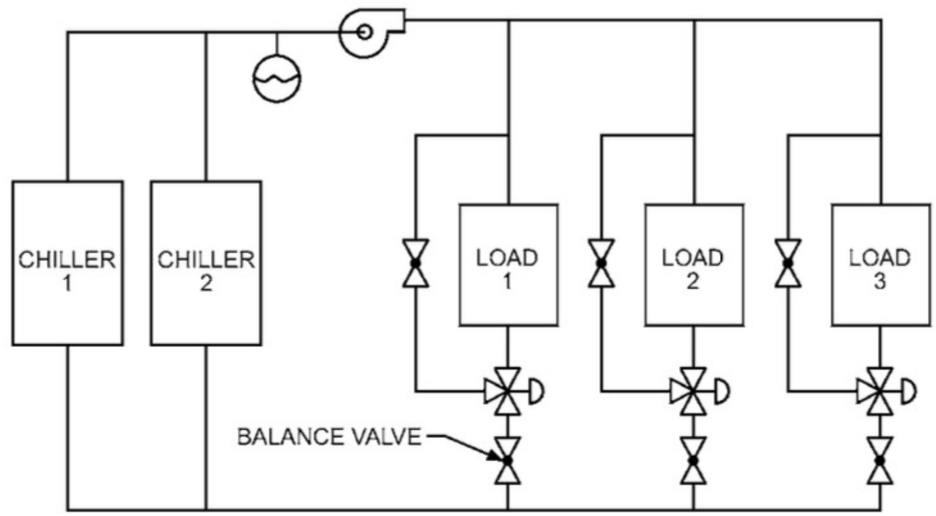
Primary and Secondary Systems

- Compound pumping

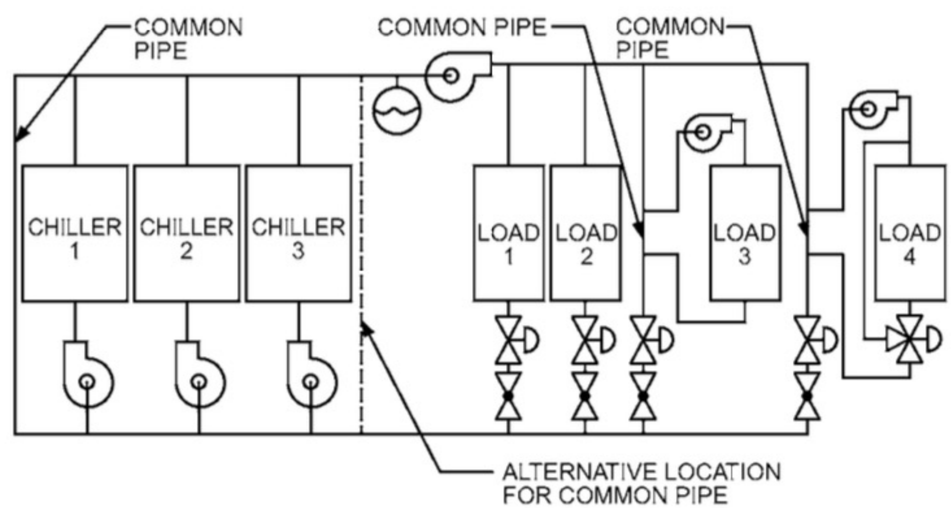


Primary and Secondary Systems

- Constant flow chilled water system

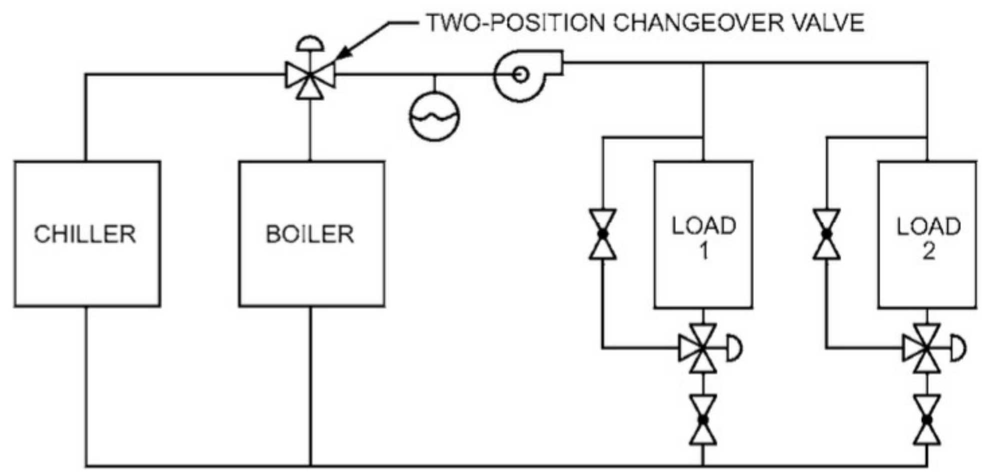


- Variable flow chilled water system

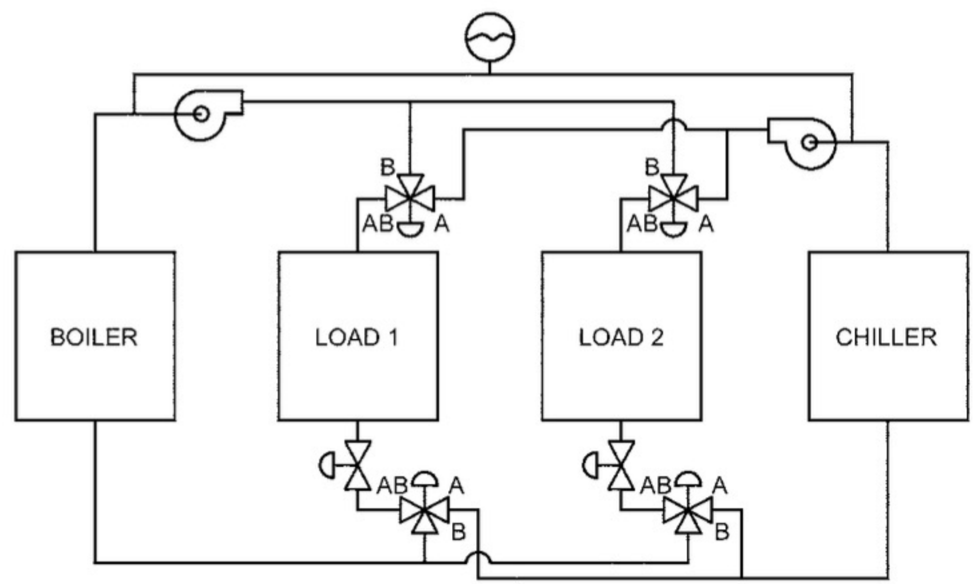


Primary and Secondary Systems

- Simplified two pipe diagram



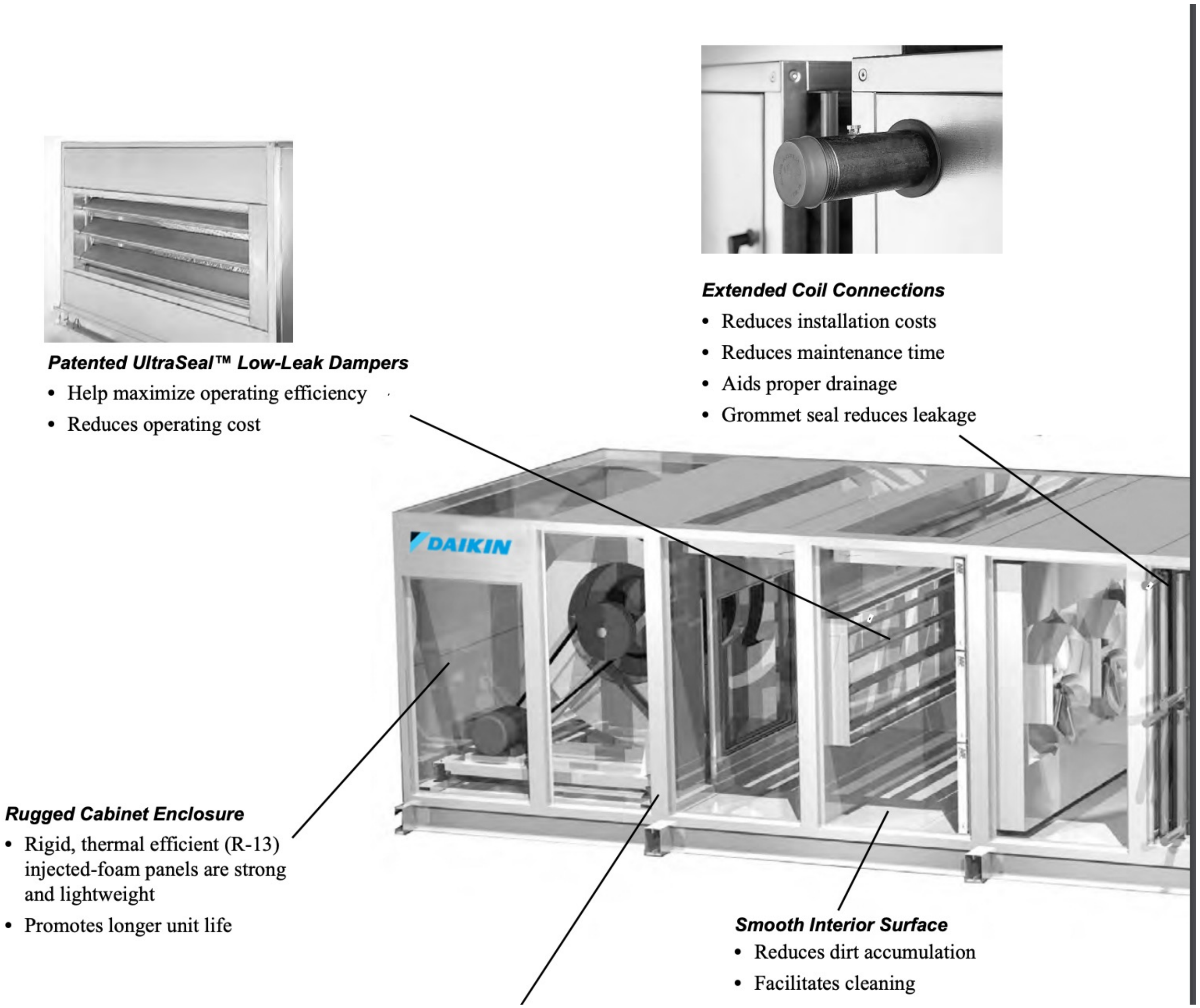
- Simplified four pipe diagram (common loads)



OTHER ITEMS

Other Items

- Account for all the head losses



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Other Items

- Account for all the head losses

Table 6: Component Pressure Drops (Inches of Water)

Unit Size	CFM	Dampers		Face & BP face		Face & BP by-pass		Plenum		Diffuser	Blender**			Attenuator		
		MXB	Econ.	Int. med.	External Large	Int. med.	External Large	Top inlet	Top outlet		One	Two	Three	3 ft.	4 ft.	5 ft.
107	29100	0.08	0.08	0.02	0.02	0.21	0.11	0.06	0.01	0.15	0.03	0.17	-	0.02	0.02	0.02
	38750	0.08	0.08	0.03	0.02	0.38	0.11	0.05	0.01	0.15	0.05	0.30	-	0.03	0.04	0.05
	48400	0.08	0.08	0.05	0.03	0.59	0.17	0.06	0.02	0.15	0.08	0.47	-	0.05	0.07	0.08
	58100	0.08	0.08	0.07	0.05	0.85	0.24	0.06	0.03	0.15	0.11	-	-	0.07	0.10	0.11
124	33600	0.07	0.07	0.02	0.01	0.21	0.06	0.06	0.01	0.15	0.02	0.09	0.33	0.02	0.02	0.03
	44800	0.07	0.07	0.04	0.02	0.43	0.12	0.06	0.02	0.15	0.04	0.18	-	0.03	0.05	0.06
	55900	0.07	0.07	0.05	0.03	0.57	0.16	0.06	0.02	0.15	0.05	0.25	-	0.04	0.07	0.08
	67100	0.08	0.08	0.07	0.04	0.82	0.23	0.06	0.03	0.15	0.07	0.35	-	0.06	0.10	0.12
141	40300	0.07	0.07	0.02	0.01	0.16	0.06	0.06	0.01	0.15	0.03	0.14	-	0.02	0.03	0.03
	53650	0.07	0.07	0.04	0.02	0.29	0.11	0.06	0.02	0.15	0.05	0.24	-	0.03	0.05	0.05
	67100	0.08	0.08	0.06	0.03	0.45	0.17	0.06	0.02	0.15	0.08	0.38	-	0.05	0.08	0.09
	80600	0.08	0.08	0.09	0.05	0.64	0.24	0.06	0.03	0.15	0.11	-	-	0.07	0.11	0.13
160	45600	0.08	0.08	0.02	0.01	0.16	0.06	0.06	0.01	0.15	0.04	0.12	0.35	0.02	0.03	0.03
	60900	0.08	0.08	0.04	0.02	0.28	0.10	0.06	0.02	0.15	0.07	0.21	-	0.03	0.05	0.05
	76100	0.08	0.08	0.06	0.03	0.43	0.16	0.06	0.02	0.15	0.11	0.33	-	0.05	0.08	0.09
	91400	0.08	0.08	0.09	0.05	0.62	0.24	0.06	0.04	0.15	0.16	0.48	-	0.07	0.12	0.13
169	48400	0.08	0.08	0.02	0.01	0.18	0.06	0.06	0.01	0.15	0.05	0.09	0.29	0.02	0.03	0.03
	64500	0.08	0.08	0.04	0.02	0.31	0.10	0.06	0.02	0.15	0.08	0.16	-	0.03	0.05	0.05
	80600	0.08	0.08	0.06	0.03	0.49	0.16	0.06	0.02	0.15	0.13	0.25	-	0.05	0.08	0.09
	96700	0.07	0.07	0.08	0.04	0.71	0.23	0.06	0.04	0.15	0.18	0.36	-	0.07	0.11	0.13

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Other Items

- Account for all flow rate (both chiller and boiler)

5 CHILLED WATER COIL(24 ins)				**SECTION**	**3**
Coil model	5WM1005C		Number of coils	2	
Total capacity	1937893	Btu/h	Number of rows	5	
Sensible capacity	1351492	Btu/h	Fins per inch	10	
Air volume	48400	cfm			
Entering db/wb	80.0 / 67.0	F	Entering water	45.0	F
Leaving db/wb	54.5 / 54.0	F	Leaving water	55.0	F
Finned height x length	45 x 155	ins	Water flow rate	387.60	gpm
Face area	96.88	ft2	Water pressure drop	18.90	ftHD
Face velocity	500	ft/m	Water velocity	4.60	ft/s
Coil air pressure drop	1.00	ins WC			
			Fluid volume	62.0	gal
			Fluid weight	523.00	lb
Connection type	Threaded		Fin material	Aluminum (.0075)	
Connection Qty x size	2 x 3.00	ins	Tube material	Copper (.020)	
Connection location	Drive side		Header material	Copper	
Connection material	Carbon steel		Case material	Galv. steel	
Glycol type (%)	- (0 %)		Drain pan	Stainless steel	
Fouling Factor	0		Drain pan side	Drive side	
			Turbospirals	None	
Coil code	5WM1005C		Electro-fin coat	None	
DOOR DATA					
Door location	Drive side		Window size	None	
Door width	8	ins	Light	Marine light kit and switch only	
Door opening	Outward				

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Other Items

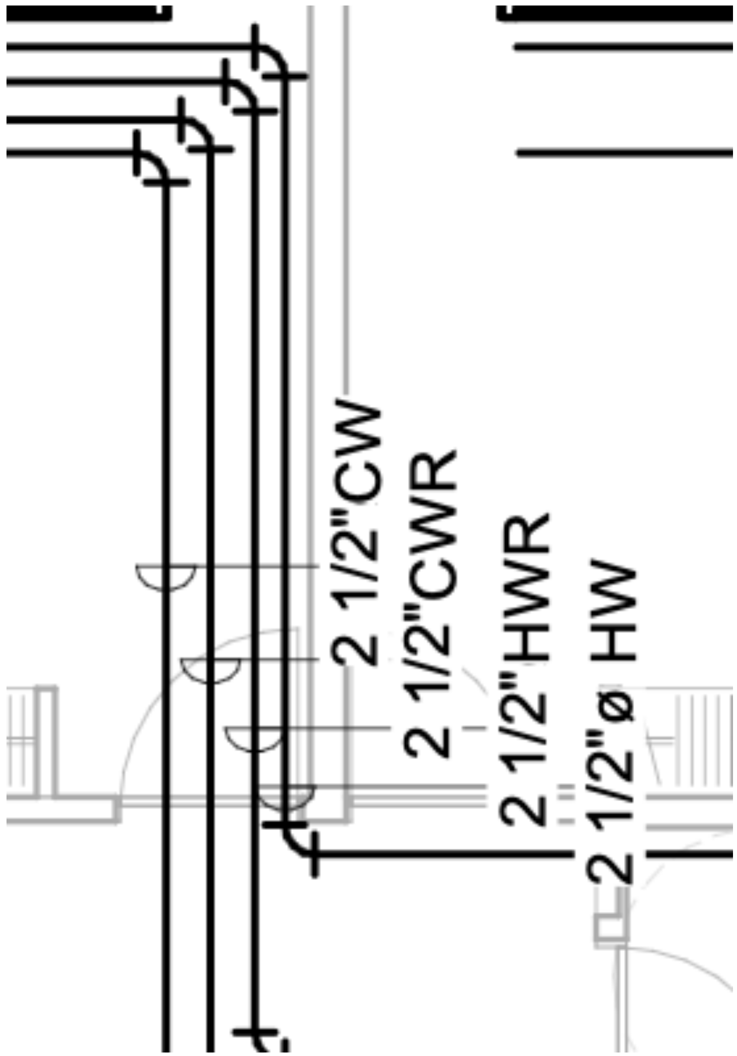
- Make sure to adjust your flow rate (i.e., chiller or boiler) based on the requirements of boilers, chillers

Table 29 — 30XA Minimum and Maximum Cooler Flow Rates

ITEM					MINIMUM		MAXIMUM	
Cooler Leaving Water Temperature*					40 F (4.4 C)		60 F (15 C)	
Cooler Entering Water Temperature†					45 F (7.2 C)		70 F (21.1 C)	
30XA UNIT SIZE	Nominal Flow Rate		Cooler	Number of Passes	Minimum Flow Rate**		Maximum Flow Rate	
	(gpm)	(L/s)			(gpm)	(L/s)	(gpm)	(L/s)
140	317.8	20.1	Standard, Flooded	2	134	8.5	538	33.9
			Plus One Pass, Flooded	3	73	4.6	293	18.5
			Minus One Pass, Flooded	1	324	20.4	1296	81.8
142	303.5	19.1	DX Cooler	—	152	9.6	607	38.2
160	365.1	23	Standard, Flooded	2	165	10.4	660	41.6
			Plus One Pass, Flooded	3	98	6.2	391	24.7
			Minus One Pass, Flooded	1	354	22.3	1418	89.5
162	347	21.9	DX Cooler	—	174	10.9	694	43.7
180	409.6	25.8	Standard, Flooded	2	202	12.7	807	50.9
			Plus One Pass, Flooded	3	73	4.6	391	24.7
			Minus One Pass, Flooded	1	416	26.2	1662	104.9
182	401.7	25.3	DX Cooler	—	201	12.6	803	50.6
200	463.9	29.3	Standard, Flooded	2	223	14.1	892	56.3
			Plus One Pass, Flooded	3	98	6.2	391	24.7
			Minus One Pass, Flooded	1	458	28.9	1833	115.6
202	447.1	28.2	DX Cooler	—	224	14.1	894	56.3
220	505.9	31.9	Standard, Flooded	2	235	14.8	941	59.4
			Plus One Pass, Flooded	3	122	7.7	489	30.9
			Minus One Pass, Flooded	1	501	31.6	2004	126.4
222	493	31.1	DX Cooler	—	246	15.5	950	59.9
240	545.8	34.4	Standard, Flooded	2	266	16.8	1063	67.1
			Plus One Pass, Flooded	3	147	9.3	587	37.0
			Minus One Pass, Flooded	1	538	33.9	2151	135.7
242	530	33.5	DX Cooler	—	265	16.7	950	59.9
260	600.3	37.9	Standard, Flooded	2	257	16.2	1027	64.8
			Plus One Pass, Flooded	3	141	8.9	562	35.5
			Minus One Pass, Flooded	1	584	36.8	2334	147.3
262	583	36.8	DX Cooler	—	292	18.4	950	59.9
280	642.2	40.5	Standard, Flooded	2	293	18.5	1173	74.0
			Plus One Pass, Flooded	3	141	8.9	562	35.5
			Minus One Pass, Flooded	1	620	39.1	2481	156.5
282	627	39.5	DX Cooler	—	313	19.8	950	59.9
300	687.5	43.4	Standard, Flooded	2	327	20.6	1308	82.5
			Plus One Pass, Flooded	3	174	11	697	44.0
			Minus One Pass, Flooded	1	687	43.3	2750	173.5
302	665	42.0	DX Cooler	—	333	21.0	1331	83.9
325	733.4	46.3	Standard, Flooded	2	361	22.8	1442	91.0
			Plus One Pass, Flooded	3	211	13.3	843	53.2
			Minus One Pass, Flooded	1	724	45.7	2897	182.8
327	720	45.4	DX Cooler	—	360	22.7	1440	90.8
350	775.4	48.9	Standard, Flooded	2	379	23.9	1516	95.6
			Plus One Pass, Flooded	3	244	15.4	978	61.7
			Minus One Pass, Flooded	1	767	48.4	3068	193.6
352	757	47.8	DX Cooler	—	379	23.9	1514	95.5

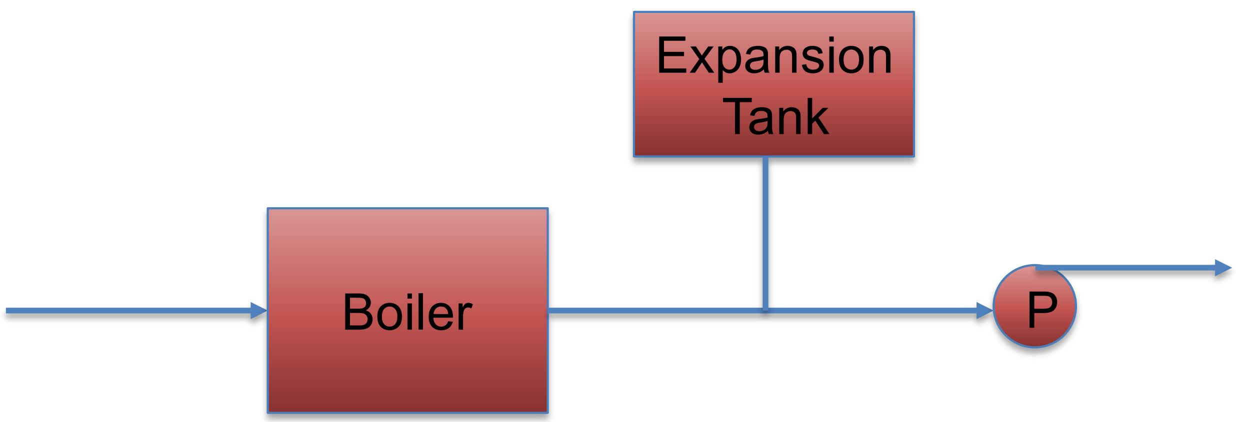
Other Items

- Add descriptions:



Design Procedure

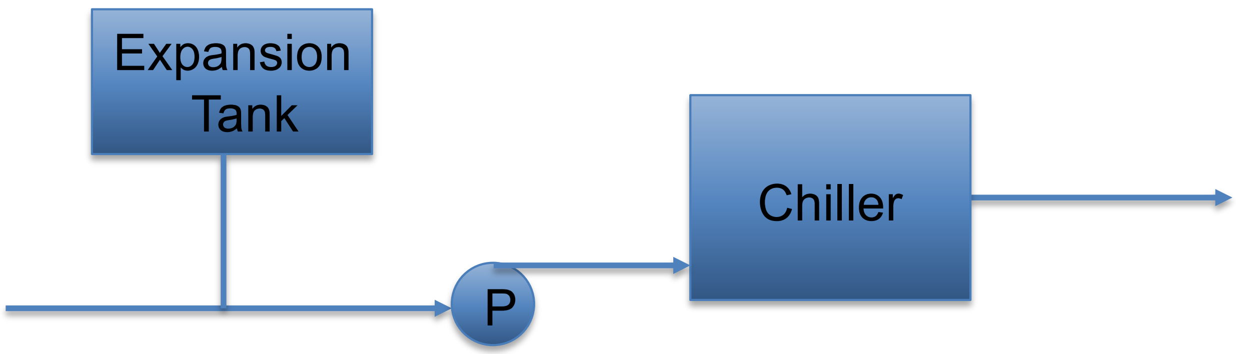
- The usual sequence of heating system equipment is the boiler, expansion tank and pump



- The one location where the absolute pressure stays constant is at the "expansion tank"

Design Procedure

- The usual sequence of cooling system equipment is the expansion tank, pump and chiller



- If the expansion tank is placed after the pump, the outlet pressure remains constant and the inlet pressure drops, which may cause cavitation

Design Procedure

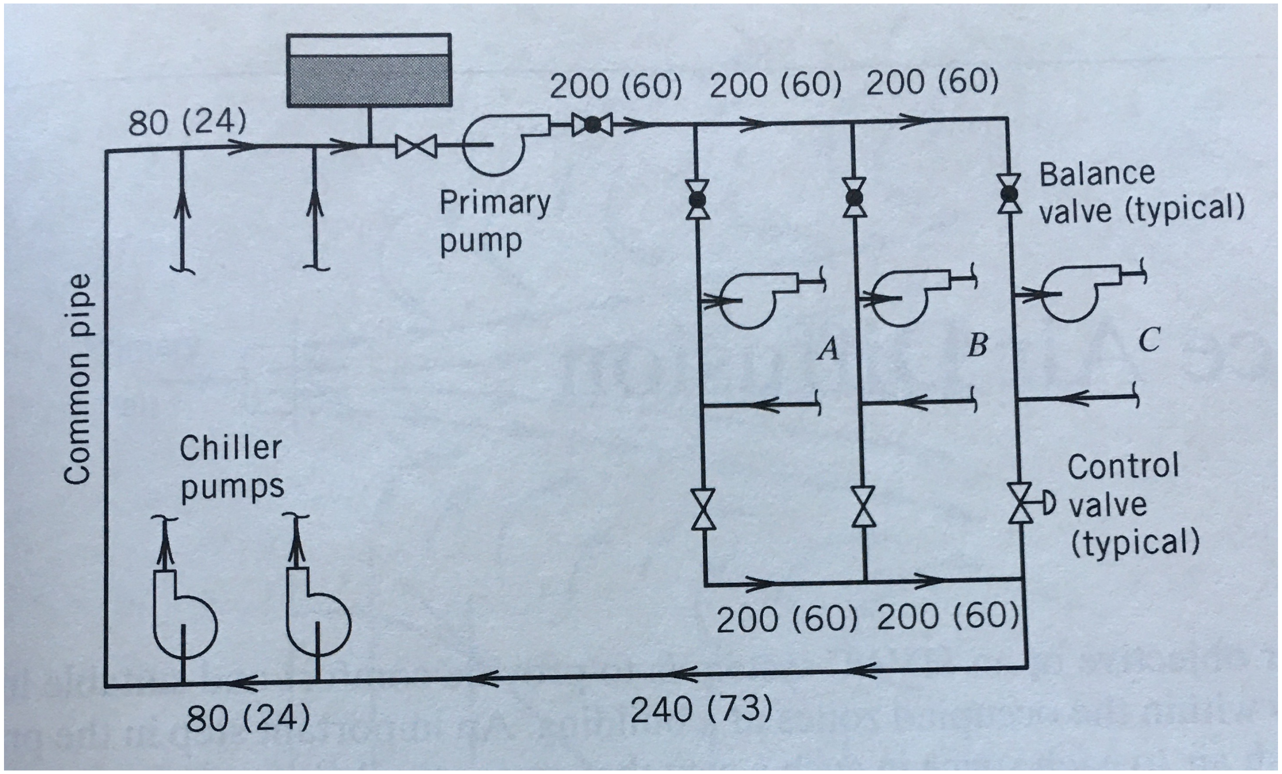
- Point of no pressure change for the expansion chambers:
  - The system connection of an expansion is known as “the point of no pressure change”
  - The pressure will always have the same as the pressure inside the tank
  - This is true if the tank is a plain steel or bladder/diaphragm type
  - This is also true whether the system pump is on or off
  - This pressure is only changed as water or air are added to or removed from the tank

EXTRA EXAMPLE 1

Extra Example 1

- Problem: Size the pipe for the system shown below. The lengths shown are the total equivalent lengths for the section exclusive of the control valve. Specify the primary pump performance requirement.
  - ❑ Pipes are Schedule 40

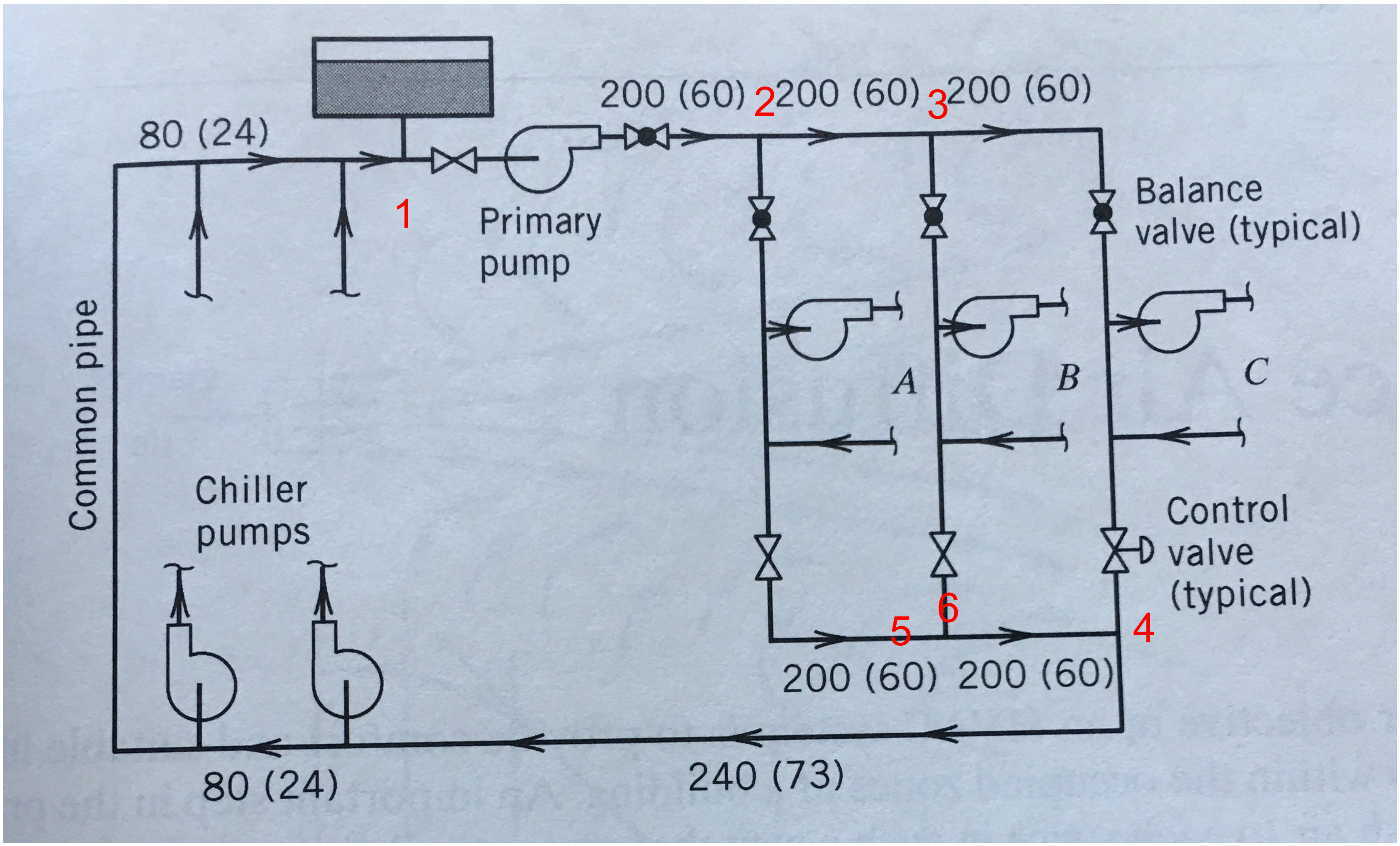
Path	GPM	Control valve head loss (ft)
A	60	40
B	70	50
C	70	50



Source: *McQuiston et al. Heating, Ventilating, and Air Conditioning, 5th Edition*

Extra Example 1

- Solution: Add numbers to the sections



Source: McQuiston et al. Heating, Ventilating, and Air Conditioning, 5th Edition

Extra Example 1

- Solution:

Section	Component	Flow Rate	Pipe size	Pipe Head Loss	Total Pipe and Fitting. Equivalent Length	Fitting/Pipe ΔP
		(gpm)	(in)	(ft/100ft)	(ft)	(ft)
1-2	Pipe/fittings	200	4	2.4	200	4.8
2-3	Pipe/fittings	140	3	4.2	200	8.4
3-4	Pipe/fittings	70	2 ½	3.5	240	8.4
Control Val. C	Control Val. C	70	n/a	n/a	n/a	50 (Given)
4-1	Pipe/fittings	200	4	2.4	400	9.6
						81.2
2-5	Pipe/fittings	60	2 ½	2.5	24-	6
Control Val. A	Control Val. A	60	n/a	n/a	n/a	40
5-4	Pipe/fittings	140	3	4.2	200	8.4
						54.4
3-6	Pipe/fittings	70	2 ½	3.5	40	1.4
Control Val. B	Control Val. B	70	n/a	n/a	n/a	50
						51.4

Source: McQuiston et al. Heating, Ventilating, and Air Conditioning, 5th Edition

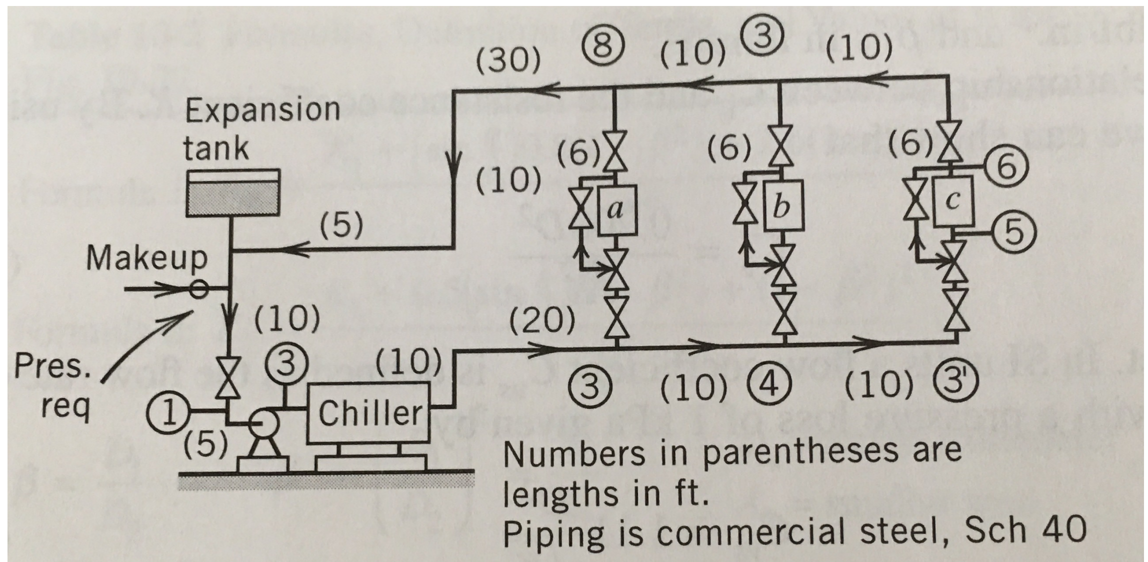
EXTRA EXAMPLE 2

Extra Example 2

- **Example:** A closed constant flow two-pipe water system might be found an equipment room. The terminal units, a, b, and c are air handling units that contain air-to-water finned tube heat exchangers. An actual system could contain a hot water generator or a chiller; A chiller is to be considered here. Size the piping and specifying the pumping requirements.

Unit	$\dot{Q}\ (gpm)$	Lost head (ft)	c_v 3-way values
Chiller	60	14	--
a	30	15	25
b	20	10	18
c	10	10	8

Parentheses are length in ft
Assume commercial steel, Sch 40



Unit	$\dot{Q}$ gpm	Lost head ft	C_v, 3-Way Valves
Chiller	60	14	—
a	30	15	25
b	20	10	18
c	10	10	8

Extra Example 2

Solution:

- Since it is a mechanical room a higher velocity could acceptable 5 ft/s and assume maximum loss to be 7 ft per 100 ft in the main

- Calculate the sizing pipes

Extra Example 2

Pipe section No	Flow rate (gpm)	Nominal size (in)	Fluid velocity (ft/s)	Lost head per 100 ft (ft/100 ft)	Pipe length (ft)	Fittings equivalent length (ft)	Total length (ft)	3-way valve head loss (ft)	Total head loss (ft)
8-1	60	2 ½	4.0	2.6	55	20	75	--	1.95
2-3	60	2 ½	4.0	2.6	35	30	65	--	1.70
3-4	30	1 ½	4.8	6.5	10	5	15	--	0.98
7-8	30	1 ½	4.8	6.5	10	5	15	--	0.98
4-5	10	1	3.8	6.5	10	18	28	3.6	5.42
6-7	10	1	3.8	6.5	16	16	32	--	2.08
4-7	20	1 ¼	4.0	6.2	6	39	45	2.9	5.69
3-8	30	1 ½	4.8	6.5	6	34	40	3.3	5.90
Chiller	60							--	14.0
Unit a	30							--	15.0
Unit b	20							--	10.0
Unit c	10							--	10.0

Extra Example 2

Solution:

- The lost head for the three parallel circuits that begin at 3 and end at 8 using the following are

$$H_c = l_{34} + l_{45} + l_c + l_{67} + l_{78} = 0.98 + 5.42 + 10.0 + 2.08 + 0.98 = 19.46\ ft$$

$$H_b = l_{34} + l_{47} + l_b + l_{78} = 0.98 + 5.69 + 10.0 + 0.98 = 17.65\ ft$$

$$H_a = l_{38} + l_a = 5.69 + 15.0 = 20.9 ft$$

Extra Example 2

Solution:

- Among the three parallel paths, they have different head losses with the specified flow rates for each coil

- To balance out the required flow rates, paths b and c require some adjustment using balancing valves to increase their lost head to that for path a, 20.9 ft

$$H_p = l_{81} + l_{45} + l_{ch} + l_{23} + l_{38} + l_a = 1.95 + 14.0 + 1.70 + 5.9 + 15.0 = 38.55\ ft$$

- A pump to produce 60 gpm at about 39 ft of head is desirable