This presentation is being brought to you by:

Rocky Mountain ASHRAE Chapter

and

McNevin Company
Aurora, CO

Waterside Economizer

Presented by:
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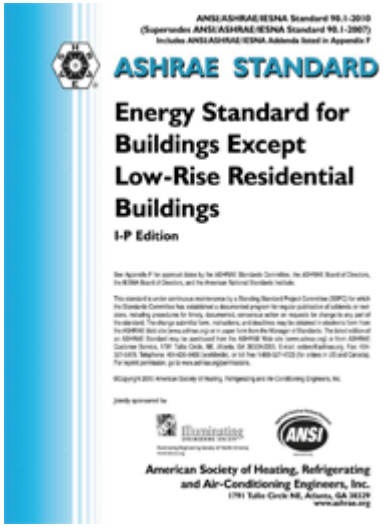
Bell & Gossett

Economizers – Goal/Definitions



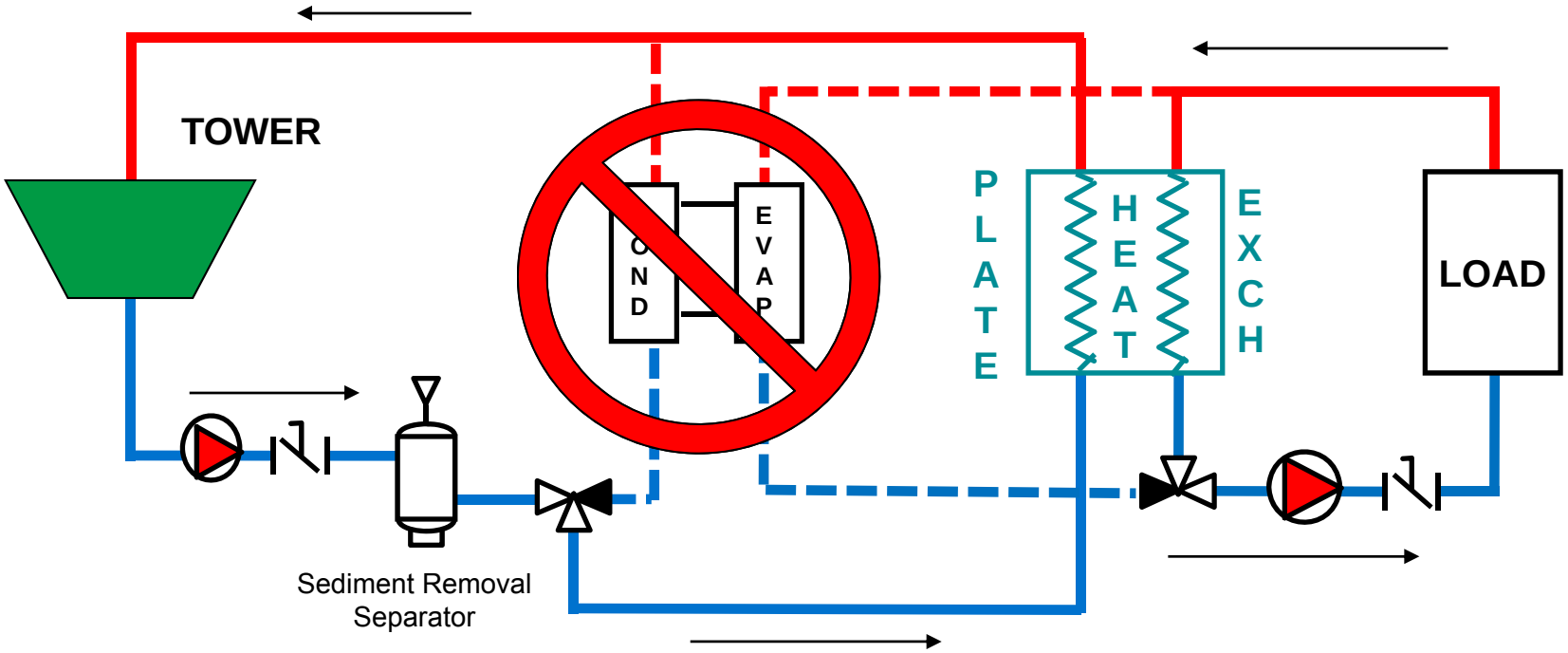
- Mechanical devices intended to reduce energy consumption or to perform another useful function such as precooling a fluid.

- Airside economizers – use cool outside air directly as a means of cooling the indoor space.

- Waterside economizers – use cooled water indirectly as a means of cooling the indoor space.

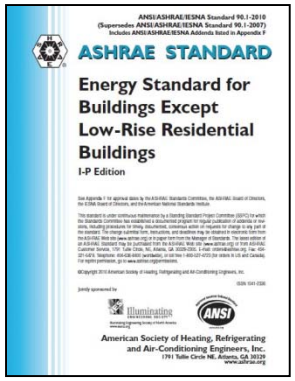
- Numerous design variations of waterside economizers – typically they utilize a cooling tower and heat exchanger to indirectly cool the chilled water loop, which is used to reject heat from the building via the hydronic coils.

Waterside Economizer – Example



Single Tower/P&F HX, Winter Cycle (Chiller off)

ASHRAE Standard 90.1-2010
CHAPTER 6
HEATING, VENTILATING, AND AIR CONDITIONING



MINIMUM SYSTEM SIZE FOR WHICH ECONOMIZER IS REQUIRED

6.5 Prescriptive Path

6.5.1 Economizers. Each cooling system that has a fan shall include either an **air or water economizer** meeting the requirements of Sections 6.5.1.1 through 6.5.1.4.

Exceptions: Economizers are not required for the systems listed below.

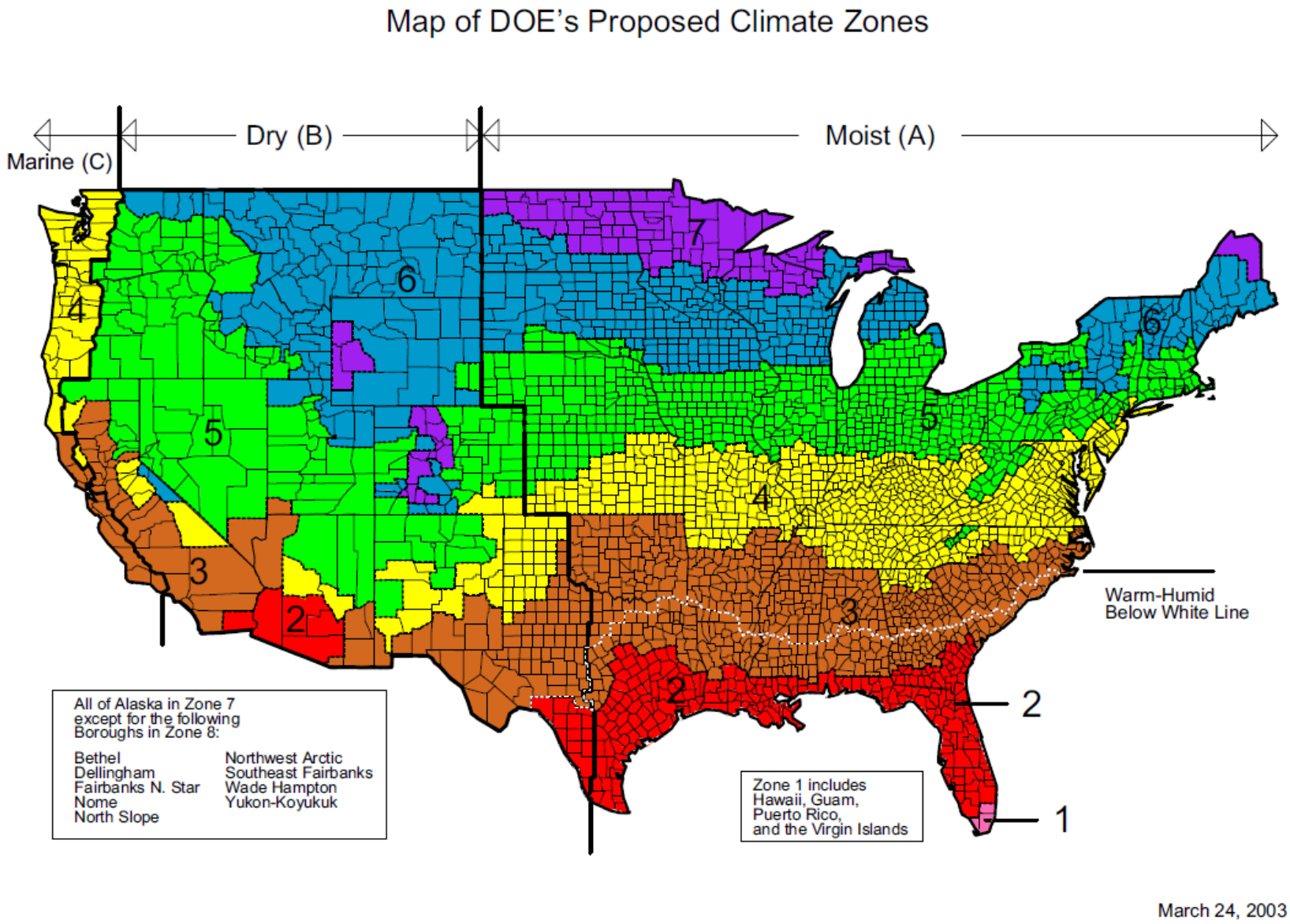
TABLE 6.5.1A Minimum Fan-Cooling Unit Size for Which an Economizer is Required for Comfort Cooling

Climate Zones	Cooling Capacity for Which an Economizer if Required
1a, 1b	**No economizer requirement**
2a, 2b, 3a, 4a, 5a, 6a 3b, 3c, 4b, 4c, 5b, 5c, 6b, 7, 8	≥54,000 Btu/h

TABLE 6.5.1B Minimum Fan-Cooling Unit Size for Which an Economizer is Required for Computer Rooms

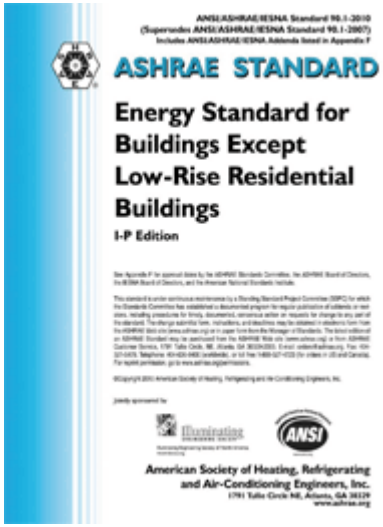
Climate Zones	Cooling Capacity for Which an Economizer if Required
1a, 1b, 2a, 3a, 4a	No economizer requirement
2b, 5a, 6a, 7, 8	≥135,000 Btu/h
3b, 3c, 4b, 4c, 5b, 5c, 6b	≥65,000 Btu/h

ASHRAE 90.1-2010



Denver is in Climate Zone 5B

Economizers
– Other Notable Exceptions



d) *Systems* that include a condenser heat recovery *system* with a minimum capacity as defined in 6.5.6.2.2a *(60% of the peak heat rejection load at design conditions)* or 6.5.6.2.2b *(preheat the peak service hot water draw to 85°F)*.

e) *Systems* that serve *residential spaces* where the *system* capacity is less than five times the requirement listed in Table 6.5.1A. *(54,000 x 5 = 270,000 BTUH or 22.5 Tons)*

g) *Systems* expected to operate less than 20 hours per week.
(For example: places of worship.)

i) For comfort cooling where the cooling *efficiency* meets or exceeds the *efficiency* improvement requirements in Table 6.3.2.
(Climate zone 5B – requires a 59% improvement.)

ASHRAE Standard 90.1-2010
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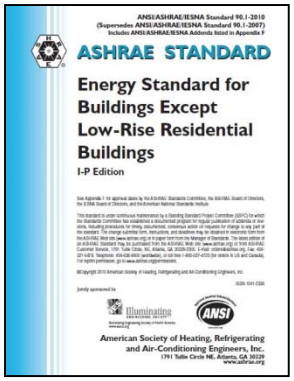


6.5 Prescriptive Path

6.5.1.2 Water Economizers

6.5.1.2.1 Design Capacity. Water economizer systems shall be capable of cooling supply air by indirect evaporation and providing up to **100% of the expected system cooling load at *outdoor air* temperatures of 50°F dry bulb/45°F wet bulb and below.**

Exceptions:

a. Systems primarily serving *computer rooms* in which 100% of the expected system cooling load at 40°F dry bulb / 35°F wet bulb is met with evaporative water economizers.

b. Systems primarily serving *computer rooms* with dry cooler water economizers which satisfy 100% of the expected system cooling load at 35°F dry bulb.

c. Systems where dehumidification requirements cannot be met using outdoor air temperatures of 50°F dry bulb/45°F wet bulb and where 100% of the expected system cooling load at 45°F dry bulb/40°F wet bulb is met with evaporative water economizers.

6.5.1.2.2 Maximum Pressure Drop. Precooling coils and water-to-water heat exchangers used as part of a water economizer system shall either have a **water-side pressure drop of less that 15 ft of water or a secondary loop shall be created** so that the coil or heat exchanger pressure drop is not seen by the circulating pumps when the system is in the normal cooling (noneconomizer) mode.

6.5.1.3 Integrated Economizer Control. Economizer *systems* **shall be integrated with the *mechanical cooling system*** and be **capable of providing partial cooling** even when additional *mechanical cooling* is required to meet the remainder of the cooling load.

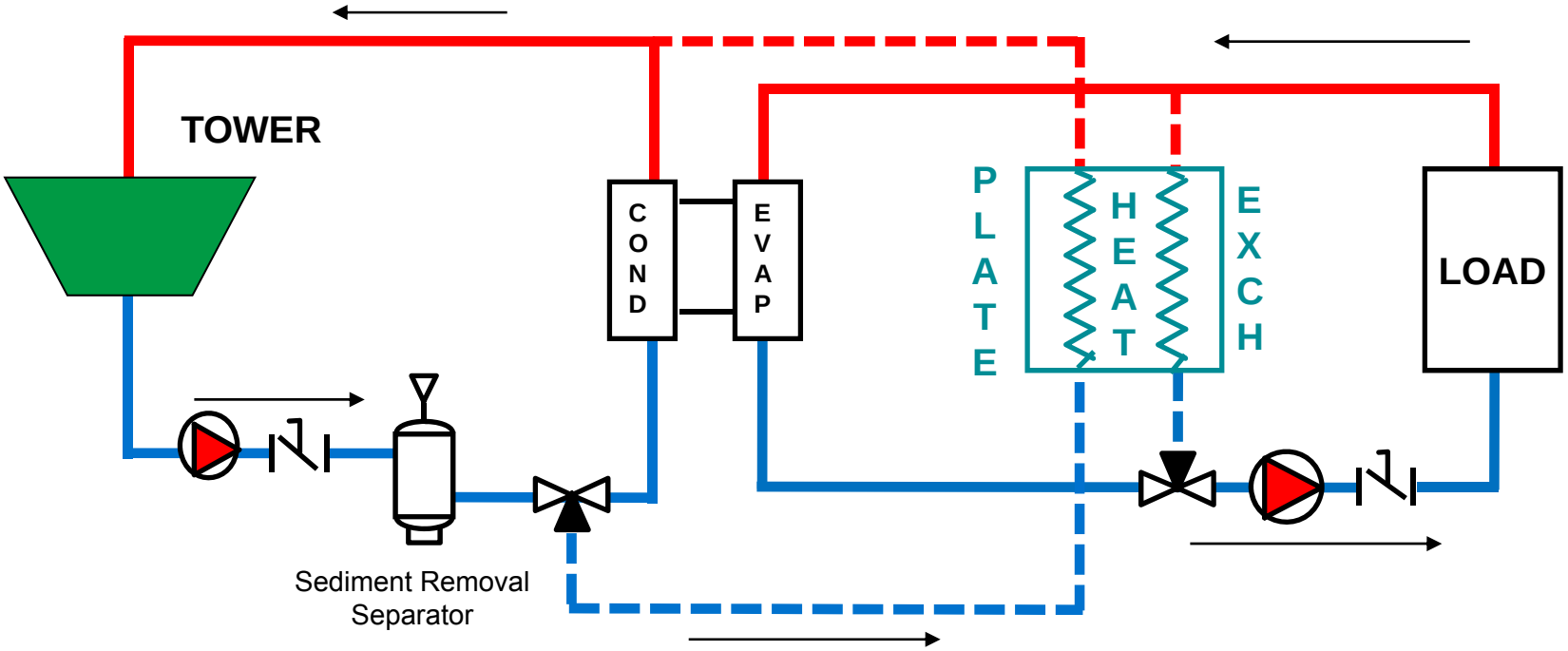
Economizer System Design Alternatives

- Cooling Tower and Heat Exchanger
  - Single Cooling Tower
  - Winter & Summer Cooling Towers
  - Winter/Summer & Summer Cooling Towers
- Closed Circuit Cooling Tower
  - Single Closed Circuit Cooling Tower
  - Winter Closed Circuit & Summer Cooling Towers
  - Winter/Summer Closed Circuit & Summer Cooling Towers
- Refrigerant Migration in Chiller (Off)
  - Cooling Tower
  - Closed Circuit Cooling Tower
- Non-Integrated Economizer Designs
  - Cannot Operate with Chiller
- Integrated Economizer Designs
  - Can Operate with or without Chiller

Economizer System Design Alternative

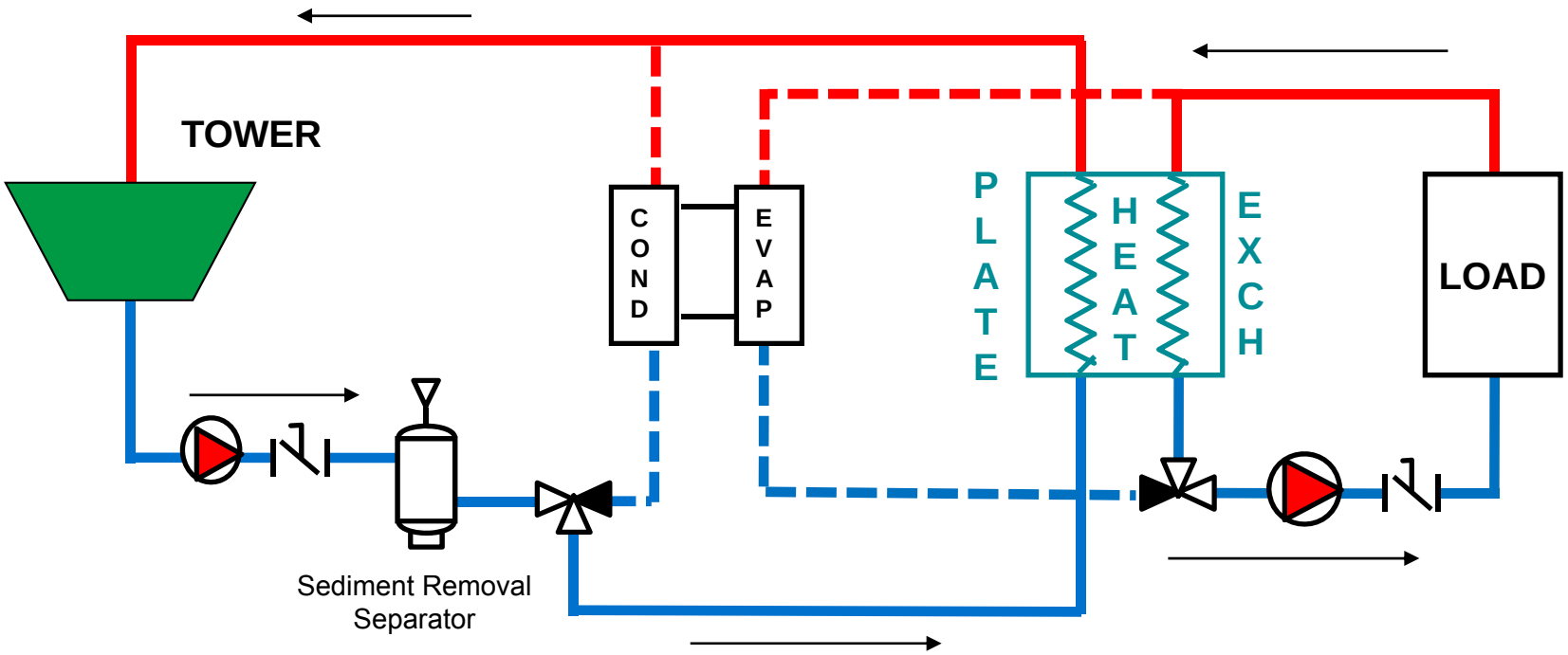
- Cooling Tower and Heat Exchanger
  - Single Cooling Tower
    - Sized for 100% of Summer Load
  - Non-Integrated Economizer
    - Does not meet Standard Requirement – Prescriptive Path
    - May meet Standard Requirement – Energy Cost Budget Method
  - Design Considerations
    - Freeze Protection Required
    - May Encounter Tower Operational Issues in Economizer Mode
      - Reduced Loads and Flows
      - Dry Areas in Fill Increase Ice Formation

Single Cooling Tower & Plate & Frame HX
Summer Cycle – Chiller On



Non-Integrated Design – Exception: ECB Method

Single Cooling Tower and Plate & Frame HX
Winter Cycle – Chiller Off – Economizer



Non-Integrated Design – Exception: ECB Method

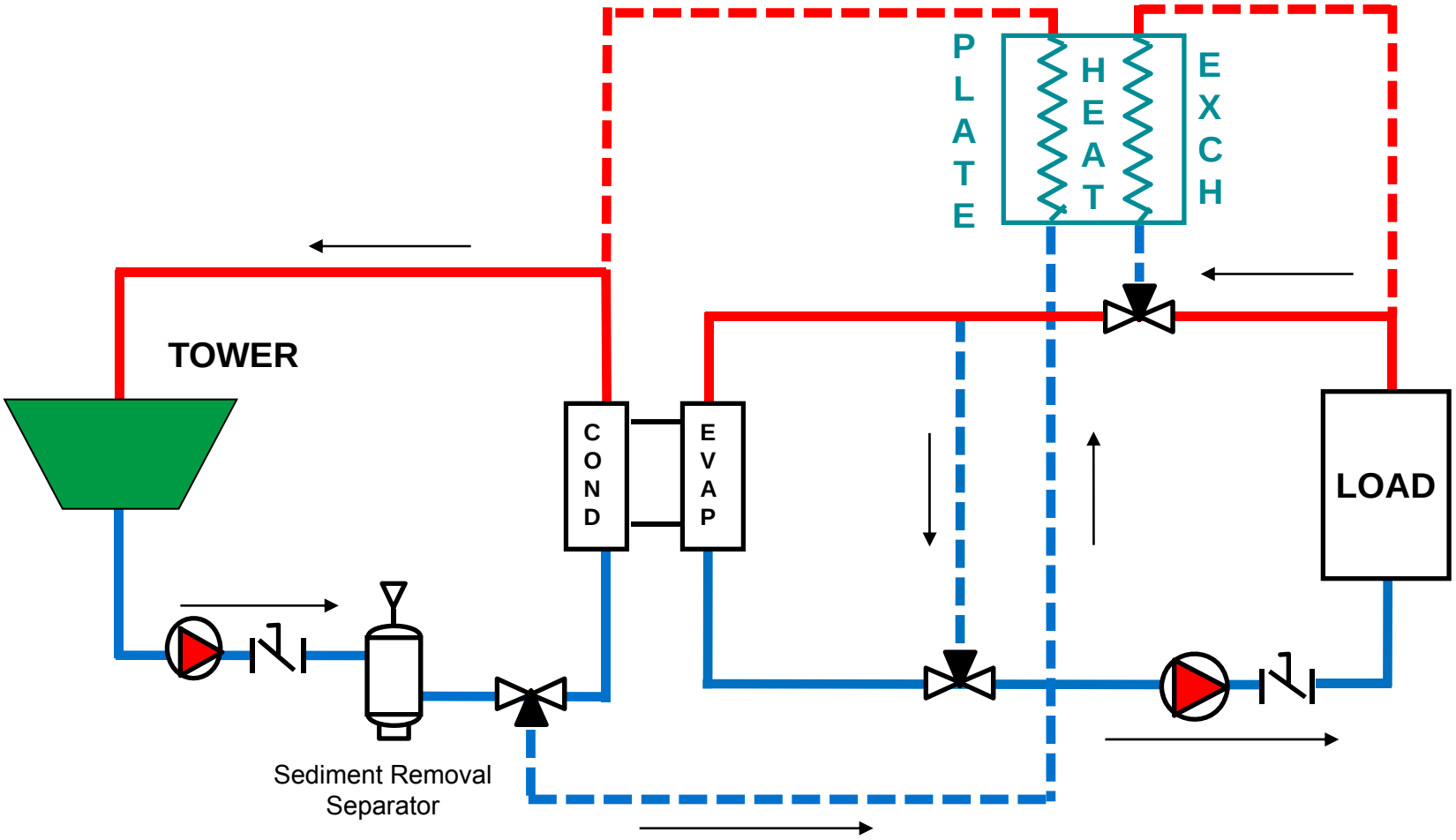
Economizer System Design Alternative

- Cooling Tower and Heat Exchanger
  - Single Cooling Tower
    - Sized for 100% of Summer Load

  - Integrated Economizer
    - Meets Standard Requirement – Prescriptive Path
    - Can Reduce Chiller Load as Outside Temps Drop
    - Need Head Pressure Control (Valves) to keep ECWT about 65°F

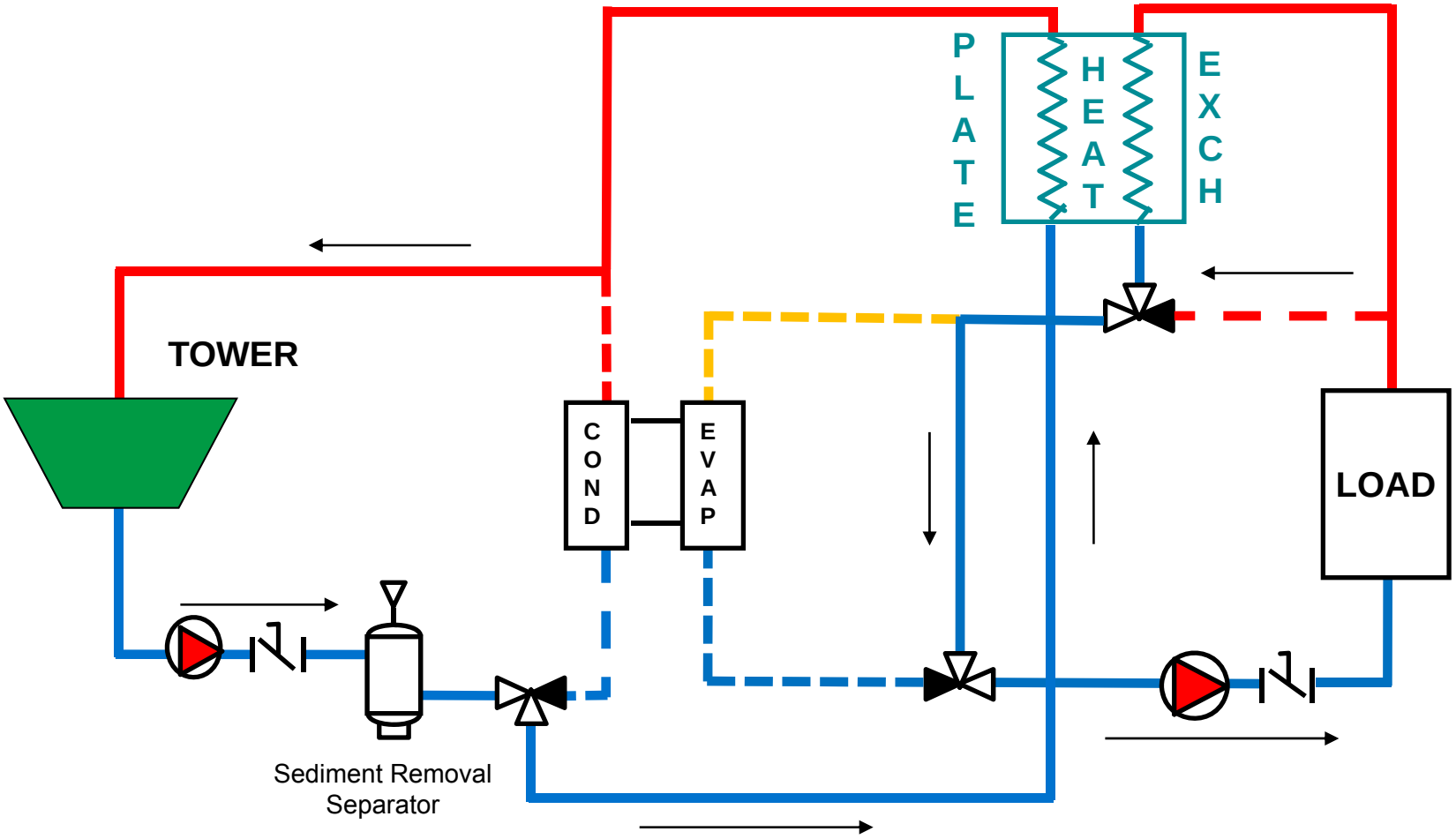
  - Design Considerations
    - Freeze Protection Required
    - May Encounter Tower Operational Issues in Economizer Mode
      - Reduced Loads and Flows
      - Dry Areas in Fill Increase Ice Formation
    - LTW Temp may be too low for Condenser in Load Shaving Mode
      - Use warmer water coming out of P&F HX

Single Cooling Tower & Plate & Frame HX
Summer Cycle – Chiller On



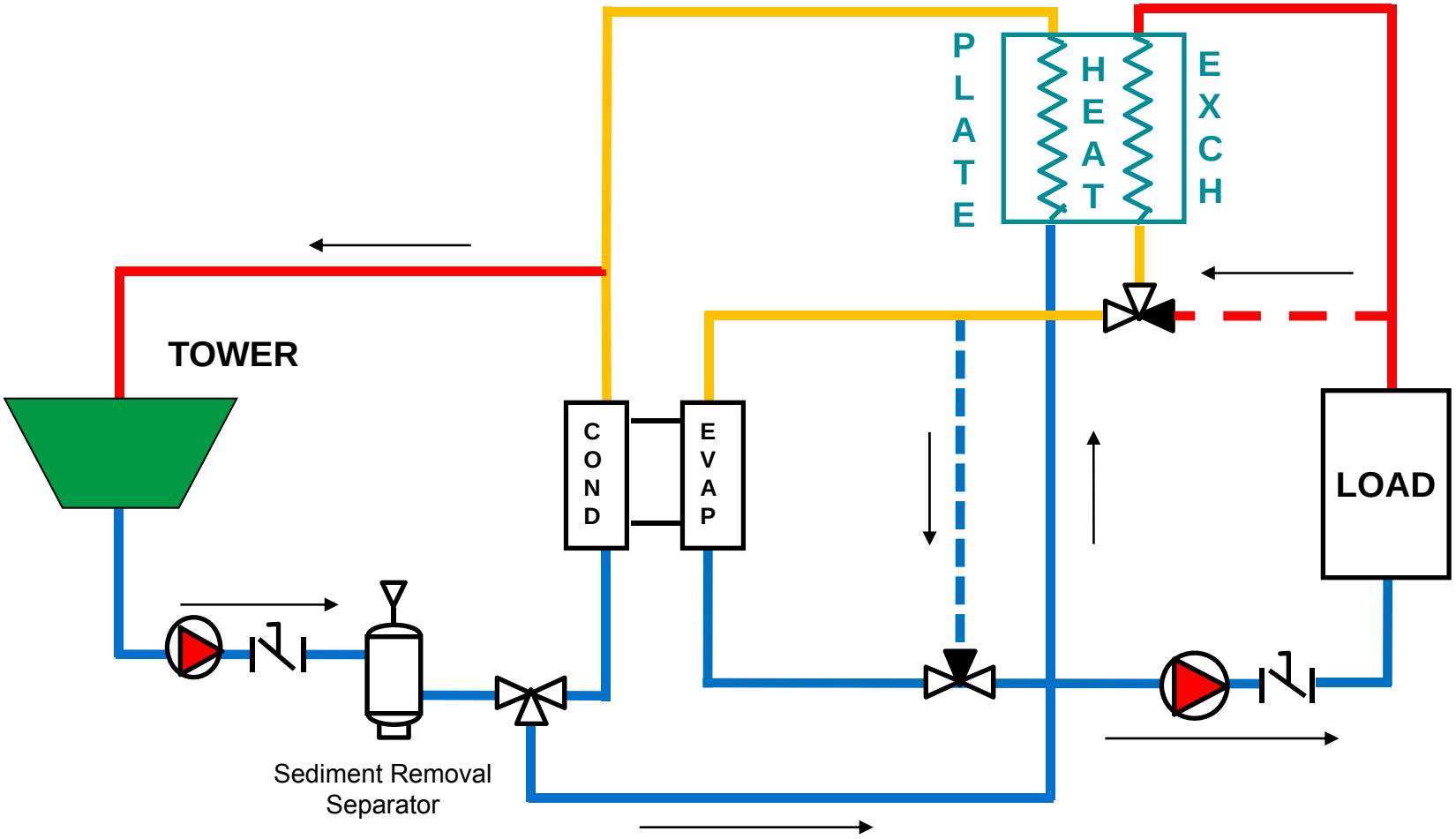
Integrated Design

Single Cooling Tower & Plate & Frame HX
Winter Cycle – Chiller Off – Economizer



Integrated Design

Single Cooling Tower & Plate & Frame HX
Summer Cycle – Chiller On – Load Shaving

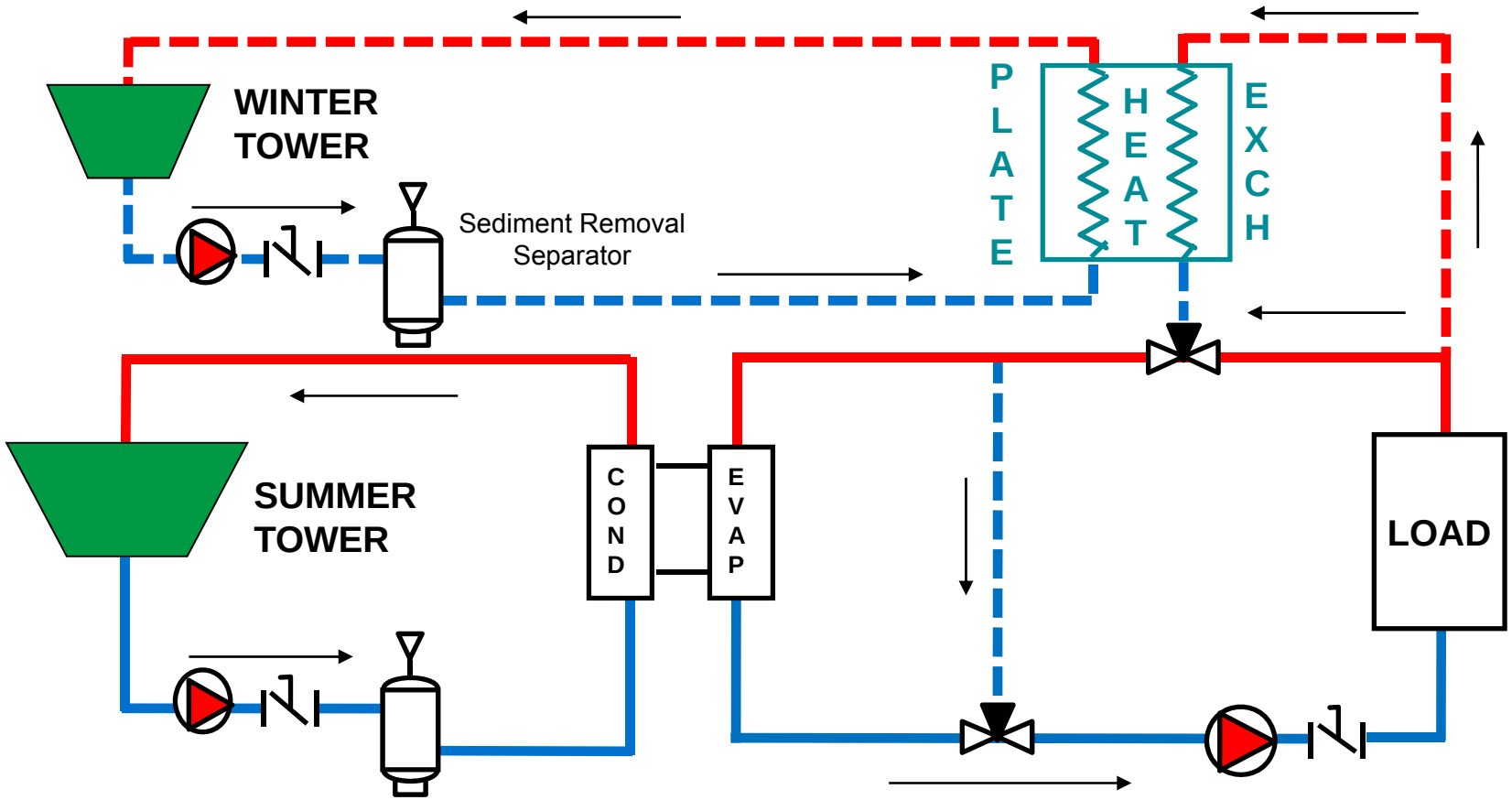


Integrated Design

Economizer System Design Alternative

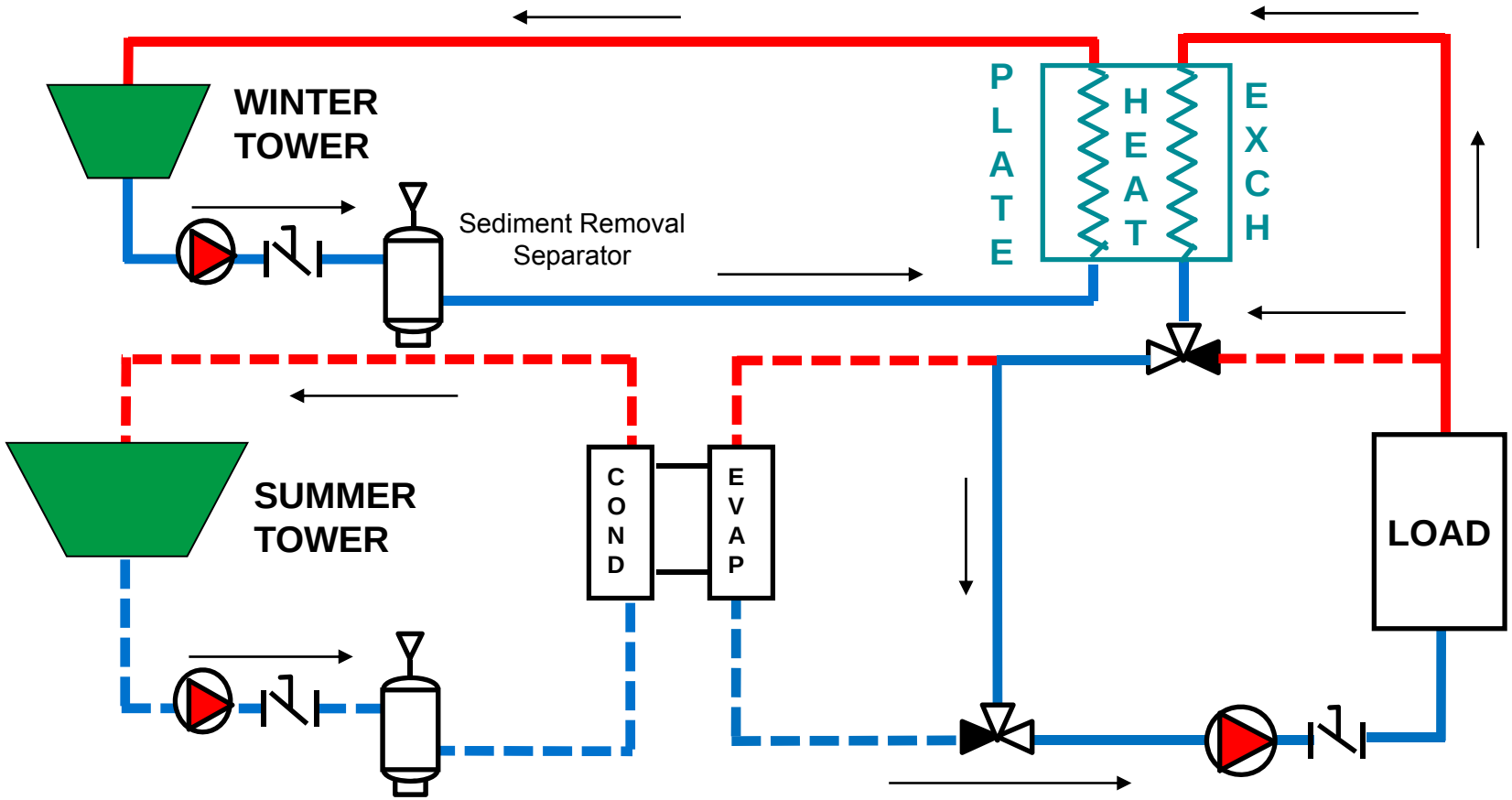
- Cooling Tower and Heat Exchanger
  - Two Cooling Towers
    - One Tower Sized for 100% of Summer Load
    - One Tower Sized for 100% of Winter Load
  - Integrated Economizer
    - Meets Standard Requirement – Prescriptive Path
    - Can Reduce Chiller Load as Outside Temps Drop
    - Need Head Pressure Control (Valves) to keep ECWT about 65°F
  - Design Considerations
    - Lowest Energy Usage – Towers Optimally Sized to Relative Loads
    - Run Only Summer Tower in Summer Mode
      - Drain During Winter
    - Run Only Winter Tower in Economizer Mode
      - Freeze Protection Required
    - Run Both Towers when Load Shaving

Two Cooling Towers & Plate & Frame HX Summer Cycle – Chiller On



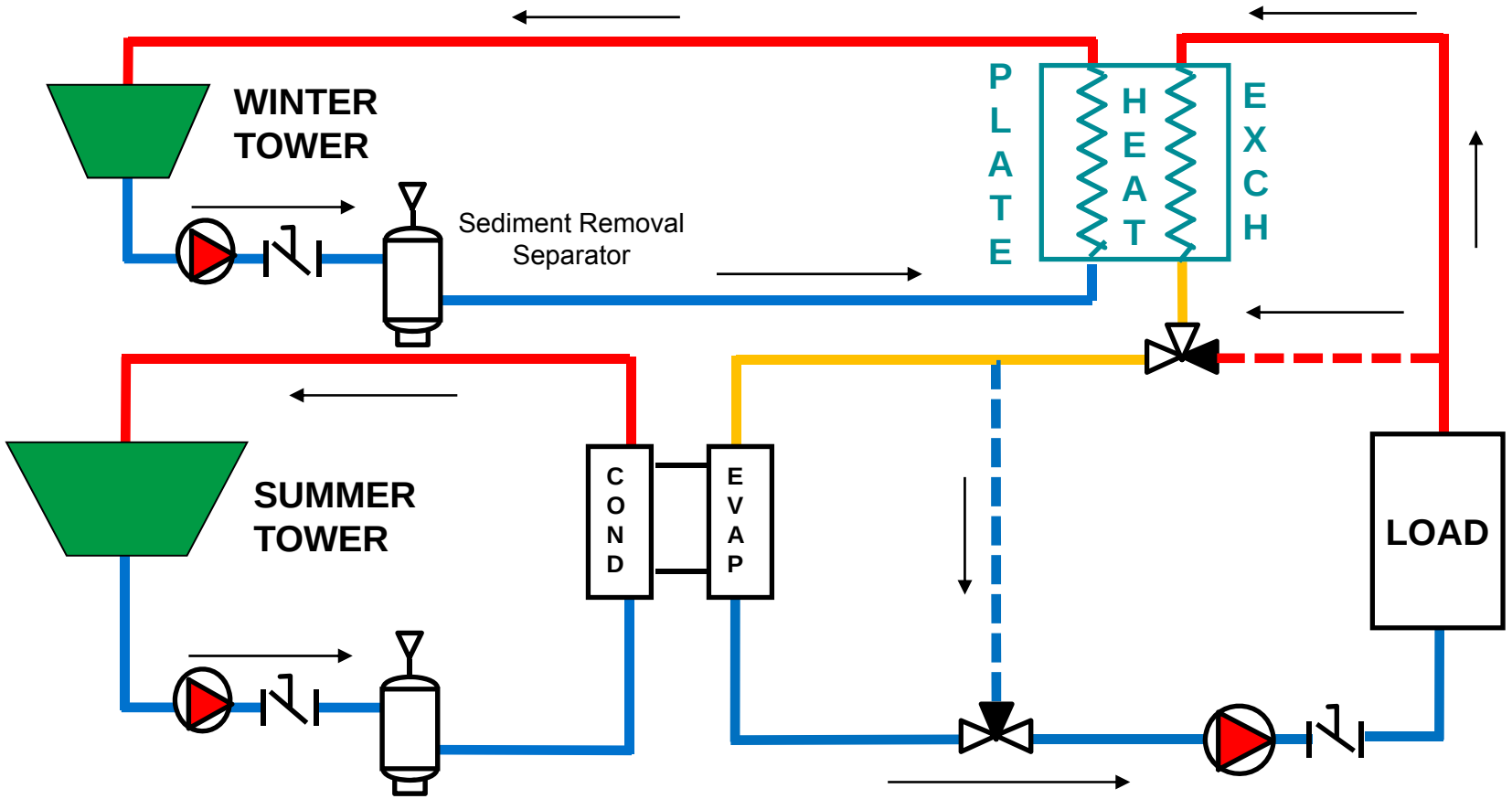
Integrated Design

Two Cooling Towers & Plate & Frame HX
Winter Cycle – Chiller Off – Economizer



Integrated Design

Two Cooling Towers & Plate & Frame HX
Summer Cycle – Chiller On – Load Shaving



Integrated Design

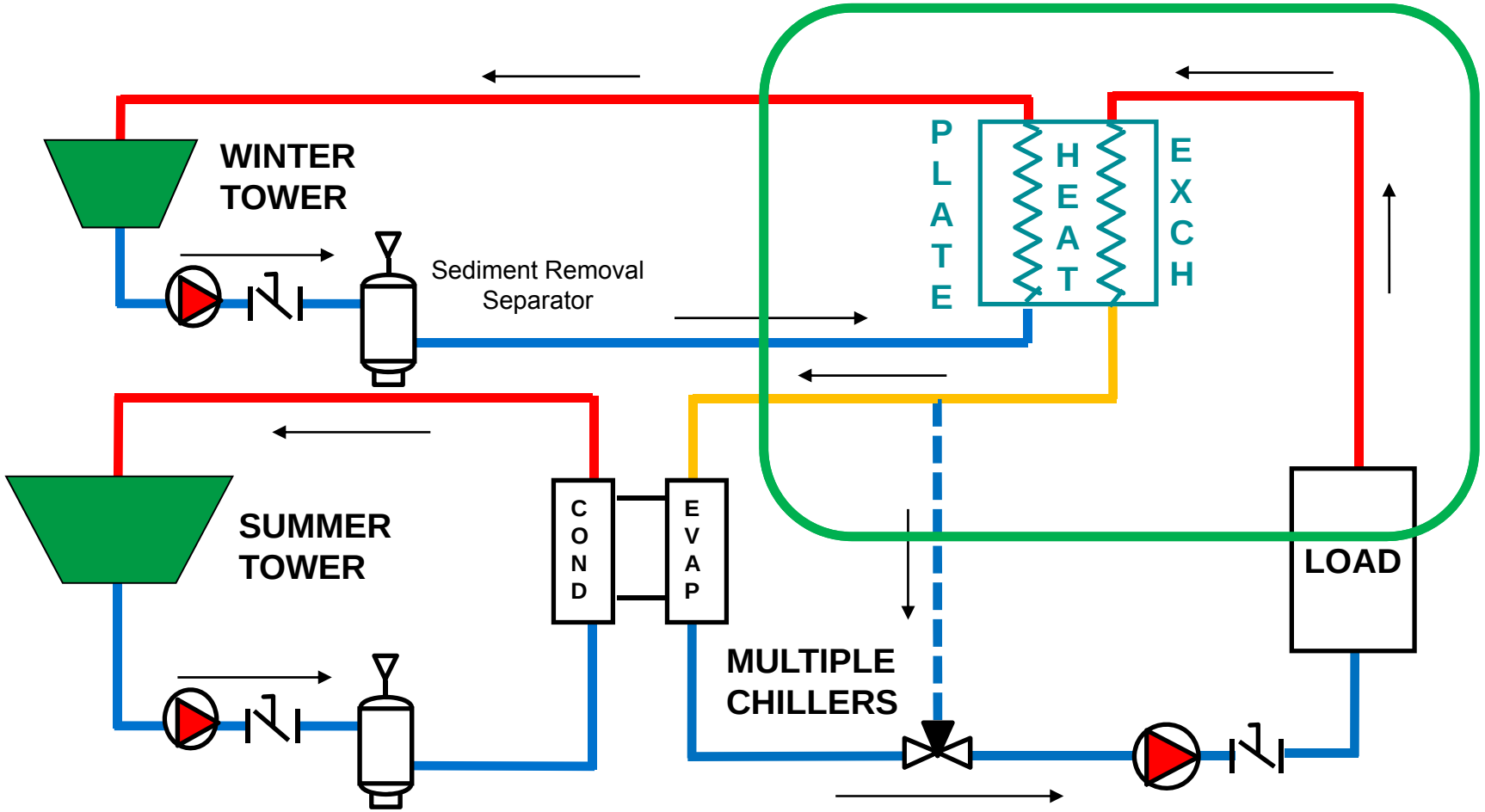
Alternative Piping Designs

- Multiple Chiller/Tower Installation
- Single Plate & Frame Heat Exchanger

- Install HX in Main (Shared Piping)
  - Low Pressure Drop (<15')
  - Can be Installed in Series With CWS and CHWR

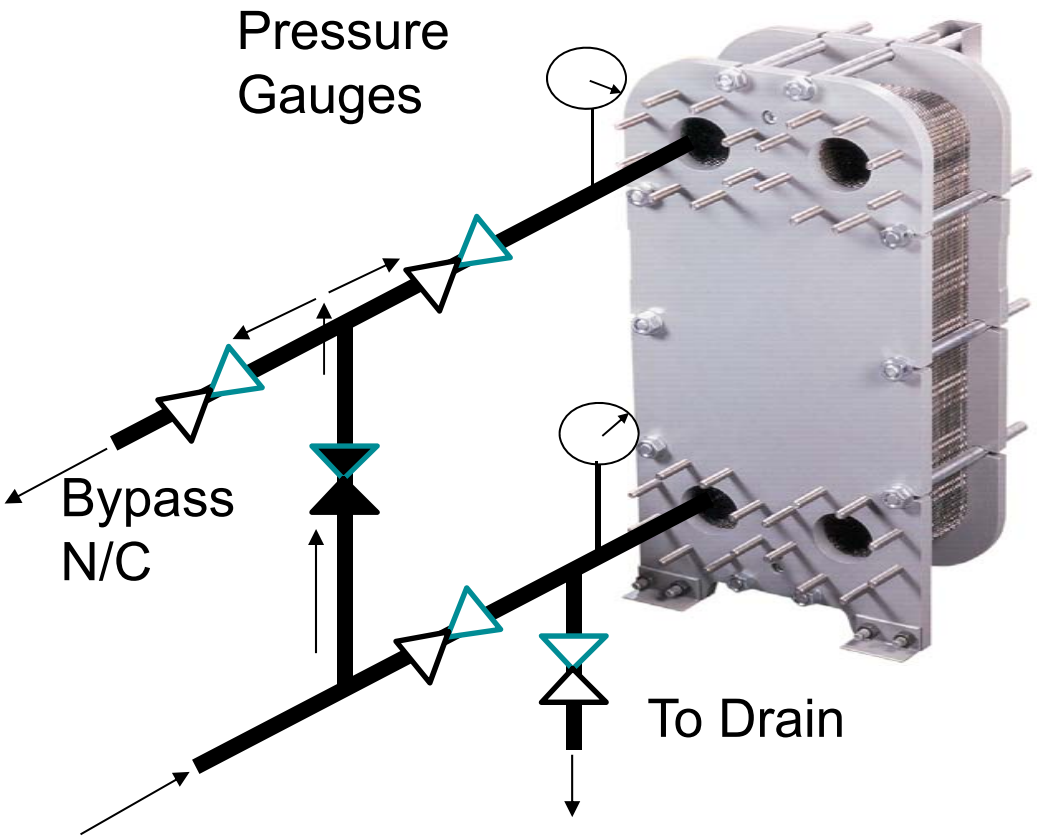
  - High Pressure Drop (≥15')
  - Must be Installed in a Separate Loop
  - Serviced by a Separate Pump

Two Cooling Towers & Plate & Frame HX
Summer Cycle – Chiller On – Load Shaving

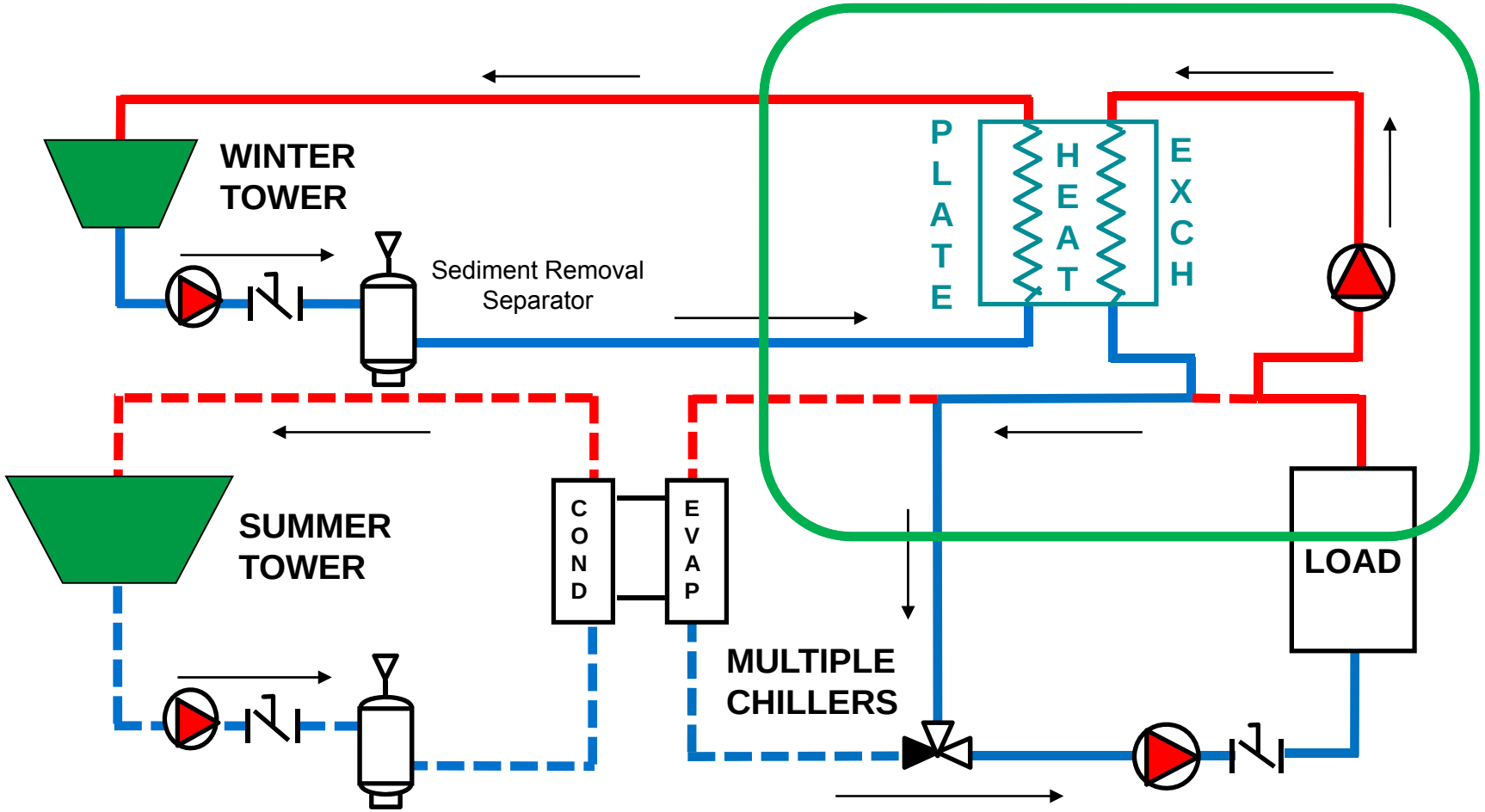


Integrated Design – Low PD HX – In Series

Bypass Flush Line



Two Cooling Towers & Plate & Frame HX
Winter Cycle – Chiller Off – Economizer

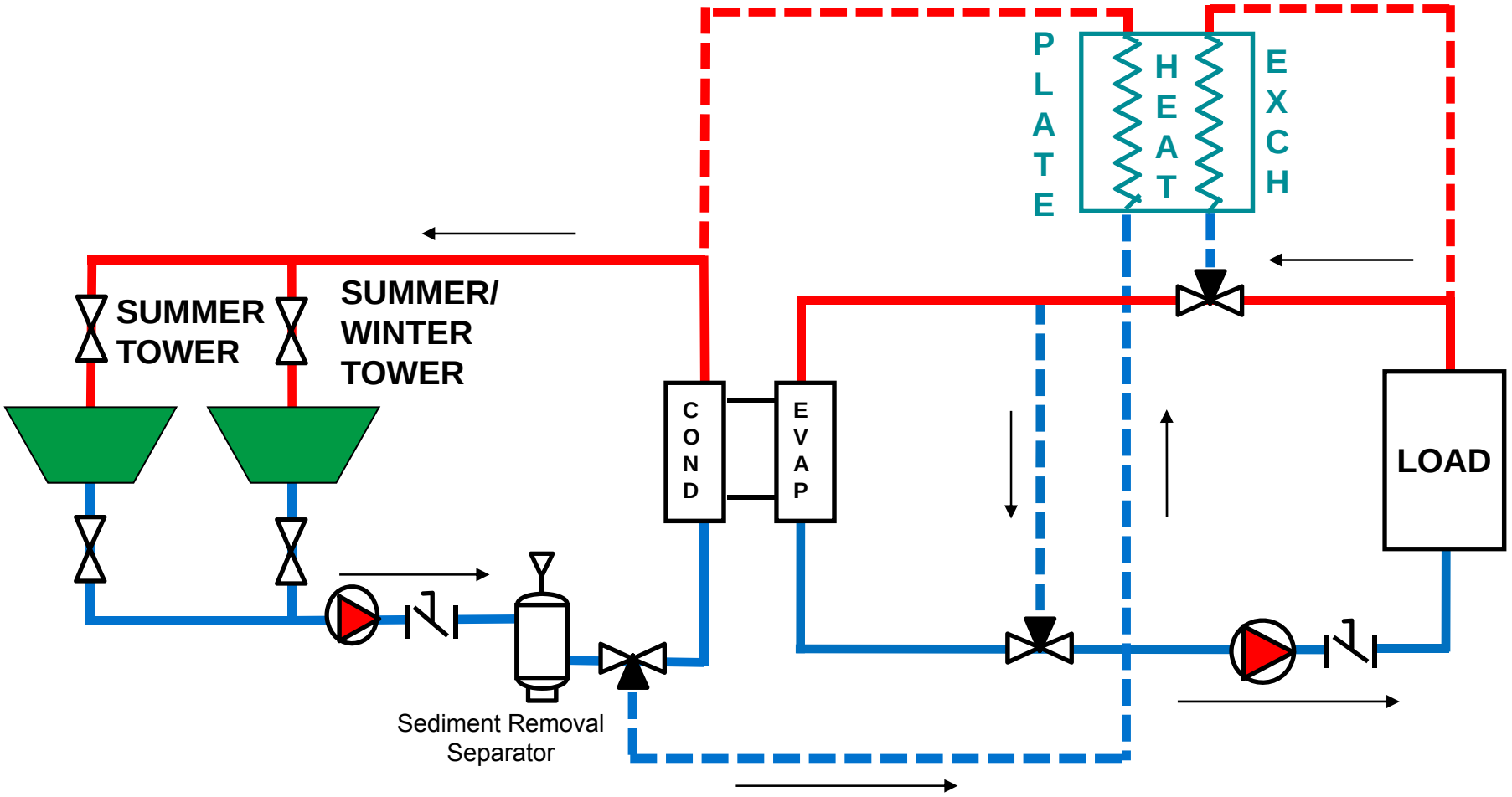


Integrated Design – High PD HX – Separate Loop

Economizer System Design Alternative

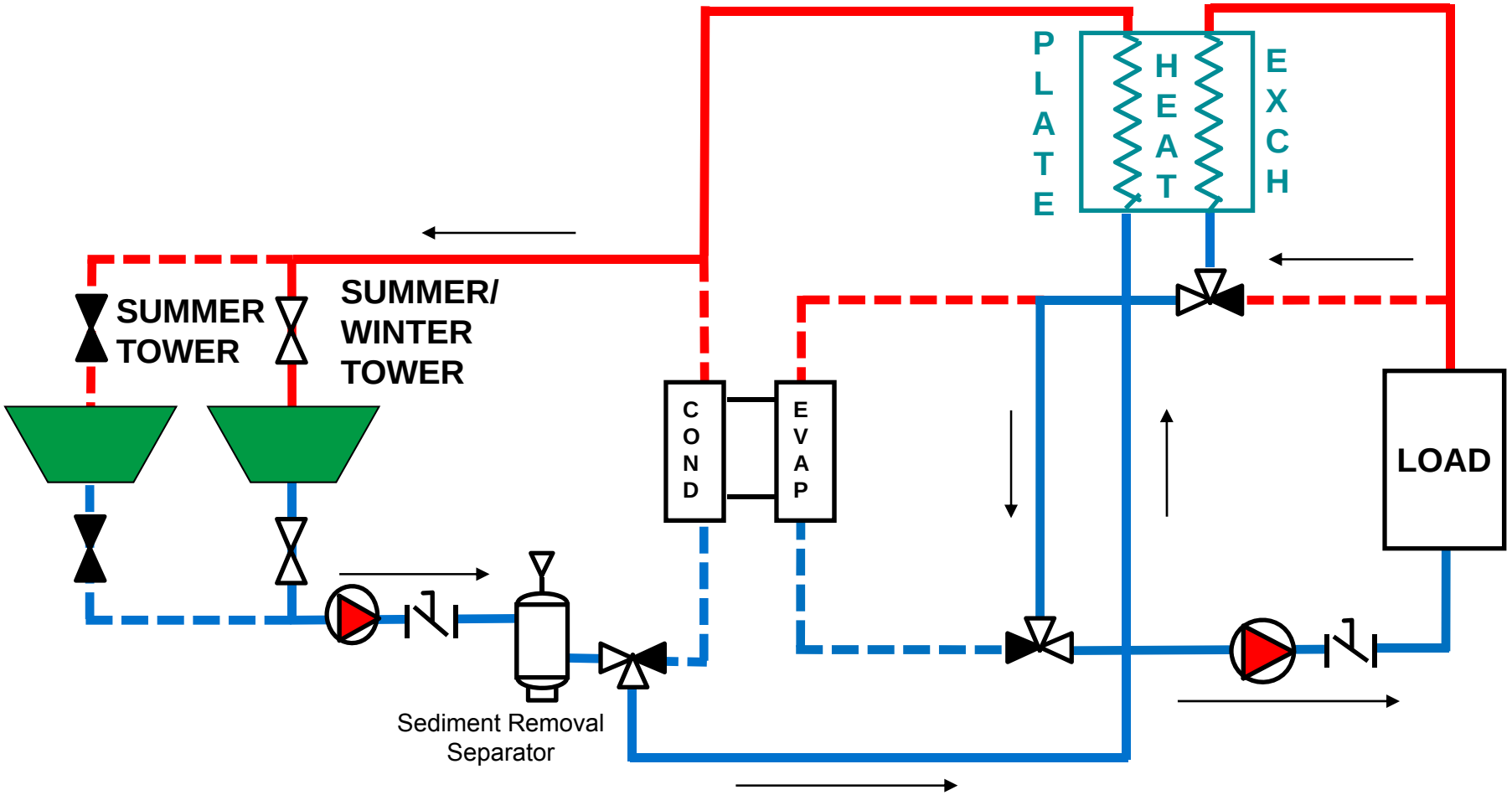
- Cooling Tower and Heat Exchanger
  - Two Identical Cooling Towers
    - Each Tower Sized for 50% of Summer Load
    - Winter Load is less than 50% of Summer Load
  - Integrated Economizer
    - Meets Standard Requirement – Prescriptive Path
    - Can Reduce Chiller Load as Outside Temps Drop
    - Need Head Pressure Control (Valves) to keep ECWT about 65°F
  - Design Considerations
    - Lower first cost alternative
    - Run Both Towers in Summer Mode
      - Drain One Tower During Winter
    - Run Only Winter Tower in Economizer Mode
      - Freeze Protection Required
    - Run One or Two Towers when Load Shaving

2 Identical Cooling Towers & Plate & Frame HX
Summer Cycle – Chiller On



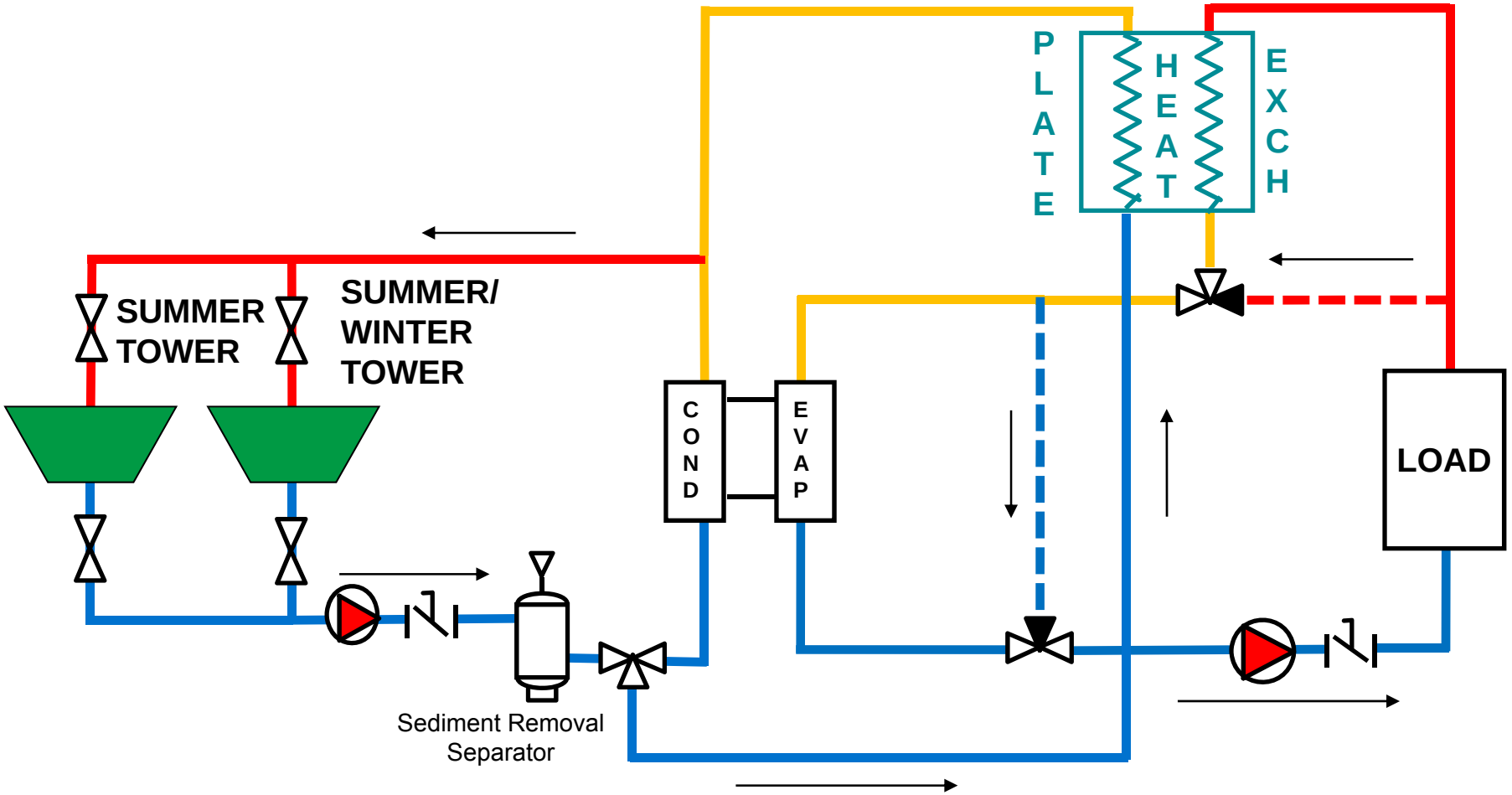
Integrated Design

2 Identical Cooling Towers & Plate & Frame HX
Winter Cycle – Chiller Off – Economizer



Integrated Design

2 Identical Cooling Towers & Plate & Frame HX
Summer Cycle – Chiller On – Load Shaving



Integrated Design

Economizer Design Requirements and Equipment Sizing Considerations

ASHRAE Standard:

- Satisfy entire design cooling load at outdoor air at 50°F DB 45°F WB.
- Use design model loads with these outdoor conditions to size system.
- External Load will be Reduced Due to Lower Outside Air Temp.
- Internal Load will be Reduced Due to Lower Enthalpy of Ventilation Air.

Minimal or no dehumidification is required during cool weather, so CHWS water temps can be higher than during the summer.

- Extends the number of hours the economizer can be in operation.
- Typical Winter *Chilled Water* Supply & Return temps are 50°F & 55°F

Lower leaving water temp requires a larger tower and increases the possibility for icing.

- Cooling tower practical minimum leaving water temp is 42°F
- Closed circuit cooling tower practical minimum leaving water temp is 45°F

Cooling Tower Sizing

- Depends Upon:
  - Load
  - Range
  - Leaving Water Temp
  - Ambient Wet-bulb Temp

- If Winter Load is Significantly Less than Summer Load, You May Not be Able to Use a Single Tower.
  - Use Multiple Towers or Multi-cell Units

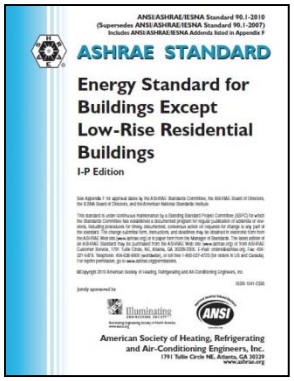
- Example:
  - Summer load is 400 tons and Winter load is 150 tons
  - Lower flow in winter results in scale build up, drift, freezing in the fill.
  - Install two 200 Ton towers, use only 1 in winter.

Cooling Tower Equipment Operation

- Reliability Depends Upon Following Criteria
  - Layout/Location
    - Avoid air recirculation – warm discharge air reintroduced into intakes can result in icing the air inlets
  - Capacity Control
    - Temperature – During subfreezing temps – use highest LWT
    - Fan Control – Reduce speed to keep LWT high
    - Water Flow Control – Avoid excessive or minimal flows
      - Subfreezing – Min 80% flow, fans on – 50% flow, fans off
  - Freeze Protection
    - Use basin heater or remote sump
    - Reverse fan operation – manual operation recommended
    - Insulate & heat trace for external piping
  - Routine Maintenance Program
    - Regular visual inspections
    - Carry out maintenance despite adverse weather conditions
    - Accurate water level control

CHAPTER 6
HEATING, VENTILATING, AND AIR CONDITIONING

SECTION 6.4
Mandatory Provisions



6.4.1.4 Verification of Equipment Efficiencies. Equipment *efficiency* information supplied by *manufacturers* shall be verified as follows: …

f. Requirements for plate type liquid-to-liquid heat exchangers are listed in Table 6.8.1H

TABLE 6.8.1H Heat Transfer Equipment

Equipment Type	Subcategory	Minimum Efficiency[a]	Test Procedure[b]
Liquid-to-Liquid heat exchangers	Plate type	NR	**AHRI 400 - 2001**

[a] NR = No requirement
[b] Section 12 contains a complete specification of the referenced test procedure, including the referenced year version of the test procedure.

AHRI Standard 400

Why are AHRI Standard 400 certified heat exchangers typically larger than those traditionally used for commercial HVAC applications.

- Prior to the development of ARI Standard 400 in 2001, many heat exchanger manufacturers and third party thermal design software companies design calculations were accurate to approx. +/- 15% on pressure drop and +/- 15% on heat transfer.

- Because many applications in commercial HVAC systems are designed with very close temperature approaches, AHRI developed testing requirements more stringent that those traditionally used.

  - Total Heat Transfer Rate > 95% of published
  - Tested Pressure Drop < 110% of published

- The tighter tolerance requirements requires more conservative heat transfer and pressure drop calculations.

AHRI Standard 400

- The AHRI Standard 400 allows for units to be certified for:

  2,000 GPM or less

  Or

  Less than 24,000,000 BTU/hr.

- Otherwise manufacturers must claim “Rated in accordance with AHRI Standard 400”.

AHRI 400-2001 Standard

EXAMPLE:

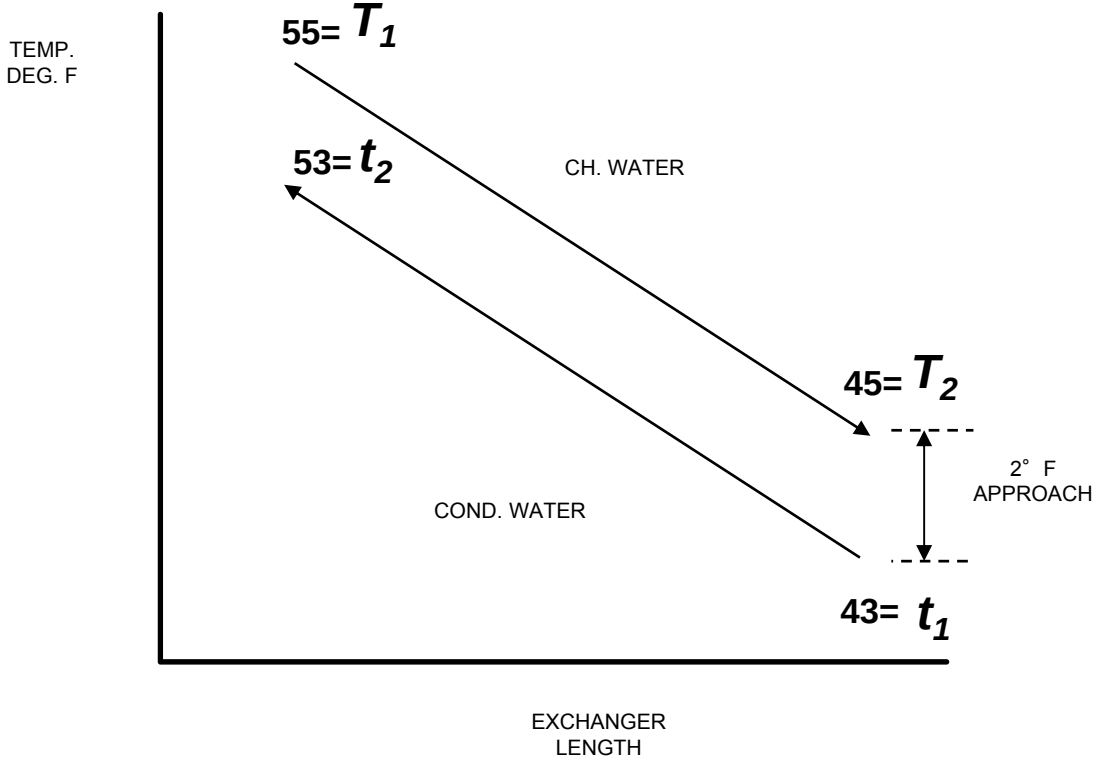


Plate & Frame Design Parameters

10ºF Delta T

2ºF Approach Temperature

LMTD = 2.0ºF

Heat Load: 5 Million btu/hr.

Heat Transfer Coefficient: 1200 btu/ft^2*h*f

Area = Q / (U*LMTD) = 2083 ft^2

AHRI 400-2001 Standard

Impact of tolerance of LMTD temperature alone on Heat Exchanger Area

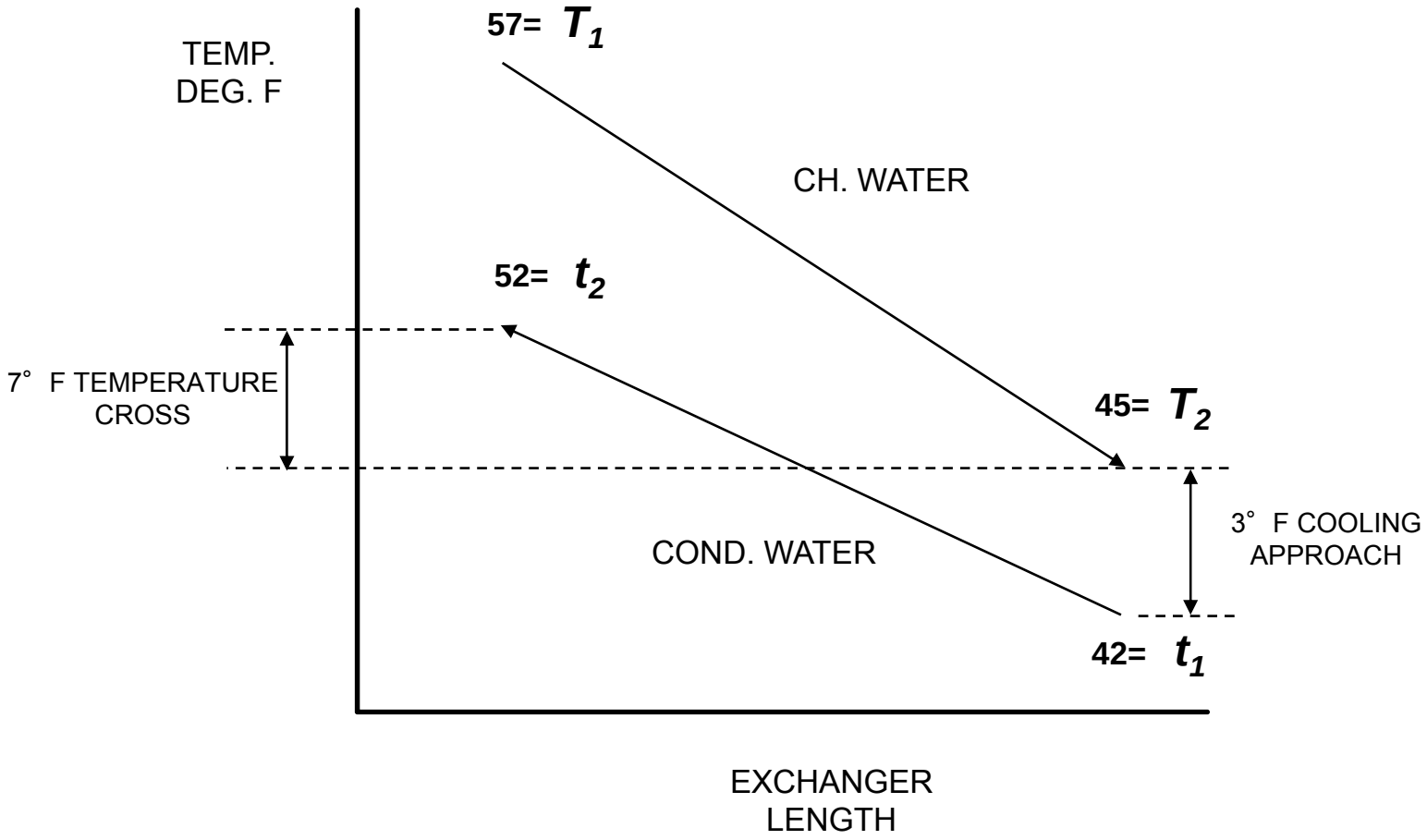
LMTD (degrees F)	Area Required (Ft^2)	Cost Index
2.0 (Design Criteria)	**2083.0**	**1.00**
2.2	1893.0	0.95
2.3	1812.0	0.93
2.5	1667.0	0.87

Results: Increase LMTD 0.2ºF, Lower cost 5%

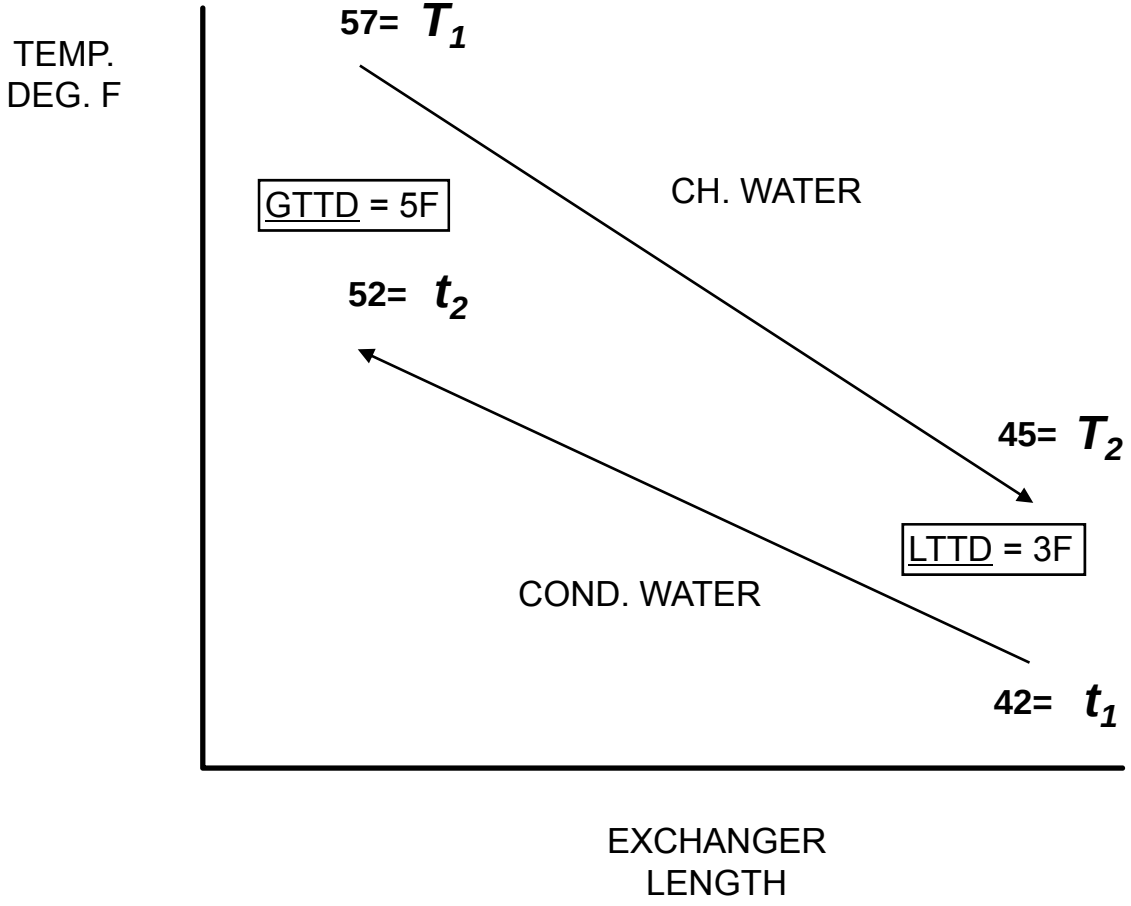
0.3ºF, Lower cost 7%

0.5ºF, Lower cost 13%

Temperature Cross and Approach



Range-LMTD Relationship



Q=UxAxLMTD

$$\text{LMTD} = \frac{\text{GTTD - LTTD}}{\ln \frac{\text{GTTD}}{\text{LTTD}}}$$

$$\text{AREA} = \frac{Q}{U \times \text{LMTD}}$$

Rule of Thumb – Optimal HX Size

$$\frac{\text{Range}}{\text{LMTD}} = 1.5 \text{ to } 2$$

Heat Transfer Area vs. Approach

CONDENSER WATER			CHILLER WATER			LMTD	AREA	APPROACH	COST
EWT	LWT	FLOW	EWT	LWT	FLOW	°F	SQ.FT.	°F	INDEX
42	52	1000	57	45	834	3.92	1390	3	1.00
42	52	1000	58	46	834	4.93	1135	4	0.85
42	52	1000	59	47	834	5.94	975	5	0.76

Temperature in °F, Flow in gpm,
Exchanger based on max pressure drop of 7 psi
10/3.92 = 2.55
10/4.93 = 2.03
10/5.94 = 1.69

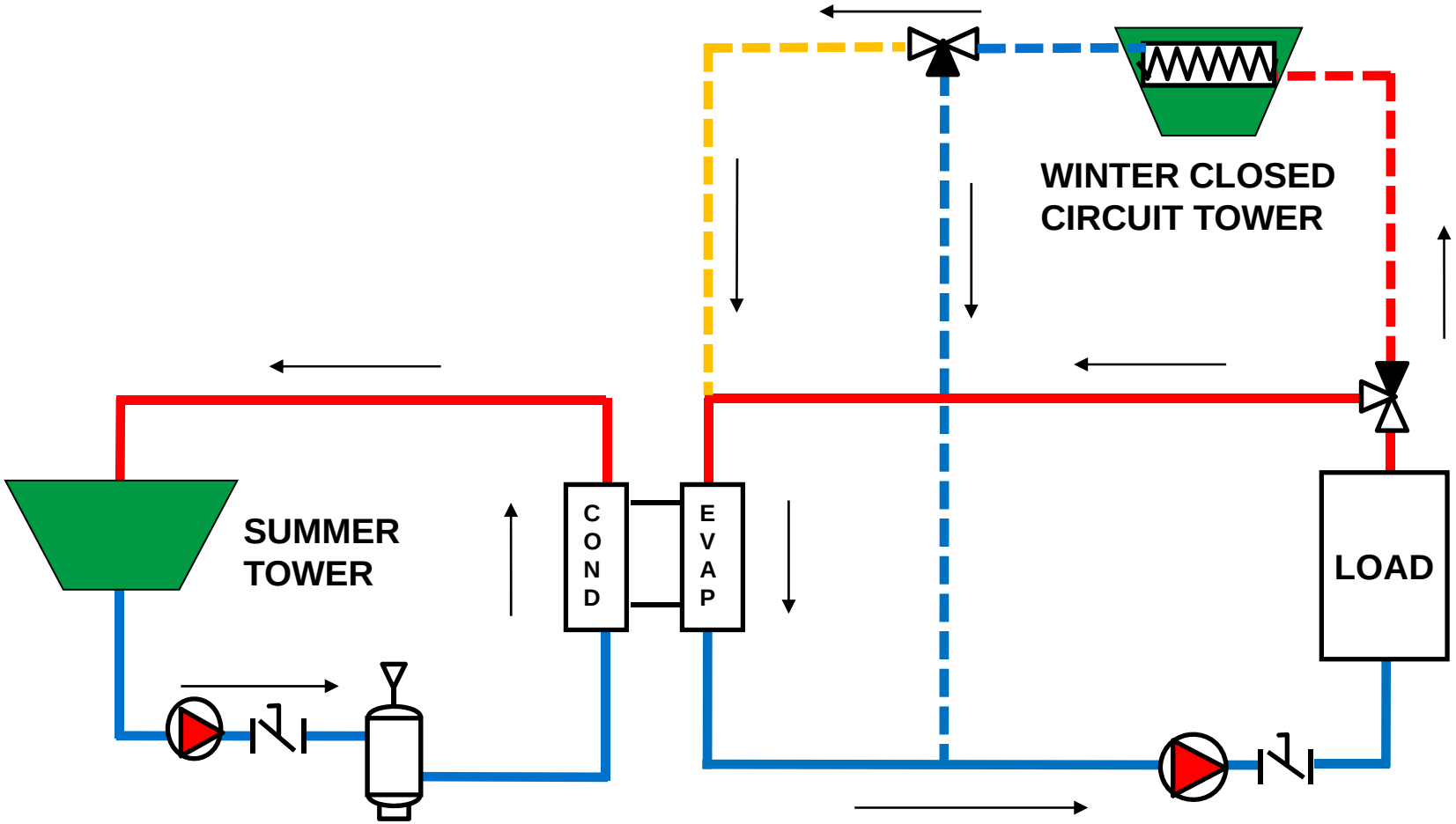
Economizer System Design Alternative

- Cooling Tower and Closed Circuit Cooling Tower
  - Two Cooling Towers
    - Cooling Tower Sized for 100% of Summer Load
    - Closed Circuit Cooling Tower Sized for 100% of Winter Load

  - Integrated Economizer
    - Meets Standard Requirement – Prescriptive Path
    - Can Reduce Chiller Load as Outside Temps Drop
    - Need Head Pressure Control (Valves) to keep ECWT about 65°F

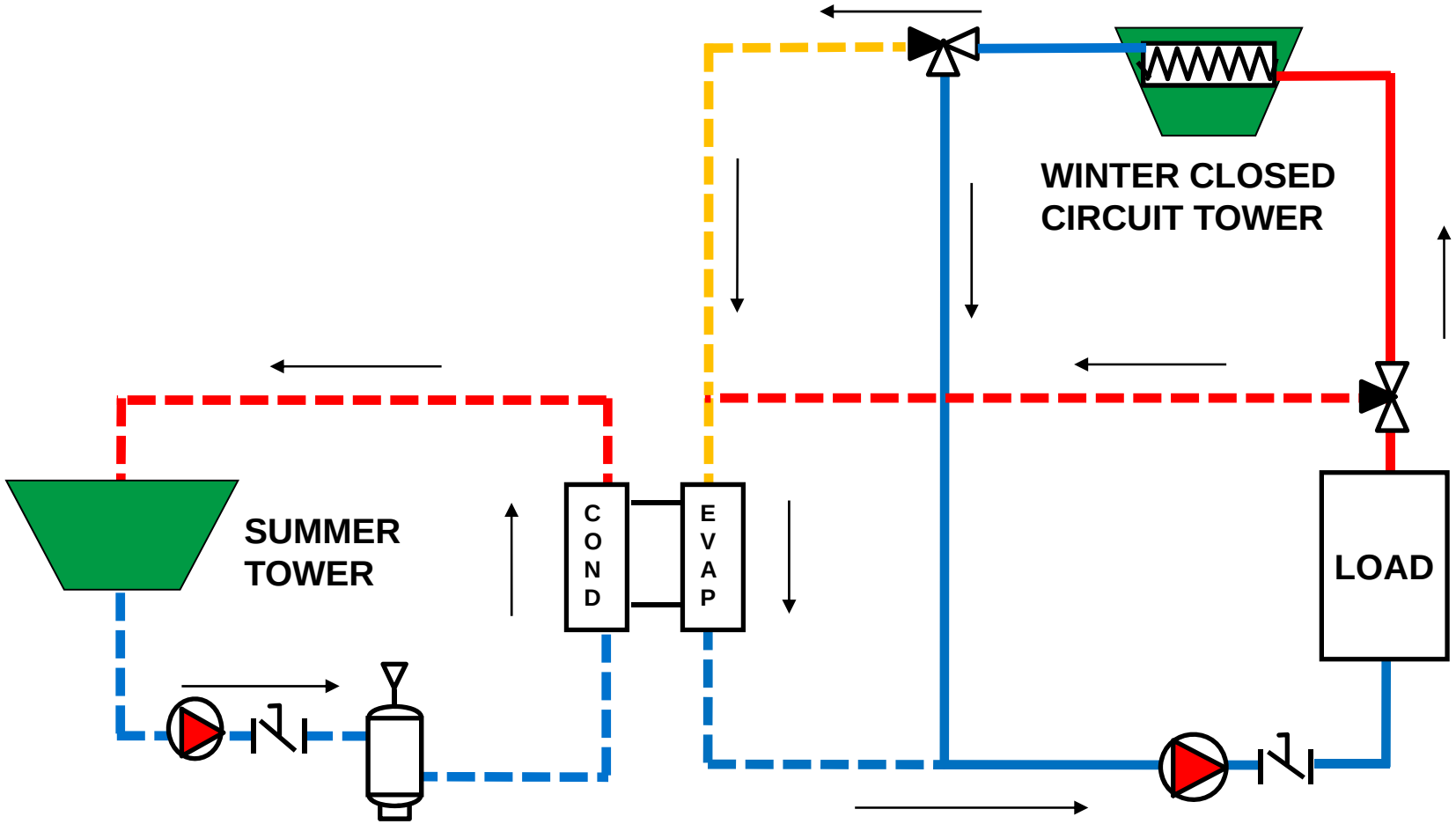
  - Design Considerations
    - Run Cooling Tower in Summer Mode
      - Drain Tower During Winter
    - Run Only Closed Circuit Cooling Tower in Economizer Mode
      - Must be winterized
      - May need glycol to prevent coil from freezing under no flow condition
    - Run Both Towers when Load Shaving

Cooling Tower & Closed Circuit Cooling Tower Summer Cycle – Chiller On



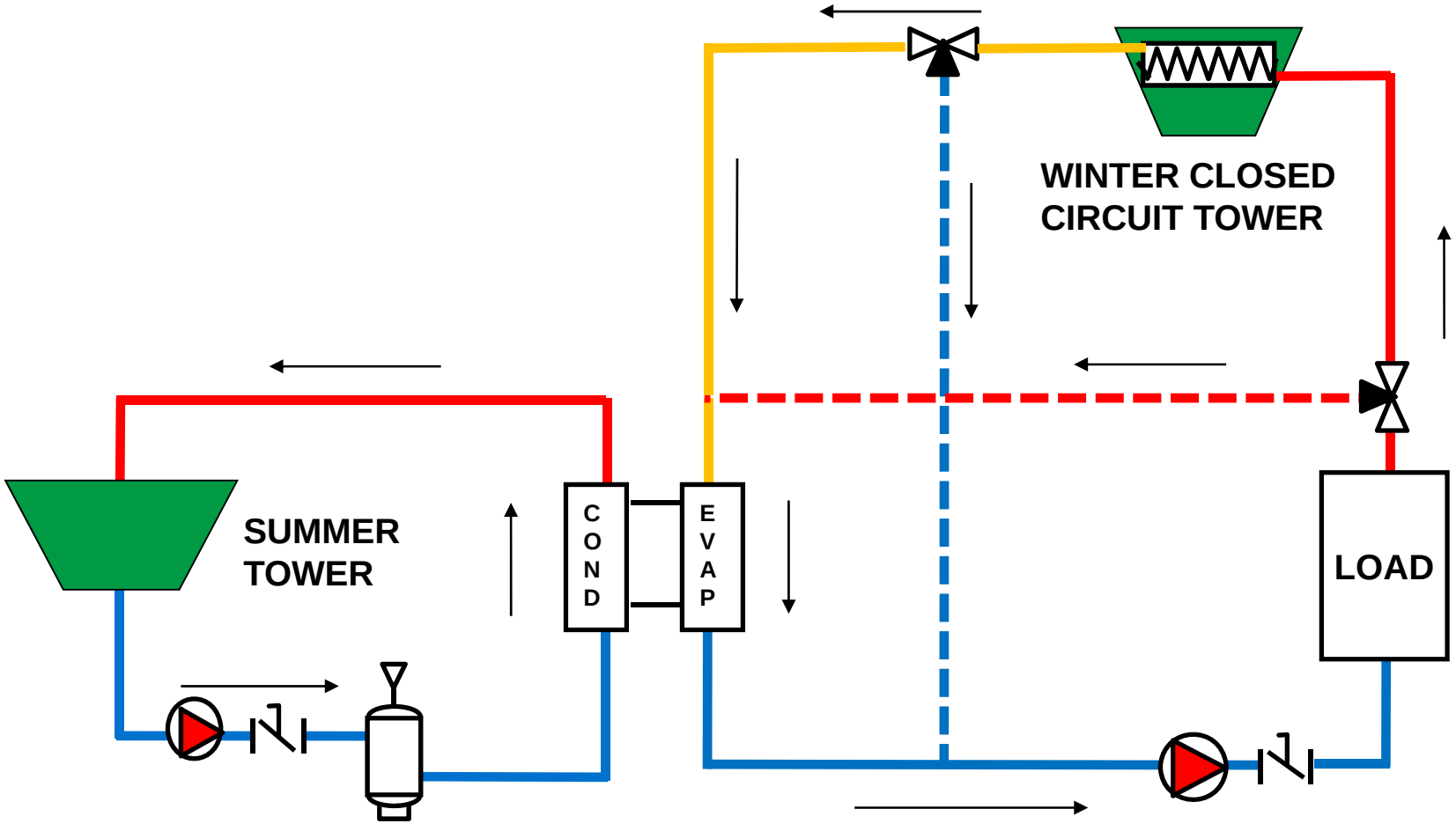
Integrated Design

Cooling Tower & Closed Circuit Cooling Tower
Winter Cycle – Chiller Off – Economizer



Integrated Design

Cooling Tower & Closed Circuit Cooling Tower
Summer Cycle – Chiller On – Load Shaving

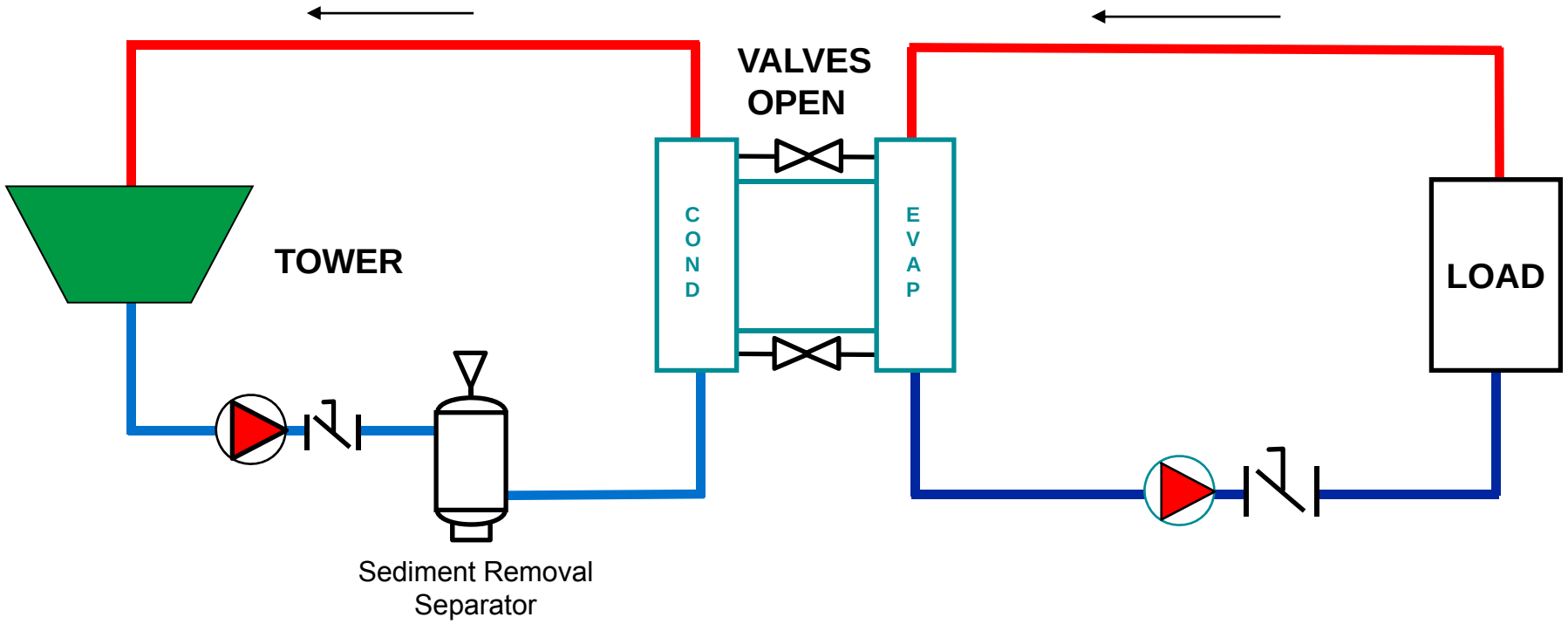


Integrated Design

Economizer System Design Alternative

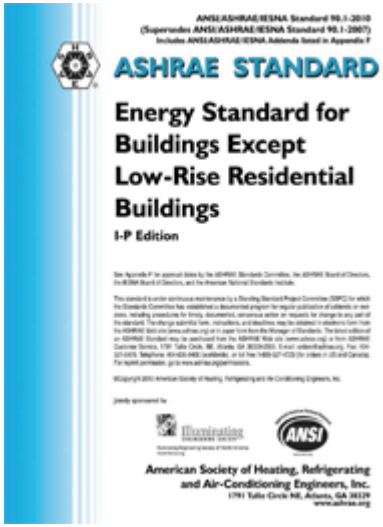
- Refrigerant Migration - Cooling Tower & Chiller (Off)
  - Single Cooling Tower
    - Sized for 100% of Summer Load
  - Non-Integrated Economizer
    - Does not meet Standard Requirement – Prescriptive Path
    - May meet Standard Requirement – Energy Cost Budget Method
  - Design Considerations
    - Refrigerant Lines with Valves Connecting Evaporator and Condenser
    - Relies on phase change and requires coldest possible LTW Temp
    - May encounter tower performance issues in Winter Mode (low load)
    - Freeze Protection Required

Single Cooling Tower – Refrigerant Migration
Winter Cycle – Chiller Off – Economizer



Non-Integrated Design – Exception: ECB Method

US DOE Requirement



States to Use 90.1-2010 by Oct. 18, 2013

WASHINGTON—ASHRAE's Washington office is reporting that the U.S. Department of Energy (DOE) has determined that ANSI/ASHRAE/IES Standard 90.1-2010, *Energy Standard for Buildings Except Low-Rise Residential Buildings,* saves more energy than Standard 90.1-2007. Specifically, DOE found national source energy savings of approximately 18.2%, and site energy savings of approximately 18.5%, when comparing the 2010 and 2007 versions of Standard 90.1.

As a result of this DOE final determination, states are required to certify by Oct. 18, 2013 that that have reviewed the provisions of their commercial building code regarding energy efficiency and updated their code to meet or exceed Standard 90.1-2010.

http://www.iccsafe.org/gr/documents/stateadoptions.pdf

Questions?

Thanks for Attending!

Waterside Economizer

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