2025 PARTNER EXCHANGE
35th Anniversary

Low-Cost, High-Value Chiller Plant Upgrades

Michelle Hull, Applications Engineer
Brian Meyers, Portfolio Leader – Controls
Stephen Scott, Sustainable Systems Leader - Canada

May 2025

WAVES of INNOVATION
TOGETHER WE RISE

TRANE

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TRANE Supply

Michelle Hull

Applications Engineer

- Michelle provides support for the field sales organization, specializing in hydronic systems and energy modeling. Her role also includes creating educational and technical resources, such as Engineers Newsletters, Engineers Newsletter Live, Application Guides, and Air Conditioning Clinics.
- Michelle joined Trane in 2019 as a Test Engineer in the La Crosse Research and Development Lab. She later transitioned to the Customer Direct Services (CDS) team as a Building Performance & Systems Engineer, where she led a cross-functional development team focused on TRACE 3D Plus and provided global support and training for CDS program users.
- Michelle holds a vocational degree in HVAC/R Service & Installation and a Bachelor of Science in Mechanical Engineering from Worcester Polytechnic Institute.

Stephen Scott, P.Eng.

Sustainable Systems Leader - Canada

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- Stephen mentors and coaches the Canadian field sales organization to drive the growth of sustainable systems offerings including electrification of heating, thermal energy storage, and next-generation refrigerants. His role also involves supporting marketing efforts, driving key metrics, and sharing best practices across the organization.

- He graduated in 1997 from Queen’s University with a Bachelor of Science degree in engineering chemistry from and completed Trane’s 98-1 Graduate Training Program. Outside of his professional life, Stephen enjoys spending time with his family, running, playing pickleball, enjoying music, reading, and photography.

Brian Meyers

Portfolio Leader - Controls

- Brian is a seasoned leader in the building automation and management space. Currently serving as the Portfolio Leader for system controls at Trane, Brian provides strategic direction across Trane's Tracer building automation systems portfolio.

- Brian has two decades of experience at Trane, where he has held various positions within the product management organization, including as a system applications engineer and product manager. Brian's work has led to multiple patents for Trane, reflecting his contributions to the building management field.

- Before joining Trane, Brian earned a Bachelor's Degree in Electrical and Computer Engineering and spent ~five years as an applications engineer in the IT field. His expertise in both IT and building management gives him unique insight into the application of modern, connected, building automation systems.

Why Are We Here?

- Reduce Investment
- Energy Efficiency
- Operator Efficiency
- Serving Building Occupants
- Self-Sufficiency

Agenda

- **Utilize existing equipment & infrastructure**
  - Cooling Tower Optimization & Control
  - Pump Pressure Reset
  - Chiller Add/Subtract

- **Upgrading existing equipment**
  - Adding a Variable Speed Drive to a Chiller

- **Upgrading existing infrastructure**
  - Converting Constant Flow Plants to Variable Primary Flow

- **Replacing existing equipment**
  - Condenser Flow Optimization

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Topic 1 - Where do you see the biggest efficiency opportunities without modifying/replacing existing Chiller Plant equipment?

0 responses

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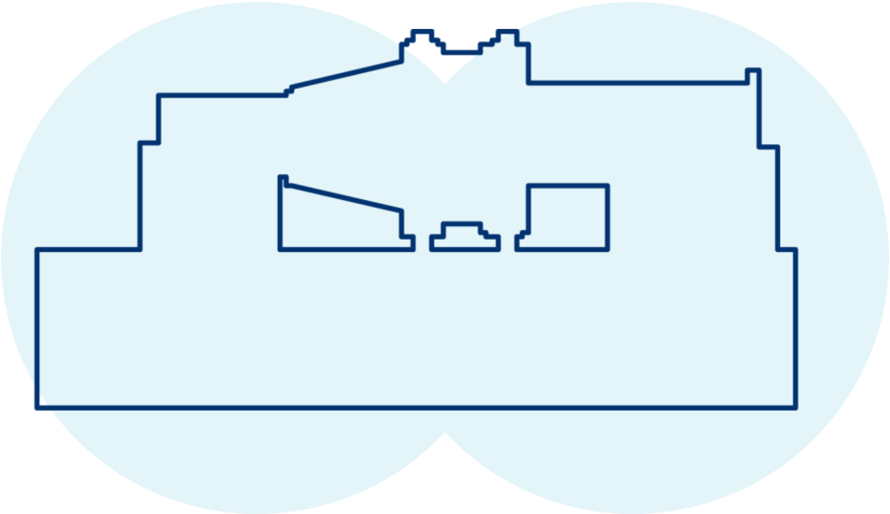
Tower Optimization

Tower Setpoint Optimization

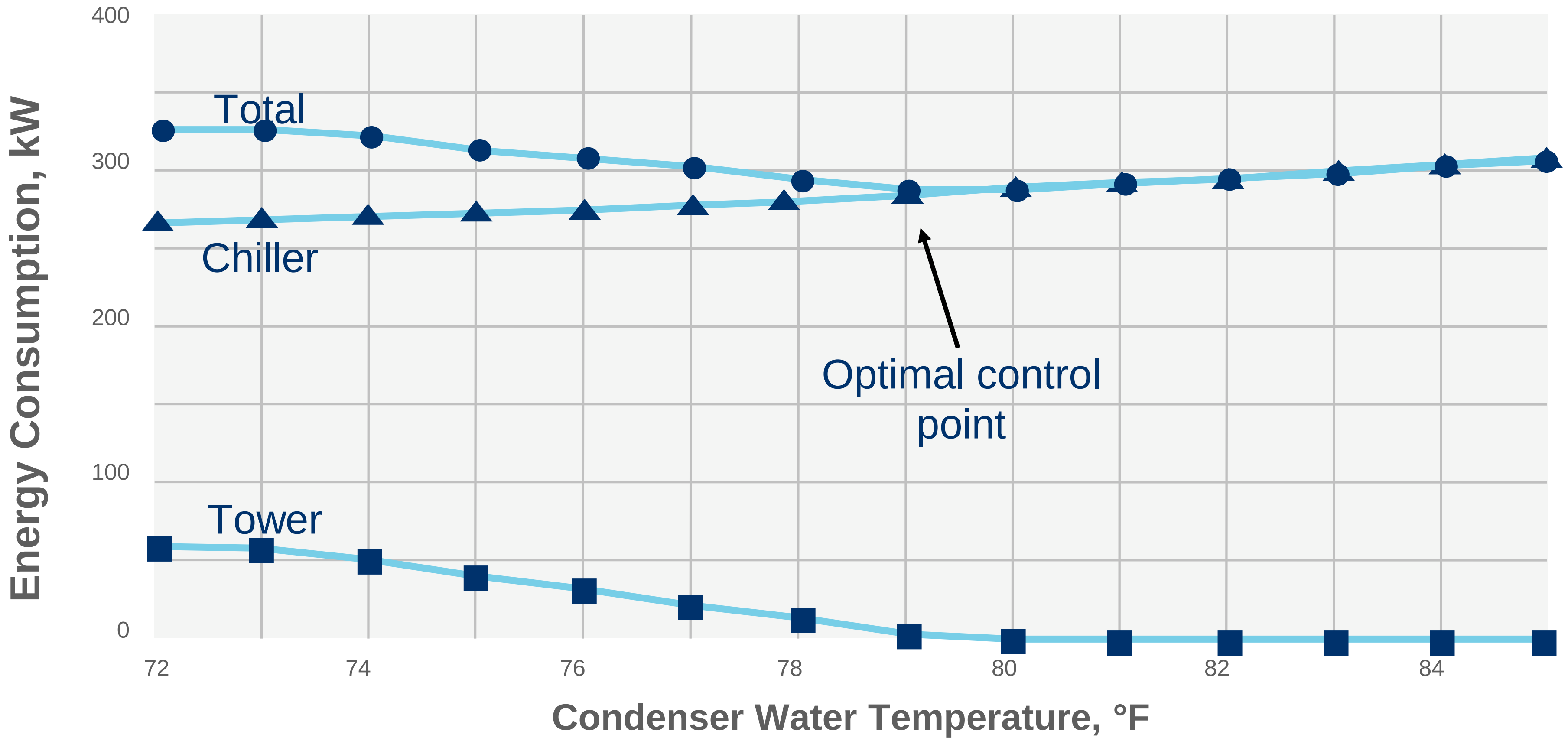
- Load
- Condenser water temperature
- Wet bulb
- Tower design



- Load
- Condenser water temperature
- Chiller design

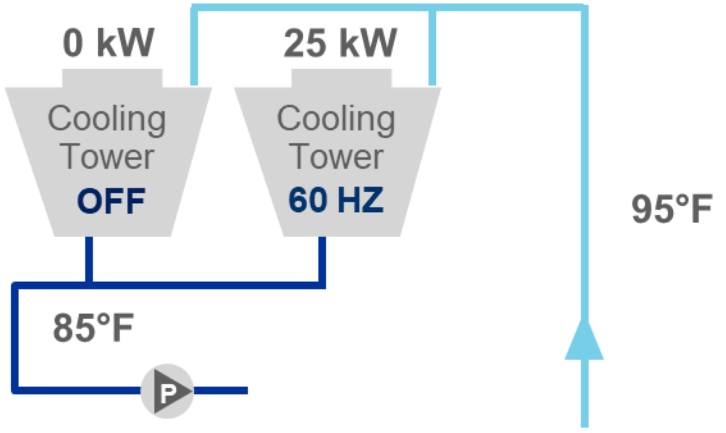
Chiller and Tower Optimization

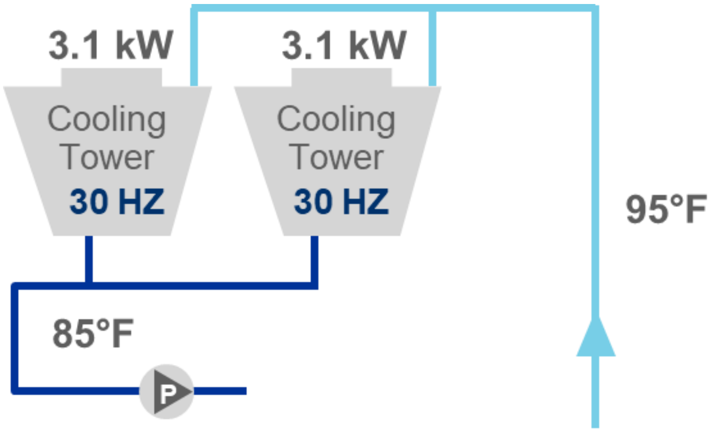
Chiller and Tower Interaction



Cooling Tower Design and Control

Leveraging Fan Laws & Heat Exchanger Surface





Base Case
Operating one cooling tower at 100% speed and full flow

$W_2 = 25\text{ kW} \times (30 / 60)^3$

$W_2 = 3.125\text{ kW}$

Total Fan kW = 25 kW

For Free Discharge Fans
$W_2 = W_1 \times (S_2 / S_1)^3$

Optimized Case
Operating two cooling towers at 50% speed and splitting the flow between the two towers.

$W_2 = 25\text{ kW} \times (30 / 60)^3$

$W_2 = 3.125\text{ kW}$

Total Fan kW = 6.25 kW

Enhanced Cooling Tower Staging

Tower Staging Optimization

Significant cooling tower fan energy savings opportunity

- Operate maximum tower cells while maintaining tower minimum flow
- Operate maximum tower fans as slowly as possible to meet setpoint
- Fans operate at same speed

Cooling Tower Design and Control

Flow Limits

Tower Optimization
Pump Optimization
Chiller Sequencing

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Flow	500-ton chiller	500-ton cooling tower
Design	1000 gpm	1000 gpm
Maximum	2469 gpm	1290 gpm
Minimum	449 gpm	780 gpm
Tower flow range can be much narrower than that of chiller		

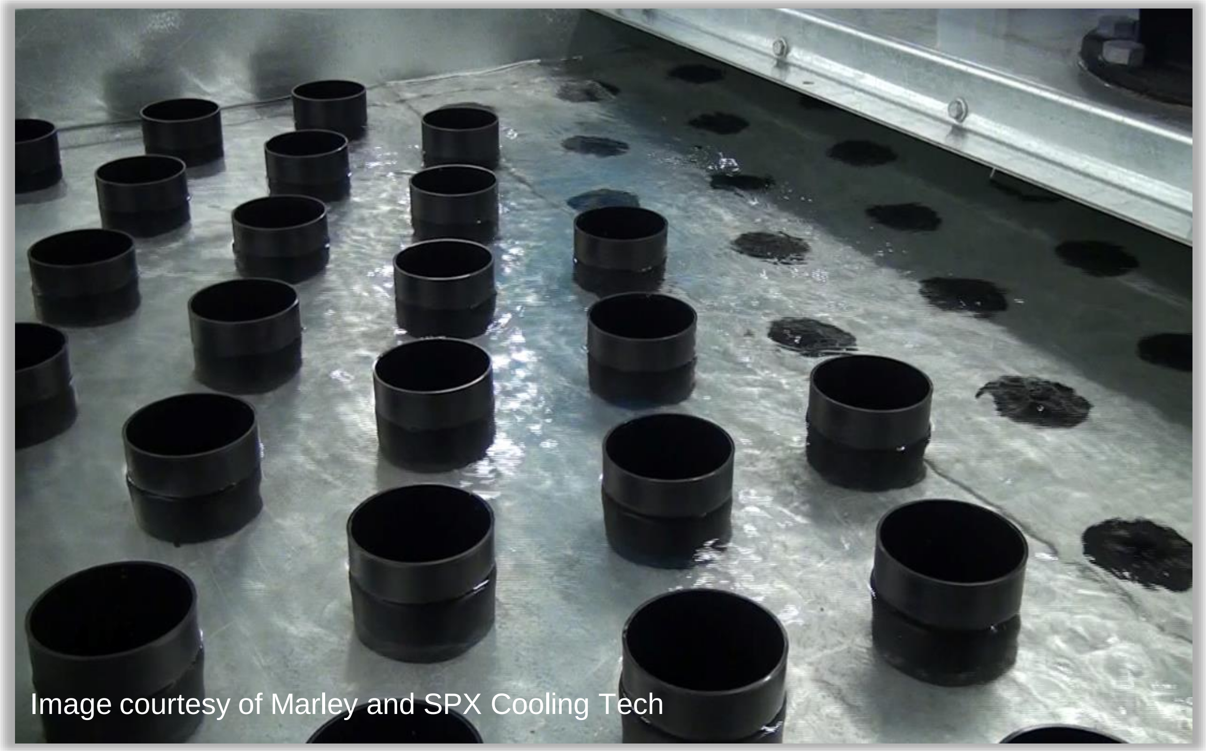
Tower Flow Limits

Flow violation	Result
Too low	"Holes" in fill coverage Lost efficiency Mineral deposits
Too high	"Over-flow" distribution Lost efficiency Lost water Lost treatment chemicals

Consult tower Manufacturer … Specify limits

Cooling Tower Minimum Flow

Mitigate flow issues with Nozzle Cup Installation



Nozzle cups can be utilized to mitigate the impact of lower flow to the tower

Distribution Pumping

Critical Valve Pressure Control

- **Traditionally controlled based on differential pressure setpoint set by a balancer at full load**

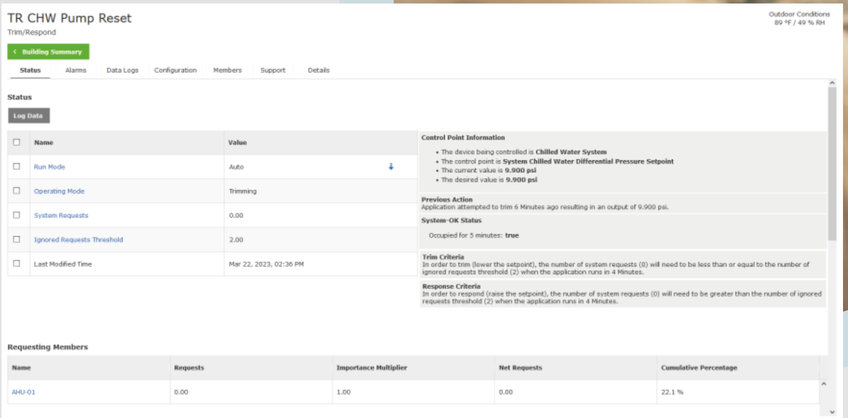
- **Common drawbacks**
  - Highest system pressure closest to pumps
  - Highest system pressure at part load
  - Two-way valve control stability
  - Large chiller plant syndrome (leaky valves)

Pump Pressure Reset

Critical Valve Pressure Control

- **Requires fully integrated systems**

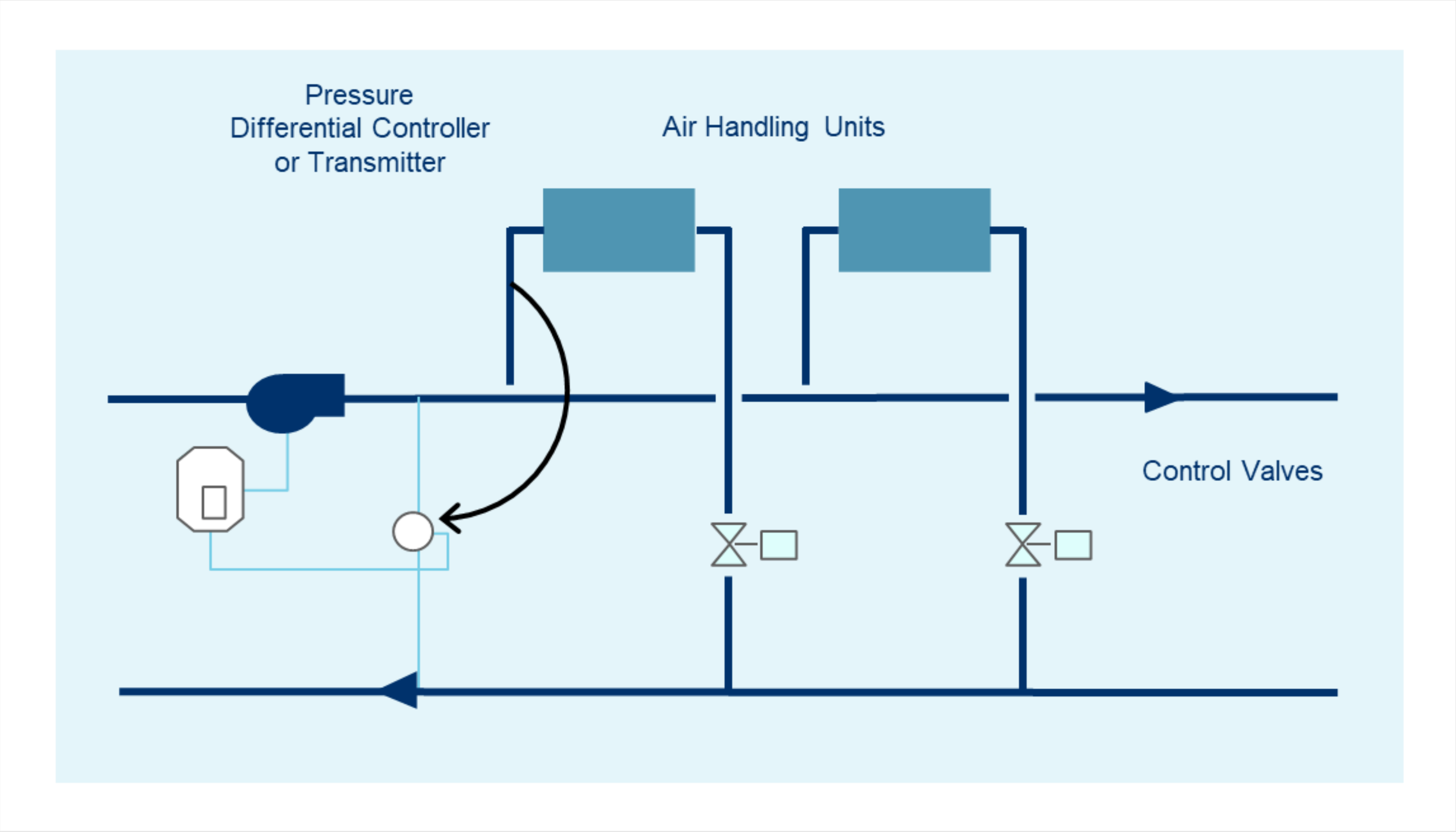
- **Execution:**
  - Monitor critical AHU valve position
  - Reset distribution differential pressure setpoint
  - Trim/Respond methodology with customizable rules based on ASHRAE Guideline 36



Pump Pressure Reset

Critical Valve Pressure Control

- **Critical valve reset**
- **Benefits:**
  - Reduced pump energy
  - Better coil control
  - Extend pump life



Add/Subtract Chillers

Tower Optimization
Pump Optimization
Chiller Sequencing

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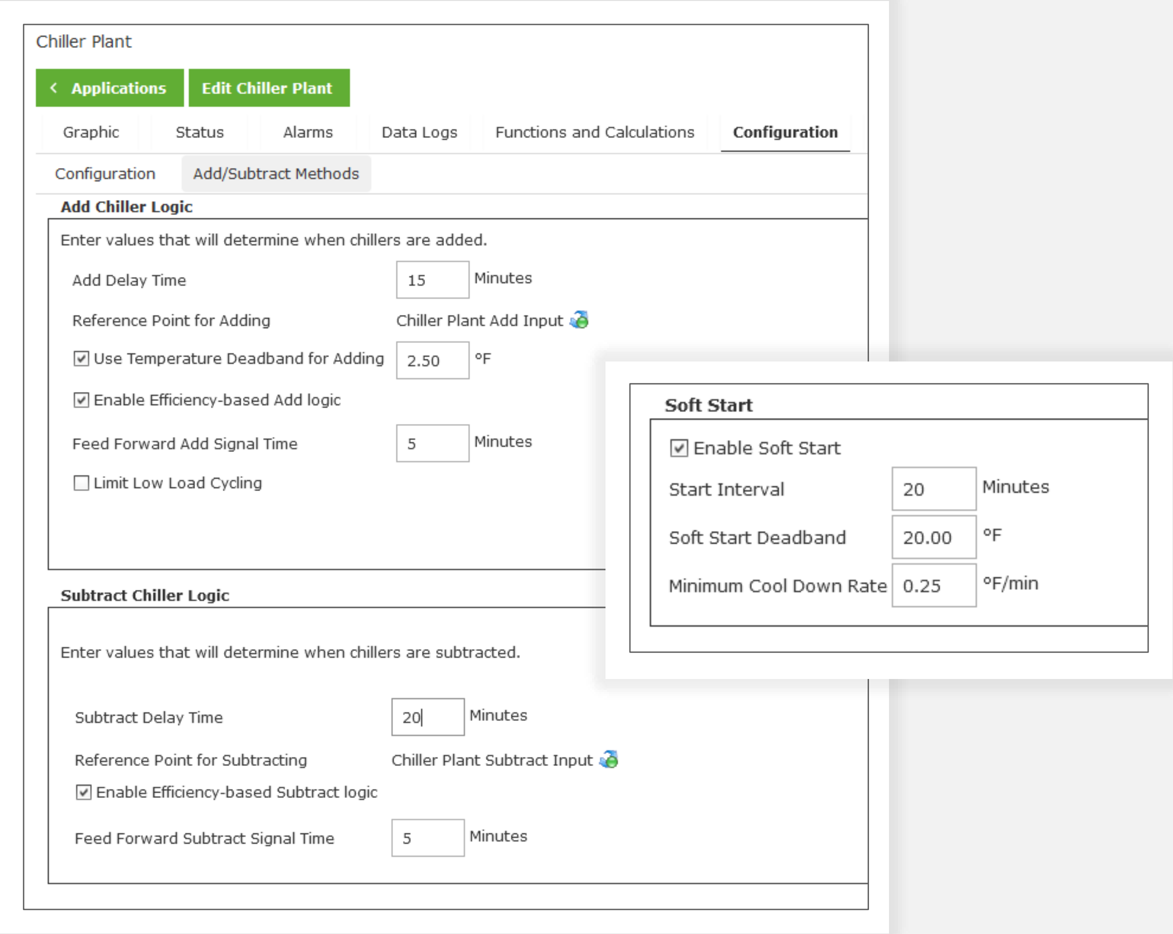
- **Add logic – When to add chillers**
  - Temperature based
  - Efficiency based
- **Subtract logic – When to subtract chillers**
  - Temperature based
  - Efficiency based
  - Flow based
  - Capacity based



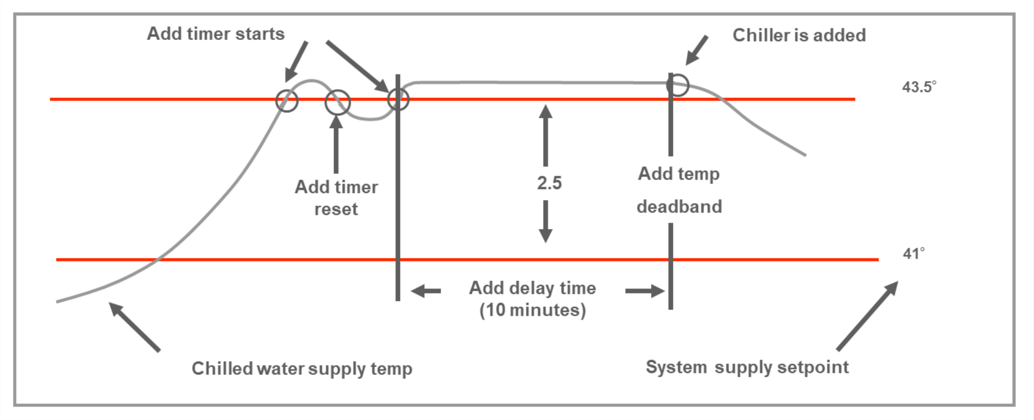
Add/Subtract Example (Temperature)

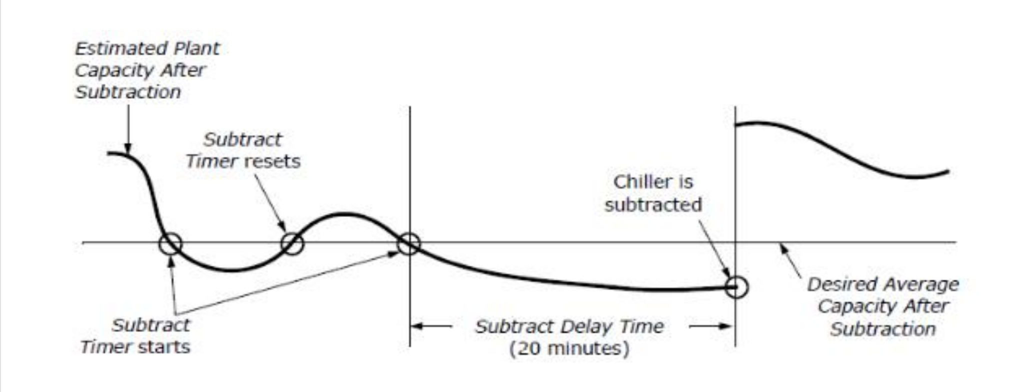
Add

- Based on supply temperature and setpoint
- Operator editable delay time and deadband

Subtract

- Based on chiller capacities
- Operator editable delay time and deadband





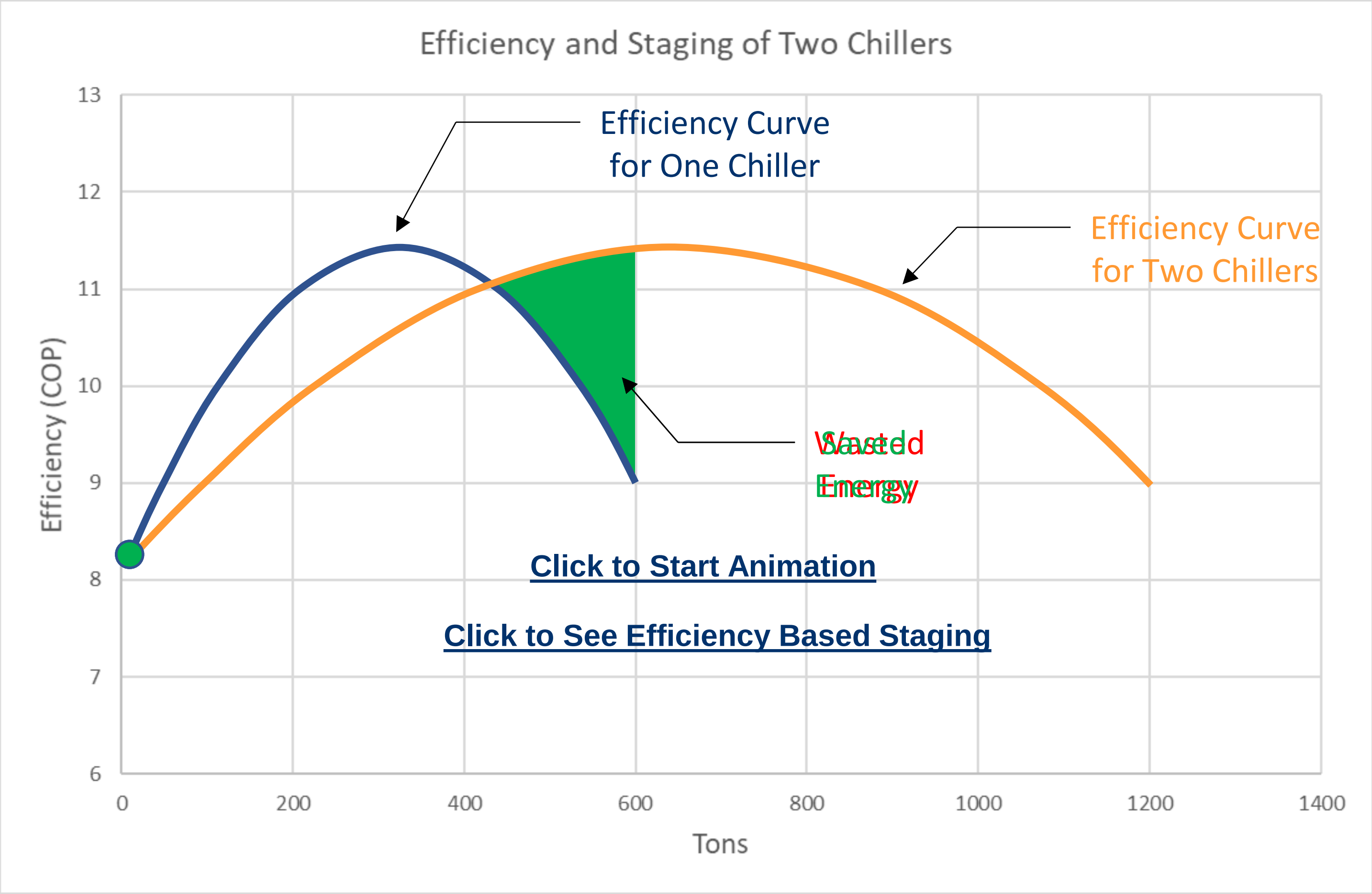
Efficiency Based Add/Subtract

Traditional Staging as Load Increases

- Chiller efficiency will follow the curve as the load increases
- At the intersection, with traditional staging, only one chiller will continue to operate until chiller is fully loaded
- This will result in wasted energy that could have been saved by operating two chillers

Efficiency Staging as Load Increases

- Chiller efficiency will follow the curve as the load increases
- At the intersection, with efficiency staging, the second chiller will be added to increase efficiency
- This will result in saved energy
- The same principle will apply when subtracting chillers



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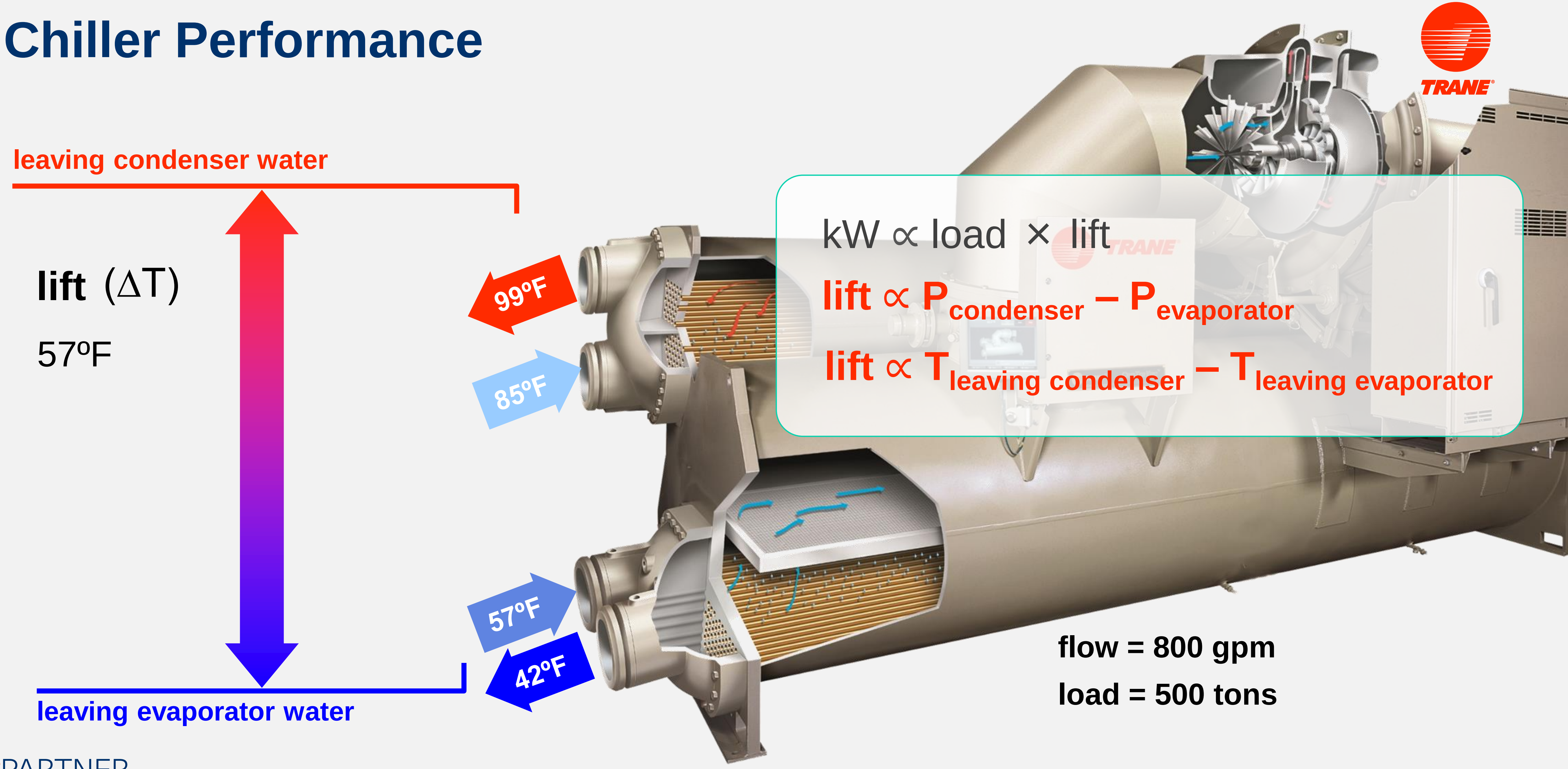
Topic 2 - Adding a variable speed drive to a chiller will **always** result in improved chiller efficiency.

- True
- False
- Uncertain

Chiller Performance



$$kW \propto load \times lift$$

$$lift \propto P_{condenser} - P_{evaporator}$$

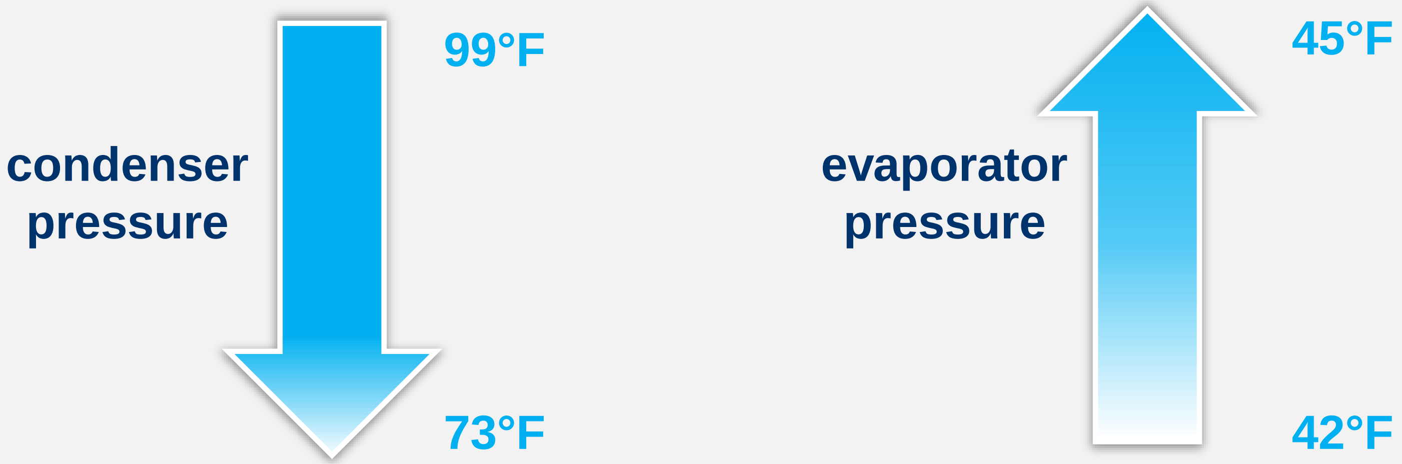
$$lift \propto T_{leaving\ condenser} - T_{leaving\ evaporator}$$

flow = 800 gpm

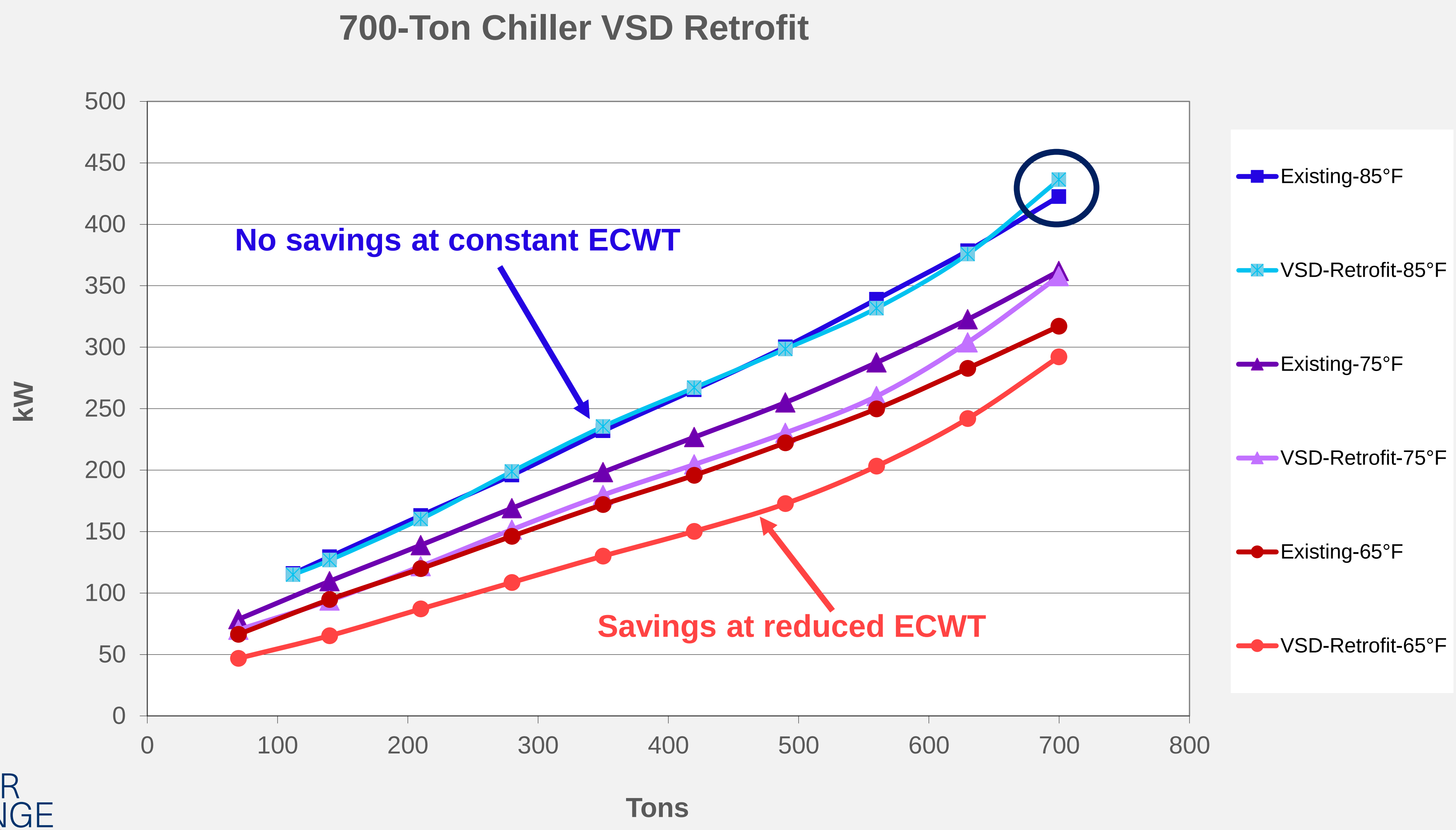
load = 500 tons

Lift Reduction During Operation

- To reduce lift:
  - Decrease condenser pressure by reducing leaving-tower water temperature
  - Increase evaporator pressure by raising chilled water setpoint
- VSDs enhance chiller lift efficiency

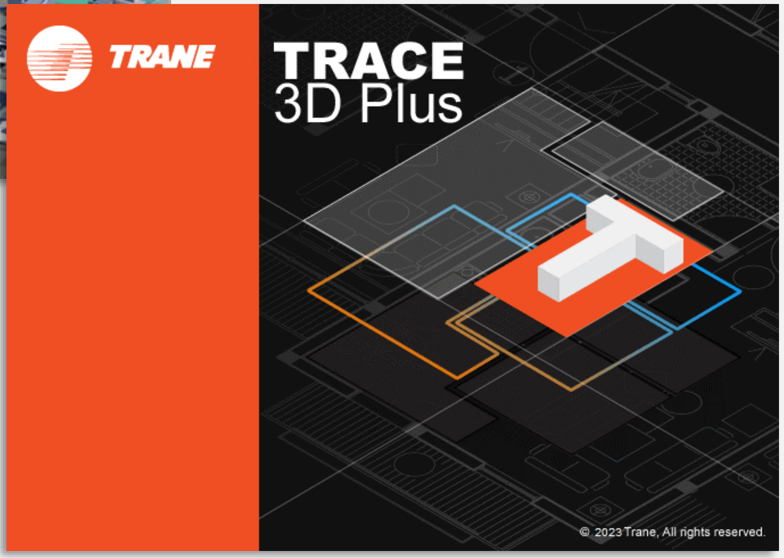


Drive Impact on Existing Chiller Performance



Will it Pay Back?

- Simultaneous
  - Weather data*
  - Building load characteristics*
- Operational hours*
- Economizer capabilities*
- Energy drawn from auxiliaries*
- Actual utility rates
  - consumption & demand



*AHRI 550/590-2015, Section D2

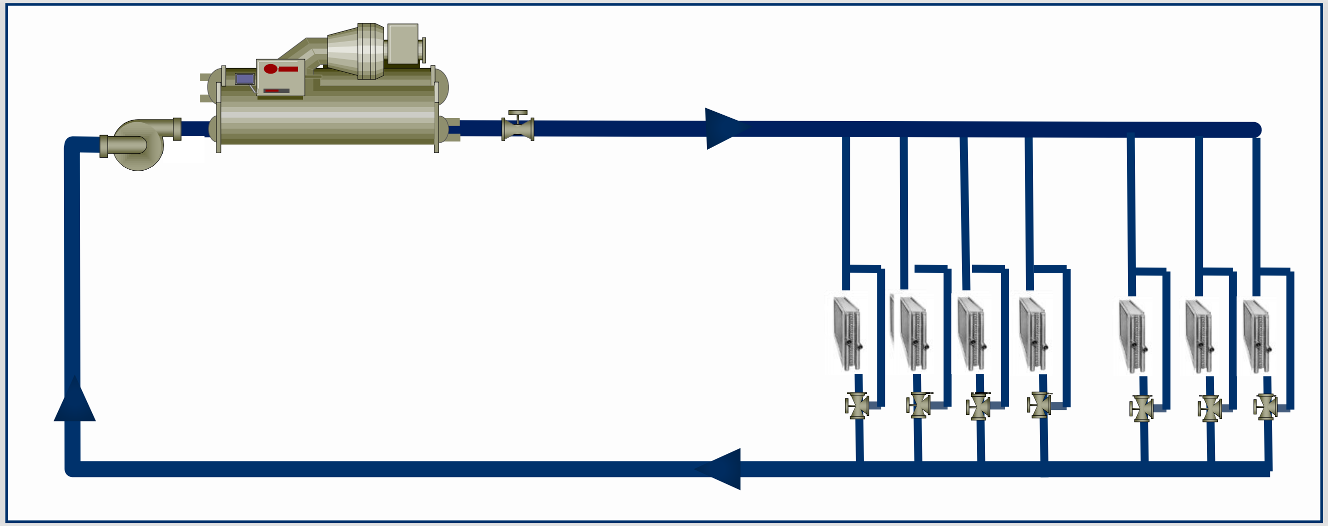
Topic 3 - You do not **always** need to install a bypass pipe when converting a constant flow system to variable primary flow.

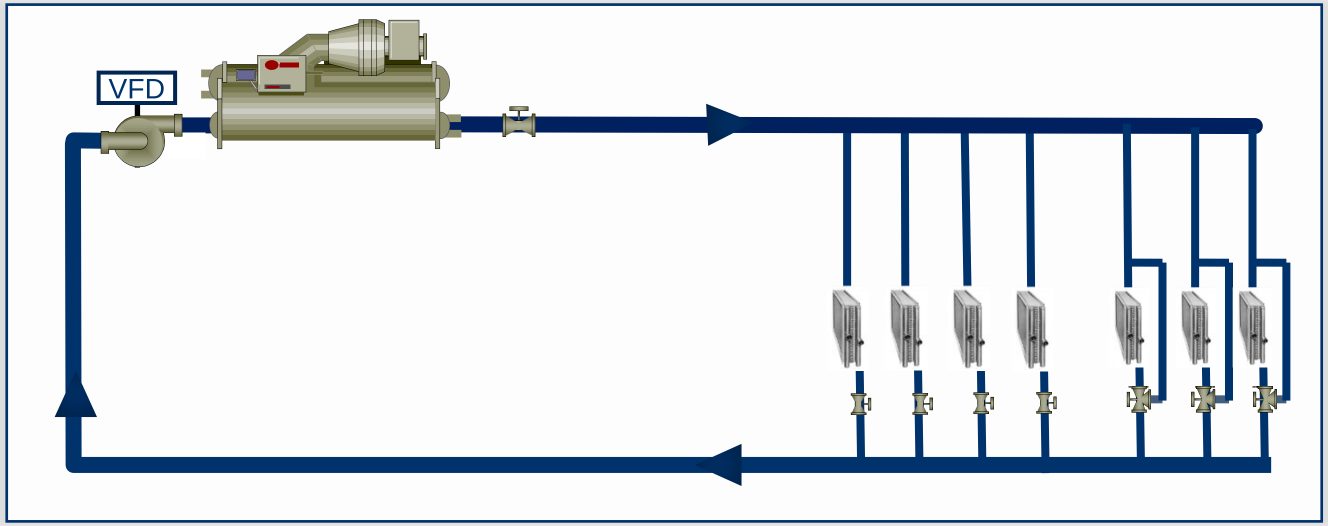
- True
- False
- Uncertain

Convert Constant Flow to Variable Primary Flow

Benefits

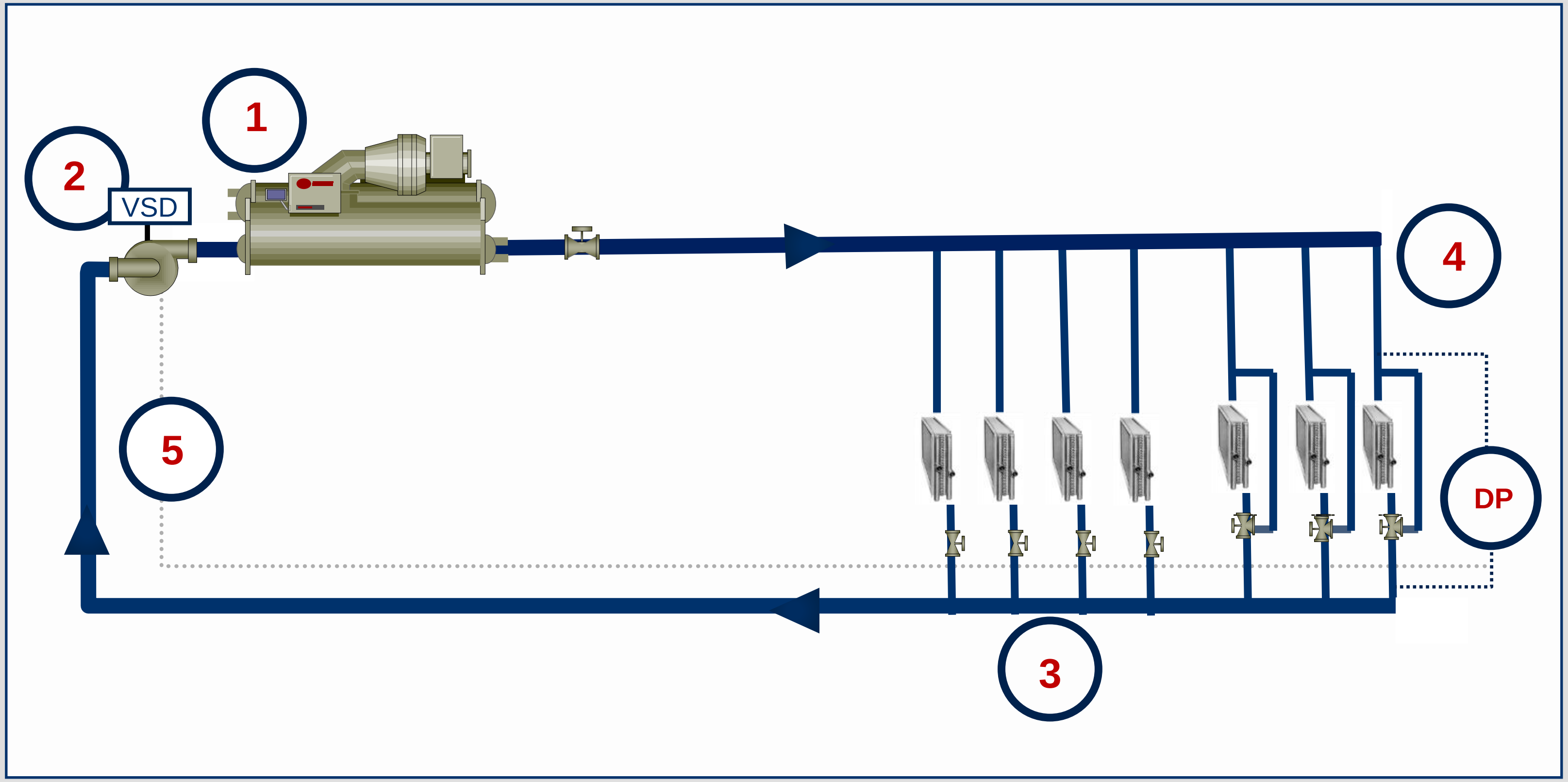
- Often accomplished without interrupting chilled water production
- Ability to be done in phases
- Reduces flow through chiller at part load and compensates for varying ΔT
- Simple in single chiller systems
- Cold water is always flowing





Convert Constant Flow to Variable Primary Flow

1. Check unit controller for VPF compatibility
2. Add VSD to pump
3. Change some 3-way valves to 2-way
4. Leave enough 3-way valves to allow minimum flow
5. Control pump VSD to maintain minimum flow



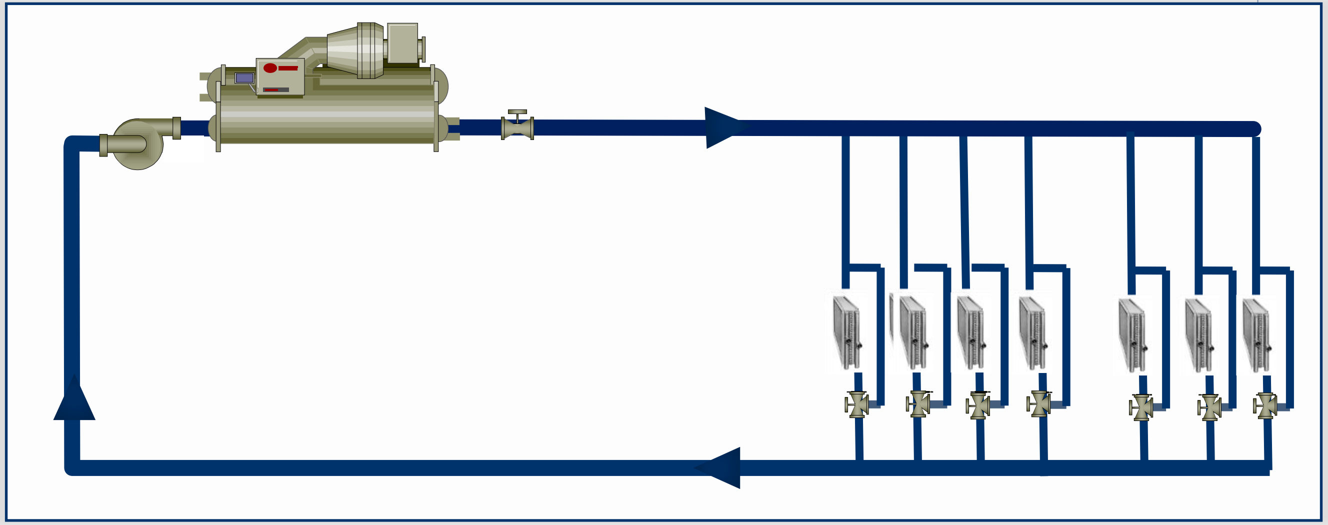
Convert Constant Flow to Variable Primary Flow

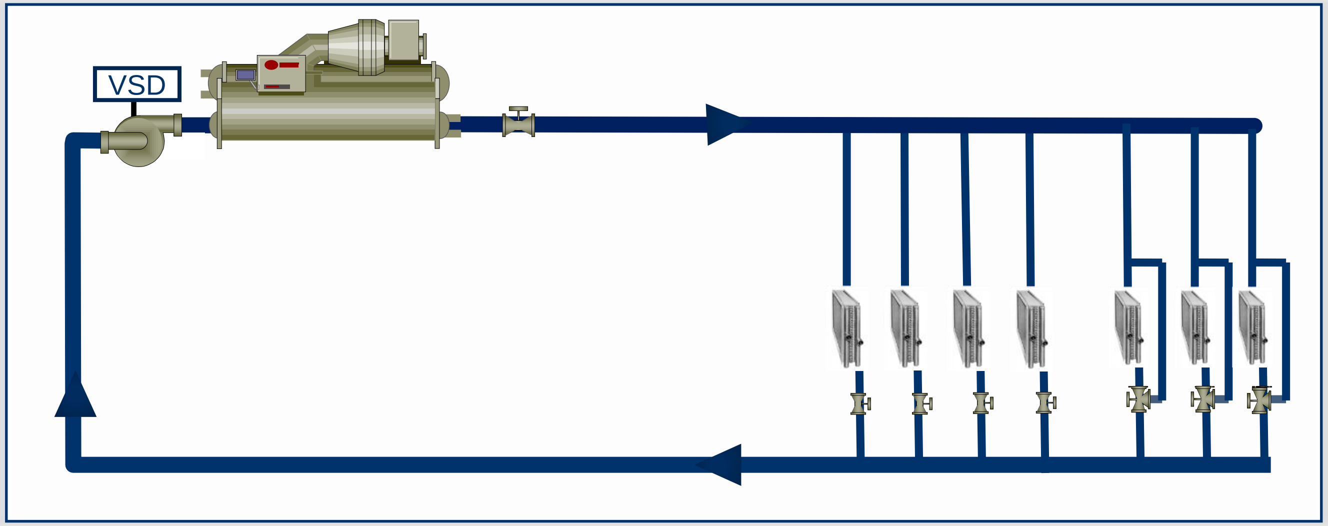
Benefits

- Often accomplished without interrupting chilled water production
- Ability to be done in phases
- Reduces flow through chillers at part load and compensates for varying ΔT
- Simple in small systems
- Cold water is always flowing

Considerations

- Chiller minimum and maximum flow rates
- Determine how many 2-way valves to convert to 3-way valves
- Pump energy
- System ΔT
- Flow rate of change capabilities





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Topic 4 - When replacing a chiller and cooling tower, do you optimize the condenser water flow to reduce energy, water use, and/or installation cost?

- Reduce Energy
- Reduce Water Use
- Reduce Installation Cost

Replacing chiller and tower? Lower the cost and energy!

Adapted from Engineer's Newsletter Live, "State-of-the-Art Chilled Water Plant Design", March 2021.

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- Scenario:
  - 20+ year old 400 Ton existing chiller, tower, condenser pumps at end of life and need to be replaced.
  - Not altering the existing chilled water system, original design 42°F/58°F.
  - Keeping existing condenser piping.
  - Original condenser flow sized for 3 gpm/ton.
  - Budget includes for variable speed compressor technology.
  - No budget for upgrading controls for chiller-tower optimization.
- Ask: How do we lower the installed cost as much as possible, and save some energy costs?

State-of-the-Art Chilled Water Systems
Quickly enter information

Building specific inputs
- Location
- Building Type
- Plant Tonnage

myPLV™
Condenser Water System Optimization

Unit of Measure	IP
Region	North America
Country	United States
State / Territory	Minnesota (MN)
City / Location	Minneapolis (6A)
Building Type and Airside Economizer	Hospital w/o Econ
Chiller Condenser Type	Water Cooled Chiller
Building Peak Load	400 tons
Number of Chillers in Plant	1
Size of Each Chiller	400 tons
Chiller Type	Variable Speed
Plant Capacity (Calculated Point)	400 tons
ASHRAE 90.1 Appx. G Oversize Factor (Calculated Point)	0%

Assumes equal size chillers in parallel

https://www.trane.com/commercial/north-america/us/en/products-systems/design-and-analysis-tools/trane-design-tools/myplv-design-tool.html

State-of-the-Art Chilled Water Systems

Condenser Flow Optimization - Inputs

Design Parameter Inputs

- Wet bulb
- Delta pressure drop
- Cooling tower Control
- Equipment Costs
- Electricity rates

Enter Tower Selection Conditions at 3 gpm/ton

Run Flow Optimizer

Tower Selection Conditions at 3 gpm/ton

Design Wet-Bulb from Weather Zone Data, 0.4% humid (°F)	74.4
Maximum Wet-Bulb from Weather Zone Data (°F)	77.6
Design Wet-Bulb (°F)	79.0
Tower Design Approach (°F)	6.0
Chiller Design Entering Condenser Water Temperature (°F)	85.0
Condenser Pump Design Pressure Rise (ft. H2O)	80.0

Tower Control Method

Tower Control Method	Fixed Tower Approach
Approach Setpoint (°F)	6.0
Minimum Entering Condenser Water Temperature (°F)	55.0

Chiller and Tower Assumptions at 3 gpm/ton

Chiller Design Efficiency at Std AHRI Conditions (kW/ton)	0.6102
Chilled Water Setpoint (°F)	42.0
Tower Performance CTI Std-201 Certified (gpm/hp)	40.0

Cost Assumptions at 3 gpm/ton

Electric Demand Charge ($/kW)	8.00
Length of Cooling Season (months)	8
Electric Consumption Charge ($/kWh)	0.065
Equivalent Pipe Length, Supply and Return (ft)	80

	Default Values	User Override (leave blank to use default)
Cooling Tower Cost ($/ton)	$ 100	
Condenser Pump Cost ($/each)	$ 9,288	
Piping Cost ($/ft)	$ 160	

Condenser Flow Optimization – Summary Results

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Design Choices

- Energy optimized
- Lowest first cost
- Balanced approach

Energy Optimized – pipes, towers, and chiller sized for 3 gpm/ton; pumps and same cost chillers reselected for flow

	Optimized vs 3 GPM/Ton
Optimized Flow (gpm/ton)	1.50
Annualized System Total (kW/ton)	0.5313
Plant Demand Peak (kW)	292.9
First Cost Savings ($)	$2,748
Annual Energy Savings (%)	23.5%
Annual Electrical Cost Savings ($)	$13,711

Select Scenario for myPLV bid forms

See Summary Report

See Detailed Results & Select Specific Flow

Component Sizing

	3 gpm/ton	Resized
Pipes	x	
Tower	x	
Pump		x
Chiller		x

Balanced – 3 gpm/ton sized pipes; reselected towers, pump and chillers (same cost chillers)

	Optimized vs 3 GPM/Ton
Optimized Flow (gpm/ton)	1.50
Annualized System Total (kW/ton)	0.5678
Plant Demand Peak (kW)	303.4
First Cost Savings ($)	$7,191
Annual Energy Savings (%)	18.2%
Annual Electrical Cost Savings ($)	$10,648

Select Scenario for myPLV bid forms

Component Sizing

	3 gpm/ton	Resized
Pipes	x	
Tower		x
Pump		x
Chiller		x

First Cost Optimized – all components reselected (same cost chiller)

	Optimized vs 3 GPM/Ton
Optimized Flow (gpm/ton)	1.50
Annualized System Total (kW/ton)	0.5801
Plant Demand Peak (kW)	304.9
First Cost Savings ($)	$10,391
Annual Energy Savings (%)	16.5%
Annual Electrical Cost Savings ($)	$9,747

Select Scenario for myPLV bid forms

Component Sizing

	3 gpm/ton	Resized
Pipes		x
Tower		x
Pump		x
Chiller		x

Condenser Flow Optimization - Balanced

Balanced – 3 gpm/ton sized pipes; reselected towers, pump and chillers (same cost chillers)

	Optimized vs 3 GPM/Ton
Optimized Flow (gpm/ton)	1.50
Annualized System Total (kW/ton)	0.5678
Plant Demand Peak (kW)	303.4
First Cost Savings ($)	$7,191
Annual Energy Savings (%)	18.2%
Annual Electrical Cost Savings ($)	$10,648

Select Scenario for myPLV bid forms

Component Sizing

	3 gpm/ton	Resized
Pipes	x	
Tower		x
Pump		x
Chiller		x

Equipment sizing at the various condenser flowrates

- Tower is downsized
- Pipes are the same size as 3 gpm/ton
- Pump(s) are downsized
- Chiller is the same cost (need to verify with actual chiller selected)

State-of-the-Art Chilled Water Systems

Condenser Flow Optimization - Balanced

Chillers have physical limits to keep the same chiller cost when reducing condenser flow

- Motor size
- Starter/frequency drive size
- Minimum condenser flow for tubes
- Compressor has limits

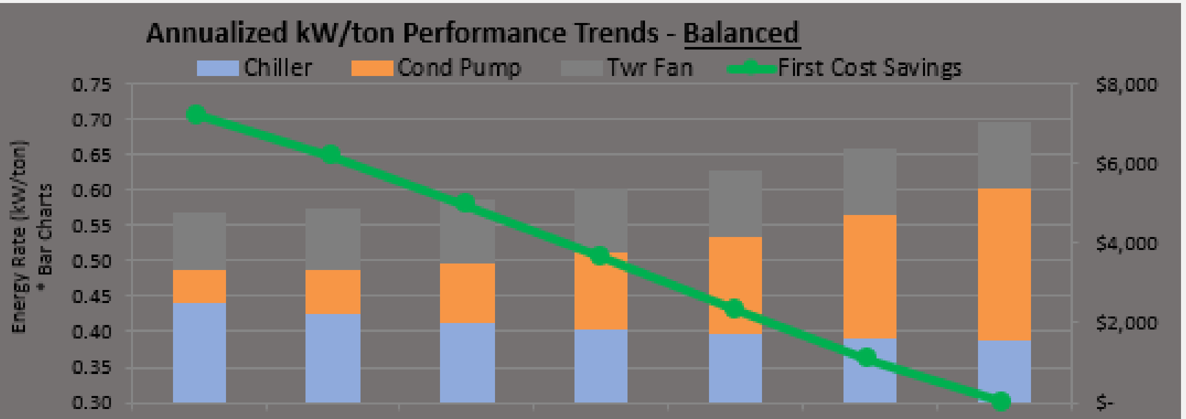
	Base	Same $
Model	CVHE050	CVHE050
Capacity (tons)	400	400
Full Load kW	244.1	279.3
kW/ton	0.6102	0.6983
Motor Size	289	289
Impeller size	242	253
Orifice size	560	500
Leaving Evap (°F)	42	42
Evap Flow (gpm)	597.4	597.4
Entering Evap (°F)	58	58
Evap PD (ft)	5.82	5.82
Entering Cond (°F)	85	85
Cond Flow (gpm)	1,200	650
Cond gpm/ton	3	1.625
Leaving Cond (°F)	94.46	102.87
Cond PD (ft)	20.5	6.98
MCA (A)	403	461
MOCP (A)	700	800

Notes:

- Evaporator: 2-pass non-marine, 050S/580/IMC1, 0.025", 0.0001 fouling.
- Condenser: 2-pass non-marine, 050S/500/TECU, 0.028", 0.00025 fouling.
- Unit mounted, refrigerant cooled AFD with harmonic filter, 460/60/3.

State-of-the-Art Chilled Water Systems

Condenser Flow Optimization – Summary Report



Condenser Flow (gpm/ton)	1.5	1.75	2	2.25	2.5	2.75	3
Optimum Energy Use	X						
Annual Electric Cost							
Consumption Cost ($)	$ 37,137	$ 37,444	$ 38,269	$ 39,444	$ 41,028	$ 43,016	$ 45,421
Demand Cost ($)	$ 19,420	$ 18,975	$ 18,738	$ 19,015	$ 19,751	$ 20,672	$ 21,785
Annual Savings vs 3 gpm/ton ($)	$ 10,648	$ 10,786	$ 10,198	$ 8,747	$ 6,426	$ 3,518	$ -
Estimated System Installed Cost vs 3 gpm/ton (pipes, towers & pump)							
System First Cost ($)	$ 54,897	$ 55,925	$ 57,135	$ 58,442	$ 59,761	$ 61,004	$ 62,088
System First Cost Savings ($)	$ 7,191	$ 6,163	$ 4,952	$ 3,645	$ 2,327	$ 1,084	$ -
System First Cost Savings (%)	11.6%	9.9%	8.0%	5.9%	3.7%	1.7%	0.0%

Simple and easy evaluation in as little as 5 minutes

Condenser Flow Optimization - Balanced

Smaller cooling towers have some added opportunities:

- Reduced make-up water use ($ and for water stressed areas)
- Potentially invest savings into other measures discussed previously
- Lower weight (lower embodied carbon)

	3 gpm/ton	1.625 gpm/ton	
Entering Tower (°F)	94.46	102.87	
Leaving Tower (°F)	85	85	
Flow (gpm)	1200	650	
Ambient Wet Bulb (°F)	79	79	
Evaporation at 50% RH (gpm)	12.2	11.4	-6.6%
Fan Motor Size (hp)	40	15	-62.5%
Shipping Weight (lb)	7411	7057	-4.8%

Breakout Workshops

Thank you!

If you would like to receive PDH credit for this session, please be sure to provide your feedback in the applicable session survey.
(Also available via the event App!)

**Surveys close June 4th, 2025*

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