Thermal Energy Storage at Rockefeller Center

Will Kain
PE, CEM, LEED AP BD+C

Gregg Fischer
PE, CEM, LEED AP O+M

CampusEnergy2020
THE POWER TO CHANGE
FEBRUARY 10-14 ▲ SHERATON DENVER DOWNTOWN ▲ DENVER, CO

VANDERWEIL POWER GROUP

TISHMAN SPEYER

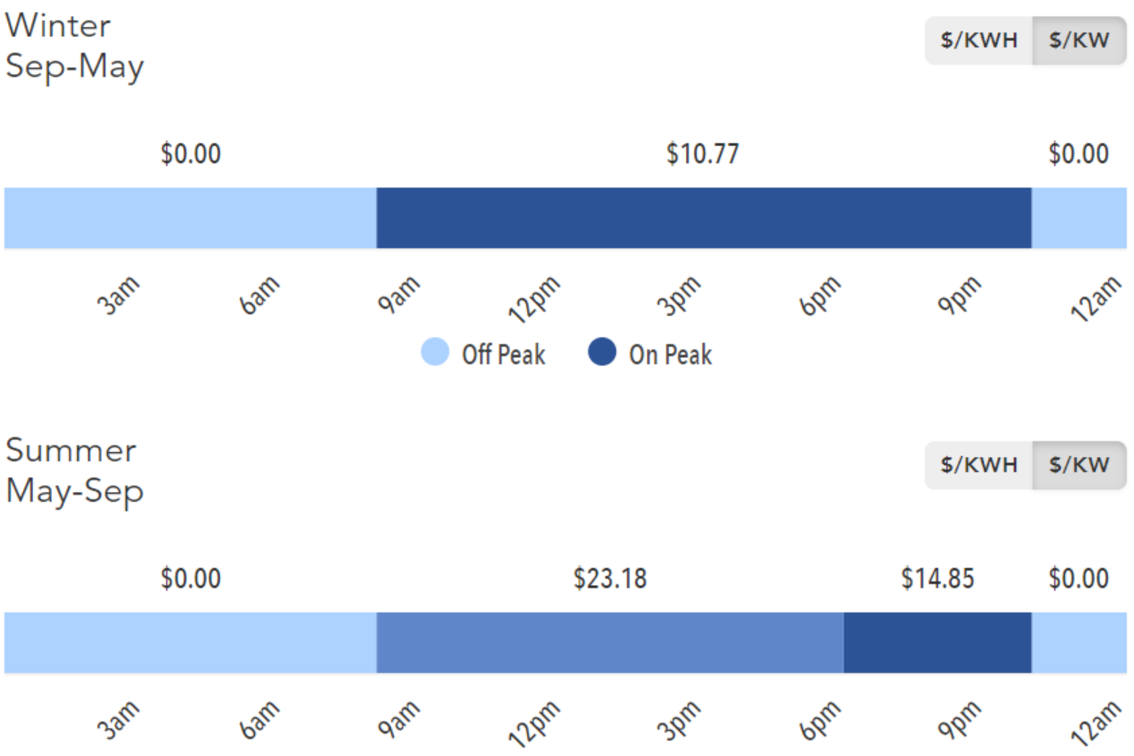
INTERNATIONAL DISTRICT ENERGY ASSOCIATION

Outline

- Why thermal energy storage (TES)?
- Rockefeller Central CHW System
- 45 Rockefeller Chiller & Thermal Storage Plant
- Modes of Operation
- Lessons Learned
- Q&A

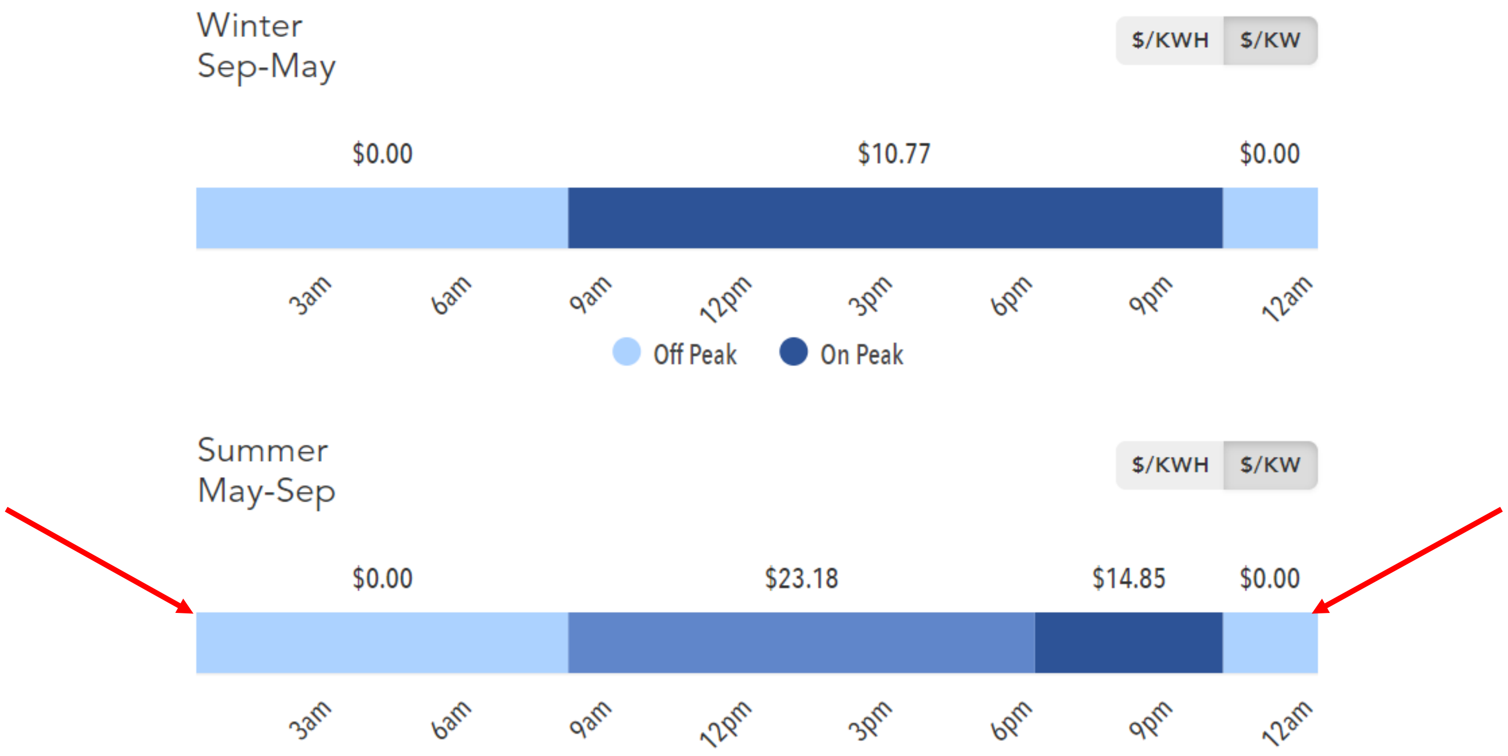
Why Energy Storage?

- **Reduced utility costs due to peak shifting**



Why Energy Storage?

- **Reduced utility costs due to peak shifting**



Why Energy Storage?

- **Utility incentive programs**
  - Demand Response Rebates
    - NYISO ICAP/SCR (day-ahead notification)
    - Con Edison CSRP (minimum 2 hours ahead notification)
    - Con Edison DLRP (day-ahead notification)
    - Rebate payments combine for approximately $210 per kW enrolled per summer
  - Capital Project Rebates
    - Con Edison Demand Management Program (DMP)
      - Awards up to $2,500 per kW of demand reduction

Con Ed Demand Management Program (DMP)

Project Type	2019 Incentive Rate ($/kW)	Project Cost Incentive Limit	Project Installation Deadlines to Qualify for Incentive
Thermal Storage	$2,520/kW	Up to 70%	August 15
High Efficiency Electric Chiller	$1,620/kW	Up to 70%	November 15
HVAC	$1,620/kW	Up to 70%	November 15
BMS Controls	$1,620/kW	Up to 70%	November 15
Lighting Controls	$1,620/kW	Up to 70%	November 15
Demand Response Enablement – Controls	$1,440/kW	Up to 70%	November 15
Steam Turbine Chiller, Double Stage Absorption Chiller, Gas Driven Chiller*	$1,440/kW	Up to 70%	November 15
Steam Turbine Chiller Control Panel for Improved Efficiency*	$720/kW	Up to 70%	November 15
Single Stage Absorption Chiller*	$720/kW	Up to 70%	November 15
Battery Storage	$1,620/kW	Up to 70%	November 15
Demand Response Enablement - Generation	$720/kW	Up to 70%	November 15

Thermal Storage

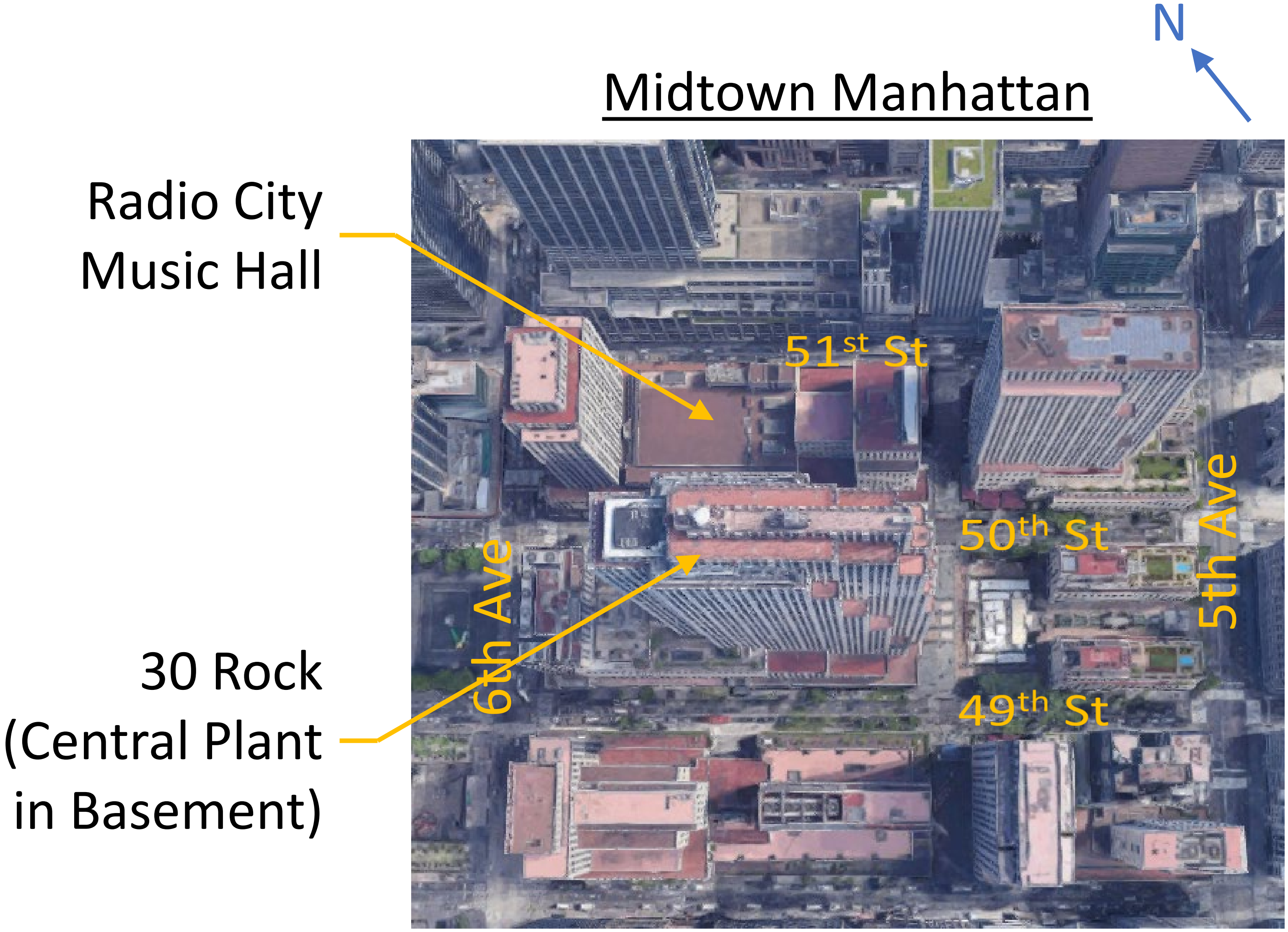
- HVAC makes up a significant portion of commercial building energy costs in summer months
- Need a CHW/glycol loop system to implement TES
- Pumping losses if in separate circuit
- Longer life cycle (30 yr)
- Low temperature CHW supply reduces secondary HVAC fan loads and extends free cooling hours

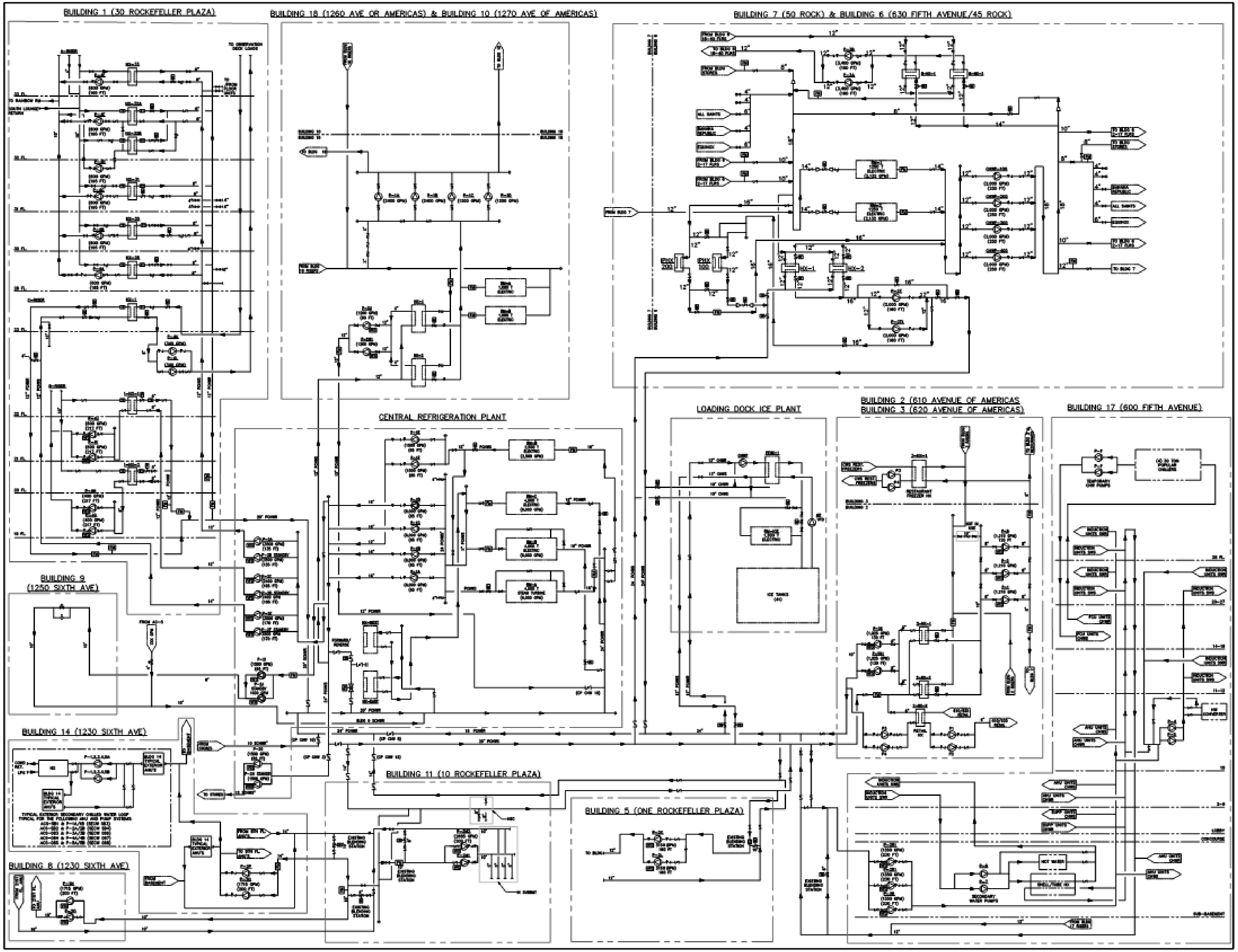
Battery Storage

- Can serve site during grid outage
- Serves diverse loads (not just HVAC)
- Hazardous waste disposal from batteries (Lithium ion, etc)
- Inverter/transformer losses
- FDNY permitting roadblocks in NYC

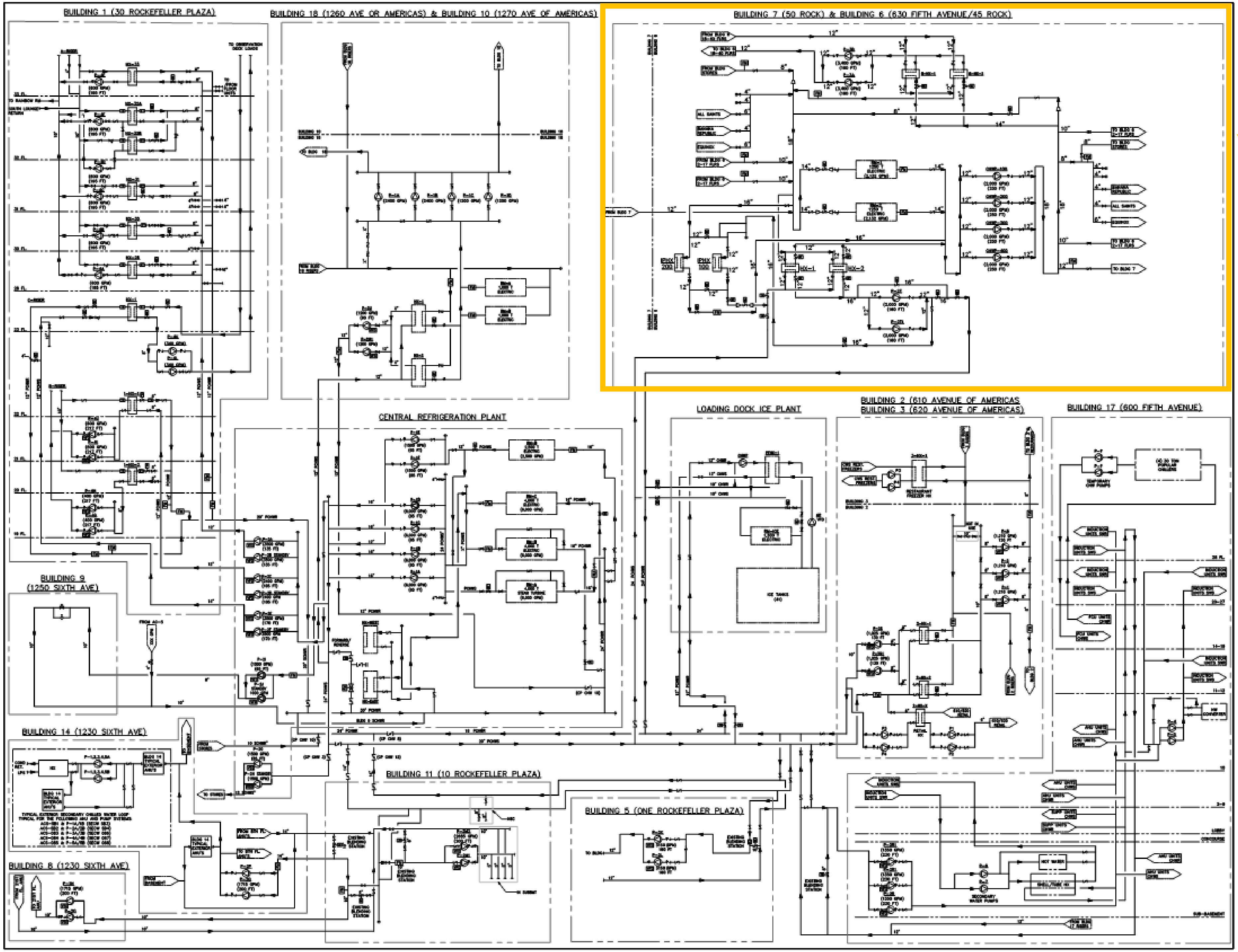
Rockefeller Center CHW Loop

- Rock Center cooling loads served by a central chilled water (CHW) loop
- Peak daytime cooling load is approximately 10,000 tons
- 30 Rock Central Chiller Plant serves 14 buildings with primary/secondary/tertiary pumping system with 14,500 tons of installed chiller capacity.





INTERNATIONAL
DISTRICT ENERGY
ASSOCIATION

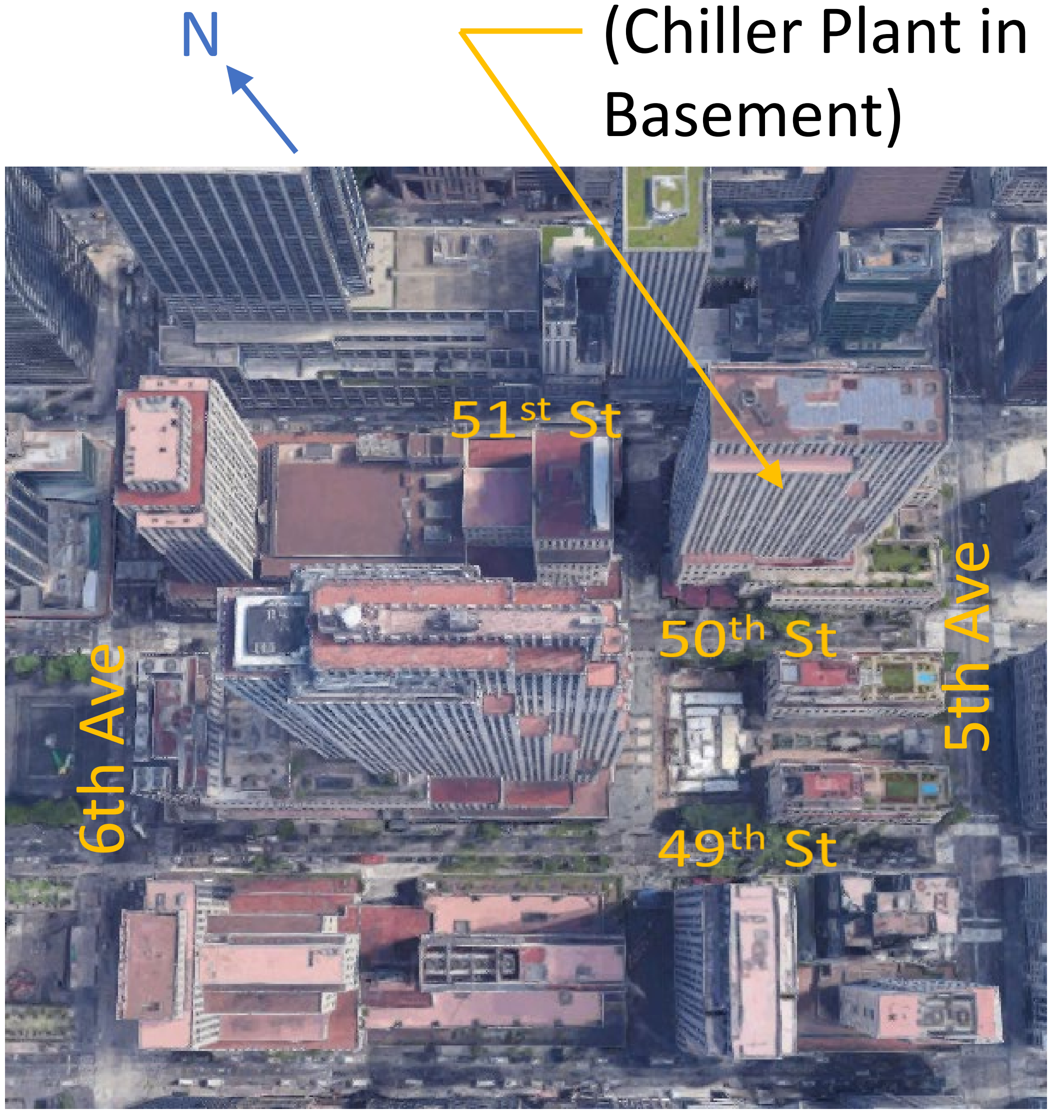


New 45 Rock Chiller & Thermal Storage Plant

INTERNATIONAL DISTRICT ENERGY ASSOCIATION

45 Rockefeller Center Chiller Plant

- 45 Rock Chiller Plant rebuilt in 2018
- 2,500 tons electric centrifugal chillers
- 1,200 ton electric centrifugal ice chiller
- 12,000 ton-hr ice storage plant
- Serves 45 Rock and 50 Rock buildings
- Import capability from Central Plant Loop via CHW plate & frame HX
- Export capability from ice storage plant



45 Rockefeller Center Chiller Plant

- 2 x 1,250 ton electric centrifugal "day" chillers
  - 40º F / 54º F CHW
  - Low supply temp reduces AHU fan energy, captures additional latent load, and extends ΔT
  - Oversize 10º F ΔT evaporator and condenser bundles allow additional flow for operational flexibility
- 1 x 1,200 ton electric centrifugal glycol chiller
  - Next-gen HCFO-1233zd(E) refrigerant carries zero ODP and extremely low GWP (<5) as compared with R-123 (77)
- All chillers can operate on either 45 Rock cooling towers or 50 Rock cooling towers for operational flexibility

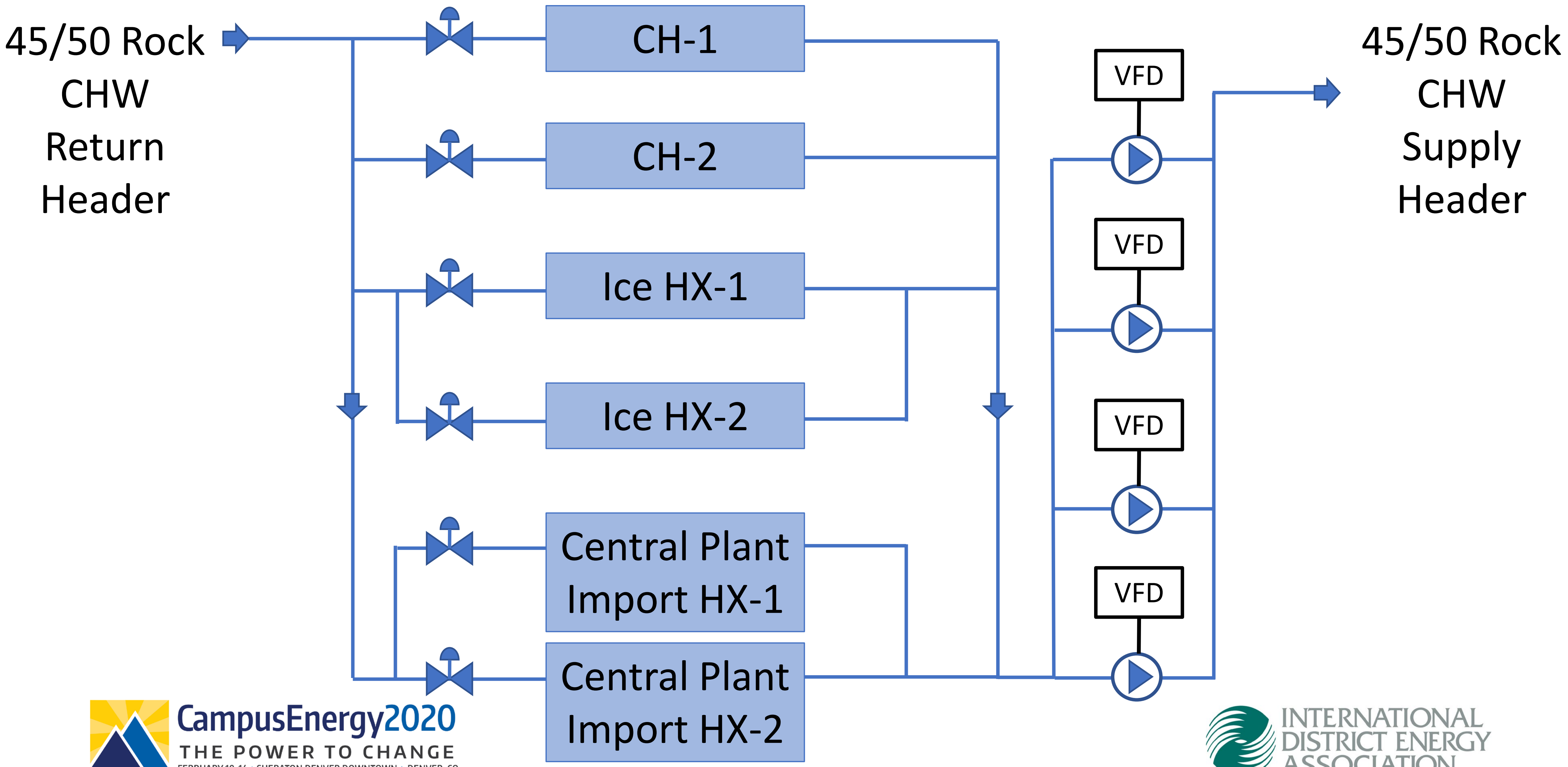
45 Rockefeller Center Chiller Plant

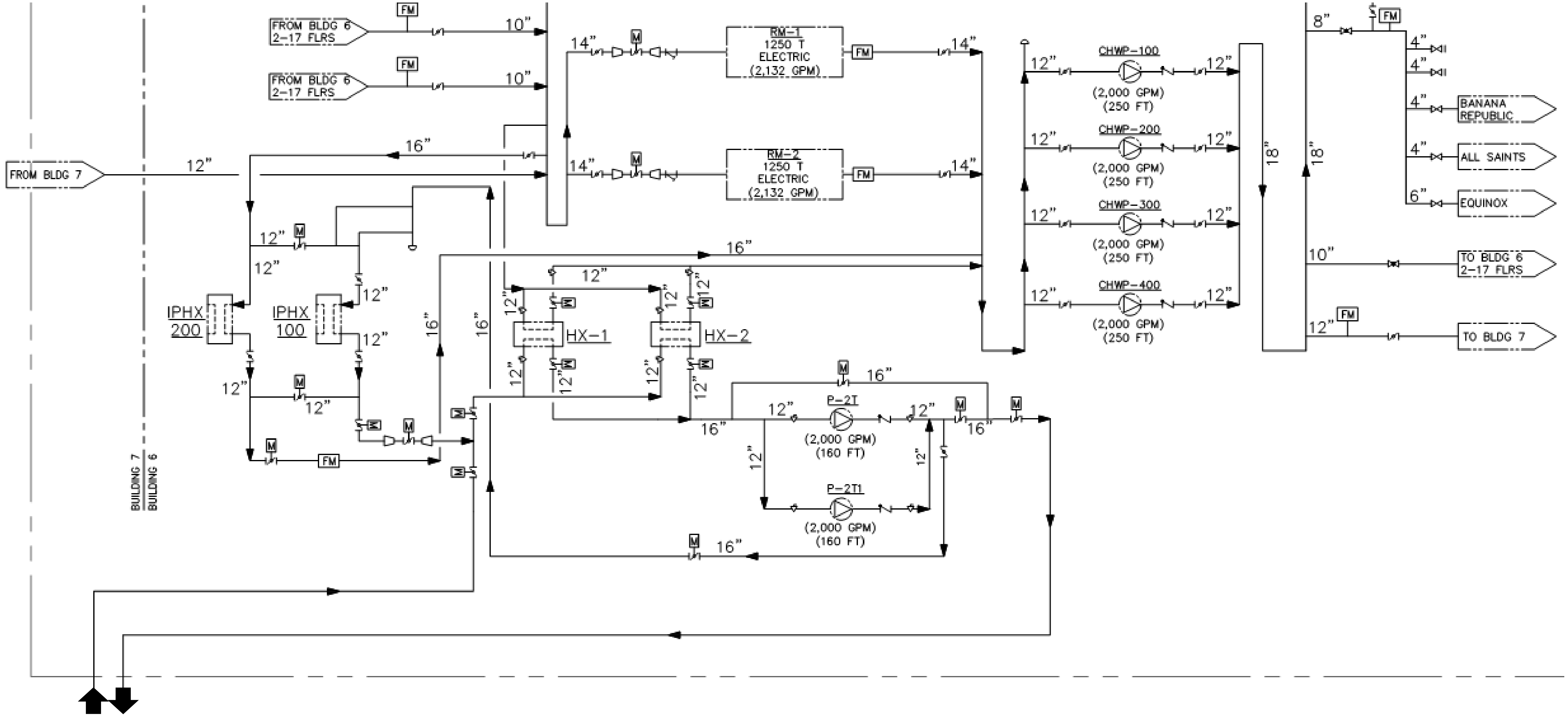
- Approximately 0.3 kW/ton improvement over previous chillers
- Previous chillers were 480V and 208V; one (1) day chiller and the ice chiller run at 4160V (40% reduction in daytime utility electrical demand charges)
- Future pump energy reductions are expected
  - Demand side control valves

Construction Schedule

- Accelerated 5-month design/build construction schedule
  - **July 2017:** Feasibility Study and DMP Application
  - **November 2017:** Design release
  - **December 2017:** Demolition and equipment pre-purchase
  - **January 2018:** Contractor RFP's released from 50% DD
  - **April 2018:** Chillers ship, make-ready work
  - **May 2018:** Instant swing over to new variable primary pumping
  - **June 2018:** Day chillers online
  - **August 2018:** Ice system online, post M&V and DMP testing
  - **September 2018:** Awarded DMP incentive

45 Rock CHW System





16” Central CHW Loop Supply/Return

Ice Storage Tanks

- Ice-on-Coil type tank
- Each tank contains spiral wound heat exchanger tubes in close proximity
- Counterflow design builds and melts (“burns”) ice evenly across the mats and the tank as a whole

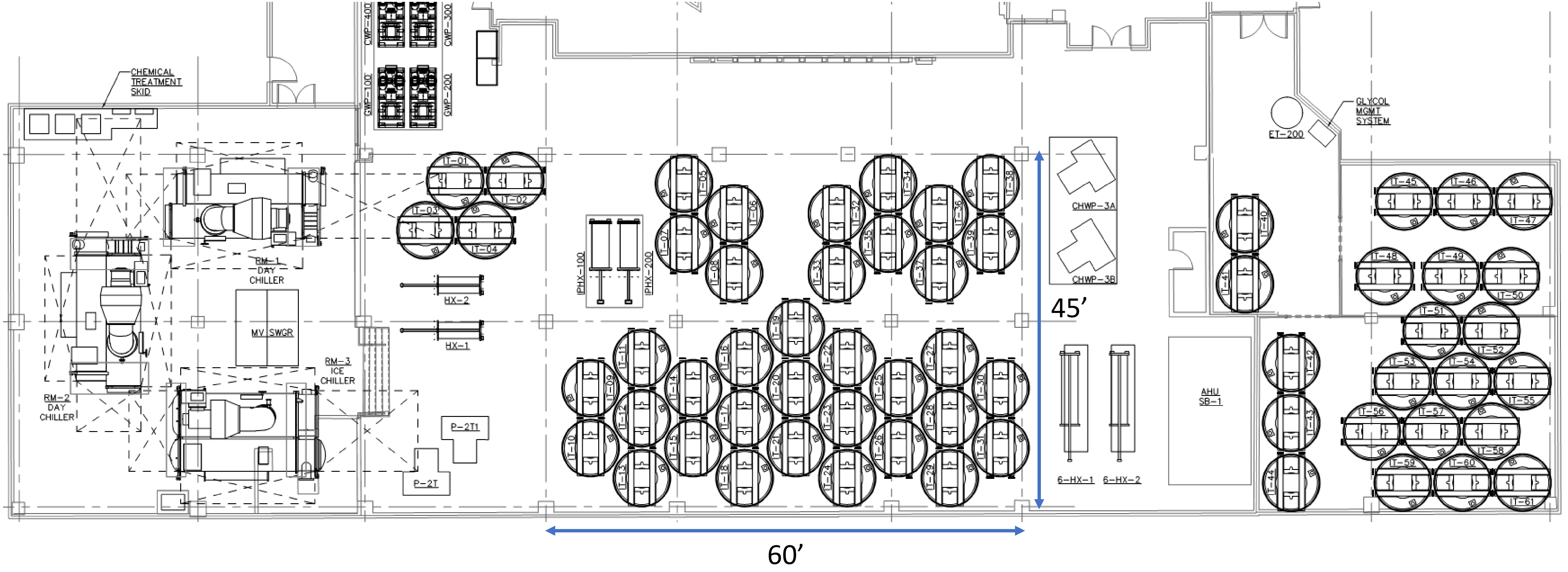
Ice Storage Tanks

- Each tank approx. 8’ diameter
    - Two sizes utilized due to headroom constraints:
    - (30) x 8 foot tall tanks →
    - (31) x 11 foot tall tanks
- Tanks connected in parallel in branch groups of 1-3
- Reverse return piping for hydraulic balancing – first tank supplied is last tank returned

Ice Storage Tanks

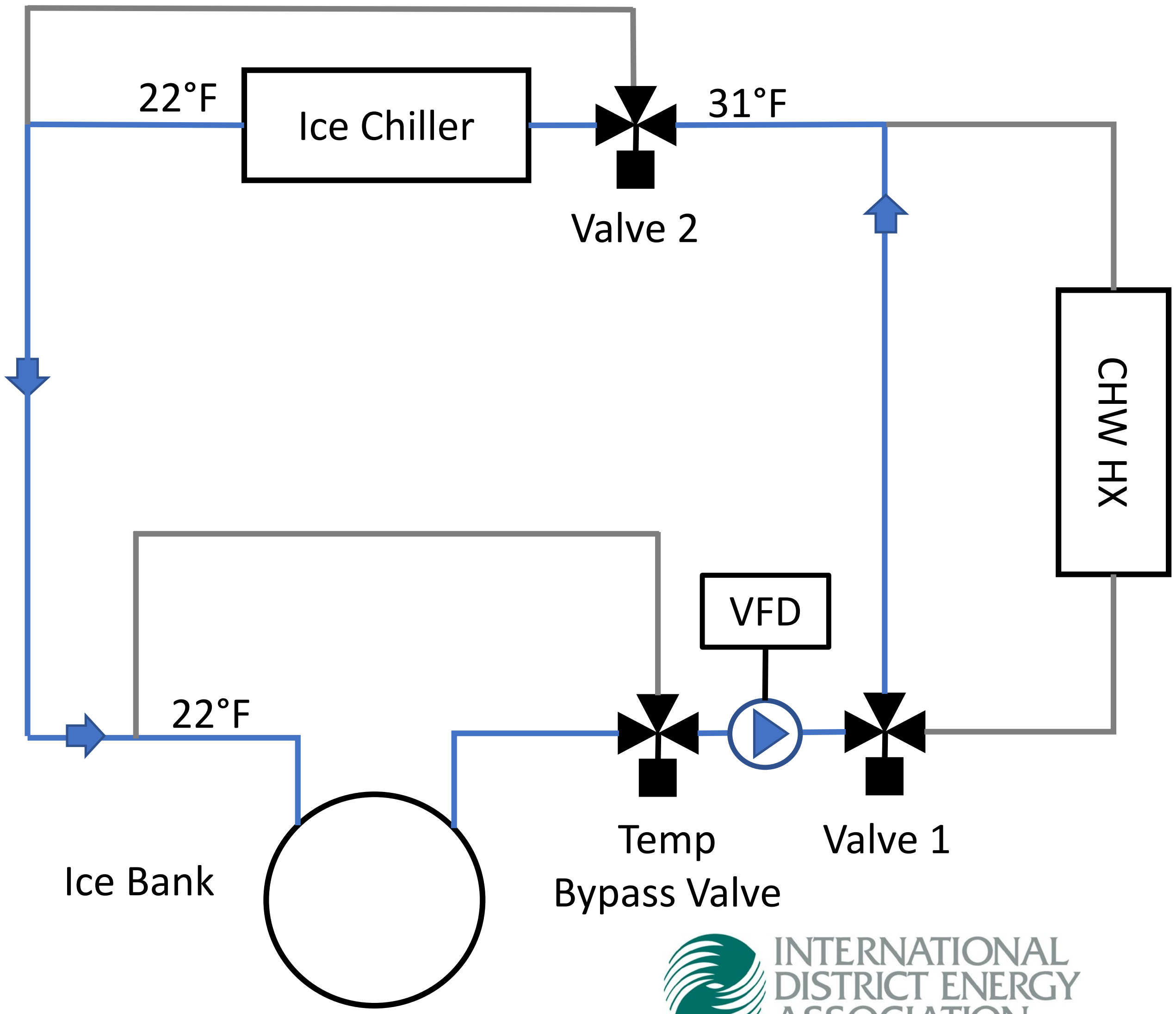
- Each tank approx. 8’ diameter
  - Two sizes utilized due to headroom constraints:
  - (30) x 8 foot tall tanks
  - (31) x 11 foot tall tanks →
- Tanks connected in parallel in branch groups of 1-3
- Reverse return piping for hydraulic balancing – first tank supplied is last tank returned

Ice Storage Tank Layout



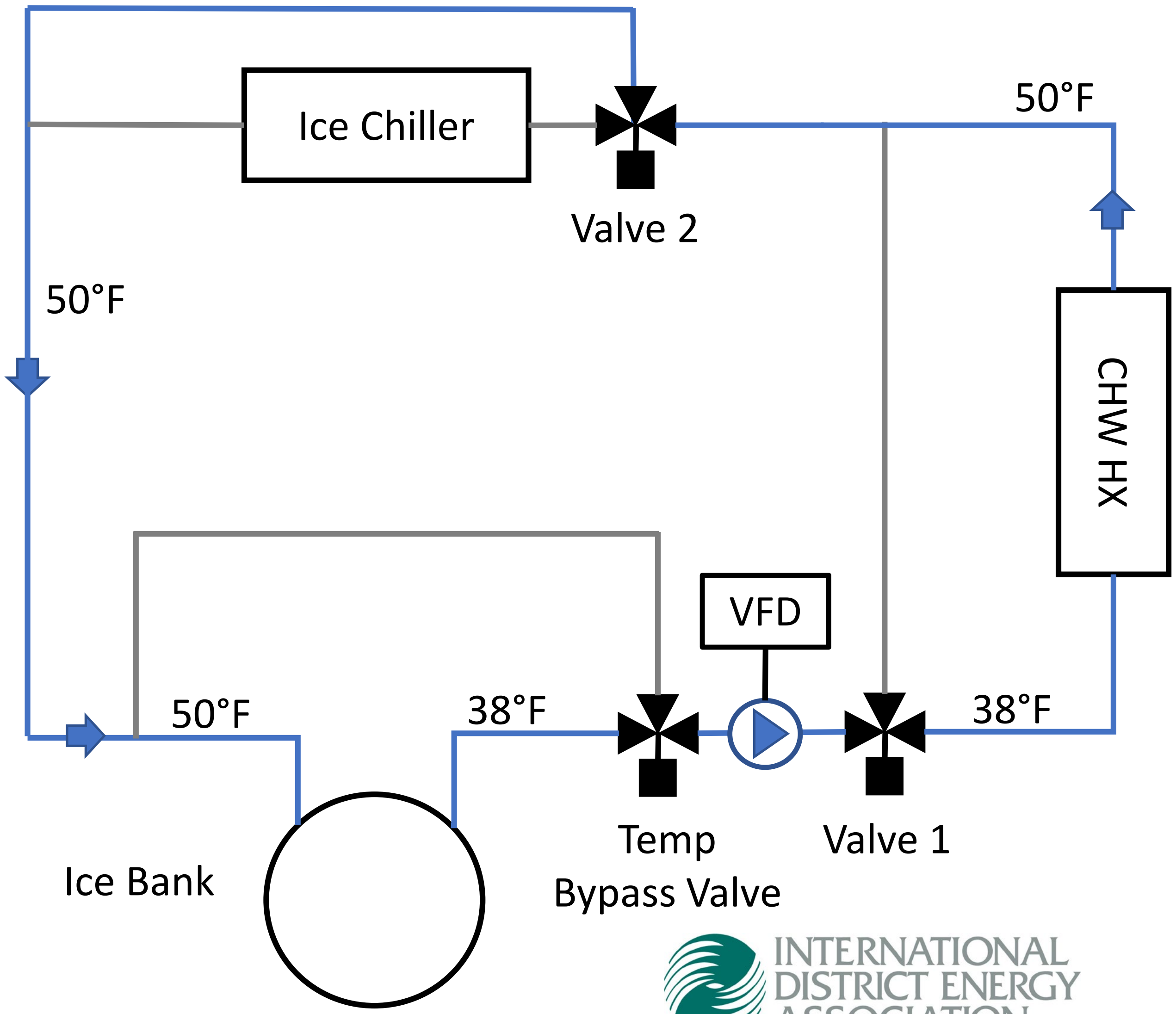
Ice Storage Plant Operation – Build Mode

- Glycol chiller RM-3 supplies 22°F glycol to ice tanks, freezing the water inside
- Build ends when glycol return temperature from tanks reaches 28°F
- Do not overbuild – freezes water over HX intended to allow expansion during freezing (“ice cap”), causing shortage of water around HX coils and impairing performance
- Low overnight temperatures improve chiller efficiency



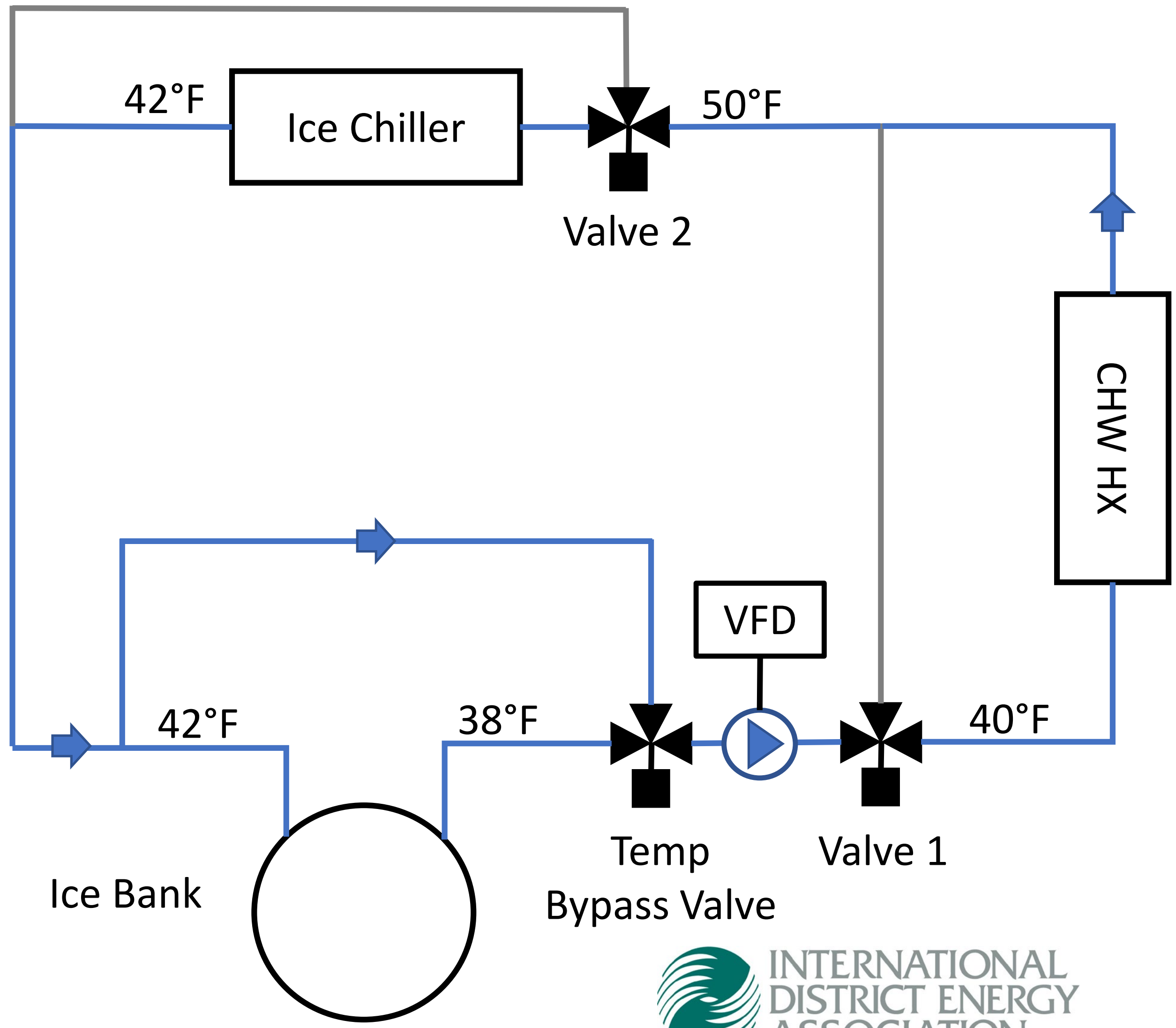
Ice Storage Plant Operation – Burn Mode

- CHW flow control through Ice HX drives ice burn rate
- Higher glycol return temperature to tanks (HX outlet) extends ton hour capacity of tanks

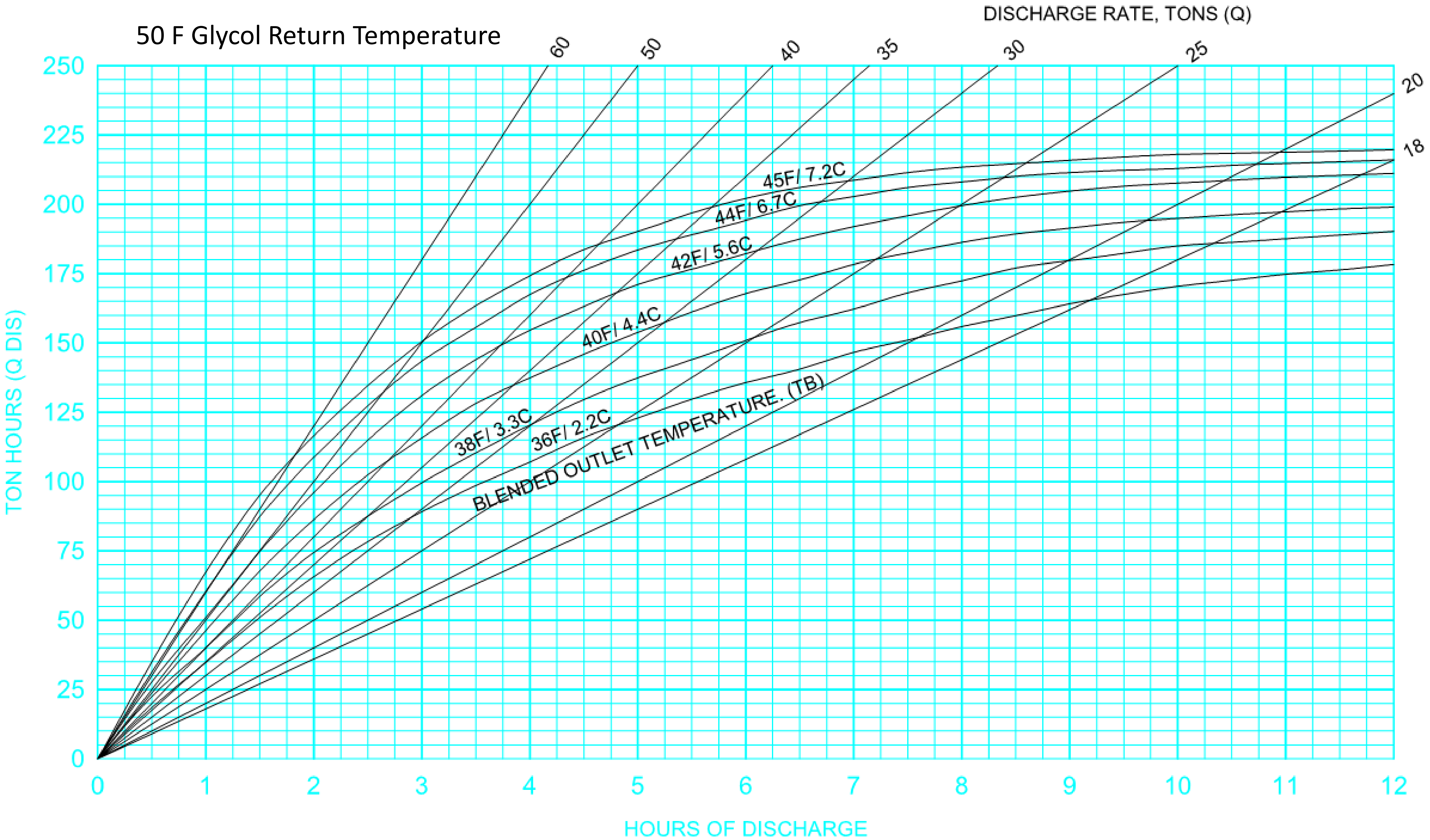


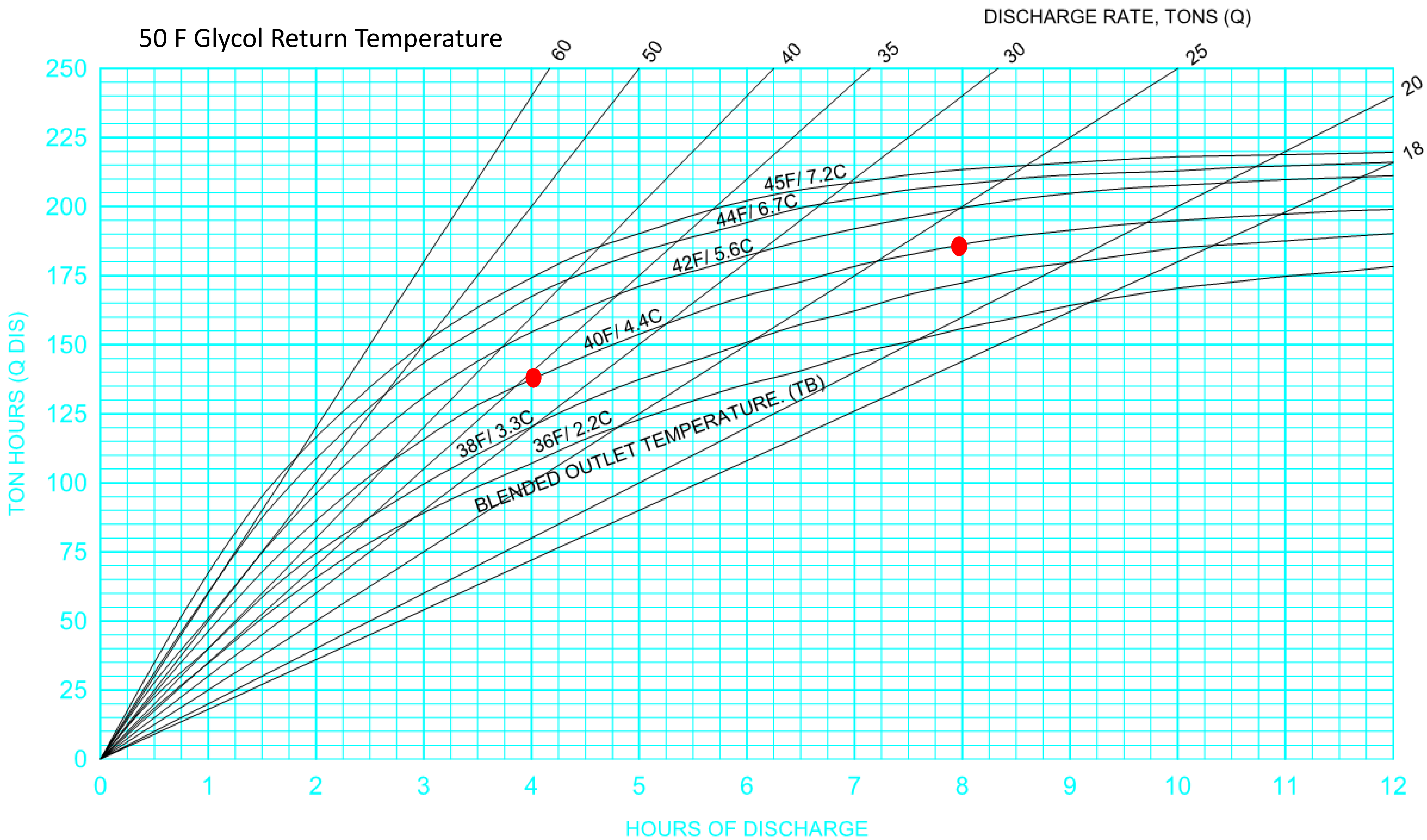
Ice Storage Plant Operation – Day Mode

- Ice Chiller runs as normal chiller
- Some flow may divert through ice bank to meet blended supply temperature setpoint
- Mode not utilized unless one or more day chillers are out of service on peak summer day



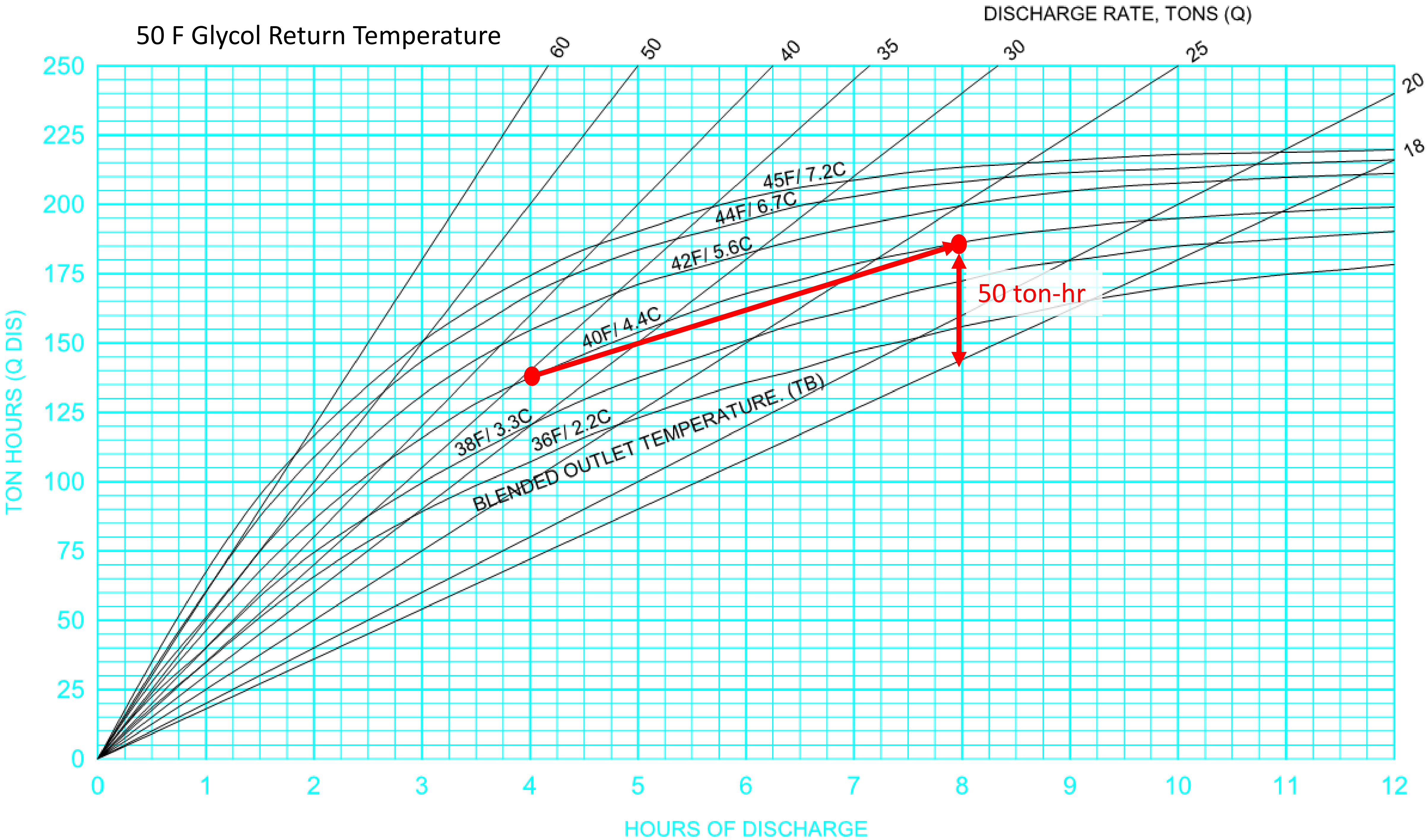
50 F Glycol Return Temperature

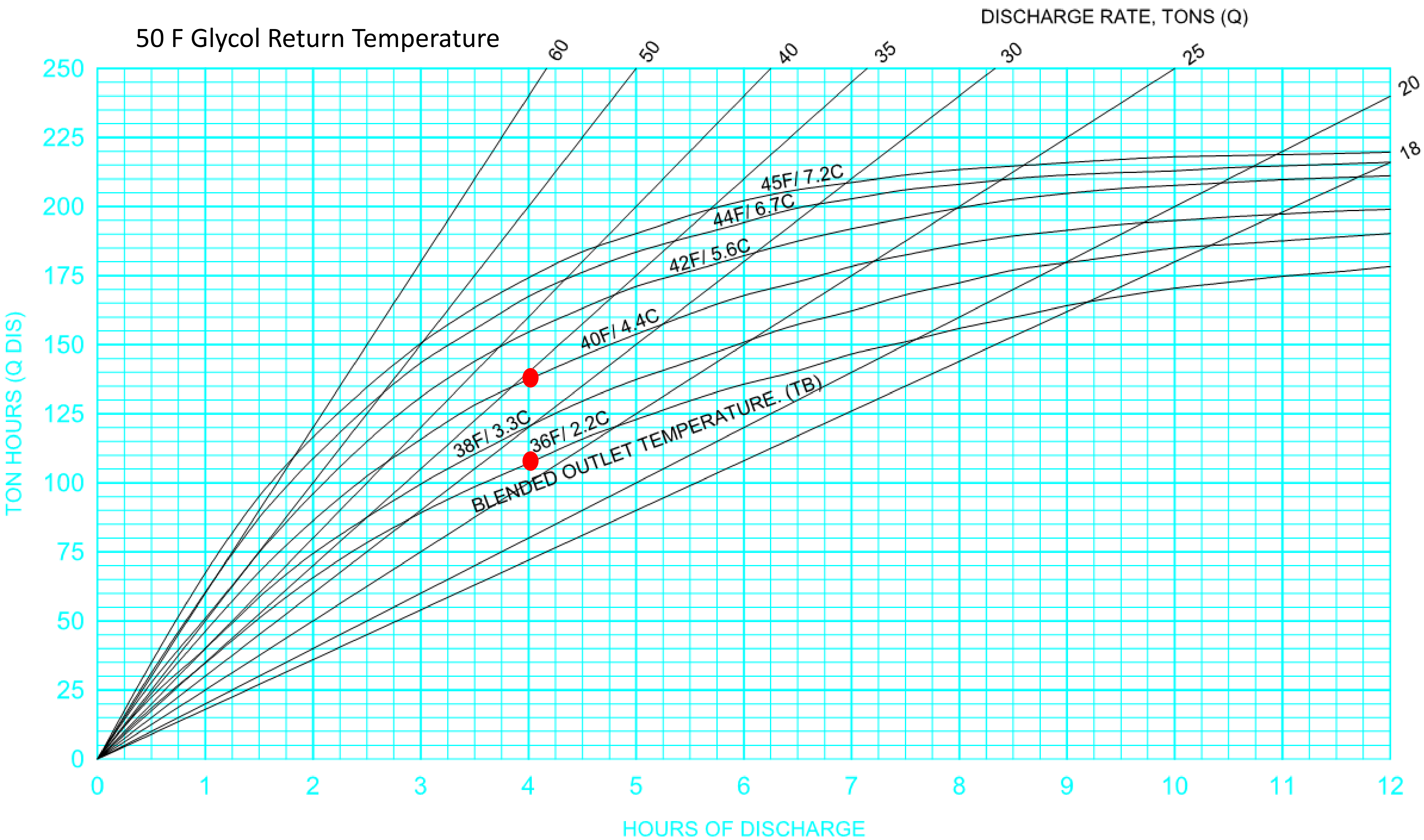


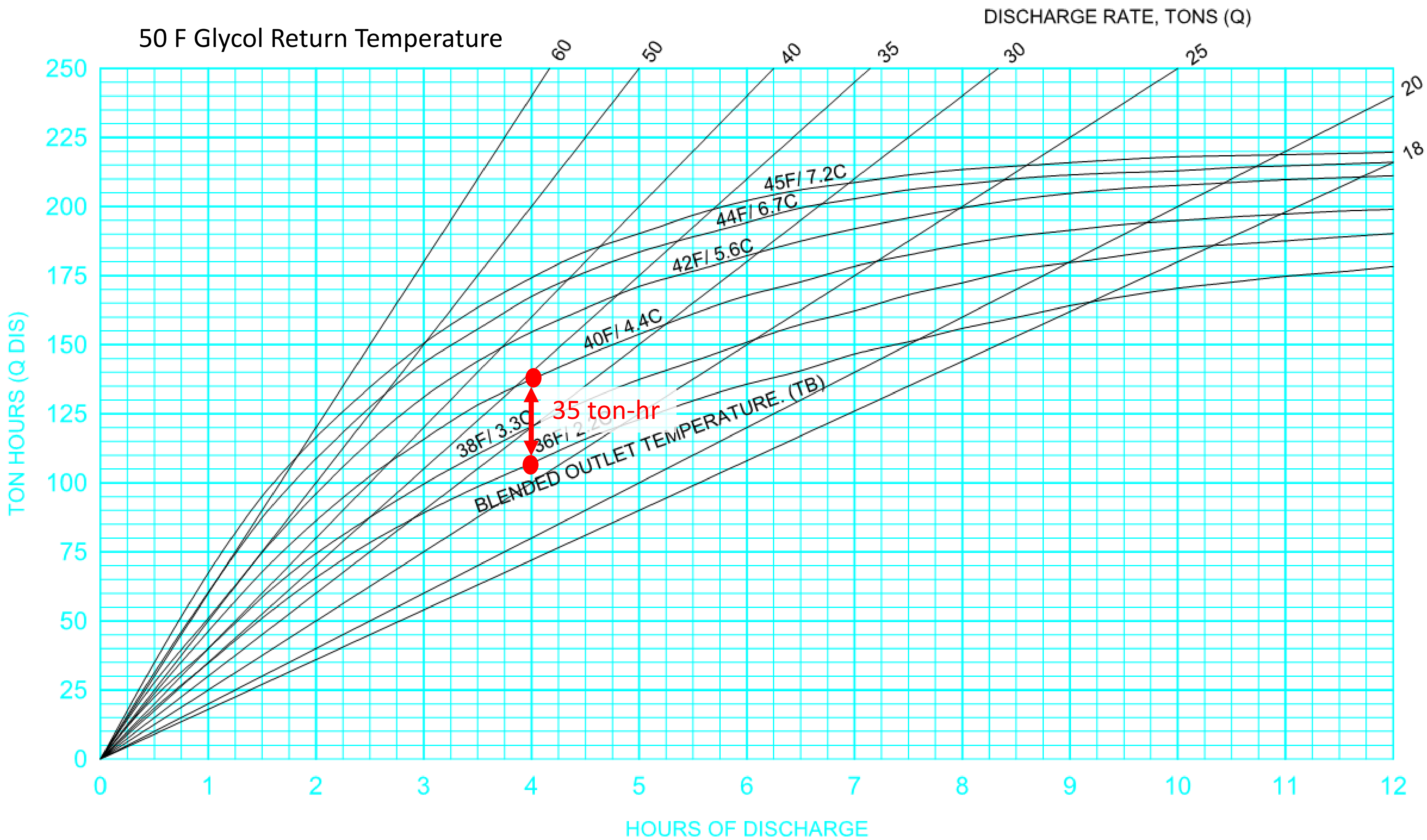


50 F Glycol Return Temperature
DISCHARGE RATE, TONS (Q)
60
50
40
35
30
25
20
18
45F/ 7.2C
44F/ 6.7C
42F/ 5.6C
40F/ 4.4C
38F/ 3.3C
36F/ 2.2C
BLENDED OUTLET TEMPERATURE. (TB)
TON HOURS (Q DIS)
250
225
200
175
150
125
100
75
50
25
0
0
1
2
3
4
5
6
7
8
9
10
11
12
HOURS OF DISCHARGE

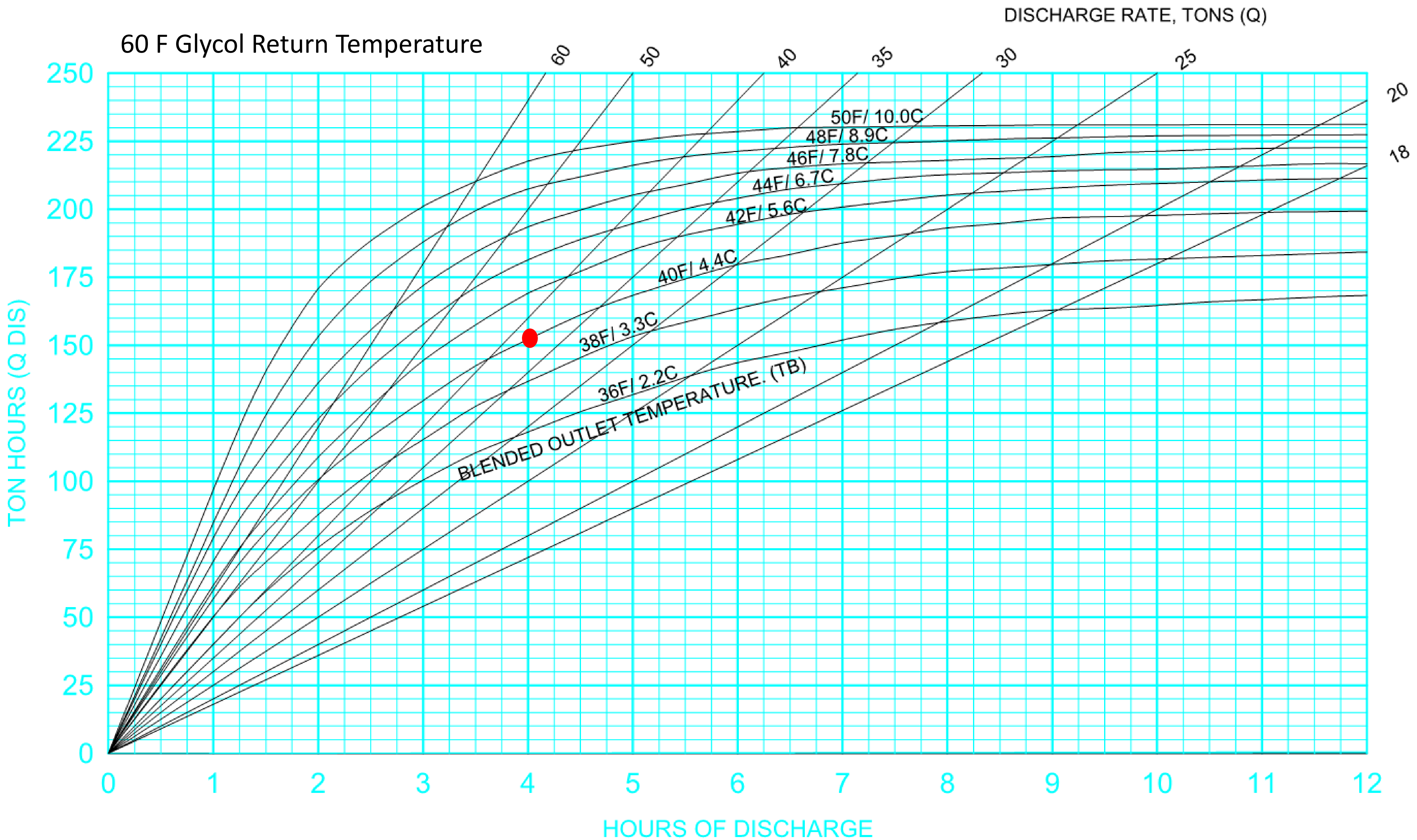
50 F Glycol Return Temperature




50 F Glycol Return Temperature
DISCHARGE RATE, TONS (Q)
60
50
40
35
30
25
20
18
45F/ 7.2C
44F/ 6.7C
42F/ 5.6C
40F/ 4.4C
38F/ 3.3C
36F/ 2.2C
BLENDED OUTLET TEMPERATURE. (TB)
TON HOURS (Q DIS)
HOURS OF DISCHARGE
250
225
200
175
150
125
100
75
50
25
0
1
2
3
4
5
6
7
8
9
10
11
12



50 F Glycol Return Temperature
DISCHARGE RATE, TONS (Q)
60
50
40
35
30
25
20
18
45F/ 7.2C
44F/ 6.7C
42F/ 5.6C
40F/ 4.4C
38F/ 3.3C
35 ton-hr
BLENDED OUTLET TEMPERATURE. (TB)
TON HOURS (Q DIS)
HOURS OF DISCHARGE
250
225
200
175
150
125
100
75
50
25
0
0
1
2
3
4
5
6
7
8
9
10
11
12


60 F Glycol Return Temperature
DISCHARGE RATE, TONS (Q)
60
50
40
35
30
25
20
18
50F/ 10.0C
48F/ 8.9C
46F/ 7.8C
44F/ 6.7C
42F/ 5.6C
40F/ 4.4C
38F/ 3.3C
36F/ 2.2C
BLENDED OUTLET TEMPERATURE. (TB)
TON HOURS (Q DIS)
250
225
200
175
150
125
100
75
50
25
0
HOURS OF DISCHARGE
0
1
2
3
4
5
6
7
8
9
10
11
12

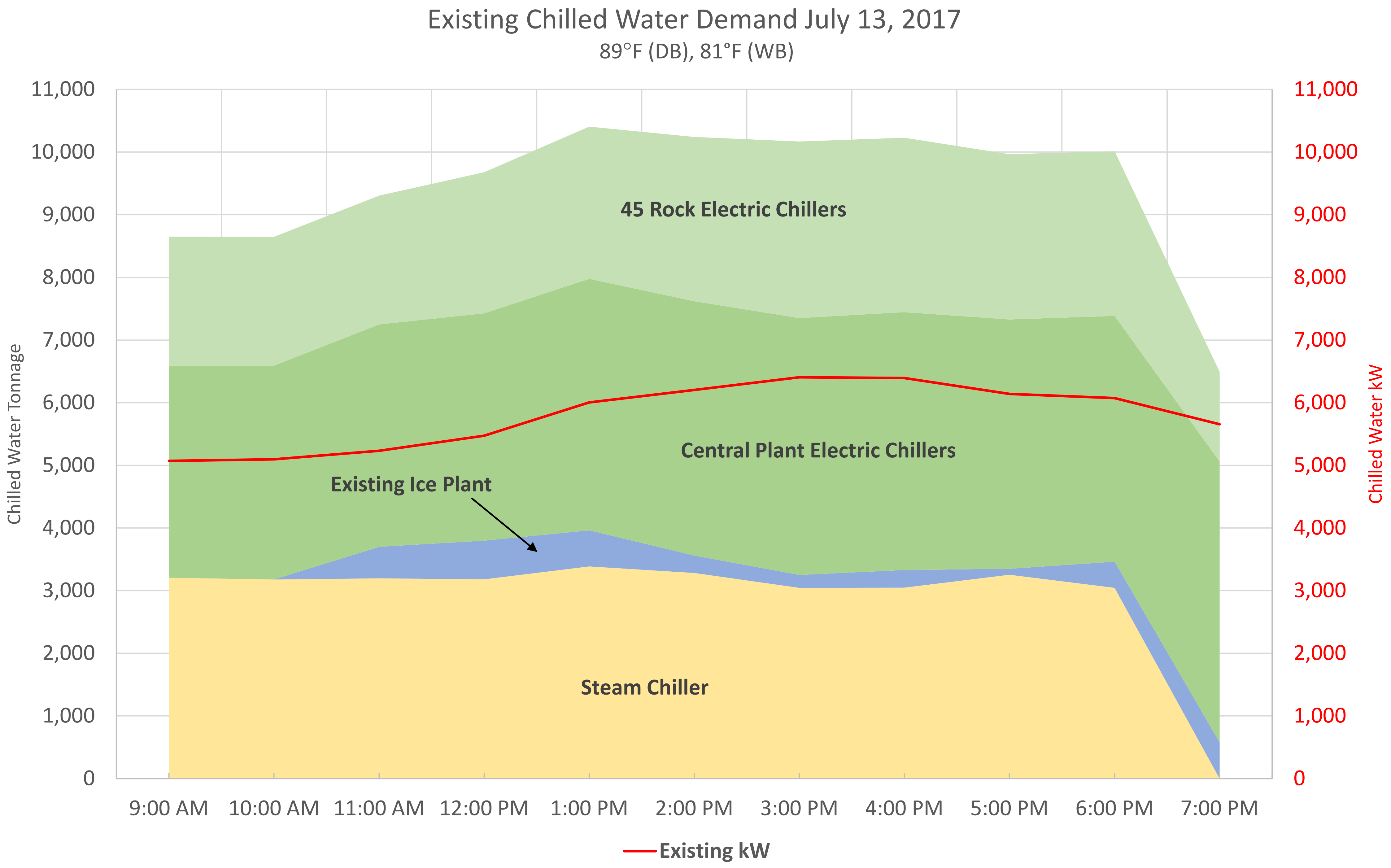
DESIGN DAY SYSTEM ANALYSIS

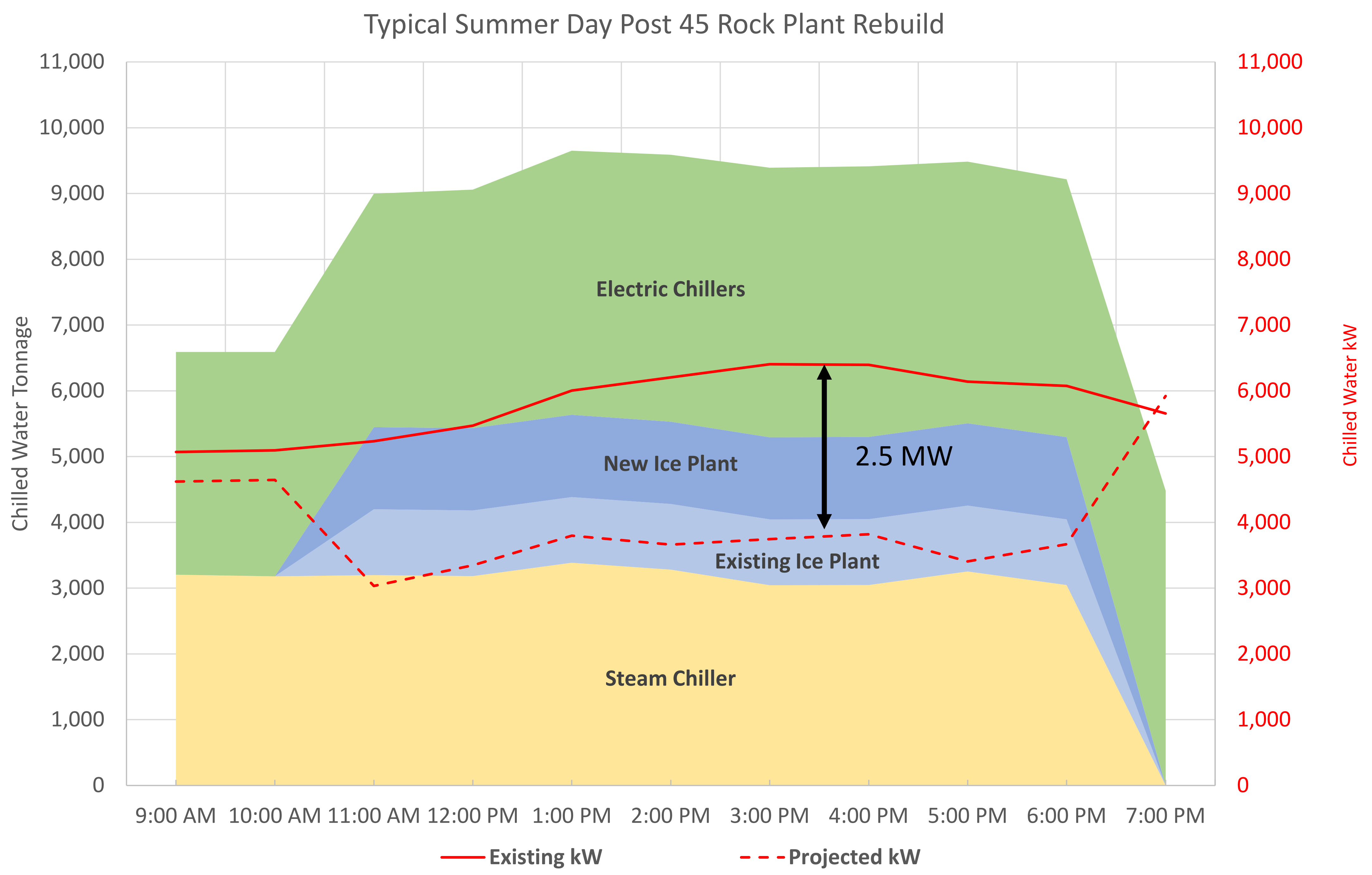
CHILLER UPSTREAM - SERIES FLOW	NOMINAL CHILLER SIZE = 1767
SYSTEM SUPPLY TEMPERATURE (F) = 42.0	NUMBER OF TANKS = 57 MODEL 1220
SYSTEM RETURN TEMPERATURE (F) = 52.0	PERCENT ETHYLENE GLYCOL = 25.0
FLOW (GPM) : DISCHARGE = 5686	DELTA P (PSI) : DISCHARGE = 12.1
CHARGE = 3600	CHARGE = 7.1

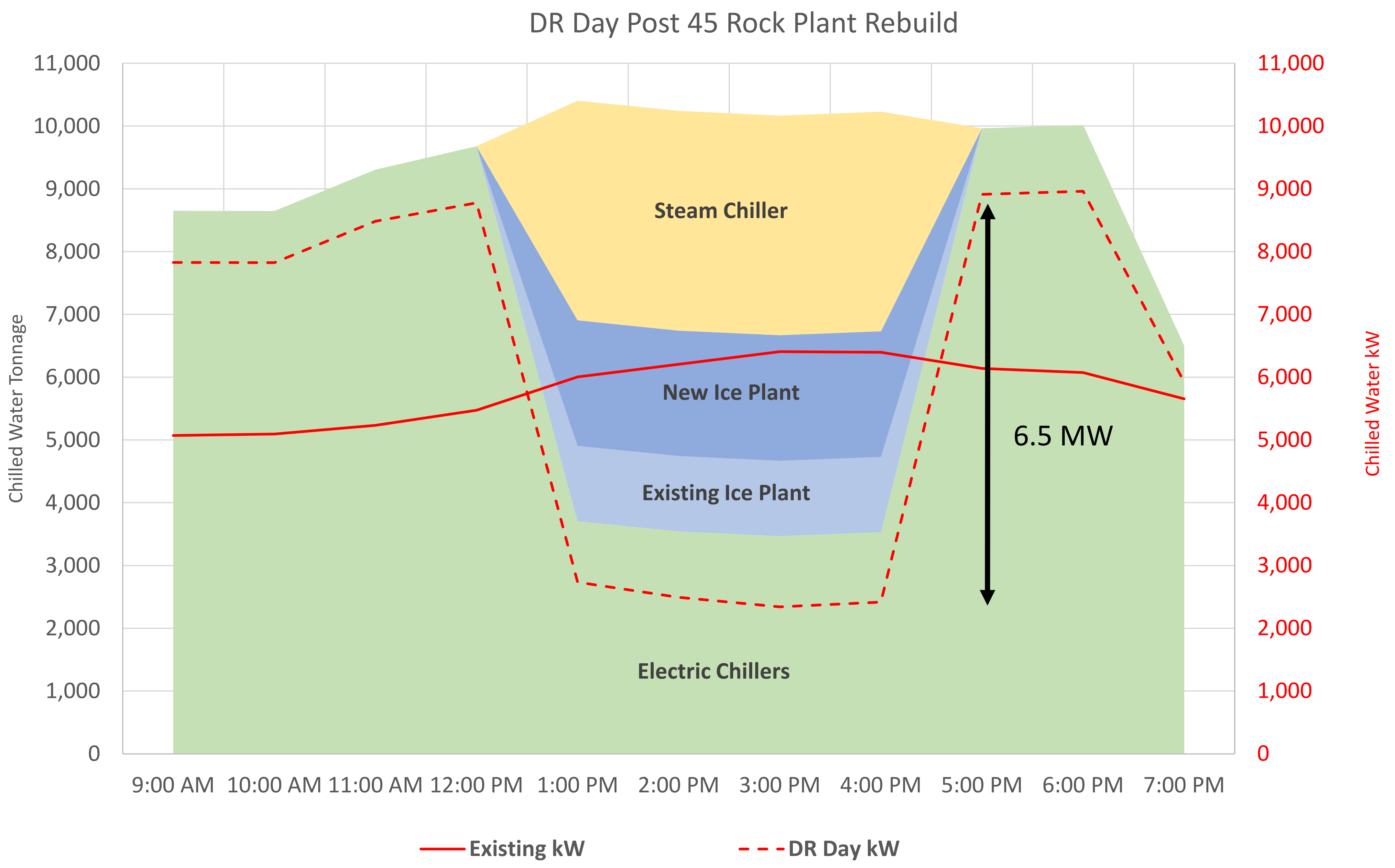
HOUR & TYPE	LOAD TONS	CHLR TONS	STRG TONS	TANK TONS	TONHRS TOTAL	TONHRS PER TANK	% CHRG	CHLR TEMP	REQD STRG TEMP	AVLB MIN TEMP	RTRN TEMP	GPM PER TANK	PD PSI	FLG
1 I	0	1202	1202	21.1	6008	105.4	42.2	22.8	31.4	31.4	31.4	63.2	7.1	
2 I	0	1202	1202	21.1	7209	126.5	50.6	22.6	31.2	31.2	31.2	63.2	7.1	
3 I	0	1202	1202	21.1	8411	147.6	59.0	22.2	30.8	30.8	30.8	63.2	7.1	
4 I	0	1202	1202	21.1	9612	168.6	67.5	21.7	30.3	30.3	30.3	63.2	7.1	
5 I	0	1202	1202	21.1	10814	189.7	75.9	21.0	29.7	29.7	29.7	63.2	7.2	
6 I	0	1202	1202	21.1	12016	210.8	84.3	20.2	28.8	28.8	28.8	63.2	7.2	
7 F	0	0	0	.0	12016	210.8	84.3	42.0	42.0	32.0	42.0	.0	.0	
8 F	0	0	0	.0	12016	210.8	84.3	42.0	42.0	32.0	42.0	.0	.0	
9 F	0	0	0	.0	12016	210.8	84.3	42.0	42.0	32.0	42.0	.0	.0	
10 F	0	0	0	.0	12016	210.8	84.3	42.0	42.0	32.0	42.0	.0	.0	
11 F	0	0	0	.0	12016	210.8	84.3	42.0	42.0	32.0	42.0	.0	.0	
12 F	0	0	0	.0	12016	210.8	84.3	42.0	42.0	32.0	42.0	.0	.0	
13 F	0	0	0	.0	12016	210.8	84.3	42.0	42.0	32.0	42.0	.0	.0	
14 F	2200	0	-2200	-38.6	9816	172.2	68.9	52.0	42.0	36.0	52.0	62.3	6.3	
15 F	2200	0	-2200	-38.6	7616	133.6	53.4	52.0	42.0	38.2	52.0	72.1	7.7	
16 F	2200	0	-2200	-38.6	5416	95.0	38.0	52.0	42.0	39.9	52.0	82.1	9.1	
17 F	2200	0	-2200	-38.6	3216	56.4	22.6	52.0	42.0	41.8	52.0	97.8	11.7	
18 F	0	0	0	.0	3216	56.4	22.6	42.0	42.0	35.4	42.0	.0	.0	
19 F	0	0	0	.0	3216	56.4	22.6	42.0	42.0	35.4	42.0	.0	.0	
20 F	0	0	0	.0	3216	56.4	22.6	42.0	42.0	35.4	42.0	.0	.0	
21 I	0	1202	1202	21.1	1202	21.1	8.4	23.3	31.9	31.9	31.9	63.2	7.1	
22 I	0	1202	1202	21.1	2403	42.2	16.9	23.2	31.8	31.8	31.8	63.2	7.1	
23 I	0	1202	1202	21.1	3605	63.2	25.3	23.1	31.7	31.7	31.7	63.2	7.1	
24 I	0	1202	1202	21.1	4806	84.3	33.7	23.0	31.6	31.6	31.6	63.2	7.1	

CampusEnergy2020
THE POWER TO CHANGE
FEBRUARY 10-14 ▲ SHERATON DENVER DOWNTOWN ▲ DENVER, CO

INTERNATIONAL
DISTRICT ENERGY
ASSOCIATION


Existing Chilled Water Demand July 13, 2017
89°F (DB), 81°F (WB)
Chilled Water Tonnage
Chilled Water kW
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
45 Rock Electric Chillers
Central Plant Electric Chillers
Existing Ice Plant
Steam Chiller
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
Existing kW


Typical Summer Day Post 45 Rock Plant Rebuild
Chilled Water Tonnage
Chilled Water kW
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
Electric Chillers
New Ice Plant
2.5 MW
Existing Ice Plant
Steam Chiller
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
Existing kW
Projected kW


DR Day Post 45 Rock Plant Rebuild
Chilled Water Tonnage
Chilled Water kW
11,000
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
9:00 AM
10:00 AM
11:00 AM
12:00 PM
1:00 PM
2:00 PM
3:00 PM
4:00 PM
5:00 PM
6:00 PM
7:00 PM
Steam Chiller
New Ice Plant
Existing Ice Plant
Electric Chillers
6.5 MW
Existing kW
DR Day kW

Ice Storage Review & Lessons Learned

- **Surge**
  - Max 90 F leaving CWR temp
  - Oversize condenser bundles
- **Footprint = $$$** especially in cities
- **Utility Capital Incentives**
  - Can make/break ROI even with high utility costs

Ice Storage Tips & Lessons Learned

- **Insulation -** 1.5" minimum for glycol
- **Reverse return** piping for hydraulic balancing – first tank supplied is last tank returned
- Complete **full burn** prior to building more ice.
- Design for **low approach** over HX to widen ice delta T, boost ice bank capacity, reduce pumping.

Ice Storage Review & Lessons Learned

- **Warming cycle** over your glycol-CHW HXs – heat the trapped cold glycol
- **Leave HX glycol valves open** after burn cycles
- Include **glycol management system** to maintain system pressure and glycol concentration, with eye wash station nearby
- Every two years, **replenish biocide** in water tanks after full tank burn
- **ASHRAE 15** refrigerant monitoring and exhaust apply normally at chillers
    - Configure refrigerant monitor for each refrigerant type employed

Q&A

Thank You!

Will Kain
PE, CEM, LEED AP BD+C

Gregg Fischer
PE, CEM, LEED AP O+M