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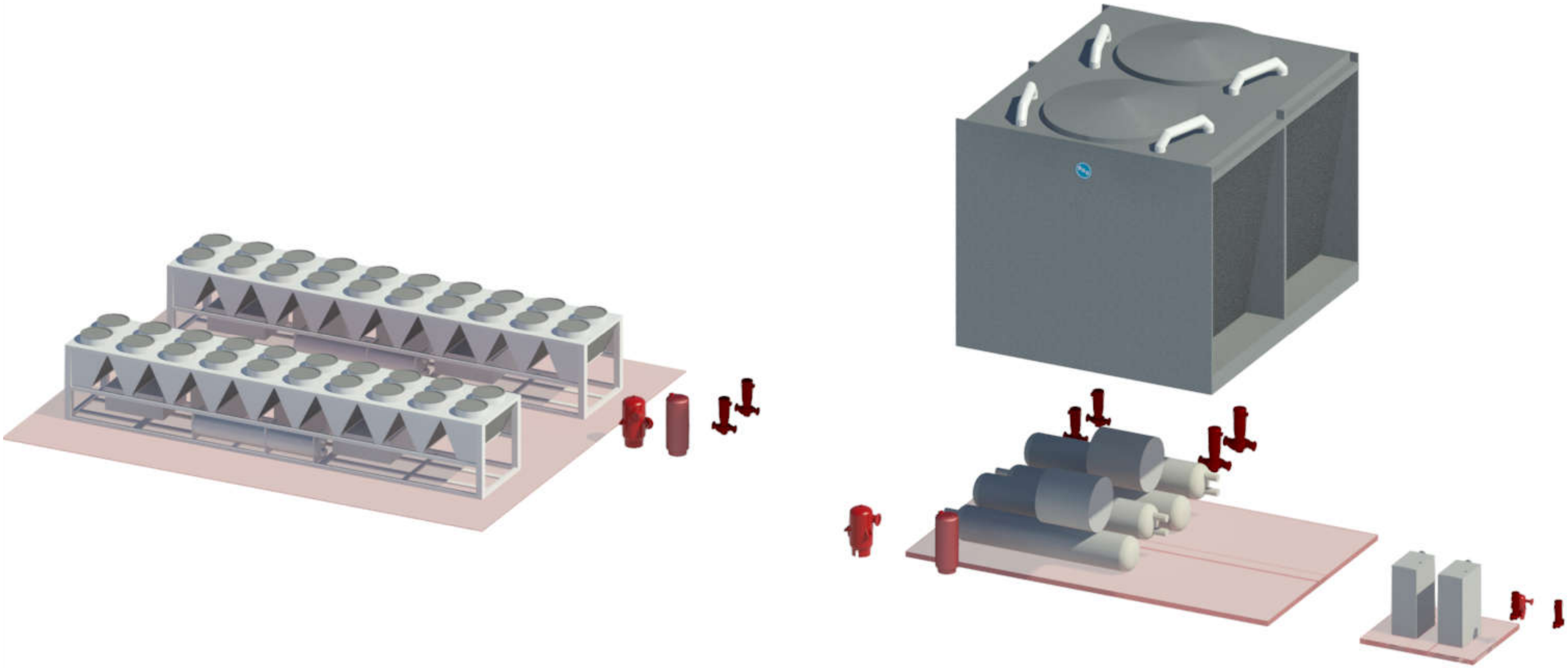
Automated Chiller and Boiler Plant Selections in Revit (1 PDH)

Automated Chiller and Boiler Plant Selections in Revit (1 PDH):



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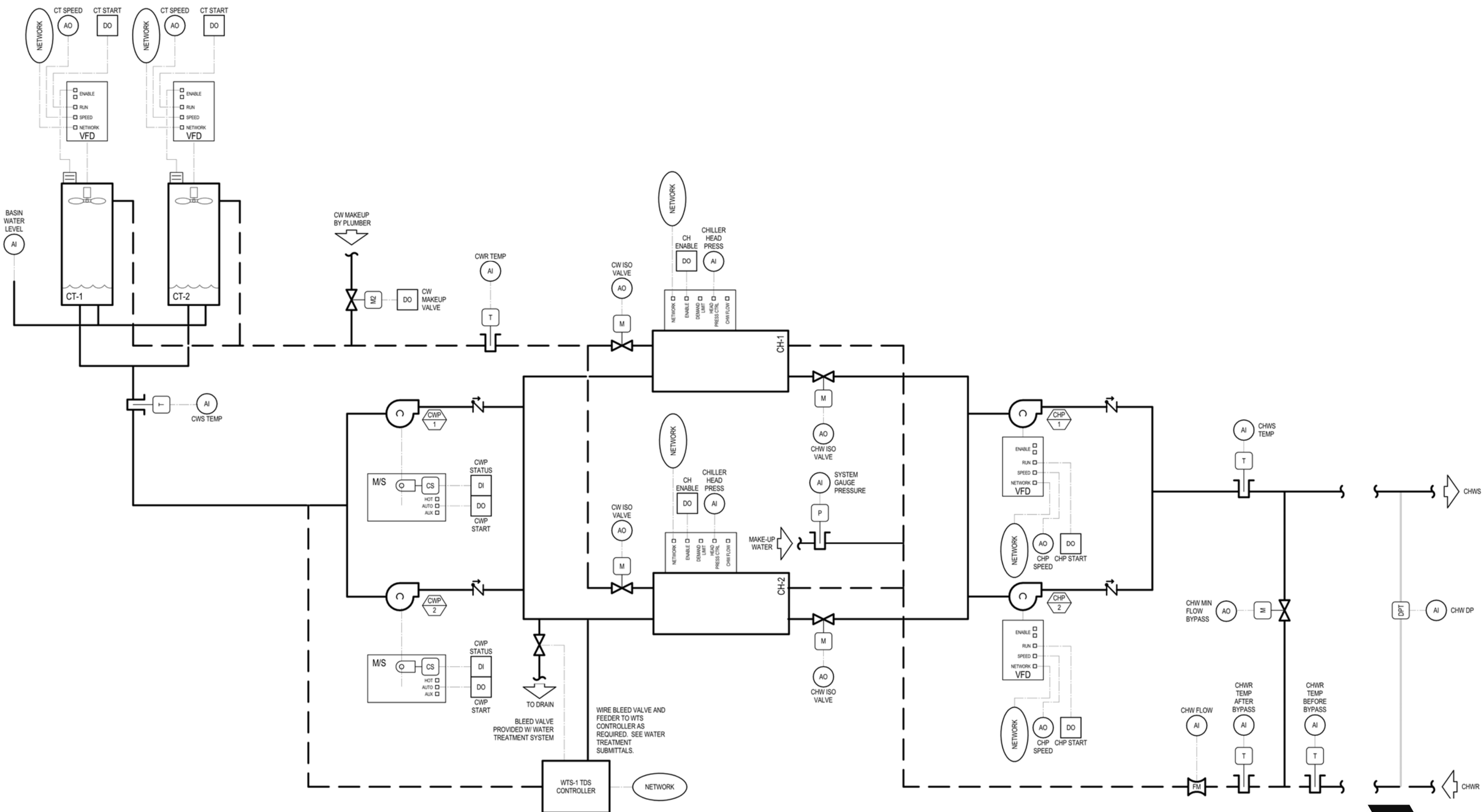
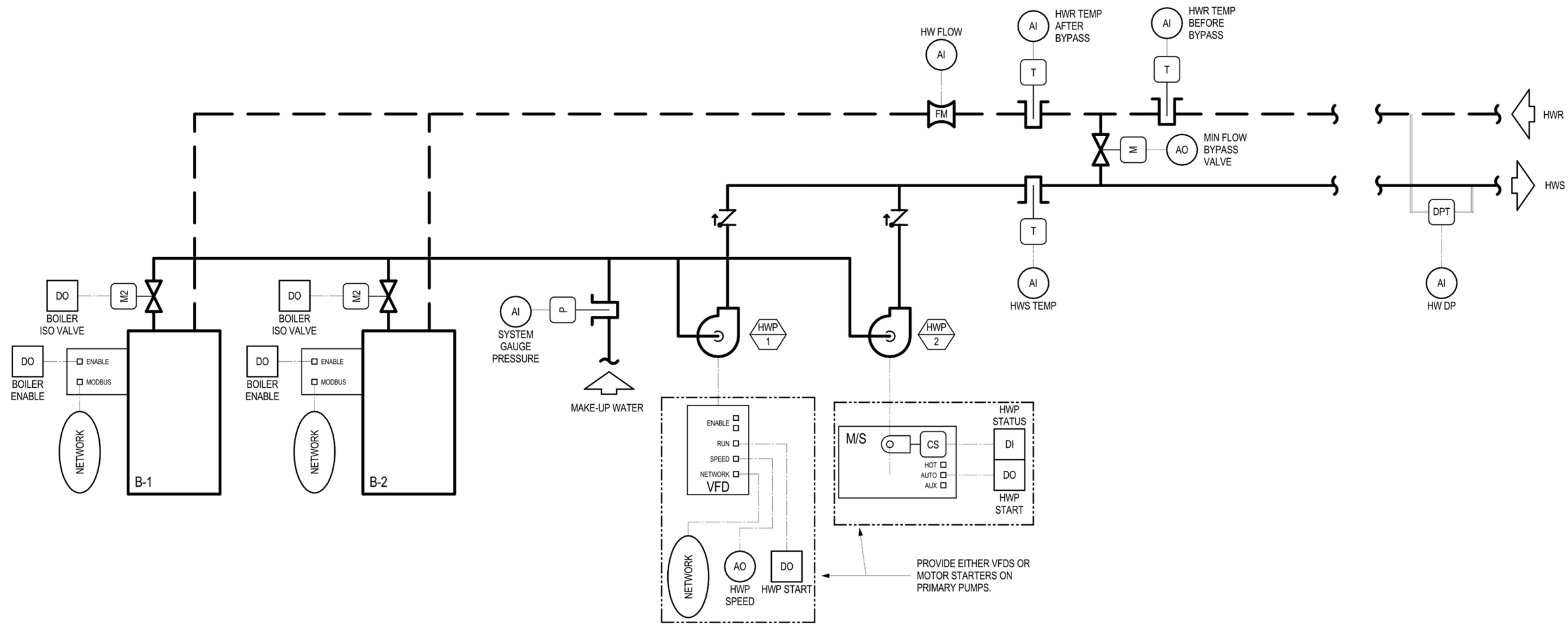
G36 Figure A-14 Variable Primary Chilled Water Plant:



G36 Figure A-23 Variable Primary Condensing Boiler Plant:



Preliminary Basis of Design Selections:

- Air Cooled Chillers: Carrier AquaForce
- Water Cooled Chillers : Trane CenTraVac
- Cooling Tower: Baltimore Air Coil (BAC) Series 3000
- Boilers: Aerco Benchmark (BMK).
- Pumps: Bell and Gossett e80-SC vertical inline pump.
- Expansion Tanks/Air separators: Bell and Gossett.

Hydronic plant sizing:

1) Meet Load

2) Economical Manufacturing Size
   - Typically needs to fit on the back of a truck.
   - Many owners request a single compressor to force redundancy and turndown.

3) Redundancy
   - Hydronic plants only operate at peak load for a few hours per year, so a little bit of fractional redundancy goes a long way.
   - 2 Chillers or Boilers sized at 67% load may provide full redundancy for 90% of the year.

4) Turndown (limit cycling).
   - Multiple chillers improve turndown capability.
   - Stable turndown is typically 20-30% of chiller capacity, so if you have two chillers sized at 50% of peak load, you have 10-15% turndown on peak load.

Chiller Sizing:

4.2.1.4 Maximum Chiller Capacity

Capacity of a single water-cooled chiller equipped with centrifugal or rotary-screw compressor(s) and or a single water-cooled absorption chiller shall not exceed 1,250 tons of refrigeration capacity. Capacity of a single air-cooled chiller equipped with rotary-screw or scroll compressors shall not exceed 250 tons of refrigeration capacity.

Chillers shall be rated and certified per AHRI conditions.

4.2.1.1 General

(a) Select cost-effective and optimum central chilled water plants and/or small chilled water systems to meet the project-specific requirements. Each installation shall consist of multiple (minimum two) chillers. For central plants, water-cooled chillers shall be centrifugal (open or hermetically sealed) or rotary-screw compressors or absorption machines. Small chilled water systems are generally equipped with air-cooled or water-cooled rotary-screw or scroll compressors. Use of reciprocating compressors is not permitted.

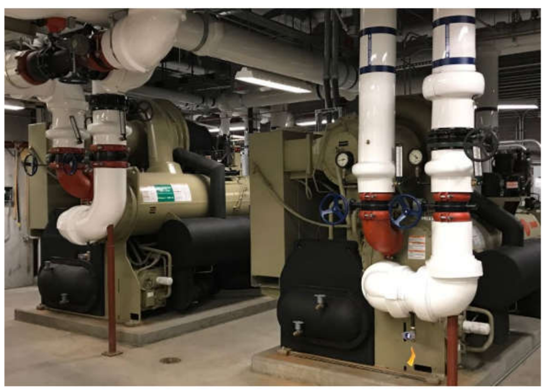
https://www.cfm.va.gov/til/dManual/dmHVAC.pdf

GSA: https://www.gsa.gov/system/files/2021%20P100%20Chp%205%20Mechanical%20Requirements.pdf

5.3.2.1 Chiller Plant

Revised section:

- Three equally sized chillers
- No oversizing/spare capacity
- Any design must meet a Turndown to 10%, stable operation
- Valving for unit isolation
- Two chillers sized for 66% of load if life cycle cost < three chillers



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ASHRAE 90.1 Chilled Water Design Temperatures:

6.5.4.7 Chilled-Water Coil Selection. Chilled-water cooling coils shall be selected to provide a 15°F or higher temperature difference between leaving and entering water temperatures and a minimum of 57°F leaving water temperature at *design conditions*.

Ideal Chilled Water Design Temperatures: 57°F - 42°F

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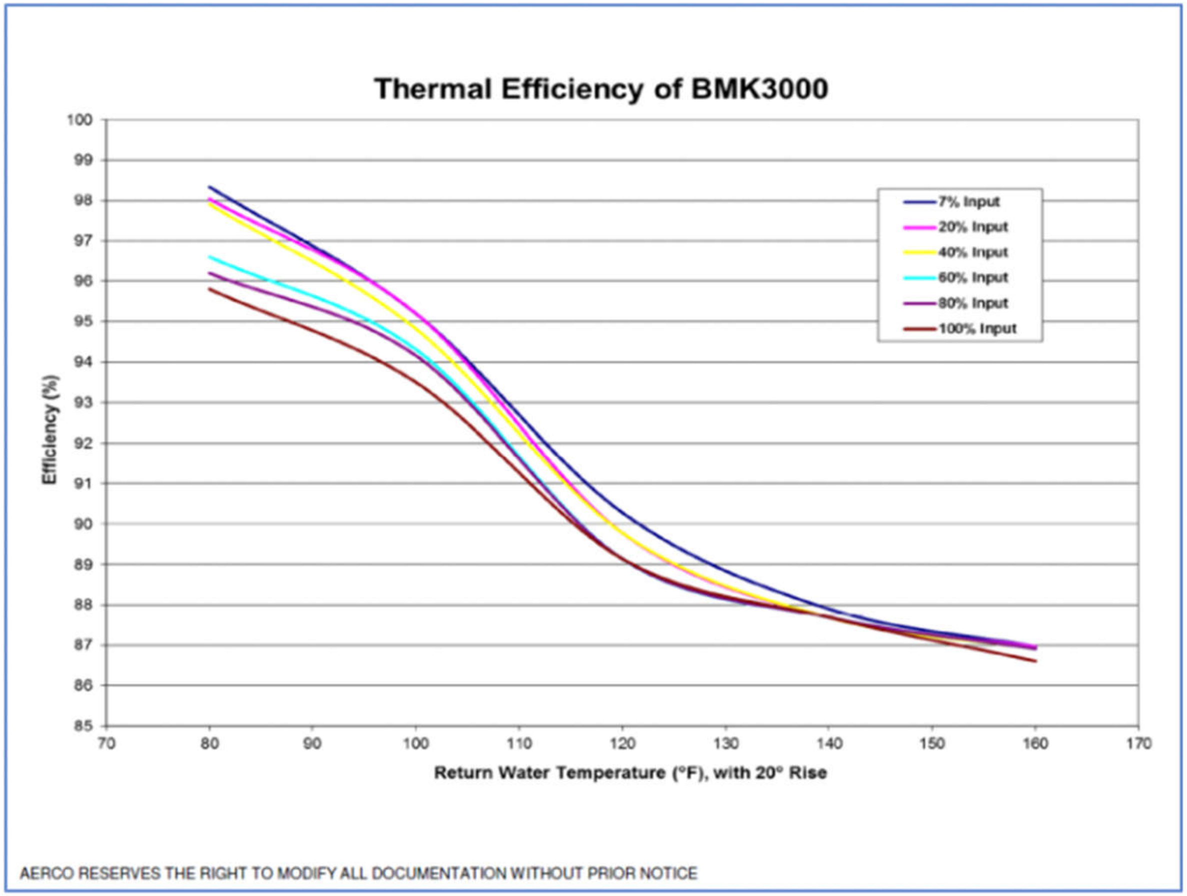
Boiler Efficiency Vs. Return Water Temperature:



Design OA Conditions For Sizing Equipment:

2021 ASHRAE Handbook — Fundamentals (IP)

MANCHESTER-BOSTON, NH, USA

WMO: **743945**

Lat: **42.930N** Lon: **71.436W** Elev: **221** StdP: **14.58** Time Zone: **-5.00 (NAE)** Period: **94-19** WBAN: **14710**

Annual Heating, Humidification, and Ventilation Design Conditions

	Coldest Month	Heating DB		Humidification DP/MCDB and HR						Coldest Month WS/MCDB				MCWS/PCWD to 99.6% DB		WSF	
				99.6%			99%			0.4%		1%					
		99.6%	99%	DP	HR	MCDB	DP	HR	MCDB	WS	MCDB	WS	MCDB	MCWS	PCWD		
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(1)	**1**	**1.8**	**7.0**	**-13.1**	**2.7**	**6.4**	**-8.3**	**3.5**	**11.8**	**23.0**	**19.8**	**20.6**	**22.4**	**8.0**	**330**	**0.508**	(1)

Annual Cooling, Dehumidification, and Enthalpy Design Conditions

	Hottest Month	Hottest Month DB Range	Cooling DB/MCWB						Evaporation WB/MCDB						MCWS/PCWD to 0.4% DB		
			0.4%		1%		2%		0.4%		1%		2%				
			DB	MCWB	DB	MCWB	DB	MCWB	WB	MCDB	WB	MCDB	WB	MCDB	MCWS	PCWD	
	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)	(j)	(k)	(l)	(m)	(n)	(o)	(p)	
(2)	**7**	**19.0**	**91.0**	**71.6**	**88.4**	**70.4**	**85.6**	**69.0**	**75.1**	**85.0**	**73.5**	**82.5**	**72.2**	**81.0**	**9.3**	**250**	(2)

Use this value for sizing dx units and air-cooled chillers. Add 5 °F to account for the heat island effect of roofs/buildings nearby.

Use this value for sizing cooling towers, typically there aren't local effects increasing the wet bulb temperature unless you put the cooling tower over a pond or something else unusual, so no need to add a safety factor.

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IECC Cooling Tower Minimum Efficiency:

TABLE C403.3.2(7)
PERFORMANCE REQUIREMENTS FOR HEAT REJECTION EQUIPMENT—MINIMUM EFFICIENCY REQUIREMENTS[i]

EQUIPMENT TYPE	TOTAL SYSTEM HEAT-REJECTION CAPACITY AT RATED CONDITIONS	SUBCATEGORY OR RATING CONDITION[h]	PERFORMANCE REQUIRED[b, c, d, f, g]	TEST PROCEDURE[a, e]
Propeller or axial fan open-circuit cooling towers	All	95°F entering water 85°F leaving water 75°F entering wb	≥ 40.2 gpm/hp	CTI ATC-105 and CTI STD-201 RS

For SI: °C = [(°F) – 32]/1.8, L/s × kW = (gpm/hp)/(11.83), COP = (Btu/h × hp)/(2550.7), db = dry bulb temperature, wb = wet bulb temperature.

a. Chapter 6 contains a complete specification of the referenced standards, which include test procedures, including the reference year version of the test procedure.
b. For purposes of this table, open-circuit cooling tower performance is defined as the water-flow rating of the tower at the thermal rating condition listed in the table divided by the fan motor nameplate power.
c. For purposes of this table, closed-circuit cooling tower performance is defined as the process water-flow rating of the tower at the thermal rating condition listed in the table divided by the sum of the fan motor nameplate power and the integral spray pump motor nameplate power.
d. For purposes of this table, dry-cooler performance is defined as the process water-flow rating of the unit at the thermal rating condition listed in the table divided by the total fan motor nameplate power of the unit, and air-cooled condenser performance is defined as the heat rejected from the refrigerant divided by the total fan motor nameplate power of the unit.
e. The efficiencies and test procedures for both open- and closed-circuit cooling towers are not applicable to hybrid cooling towers that contain a combination of separate wet and dry heat exchange sections. The certification requirements do not apply to field-erected cooling towers.
f. All cooling towers shall comply with the minimum efficiency listed in the table for that specific type of tower with the capacity effect of any project-specific accessories and/or options included in the capacity of the cooling tower.
g. For purposes of this table, evaporative condenser performance is defined as the heat rejected at the specified rating condition in the table, divided by the sum of the fan motor nameplate power and the integral spray pump nameplate power.
h. Requirements for evaporative condensers are listed with ammonia (R-717) and R-448A as test fluids in the table. Evaporative condensers intended for use with halocarbon refrigerants other than R-448A must meet the minimum efficiency requirements listed with R-448A as the test fluid. For ammonia, the condensing temperature is defined as the saturation temperature corresponding to the refrigerant pressure at the condenser entrance. For R-448A, which is a zeotropic refrigerant, the condensing temperature is defined as the arithmetic average of the dew point and the bubble point temperatures corresponding to the refrigerant pressure at the condenser entrance.
i. This table is a replica of ASHRAE 90.1 Table 6.8.1-7 Performance Requirements for Heat Rejection Equipment—Minimum Efficiency Requirements.

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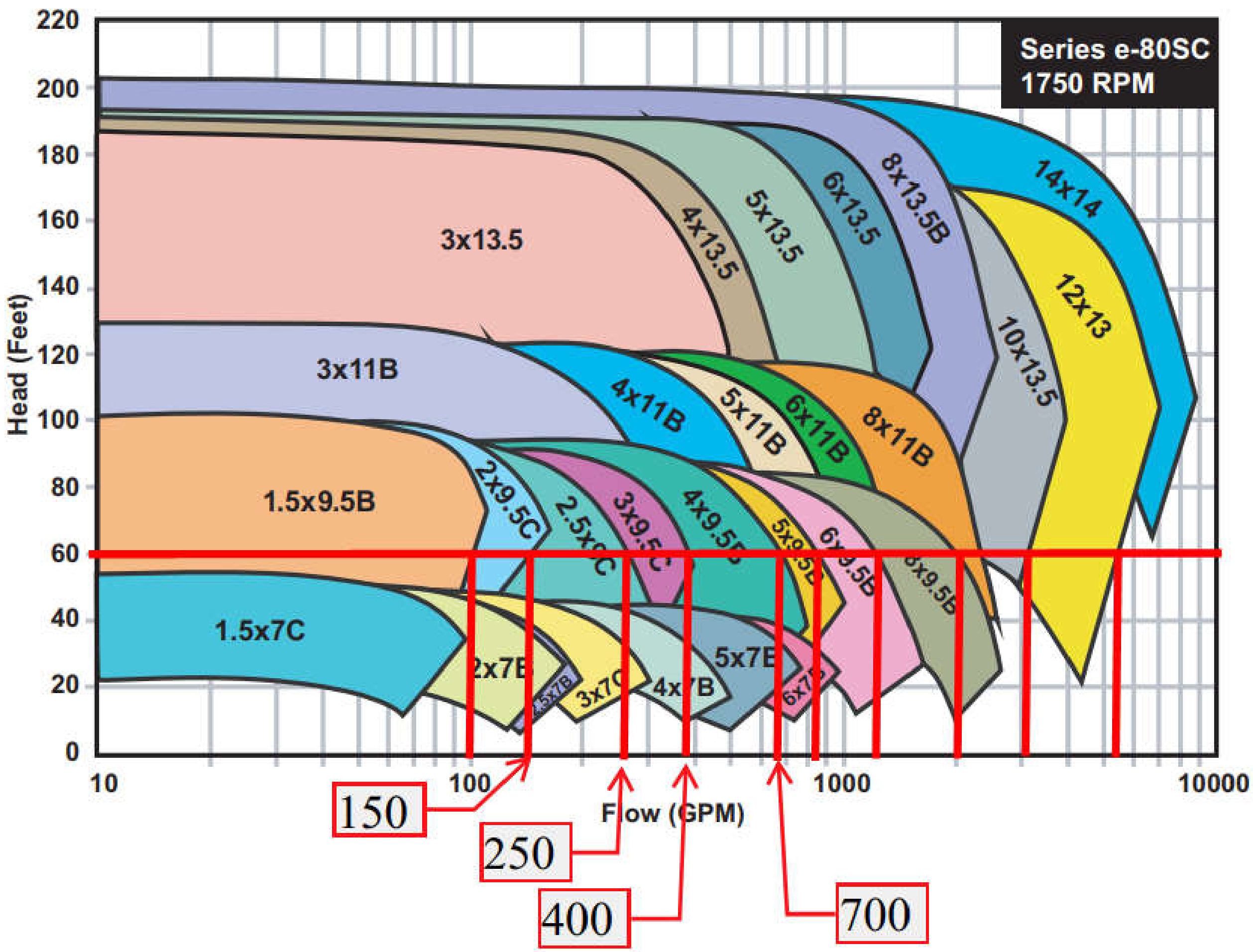
Pump Selections:

Standard Performance Curves



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Estimating System Volume:

Reference

Table 15 – Method for Estimating System Volume (Vs)

The following equation is based on the two largest dimensions (length, width, height) of the building and the gallon per lineal foot of the largest diameter main (in inches) of the building. An approximation is made considering the length of the main in a reverse return piping system where the thermal source (boiler/chiller) is located furthest from the last terminal (load) before returning to the source. This distance (supply and return) is doubled to approximate the volume represented in all additional circuit piping, boiler or chiller, fan coils, valves and fittings.

Actual system volumes in systems that were estimated by this method have been checked in a number of buildings. In reverse-return systems, the estimates were over-sized by 10% to 15%. In other systems checked, over-sizing ranged to 25%.

$Vs = (Dim_1 + Dim_2) \times 4 \times \text{gal./lin. ft.}$

Where:

$(Dim_1 + Dim_2)$ = The sum of the two largest dimensions of the building (in feet).

4 = Is a constant

Gal./lin. ft. = The gallons per lineal feet of the largest pipe, or main (in inches). Select from Table 2 or estimate as follows:

$\frac{(Dia)^2}{24}$

Example:

Width 120'
Length 408'
Height 200'
Main shown as 6" pipe

$Vs = (\text{length} + \text{height}) \times 4 \times \frac{(Dia")^2}{24}$

$Vs = (408' + 200') \times 4 \times \frac{(36)}{24}$

$Vs = 608 \times 4 \times (1.5)$

$Vs = 3,648$ Gal.

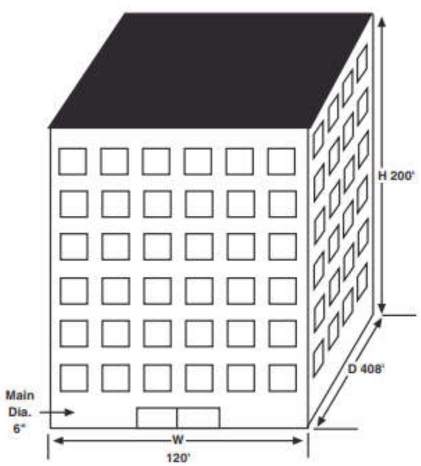
Simplified equation derived from above:

$Vs = \frac{(Dim_1 + Dim_2) \times (Dia")^2}{6}$

Example:

$Vs = \frac{(408 + 200) \times 36}{6}$

Vs=3,648 Gal.



Amtrol: https://us.v-cdn.net/5021738/uploads/editor/1f/bcmjeynivf26.pdf

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Estimating System Volume Based On Load Only:

$$Characteristic\ Length, CL\ (ft) = \left(Load\ (tons) * 300\frac{sf}{ton} * 12\ ft\right)^{1/3}$$

$$Chilled\ Volume\ (gal) = \frac{main\ diameter\ (in)^2 * \left(Load\ (tons) * 300\frac{sf}{ton} * 12\ ft\right)^{1/3}}{2}$$

Example (2600 ton system, 6” Main):

$$Chilled\ Volume\ (gal) = \frac{6^2 * (2600 * 300 * 12\ )^{1/3}}{2} = \ 3793\ gallons$$

$$Heating\ Volume\ (gal) = \frac{main\ diameter\ (in)^2 * \left(Load\ (MBH) * 35\frac{sf}{MBH} * 12\ ft\right)^{1/3}}{2}$$

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Expansion Tank Sizing (ASHRAE Fundamentals):

$$V_a \geq V_e$$

$$\geq V_s\left[\frac{v_h}{v_c} - 1\right] \tag{5}$$

$$V_t \geq \frac{V_e}{1 - (P_a + P_i)/(P_a + P_{max})} \tag{6}$$

where

V_t = the tank volume

V_a = the tank "acceptance" volume. This is the capacity of the bladder (for bladder tanks) or the volume of the waterside of the tank when the diaphragm is fully extended (for diaphragm tanks). With so-called "full acceptance" tanks, the bladder can open to the full shape of the tank, so the tank's acceptance volume and total volume, V_t, are equal.

V_e = the increase in volume of water as it expands from its minimum temperature to its maximum temperature.

v_c = the specific volume of water at the minimum temperature, T_c.

v_h = the specific volume of water at the minimum temperature, T_h.

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Easy Button and Engineering On Demand:

Cooling Source Selection
Project Load : Cooling Source
0-100 Tons : DX
100-500 Tons : Chilled Water (Air Cooled)
> 500 Tons : Chilled Water (Water Cooled)

Heating Source Selection
Project Load : Heating Source
0-1,500 MBH : Gas (if available) or Electric
> 1,500 MBH : Hot Water (If gas is available)

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Cooling Types:

DX (Air To Air):

Air Cooled Chiller (Air To Water):

Water Cooled Chiller (Water To Water):

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Cooling Type Comparison Chart:

Cooling Type Comparison Chart								
System Type	Upfront Cost	Energy Cost	Water Costs	Maintenance Cost	System Life	Difficulty To Add Redundancy	Space Required	Acoustic Options
Distributed DX (DX RTUs)	Low	High	None	Medium	Short	Hard	High	Low
Air Cooled Chiller Plant	Medium	Medium	None	Low	Medium	Easy	Medium	Medium
Water Cooled Chiller Plant	High	Low	High	High	Long	Easy	Low	High

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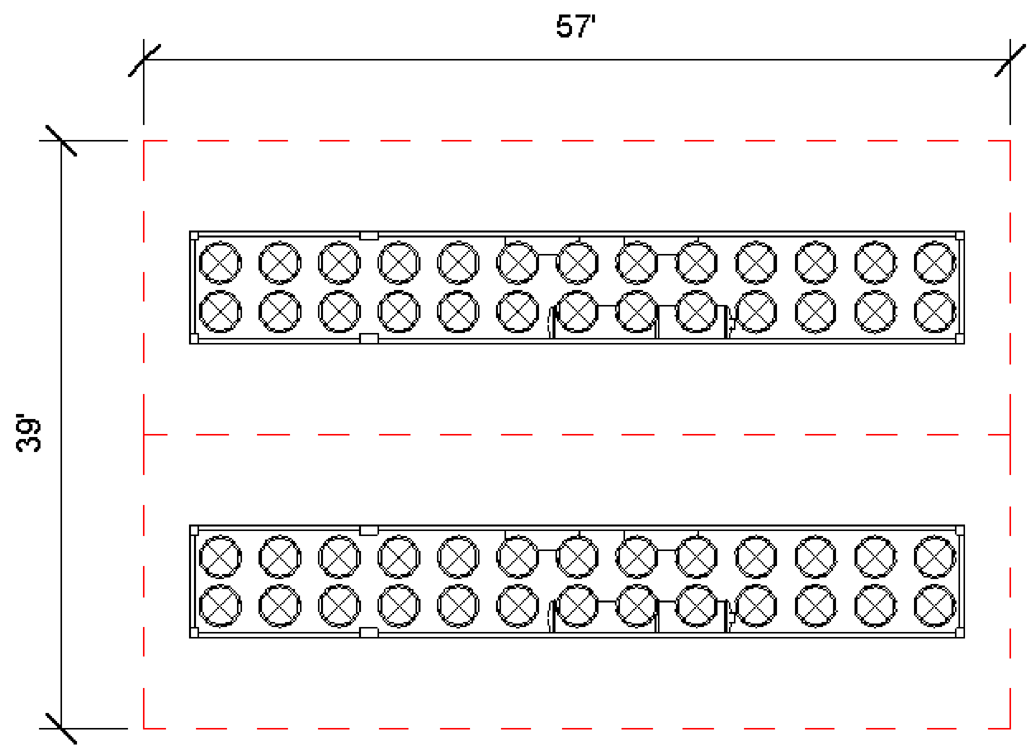
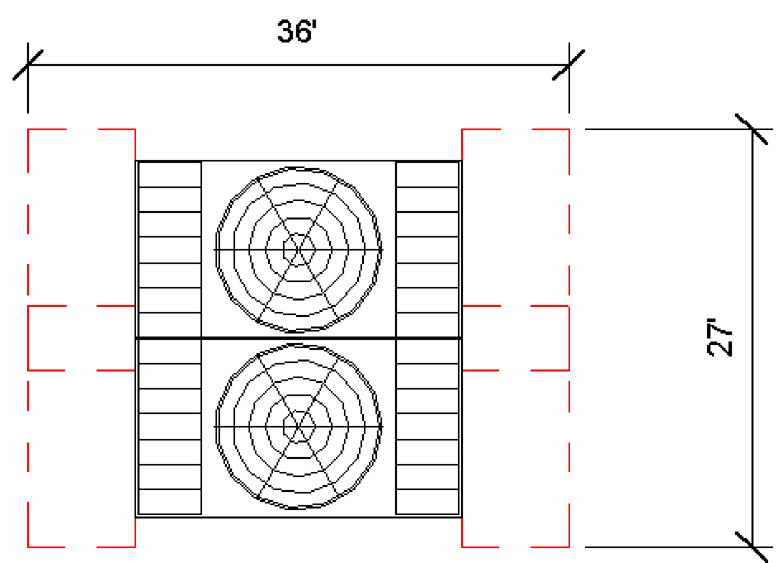
Outdoor Area Required:

(2) 500 Ton Unit Space Comparison

Air Cooled Chiller (Carrier AquaForce 30XA):
57’ x 39’ = 2223 sf

Water Cooled Cooling Towers (BAC 3000 XES3E-1222-10L):
36’ x 27’ = 972 sf





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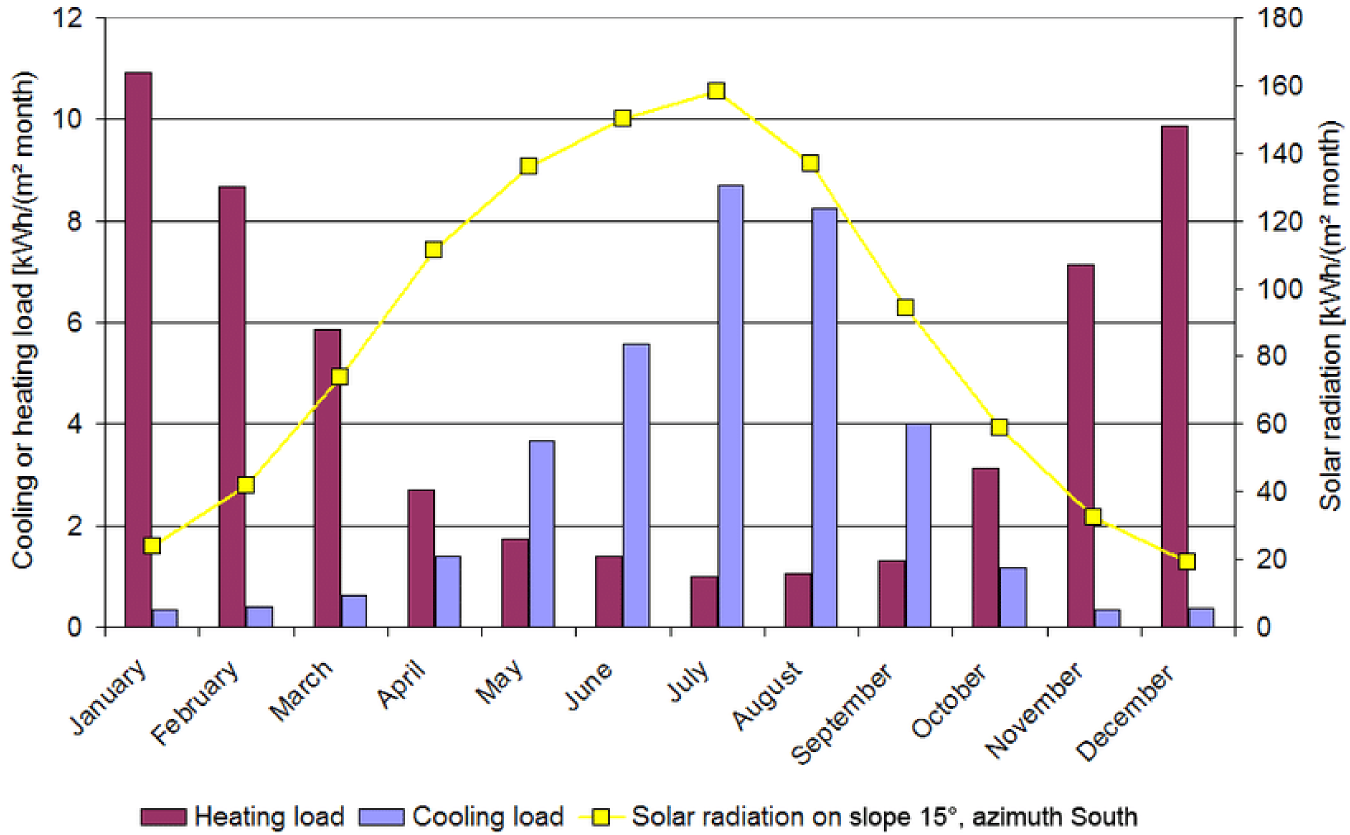
Acoustic Options:

Dx: The compressor sits directly on top of ductwork, transferring sound directly into the occupied space.

Air Cooled: The compressor can go anywhere outside, which may transfer sound to the property line.

Water Cooled: The compressors can go inside, and cooling towers are much quieter than compressors.

Cooling Load Profiles:



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AHRI 550/590 :

AHRI 550/590:

5.4.3 *Determination of Part-load Performance*. For Water-chilling Packages covered by this standard, the IPLV.IP or NPLV.IP shall be calculated as follows:

Determine the Part-load energy efficiency at 100%, 75%, 50%, and 25% load points at the conditions specified in Table 6.

Use Equation 22a to calculate the IPLV.IP or NPLV.IP for units rated with COP_R and EER.

$$\text{IPLV.IP or NPLV.IP} = 0.01 \cdot A + 0.42 \cdot B + 0.45 \cdot C + 0.12 \cdot D \qquad \text{22a}$$

For COP_R and EER where:

A = COP_R or EER at 100% load
B = COP_R or EER at 75% load
C = COP_R or EER at 50% load
D = COP_R or EER at 25% load

Use Equation 22b to calculate the IPLV.IP or NPLV.IP for units rated with kW/ton_R:

$$\text{IPLV.IP or NPLV.IP} = \frac{1}{\frac{0.01}{A} + \frac{0.42}{B} + \frac{0.45}{C} + \frac{0.12}{D}} \qquad \text{22b}$$

Where:

A = Power Input per Capacity, kW/ton_R at 100% load
B = Power Input per Capacity, kW/ton_R at 75% load
C = Power Input per Capacity, kW/ton_R at 50% load
D = Power Input per Capacity, kW/ton_R at 25% load

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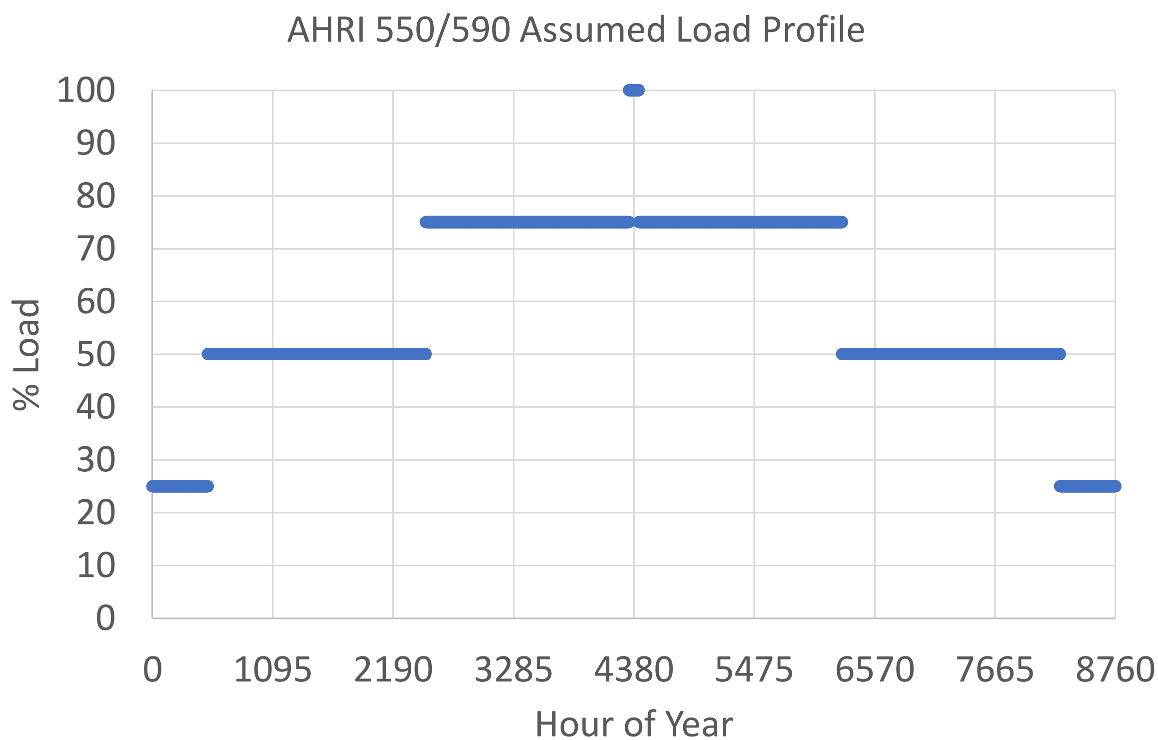
AHRI 550 Assumed Load Profile:



1 Ton Capacity =

8760*1*0.12*0.25 + 8760*1*0.45*0.5 + 8760*1*0.42*0.75 + 8760*1*0.01*1 = 5080 Ton*hours (61 million Btus)

IECC Equipment Efficiencies:

EQUIPMENT TYPE	SIZE CATEGORY	UNITS	PATH A	PATH B	TEST PROCEDURE[c]
Condensing units, air cooled	≥ 135,000 Btu/h	—	—	10.5 EER 11.8 IEER	AHRI 365
Air cooled chillers	< 150 tons	EER (Btu/Wh)	≥ 10.100 FL	≥ 9.700 FL	AHRI 550/590
			≥ 13.700 IPLV.IP	≥ 15.800 IPLV.IP	
	≥ 150 tons		≥ 10.100 FL	≥ 9.700FL	
			≥ 14.000 IPLV.IP	≥ 16.100 IPLV.IP	
Water cooled, electrically operated centrifugal	< 150 tons	kW/ton	≤ 0.610 FL	≤ 0.695 FL	AHRI 550/590
			≤ 0.550 IPLV.IP	≤ 0.440 IPLV.IP	
			≤ 0.610 FL	≤ 0.635 FL	
			≤ 0.550 IPLV.IP	≤ 0.400 IPLV.IP	
	≥ 300 tons and < 400 tons		≤ 0.560 FL	≤ 0.595 FL	
			≤ 0.520 IPLV.IP	≤ 0.390 IPLV.IP	
	≥ 400 tons and < 600 tons		≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.500 IPLV.IP	≤ 0.380 IPLV.IP	
	≥ 600 tons		≤ 0.560 FL	≤ 0.585 FL	
			≤ 0.500 IPLV.IP	≤ 0.380 IPLV.IP	

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Recurring Costs:

Energy Costs:

Dx:

11.8 IEER = 11.8 / 12 = 1.123 kW/ton

Yearly energy cost: 0.876 kW/ton * 5,080 ton*hrs * $0.168 $/kWh = $958.56/ton

Air Cooled

13.7 IPLV = 12/13.7 = 0.876 kW/ton

Yearly energy cost: 0.876 kW/ton * 5,080 ton*hrs * $0.168 $/kWh = $747.73/ton

Water Cooled

0.5 kW/ton + 0.15 kW/ton (cooling tower and condenser pump) = 0.65 kW/ton

Yearly energy cost: 0.65 kW/ton * 5,080 ton*hrs * $0.168 $/kWh = $554.82/ton

Water use costs:

DX/Air Cooled: None

Water Cooled:

15,000 btu Tr/ton*hr / 970 btu/lb / 8.33 lbs/gal = 1.9 gal/ton*hr

(1.9 gal/ton*hr) * 5,080 ton*hr * $2.50/1000 gal = $23.25/ton

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Recurring Costs (cont.):

Maintenance Costs

Dx: $16/ton

Air Cooled: $16/ton

Water Cooled: $35/ton

Total Yearly cost:

Dx: $958.56 + $0.00 + $16 = $974.56/ton

Air Cooled: $747.73 + $0.00 + $16 = $763.73/ton

Water Cooled: $554.82 + $23.25 + $35 = $613.07/ton

Installation Costs:

50 Tons:

Dx: $706/ton * 50 tons = $35,300

100 Tons

Dx: $650/ton * 100 tons = $65,000

Air Cooled: $1250/ton * 100 tons = $125,000

250 Tons:

Dx: $650/ton * 250 tons = $162,500

Air Cooled: $1,100/ton * 250 tons = $275,000

Water Cooled: $2,000/ton * 250 tons = $500,000

500 Tons:

Dx: $650/ton * 500 tons = $325,000

Air Cooled: $900/ton * 500 tons = $450,000

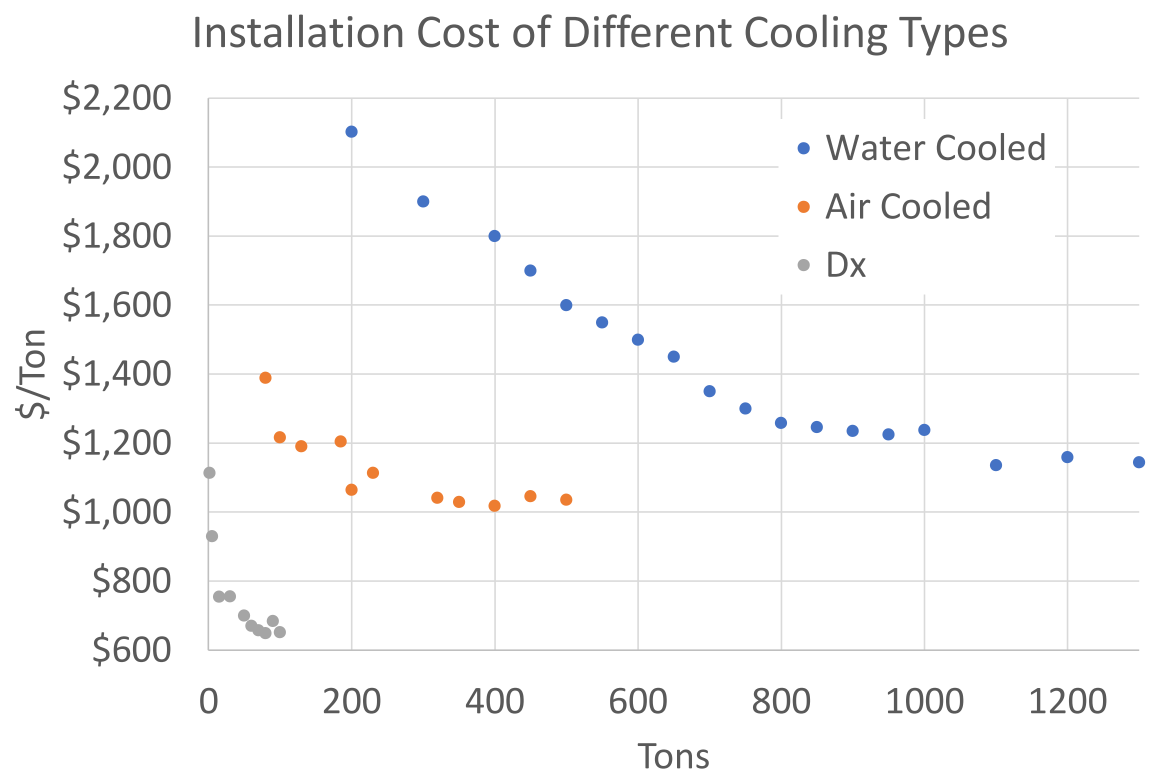
Water Cooled: $1600/ton * 500 tons = $800,000

750 Tons:

Dx: $650/ton * 750 tons = $487,500

Air Cooled: $900/ton * 750 tons = $675,000

Water Cooled: $1,335/ton * 750 tons = $1,000,000



5 Year Total Cost Of Ownership:

	DX		Air Cooled		Water Cooled	
Size (Tons)	Installation Cost	Yearly Recurring Costs	Installation Cost	Yearly Recurring Costs	Installation Cost	Yearly Recurring Costs
50	$35,300.00	$32,181.50	-	-	-	-
100	$65,000.00	$64,363.00	$125,000.00	$50,518.00	-	-
250	$162,500.00	$160,907.50	$275,000.00	$126,295.00	$375,000	$108,613
500	$325,000.00	$321,815.00	$450,000.00	$252,590.00	$600,000	$217,225
750	$487,500.00	$482,722.50	$487,500.00	$378,885.00	$900,000	$325,838

5 Year Total Cost of Ownership			
Size (Tons)	DX	Air Cooled	Water Cooled
50	$278,941	-	-
100	$552,282	$506,866	-
250	$1,380,705	$1,229,664	$1,266,341.70
500	$2,761,410	$2,359,328	$2,332,683.40
750	$4,142,115	$3,351,492	$3,299,025.10

Cooling Source Selection
Project Load : Cooling Source
0-100 Tons : DX
100-500 Tons : Chilled Water (Air Cooled)
> 500 Tons : Chilled Water (Water Cooled)

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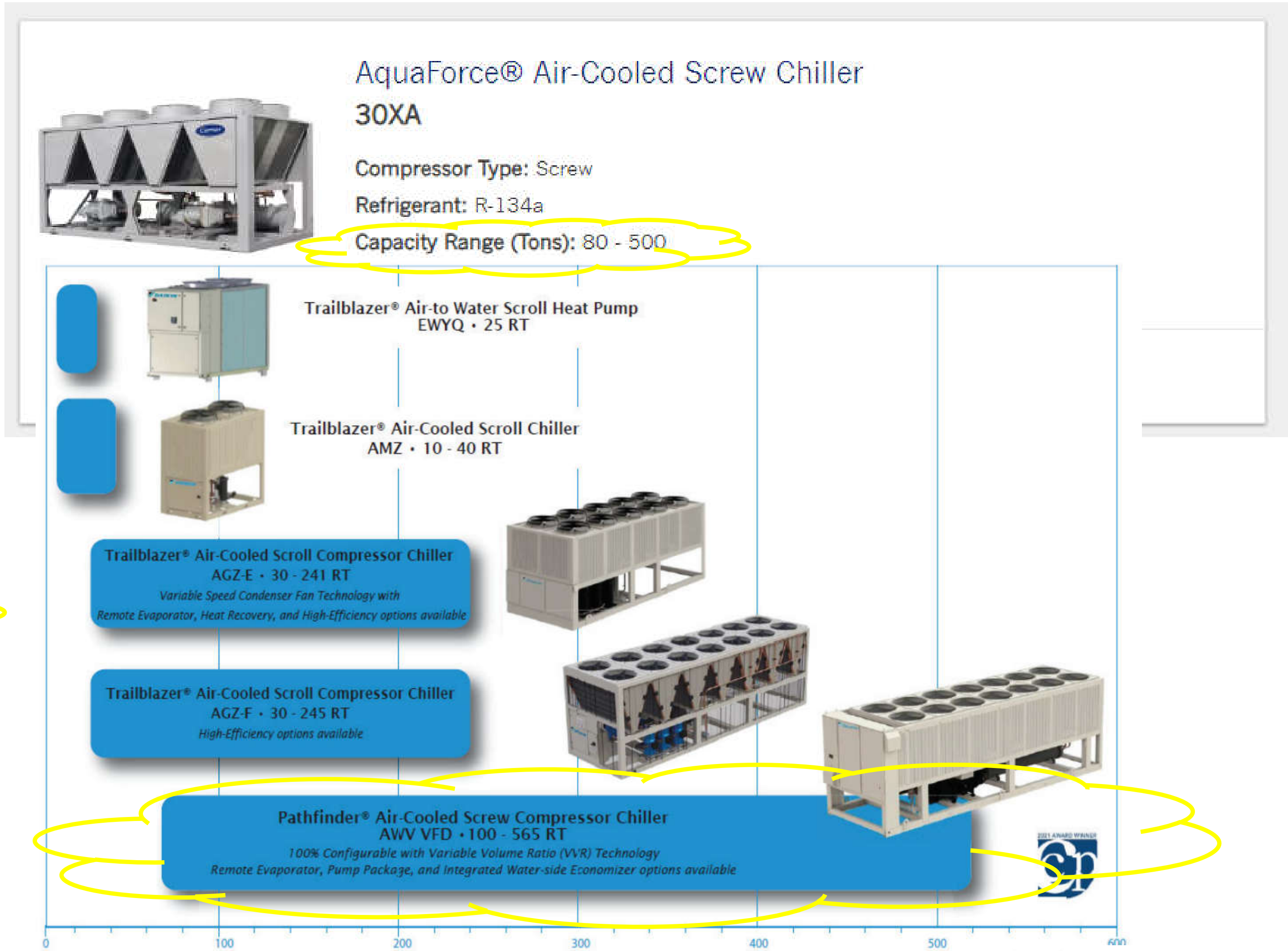
Air Cooled Chiller Size Ranges:

Sintesis® Air-Cooled Chillers

At a Glance:

- Capacity Range: 115 to 520 tons
- Refrigerant: R-134a or R-513A
- Compressor Design: Helical rotary screw
- Energy Efficiency Rating (EER): IPLV: 16.0-18.0 (high-efficiency)



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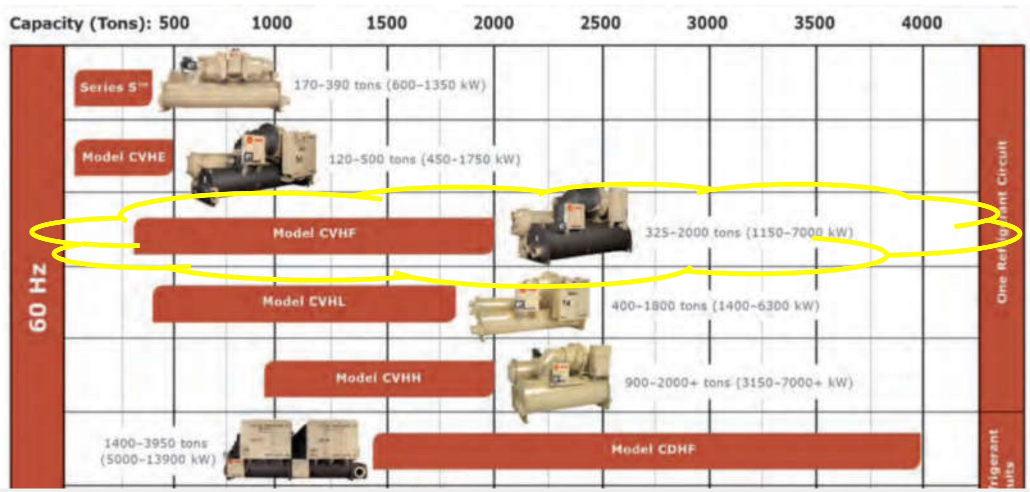
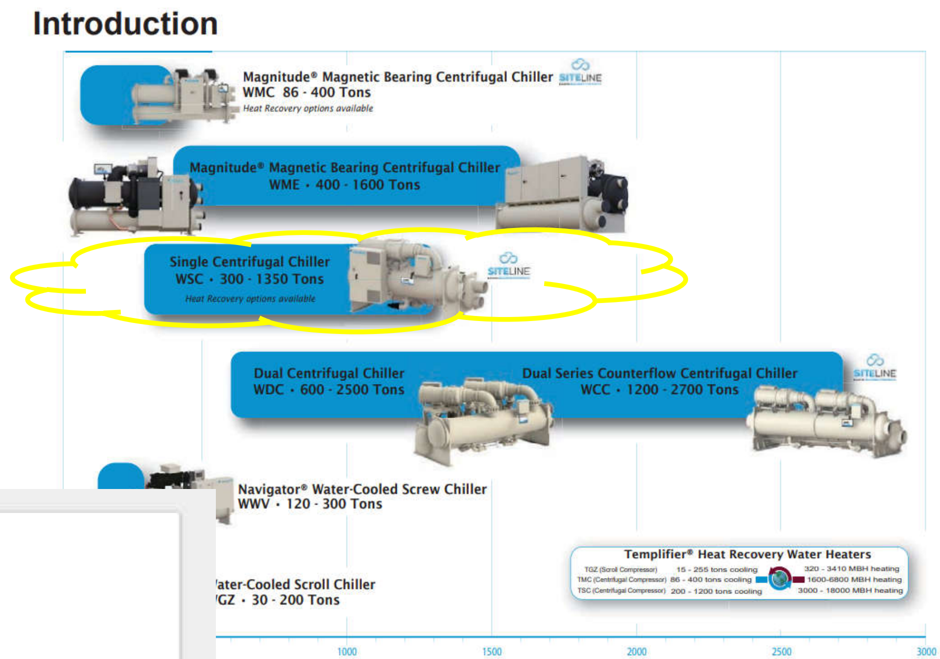
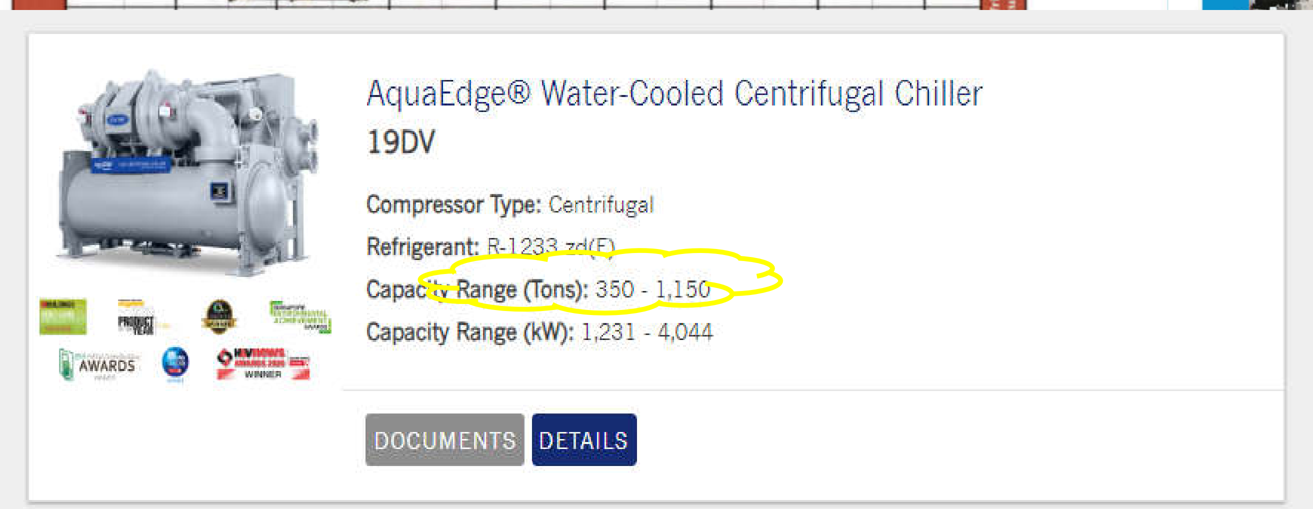
Water Cooled Chiller Size Ranges:







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