TRANE

# Agenda and Objectives

Ingersoll Rand

Trane Engineers Newsletter Live Series

## Upgrading Existing Chilled-Water Systems

The discussion for upgrading a chilled-water system begins for several reasons: repurposing a building, reducing energy use or replacing outdated equipment to name a few. A U.S. DOE-funded study concluded that commissioning is indeed cost-effective for both new and existing buildings with potential energy cost savings of over $18 billion.

This course will provide designers with specific strategies for chiller upgrades, optimization or replacement. We'll also discuss reusing components of a chilled-water system and identify control upgrades that are often beneficial.

By attending this ENL you will be able to:

1. Identify opportunities to upgrade or repurpose chillers
2. Apply various design strategies and compare the energy-saving opportunities they offer existing systems
3. Apply the use of variable flow in existing systems
4. Identify and apply control strategies to optimize and reduce system energy use and lower energy costs

Agenda

1) Overview
    - a) Repurposing a building
    - b) Remove false loads
    - c) Retune/recommission
2) Change the chiller
    - a) Retrofit (incentives, drive, free cooling, reselection)
    - b) Replace
3) Select different design parameters
    - a) Expand on use of additional lift (how it's supposed to run)
    - b) Retrofit chilled-water opportunities
    - c) Retrofit condenser water opportunities
4) Change system configuration
    - a) Primary-secondary
    - b) Variable primary/variable secondary
    - c) VPF
    - d) Unit control retrofits
    - e) Ice
5) Enhanced controls
    - a) How many chillers to operate
    - b) Pump pressure optimization
    - c) Chiller tower optimization
    - d) VFD tower
    - e) Variable condenser water flow
6) Summary, resources

# Presenters

Trane Engineers Newsletter Live Series

## Upgrading Existing Chilled-Water Systems

(2011)

**Susanna Hanson | applications engineer | Trane**

Susanna is an applications engineer at Trane with over eleven years of experience with chilled-water systems and HVAC building load and energy analysis. Her primary responsibility is to aid system design engineers and Trane personnel in the proper design and application of HVAC systems. Her main areas of expertise include chilled-water systems and ASHRAE Standard 90.1. She is also a Certified Energy Manager.

She has authored several articles on chilled water plant design, and is a member of ASHRAE SSPC 90.1 Energy Standard for Buildings Except Low-Rise Residential Buildings. Susanna earned a bachelor's degree in industrial and systems engineering from the University of Florida, where she focused on building energy management and simulation.

**Mick Schwedler, PE | manager, applications engineering | Trane**

Mick has been involved in the development, training, and support of mechanical systems for Trane since 1982. With expertise in system optimization and control (in which he holds patents), and in chilled-water system design, Mick's primary responsibility is to help designers properly apply Trane products and systems. To do so, he provides one-on-one support, writes technical publications, and presents seminars.

Mick is the immediate past Chair of SSPC 90.1, which was responsible for writing ANSI/ASHRAE/IESNA 90.1-2007, a prerequisite for LEED. He also contributed to the ASHRAE GreenGuide and is a former member of the LEED Energy and Atmospheric Technical Advisory Group (TAG). Mick earned his mechanical engineering degree from Northwestern University and holds a master's degree from the University of Wisconsin Solar Energy Laboratory.

**Bonnie Spalding | service products manager | Trane**

Bonnie joined Trane in 2004 as a Marketing Engineer for the Rental Services business. Currently she manages the Trane Service Products group, the team responsible for providing chiller upgrade and retrofit products including refrigerant conversions, purges, AdaptiView controls, frequency drives, CenTraVac motors and starters. The primary goal of her team is to help building owners/operators reduce HVAC operating costs through modernization of their chillers.

Prior to Trane she spent 15 years in engineering, sales, and marketing within the Ingersoll Rand air compressor business. Bonnie earned her Bachelor of Science degree in Mechanical Engineering from University of North Carolina at Charlotte.

## Upgrading Existing Chilled-Water Systems

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upgrading existing chilled-water systems

## What You'll Learn…

- Strategies for chiller upgrades, optimization or replacement
- How to apply various design strategies
- Apply the use of variable flow in existing systems
- Identify and apply control strategies to optimize and reduce system energy use and lower energy costs.




## Agenda

- Motivation for upgrade, replacement
- Upgrading existing chillers
- Repurposing chillers
- Retrofitting the chilled water system
- Control upgrades
- Condenser-side opportunities

## Today's Presenters

**Bonnie Spalding**
Service Products Manager

## Today's Presenters

**Mick Schwedler**
Applications
Engineering Manager

**Susanna Hanson**
Applications
Engineer

## Overview

- What prompts an upgrade?
  - System not working well anymore
  - Building repurposed or loads reduced
  - Re-commissioning for efficiency, other benefits
    - Existing buildings: median 15% cost savings, payback 0.7 years
    - New buildings: median payback period 4.8 years
    - Widespread commissioning of existing commercial buildings could save the nation over $18 billion a year in energy costs alone

Source: http://eetd.lbl.gov/emills/PUBS/Cx-Costs-Benefits.html




## What's Not Working

- Equipment aged out or requires too much maintenance
- Out of capacity
- Energy bills are too high

## Building Repurposed

- Space use classification changes
- Tenants attracted and retained by operation, comfort
- Process or manufacturing loads added or removed




## Reduce Loads

**Remove load before modifying chilled water system**

- Lighting retrofits, local or task lighting addressed
- Envelope retrofits (windows, doors, insulation, etc.)
- Localized heating and cooling removed or reduced
- Items identified in an energy audit

## Reduce Loads

- Simultaneous heating and cooling
  - Stuck or broken valves
  - Leaky return dampers
- Control issues
  - Rogue zones
    - Zones that are rarely or never satisfied hinder system control algorithms
  - Overrides
    - Temperature
    - Flow
    - Schedule

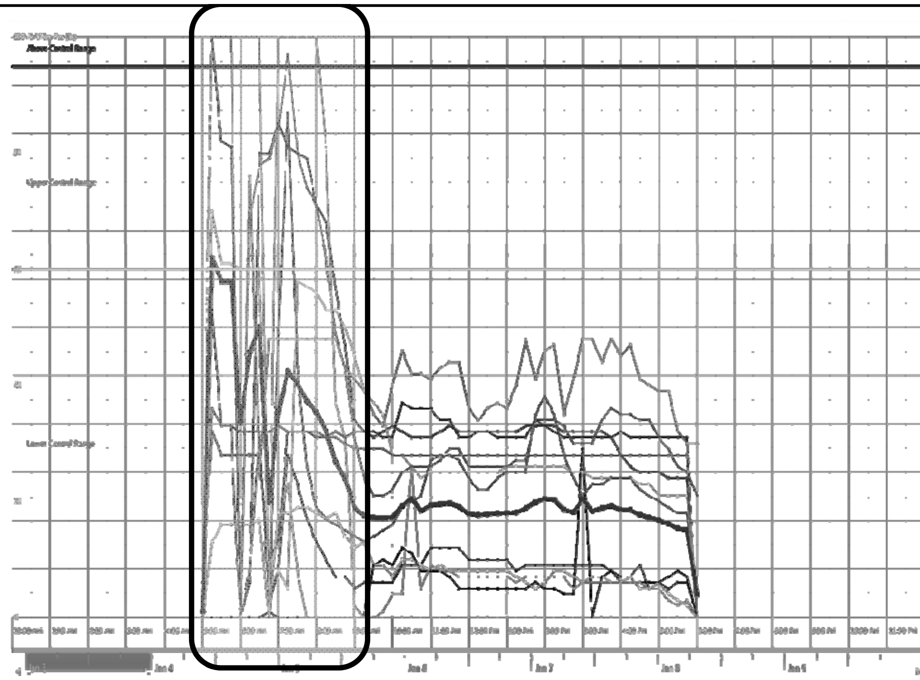
 

## Retune or Recommission

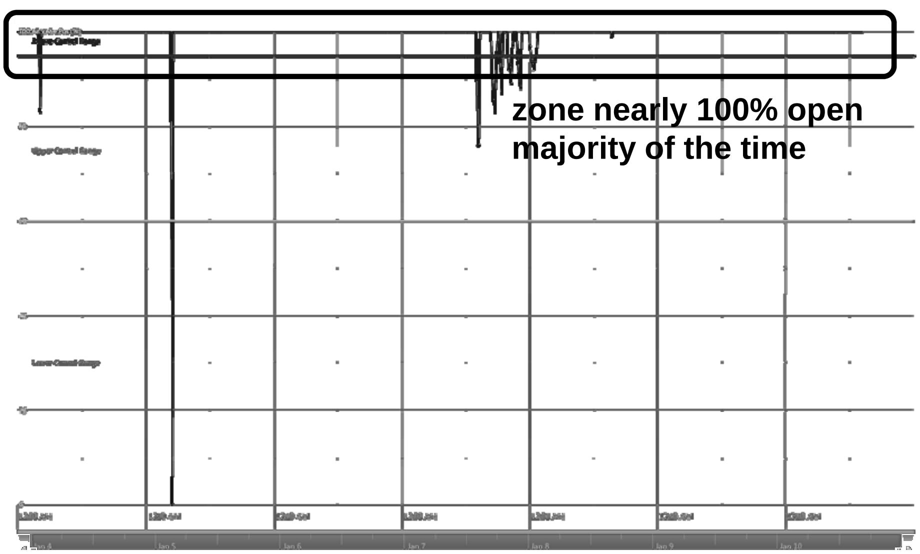
- Does the system work well as it was designed?
- Does the system as designed not work well?

- What modes of operation are working/not working?
- What triggered the problem?
- Can control be improved?






zone nearly 100% open
majority of the time

## Retune or Recommission

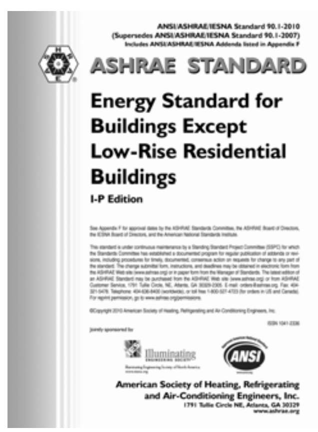
- Does the system work well as it was designed?
- Does the system as designed not work well?

- What modes of operation are working/not working?
- What triggered the problem?
- Can control be improved?
- **System size truly the problem—what can be done?**




## Chiller Upgrade Options

- Replace the chiller
  - Size the new chiller properly
  - Compare new chiller options
    - Variable speed drive
    - High efficiency
- Retrofit with a drive
- Comply with ASHRAE 90.1



## Upgrading Existing Chilled-Water Systems

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**Chiller Replacement**

## Replace the Chiller

- High efficiency or drive?
  - Incentives?
- Conservatism factor
  - Lift or tons?
- Expanded lift or capacity reselection
  - Pipes are usually unchanged
  - Space for towers may be limited
  - Simultaneous heating and cooling (heat recovery?)
  - Escalating on-peak energy or demand charges (ice or reduced peak kW from chiller)

air-cooled chillers
## ASHRAE 90.1

| Capacity (tons) | 2007 | 2010 |
|---|---|---|
| <150 | 9.562 EER<br>10.416 IPLV | 9.562 EER<br>12.500 IPLV |
| ≥ 150 | 9.562 EER<br>10.416 IPLV | 9.562 EER<br>12.750 IPLV |

- Positive displacement chillers evaluated at AHRI Standard 550/590 “standard” conditions
  (there is no derate for non-standard conditions)




water-cooled positive displacement chillers
## ASHRAE 90.1

| Capacity (tons) | 2007 | 2010 Path A | 2010 Path B |
|---|---|---|---|
| <75 | 0.790<br>0.676 | 0.780<br>0.630 | 0.800<br>0.600 |
| ≥ 75 and < 150 | | 0.775<br>0.615 | 0.790<br>0.586 |
| ≥ 150 and < 300 | 0.717<br>.0627 | 0.680<br>0.580 | 0.718<br>0.540 |
| ≥ 300 | 0.639<br>0.571 | 0.620<br>0.540 | 0.639<br>0.490 |

- **Positive displacement chillers evaluated only at AHRI Standard 550/590 “standard” conditions**

### water-cooled centrifugal chillers
## ASHRAE 90.1

| Capacity (tons) | 2007 | | 2010 Path A | | 2010 Path B | |
|---|---|---|---|---|---|---|
| | Full Load | IPLV | Full Load | IPLV | Full Load | IPLV |
| <150 | 0.703 | 0.669 | 0.634 | 0.596 | 0.639 | 0.450 |
| ≥ 150 and < 300 | 0.634 | 0.596 | | | | |
| ≥ 300 and < 600 | 0.576 | 0.549 | 0.576 | 0.549 | 0.600 | 0.400 |
| ≥ 600 | 0.576 | 0.549 | 0.570 | 0.539 | 0.590 | 0.400 |

- **requirements must be adjusted for “non-standard” conditions**




### centrifugal chiller nonstandard adjustment
## ASHRAE 90.1

- Full load requirement = Table FL / kAdj
- NPLV requirement = Table IPLV / kAdj
- Kadj = A * B where
  - A = 0.00000014592 * (LIFT)^4 – 0.0000346496 * (LIFT)^3 + 0.00314196 * (LIFT)^2 – 0.147199 * (LIFT) + 3.9302
    - LIFT = LvgCond - LvgEvap
    - LvgCond = Full-load condenser leaving water temperature (°F)
    - LvgEvap = Full-load leaving evaporator temperature (°F)
  - B = 0.0015 * LvgEvap + 0.934
- Applicable over the following full-load design ranges:
  - Minimum Leaving Evaporator Temperature: 36°F
  - Maximum Leaving Condenser Temperature: 115°F
  - LIFT ≥ 20°F and ≤ 80°F

## Chiller Replacement

- Correctly size the new chiller
  - Determine actual building load
  - Downsize chiller if possible
  - Upsizing? Higher efficiency to reuse electrical service

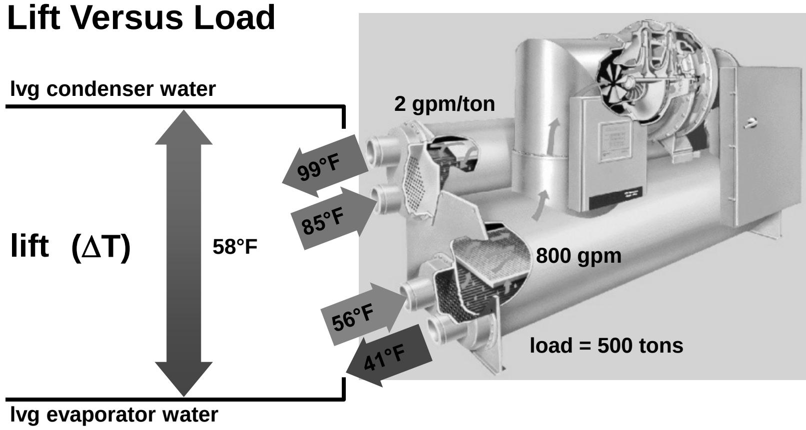
| Chiller Size | Chiller Efficiency | Electrical Service |
|---|---|---|
| 400 tons | 0.68 kW/ton | 272 kW |
| 550 tons | 0.50 kW/ton | 275 kW |
| 550 tons with VFD | 0.57 kW/ton | 314 kW |
| **Max Chiller Size** | **Chiller Efficiency** | **Electrical Service** |
| 574 tons with VFD | 0.53 kW/ton | 300 kW |
| 600 tons | 0.50 kW/ton | 300 kW |




## Chiller Replacement

- Correctly size the new chiller
  - Determine actual building load
  - Downsize chiller if possible
  - If more chiller capacity is needed, higher efficiency reduces need for expanding electrical service
- Replace with higher efficiency chiller
  - Reduce demand and consumption
  - Constant speed or variable speed?

## Lift Versus Load




$$\text{load} \ \alpha \ \text{gpm} \times (T_{\text{ent evp}} - T_{\text{lvg evp}})$$

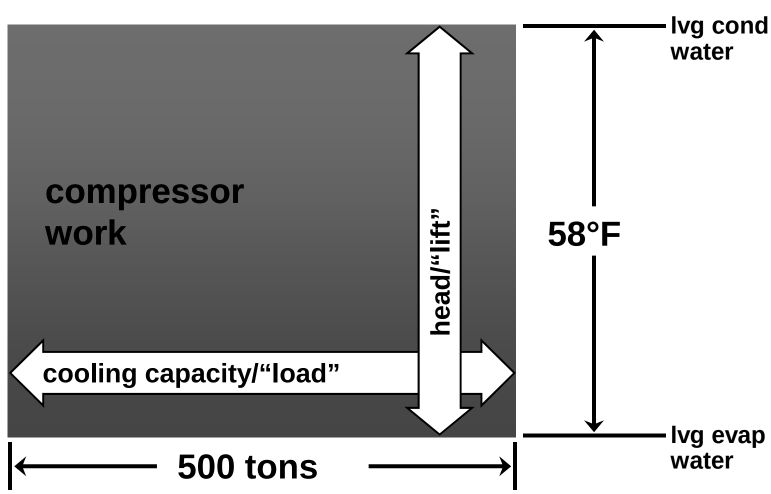
$$\text{lift} \ \alpha \ P_{\text{cnd}} - P_{\text{evp}}$$

$$\text{lift} \ \alpha \ T_{\text{lvg cnd}} - T_{\text{lvg evp}}$$



## Compressor Work and Chiller Efficiency

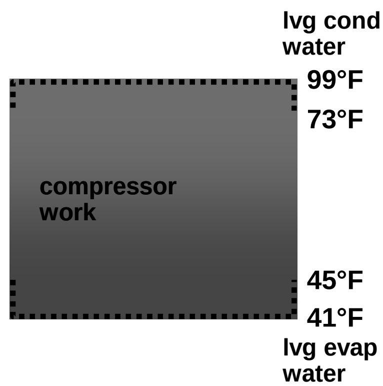




## Lessons Learned

- To reduce lift:
  - Decrease condenser pressure by reducing leaving-tower water temperature
  - Increase evaporator pressure by raising chilled water setpoint
- VSDs optimize chiller <u>lift</u> efficiency







**constant or variable speed?**

## Chiller Replacement

- Compare same price VSD chiller and higher full load efficiency chiller
  - Make sure each chiller meets ASHRAE 90.1 full and part-load requirements
- Use comprehensive analysis to determine which to purchase

same-price chiller

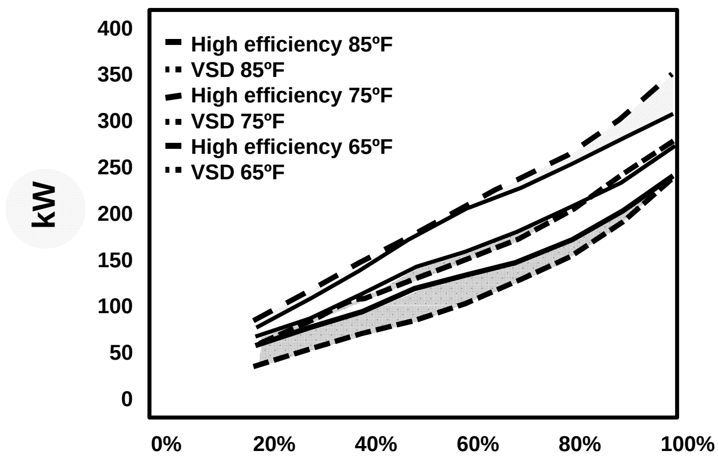
## Example Performance

| Option | Full Load (kW/ton) | IPLV (kW/ton) |
|---|---|---|
| VSD | 0.572 | 0.357 |
| High Efficiency | 0.501 | 0.430 |

same-price chiller

## Example Performance



## same-price chiller
# Observations

- At high condenser water temperatures, constant speed is more efficient
- At low condenser water temperatures (low lift), variable speed is more efficient
- Analysis is required
  - Load and condenser water temperature do not vary directly with one another
  - Account for loads at different ECWT




## guidance
# VSD or High Efficiency?

- High efficiency
  - Significant demand charges
  - Humid climates
  - Multiple chillers in the plant
  - Economizer that reduces low load/low lift operating hours
- VSD
  - Many hours at low condenser water temperature—and low load
  - Perhaps only on one chiller
  - Factor in replacement of VSD when performing life cycle assessment

## Upgrading Existing Chilled-Water Systems

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**Chiller Retrofits**

## Chiller Upgrade Options

- Comply with ASHRAE 90.1
- Replace the chiller
  - Size the new chiller properly
  - Compare new chiller options
    - Variable speed drive
    - High efficiency
- **Retrofit**
  - **Add a variable speed drive**
  - **Re-select**
  - **Field modifications**

## Add VSD to Existing Chiller

- Comply with ASHRAE 90.1 requirements for retrofits
  - Ensure that modification will not result in an increase in annual energy consumption
- Controls updates if necessary or beneficial
- Perform return on investment analysis
- Understand how a drive may benefit chiller performance

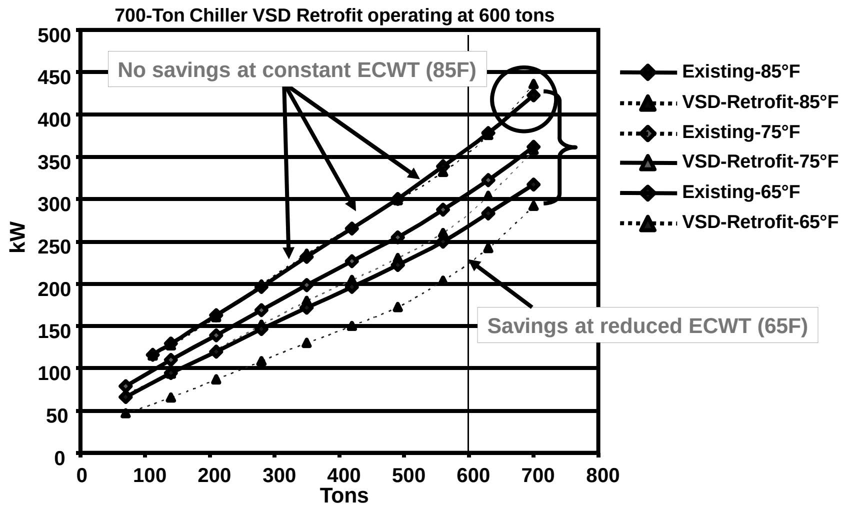
## VSD
## Existing Chiller Performance

- Demand rises 2–4% at design conditions
- Largest benefit at lower condenser water temperatures
- Corrects for improper impeller sizing
  - Due to original design conservatism
  - Due to changes in loads
  - Due to other duty changes
    - Ice builder now in normal cooling line-up
    - Heat recovery not needed all the time
    - Series chiller conversion from parallel

drive impact

## Existing Chiller Performance







drive retrofit

## Issues to Consider

Utility rates?
Demand Charge?
Ratchet?

- VSD efficiency loss at full load
- If chiller was oversized the demand may be lower

How often will it operate at advantageous conditions?

- 24/7 operation may be beneficial
- Economizer reduces the loads at advantageous conditions

drive retrofit

## Issues to Consider

How much energy is consumed by the cooling tower?

- Need to balance tower and chiller energy
- Is tower retrofit also needed

Is the chiller oversized for the load?

- Load reduction in conjunction with reduced CW temperatures may offer significant savings




rate of return

## Return on Investment

- Investment
  - First costs
  - Incentives
- Annual operating costs
  - Calculated savings
- Life-cycle cost analysis
- Payback

## Financial Incentives

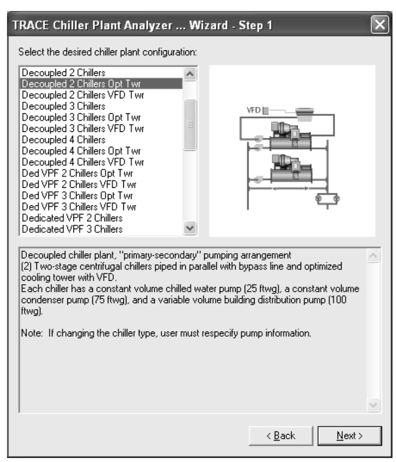
- Government
  - Tax incentives
    - Corporate, property, sales
  - Grants
- Utility
  - Rebates
  - Rate discounts
  - Low/no interest loans
- Resource:
  - DSIRE (Database for State Incentives for Renewables & Efficiency) found at dsireusa.org




## Annual Operating Costs

**Energy Savings Modeling**

- Peak cooling load
- Simultaneous
  - Weather data
  - Building profile
  - Building location
- Operational hours
- Economizer capabilities
- Auxiliary energy
- Actual utility rates



## Chiller Upgrade Options

- Comply with ASHRAE 90.1
- Replace the chiller
  - Size the new chiller properly
  - Compare new chiller options
    - Variable speed drive
    - High efficiency
- **Retrofit**
  - **Add a variable speed drive**
  - **Re-select**
  - **Field modifications**

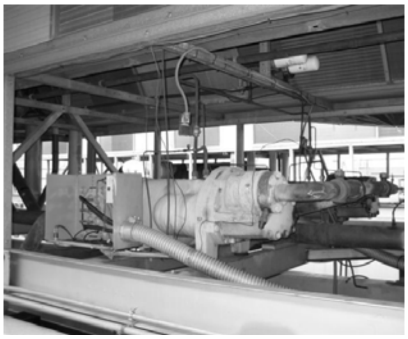
## Re-select/Renew

**When planning to overhaul chiller consider:**

- Re-selecting for current operating parameters
  - Best efficiency for new load conditions
  - Trim or replace impellers on centrifugal chiller
  - Ice making—adding glycol
  - Adding heat recovery to air cooled chiller
- Re-tubing if considerable number plugged or plugging
  - More efficient designs available
  - Renew to original efficiency
- Remanufactured motor—make sure inverter compatible
- Investing in labor already so be sure to optimize retrofit opportunities

## Overhauled Chillers



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## Chiller Retrofit Summary

- Several options available
- Take advantage of significant maintenance activities to maximize the labor content
- Look at ROI
  - First and life cycle costs
  - Potential savings
  - Incentives
- Evaluate independently and in conjunction for best ROI
- Know where your building load is going

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## Upgrading Existing Chilled-Water Systems

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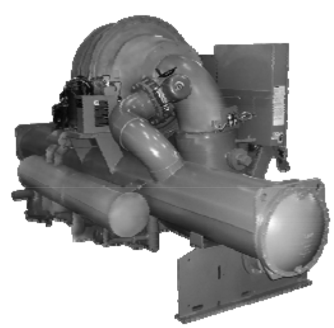
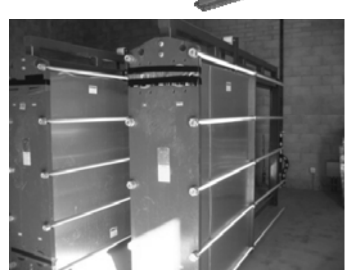
**Chiller Reselections**

## Free Cooling

- On the CTV chiller
  - Refrigerant migration
- Upstream of the chiller
  - Heat exchanger
  - Dry cooler (with air-cooled chiller)





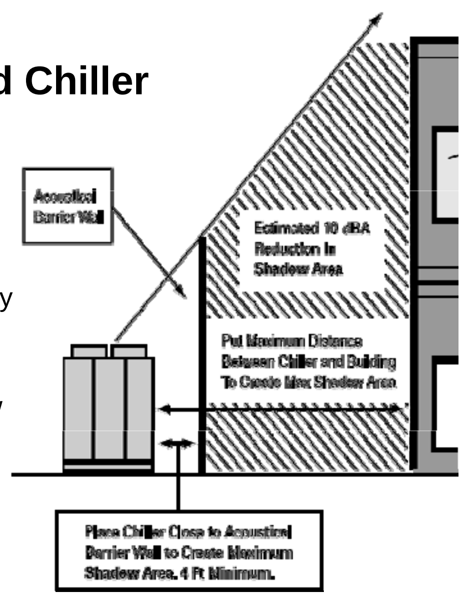
## Existing Air-cooled Chiller

- Add ice storage
  - Centrifugal-like performance
  - "Right sizes" an undersized or oversized system
  - Saves energy and energy cost

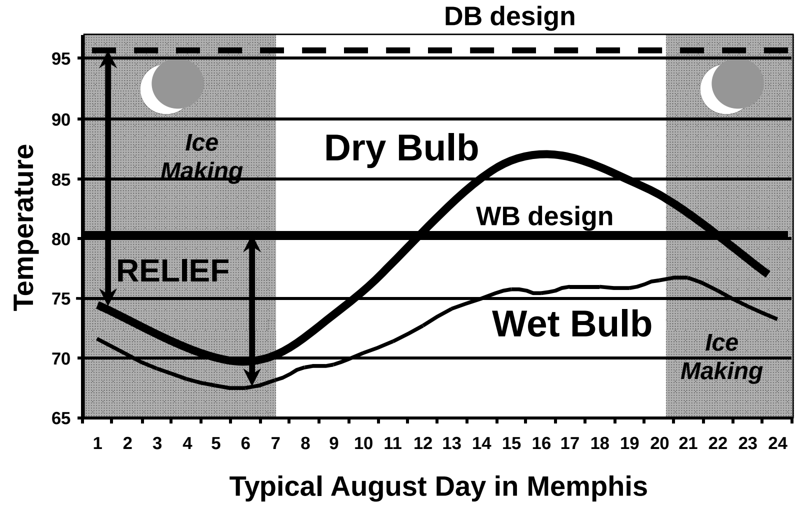



## Existing Air-cooled Chiller

- Consider acoustic attenuation
  - What is the neighborhood?
- Finish ice production quickly
  - Easier to do in the shoulder months
- Consider condenser airflow when constructing walls



## Condenser Relief



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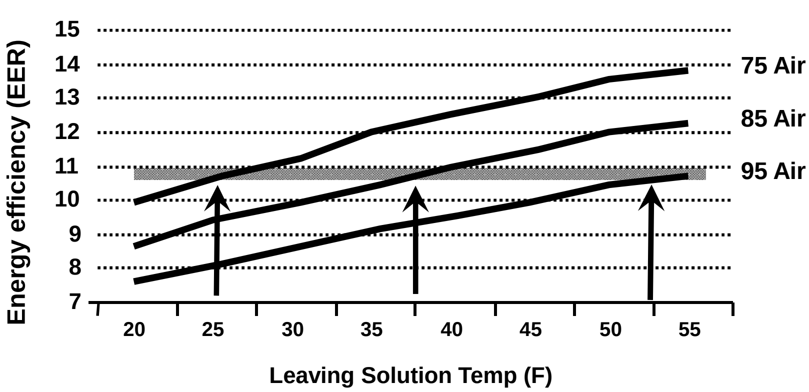
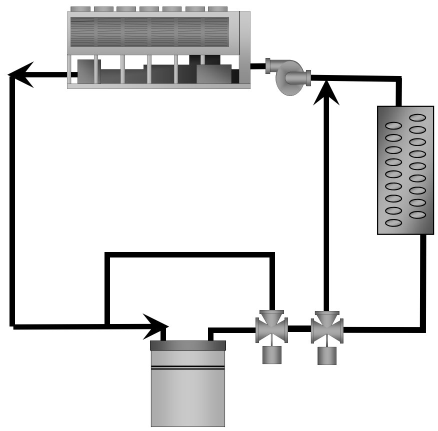
## Leaving Solution Temp and Ambient Relief



## Simple Air-cooled Chilled Water System

- Chiller
- Downstream ice tanks
- Blending valve
- Diverting valve
- Controls
- Heat transfer fluid





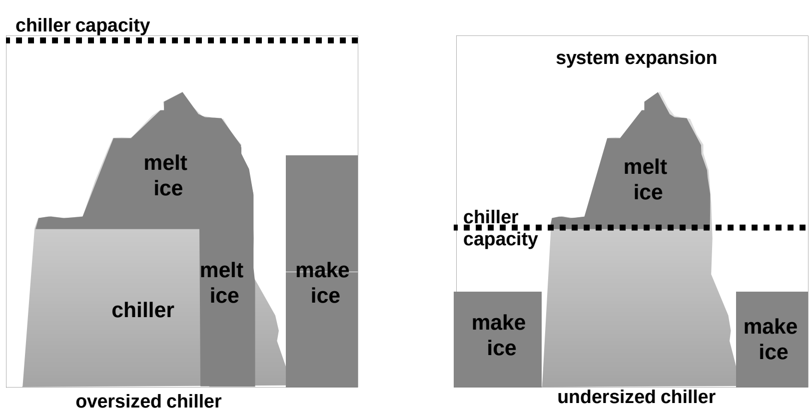

## Right-sizing with Ice and Existing Chillers

**Full storage or oversized chiller**

- Short on-peak windows
- Good rebates available

**Partial storage or undersized chiller**

- Reduces peak demand
- Shifts load to more efficient time



## Proper Use of Glycol—Coils

| solution | entering fluid °F | coil rows | total capacity MBh | pressure drop (air) in. $H_2O$ | fluid flow rate gpm | pressure drop (fluid) ft. $H_2O$ |
|---|---|---|---|---|---|---|
| water | 45 | 6 | 455 | 0.64 | 75.5 | 6.89 |
| 25% EG | 45 | 6 | 395 | 0.62 | 86.4 | 7.83 |
| 25% EG | 45 | 8 | 455 | 0.83 | 86.4 | 9.81 |
| 25% EG | 45 | 6 | 455 | 0.65 | 120.7 | 14.3 |
| 25% EG | 40 | 6 | 455 | 0.64 | 84.1 | 7.52 |
| 25% EG | 38 | 6 | 455 | 0.64 | 76.8 | 6.41 |

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## Upgrading Existing Chilled-Water Systems

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System Design Options

## Upgrade Options

- Change the chiller
  - Retrofit
  - Replace
- Change design parameters
- Change system configuration
- Enhance controls

 

## Design Parameters

- Many chilled water systems selected at:
  - Chilled water
    - 44°F
    - 2.4 gpm/ton (10°F ΔT)
  - If water-cooled, condenser water
    - 85°F Entering
    - 3 gpm/ton (9.4°F ΔT)
- ASHRAE GreenGuide Guidance
  - Chilled water
    - 12°F to 20°F ΔT
    - 2.0 to 1.2 gpm/ton
  - Condenser water
    - 12°F to 18°F ΔT
    - 2.5 to 1.6 gpm/ton

 

## High Performance Design Parameters

- Kelly and Chan
  - Chilled water ΔT: 18°F
  - Condenser water ΔT: 14.2°F (3.6–8.3% energy savings in various climates)

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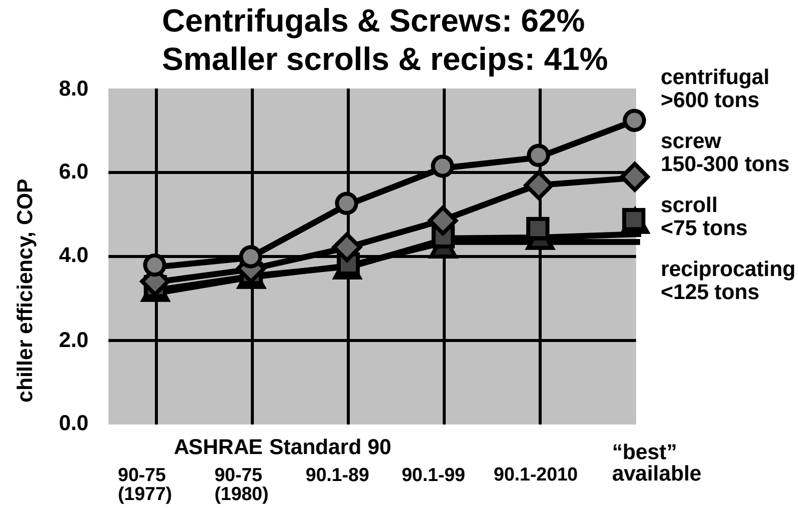
## Chiller Performance Improvements

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## Retrofit Applications

- Chilled water side
  - Coil
    - It's a simple heat transfer device

      **Q = U x A x LMTD**

    - Reacts to colder entering water by returning it warmer

## Cooling Coil Performance

| | | |
|---|---|---|
| **MBH** | **504** | **504** |
| **EWT** | **44°F** | **41°F** |
| **GPM** | **101** | **63** |
| **GPM/ton** | **2.4** | **1.5** |
| **LWT** | **54°F** | **57°F** |
| **WTR** | **10°F** | **16°F** |

**GPM reduction of 37.6%**

retrofit applications

## Reducing Coil Water Flow Rate

- Energy reduction
  - Pumps use less energy
  - $(1 - 0.376)^{2.5} = 0.3$
    - 70% reduction
  - Chiller energy increase offset by pump energy reduction
- System expansion
  - Existing coils use less, but colder water
  - Existing pipes and pumps can serve additional coils

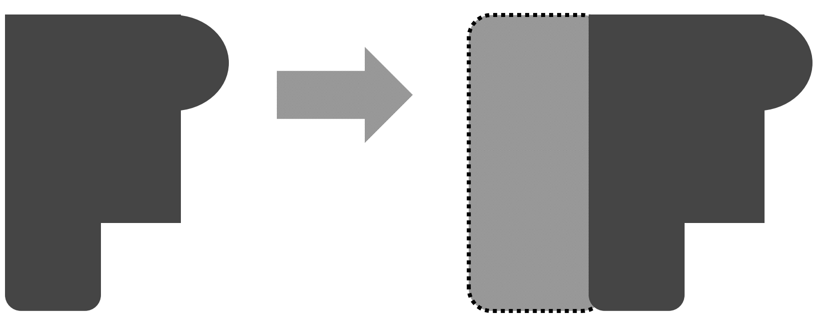
**kW → $gpm^3$**

**Tons = gpm x ΔT / 24**




## Reduce Existing Coil Flow to Satisfy Flow Requirements for an Addition

- Present facility
  - 2,000 tons
  - Chilled water: 44°F, 10°F ΔT
  - 4,800 gpm
- Desired facility
  - 3,000 tons
  - Chilled water: 40°F, 16°F ΔT
    - Existing coils: 2,880 gpm
    - Coils in addition: 1,920 gpm



## When Reducing Chilled Water Temperature in an Existing System, Examine

- Pipe insulation
- Existing oversized control valves
  - At lower flow rates control is poor
  - Changed valves on largest existing coils




retrofit applications

## Reducing Coil Water Flow Rate

- Satisfy increased space loads
  - Existing coils use the same flow rate of colder water to satisfy increased loads

**Tons = gpm x ΔT / 24**

## Condenser Side Retrofit Applications

- Situation
  - Chiller needs to be replaced
  - Cooling needs have increased by 50%
  - Cooling tower and pipes were replaced two years ago
  - Pipes run under the parking lot and nobody wants to dig them up!

## Performance with reselected chiller
## Same tower, condenser water pump and pipes

| | Existing | 38% Increase | 51% Increase |
|---|---|---|---|
| **Capacity (tons)** | 153 | 212 | 231 |
| **Flow rate (gpm)** | 450 | 450 | 450 |
| **Design Wet Bulb (ºF)** | 78 | 78 | 78 |
| **Condenser Entering Water Temperature(ºF)** | 85 | 87 | 87.6 |
| **Condenser Leaving Water Temperature (ºF)** | 94.9 | 100.6 | 102.5 |
| **Chiller kW/ton** | .837 | .743 | .765 |

## Performance with *reselected* chiller
## Same tower, condenser water pump and pipes

| | Same Capacity | 38% Increase | 51% Increase |
|---|---|---|---|
| **Capacity (tons)** | 153 | 212 | 231 |
| **Flow rate (gpm)** | 450 | 450 | 450 |
| **Design Wet Bulb (ºF)** | 78 | 78 | 78 |
| **Condenser Entering Water Temperature(ºF)** | 85 | 87 | 87.6 |
| **Condenser Leaving Water Temperature (ºF)** | 94.7 | 100.6 | 102.5 |
| **Chiller kW/ton** | .679 | .743 | .765 |




# Condenser System Performance

| | Existing | 38% Increase | 51% Increase | SAME CHILLER POWER 18% Increase |
|---|---|---|---|---|
| **Capacity (tons)** | 153 | 212 | 231 | 180.6 |
| **Chiller kW** | 128.0 | 157.7 | 177.1 | 125.8 |
| **Tower kW** | 5.9 | 5.9 | 5.9 | 5.9 |
| **Pump kW (assume 40' of piping pressure drop)** | 8.6 | 7.3 | 6.9 | 7.9 |
| **Condenser system kW** | 142.5 | 170.9 | 189.9 | 139.6 |
| **Condenser system kW/ton** | .931 | .806 | .822 | .773 |

## Use the existing infrastructure to satisfy present requirements

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## Upgrade Options

- Change the Chiller
  - Retrofit
  - Replace
- Change design parameters
- Change system configuration
- Enhance controls

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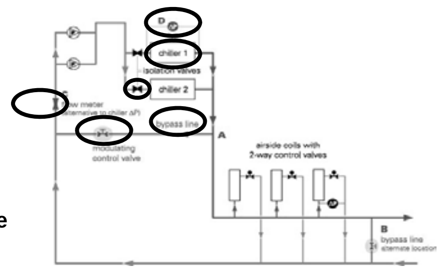
## VPF System Requirements

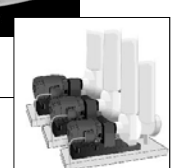
- Limits (consult manufacturer)
  - Absolute flows—minimum and maximum
- Always need a method to allow minimum flow (bypass)
- Flow rate changes
  - **2% of design flow per minute not good enough**
  - **10% of design flow per minute borderline**
  - **30% of design flow per minute many comfort cooling applications**
  - **50% of design flow per minute best**

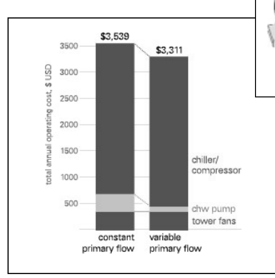


## Why Consider Variable Primary Flow (VPF) Now?

- Chiller control sophistication
- Operating cost savings
  - Pump energy
  - Response to low ΔT Syndrome





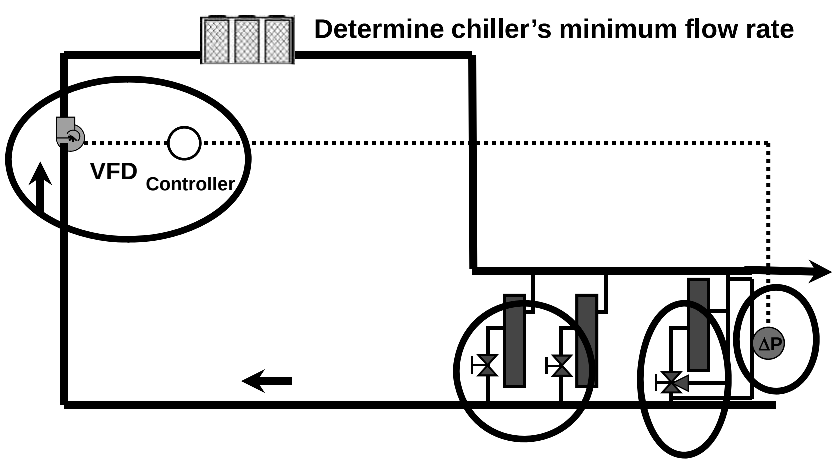

 

## Convert to VPF?

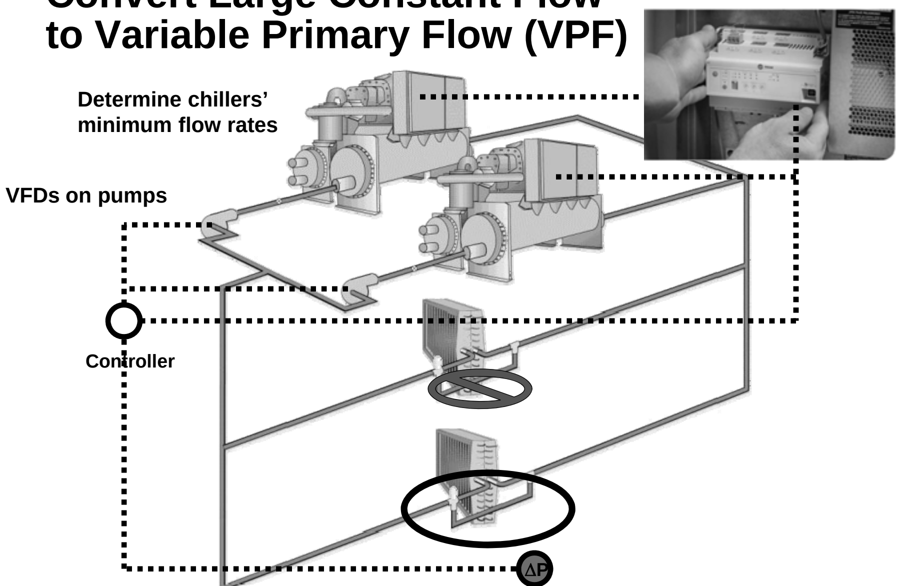
- Constant volume (flow) systems
  - Small
  - Large
- Primary-secondary
  - Convert by moving pumps
  - Convert by changing primary pump control




## Convert Small Constant Flow to VPF

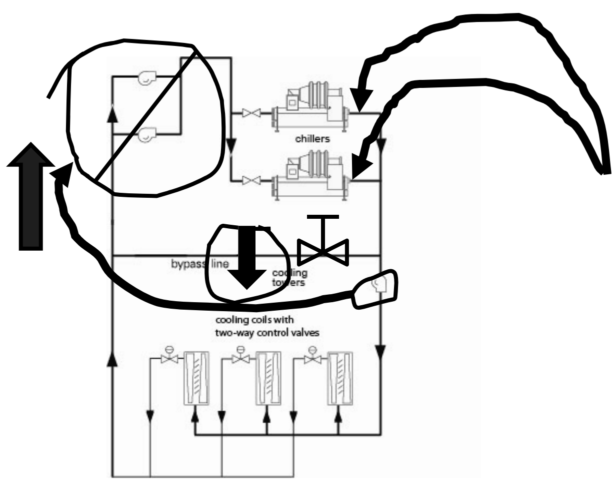


## Convert Large Constant Flow to Variable Primary Flow (VPF)



## Convert Primary Secondary to Variable Primary Flow (VPF)?



## Convert Primary-Secondary to VPF

**Challenges of full change**

- Remove primary pumps
- Secondary pumps moved
- Additional pressure drop must be satisfied by secondary pumps
- Bypass line resizing
- Flow measurement devices needed

**Benefits of full change**

- Can now respond to “low ΔT syndrome”
- Have a true VPF system
- Frees up a lot of space
  - Can install more capacity

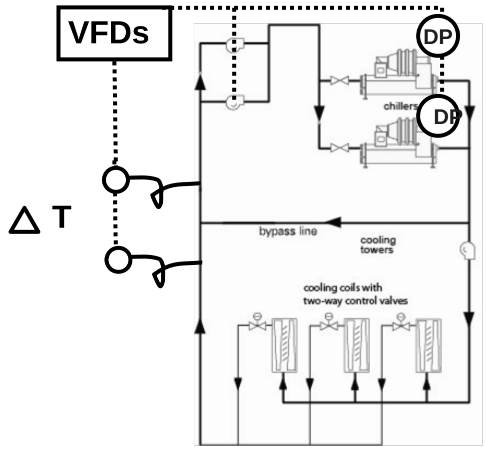



## Letter to the Editor, HPAC July 2000

- *“…When we installed the new chillers we also converted the existing system from conventional primary-secondary to variable-volume-primary operation. When we did this we eliminated the 11 existing primary-secondary pumps and replaced them with four variable-volume-primary pumps.* ***<u>Making this change allowed us to install a 1000-ton chiller in the space previously occupied by most of the 11 pumps</u>****…’*

Colin T. Oakley, DuPage County Power Plant

## Convert Primary Secondary to Variable Primary–Variable Secondary



## Convert to VPF?

- Constant volume (flow) systems
  - Small
  - Large
- Primary-secondary
  - Convert by moving pumps
  - Convert by changing primary pump control

## Upgrading Existing Chilled-Water Systems

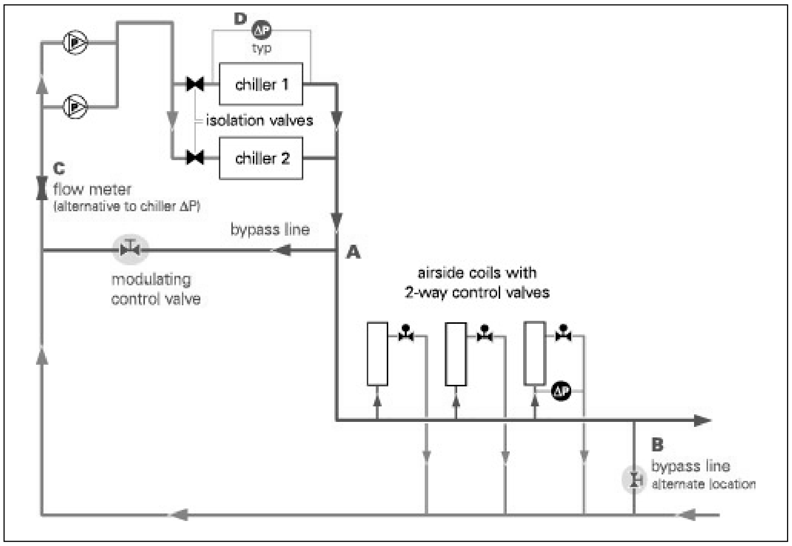
engineers newsletter LIVE

**Unit Control Upgrades**

## Onboard (Unit) Chiller Controls

- Adapt
  - Feedback (e.G. Leaving water temperature)
  - Hold or reduce capacity (demand limit) prior to trip
  - Maximize capabilities for the conditions
  - Multiple objective limit arbitration
    - Figure out what's most dire, manage to it
    - Stay online as long as possible
- Predict
  - Feedforward (e.g. return water temperature, flow)
- Anticipate
  - Auto-tune based on flow, temperature, IGV, speed
  - Filter setpoints

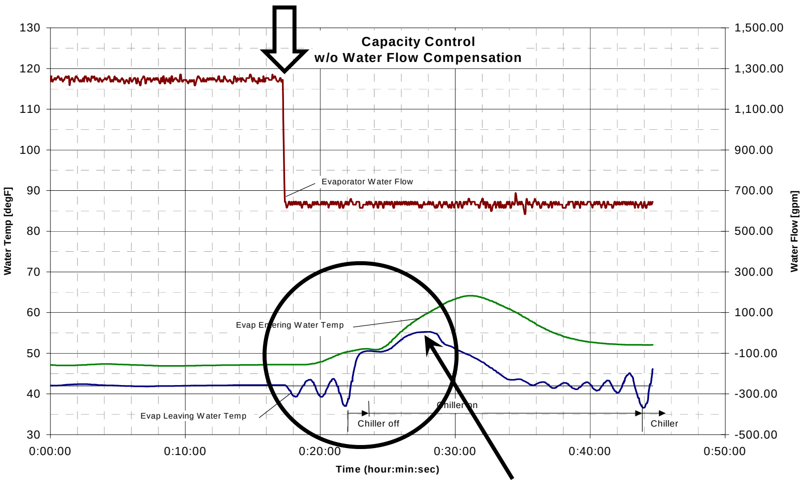
## Rapid Flow Rate Change



old, feedback controls

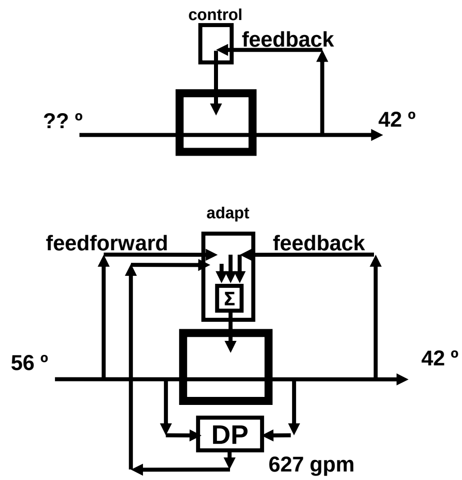
## 50% Flow in 30 Seconds



## Predictive Control

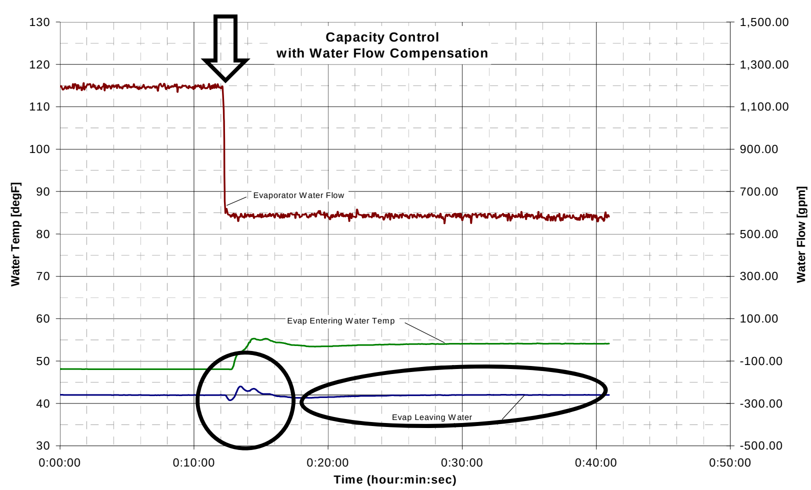
- Feedback: wait until temperature is affected
- Feedforward: react *before* temperature is affected
- Auto-adjust control gains
  - Small gains for lower flow conditions
  - Aggressive gains for higher flow conditions







### compensated feed-forward
## 50% Flow in 30 Seconds



## VSD Control

- Simultaneously optimize speed and inlet guide vanes for optimal efficiency
- Integrated variable evaporator flow

## Summary

- Unit control upgrades
  - Many reasons to upgrade
    - Tech support
    - Parts availability/costs
  - If going to VPF your control must be capable

## For More Information on VPF

- http:/trane.com/commercial /library/newsletters.asp (1999 and 2002)
- “Primary-Only vs. Primary-Secondary Variable Flow Systems,” Taylor, ASHRAE Journal, February 2002
- “Don’t Ignore Variable Flow,” Waltz, Contracting Business, July 1997
- “Comparative Analysis of Variable and Constant Primary-Flow Chilled-Water-Plant Performance,” Bahnfleth and Peyer, HPAC Engineering, April 2001
- “Campus Cooling: Retrofitting Systems,” Kreutzmann, HPAC Engineering, July 2002

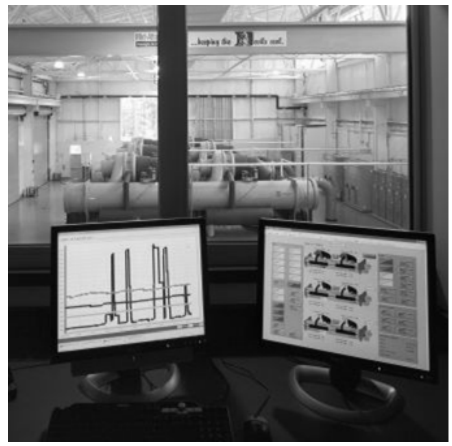
## Upgrading Existing Chilled-Water Systems

engineers newsletter LIVE

**System Controls**

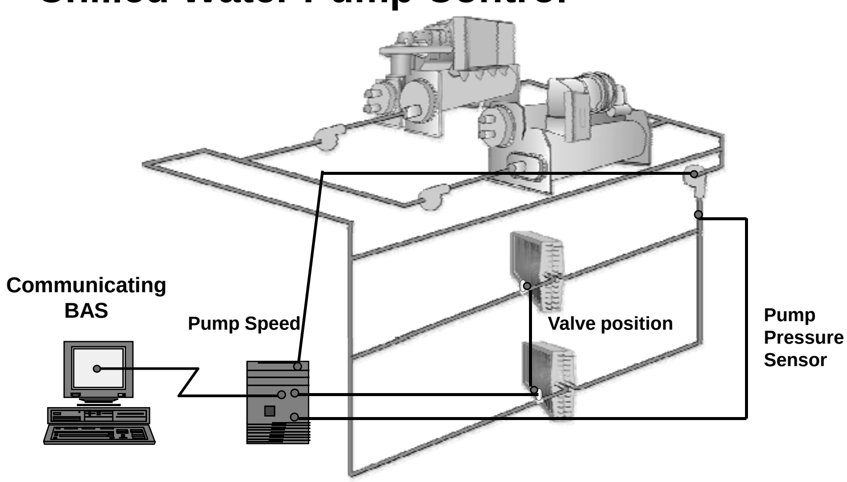
## System Controls

- Pump pressure optimization
- # of chillers to operate
- Chiller-tower optimization
- # of towers to operate
- Variable condenser flow



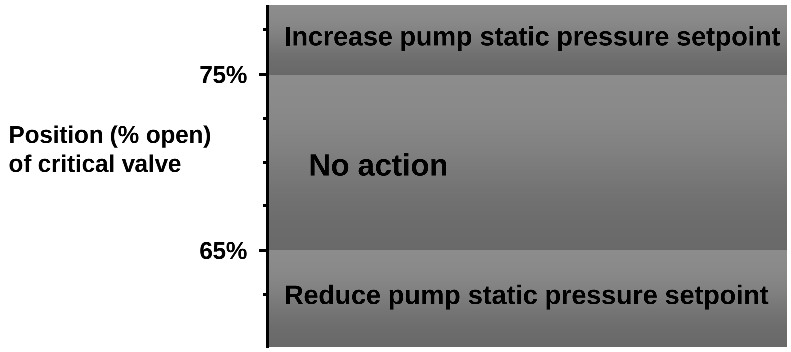
 

## Chilled Water Pump Control



## Pump-Pressure Optimization




**Required for DDC systems by 90.1-2010**

## Number of Chillers to Operate

- Operate one at nearly full load or two at part load?
- Examine IPLV assumptions

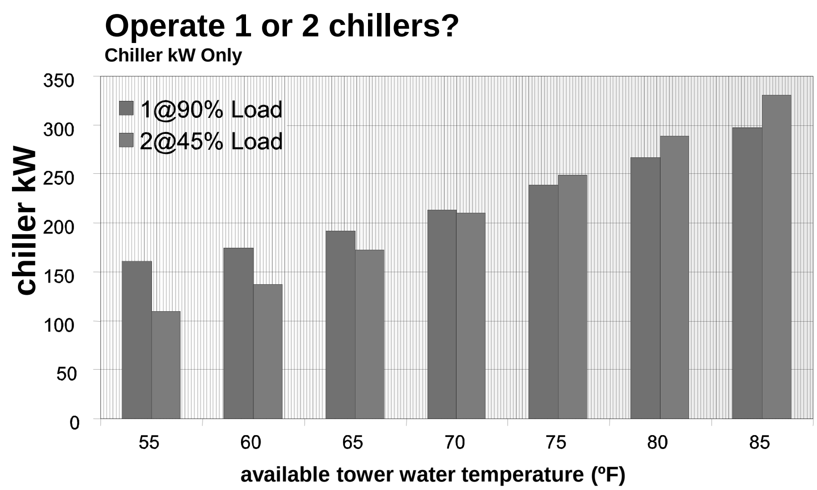
## VSDs and centrifugal chillers
# A Closer Look at IPLV

| Load | Weighting | [redacted] | kW/Ton |
|---|---|---|---|
| 100% | 0.01 | [redacted] | 0.572 |
| 75% | 0.42 | [redacted] | 0.420 |
| 50% | 0.45 | [redacted] | 0.308 |
| 25% | 0.12 | [redacted] | 0.372 |

**VSDs improve part-lift performance, so running two chillers with VSDs at part load seems more efficient than one chiller at double the same load, but …is dependent on condenser water temperature**

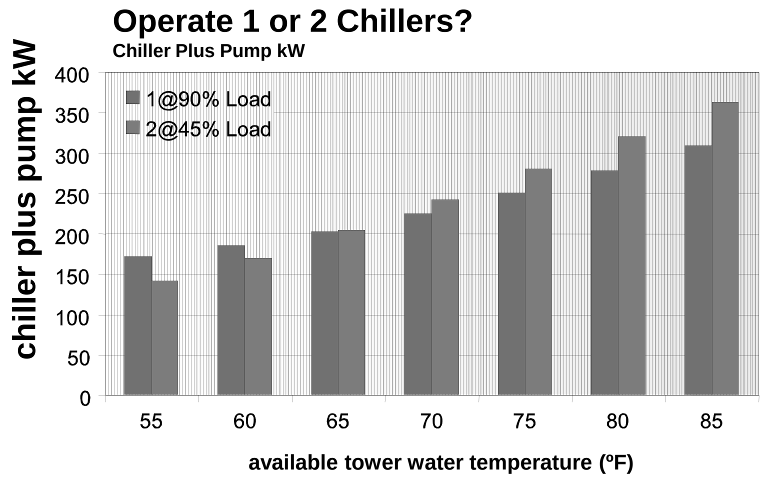
## chiller power only
# 45% Plant Load



chillers plus pumps

# 45% Plant load

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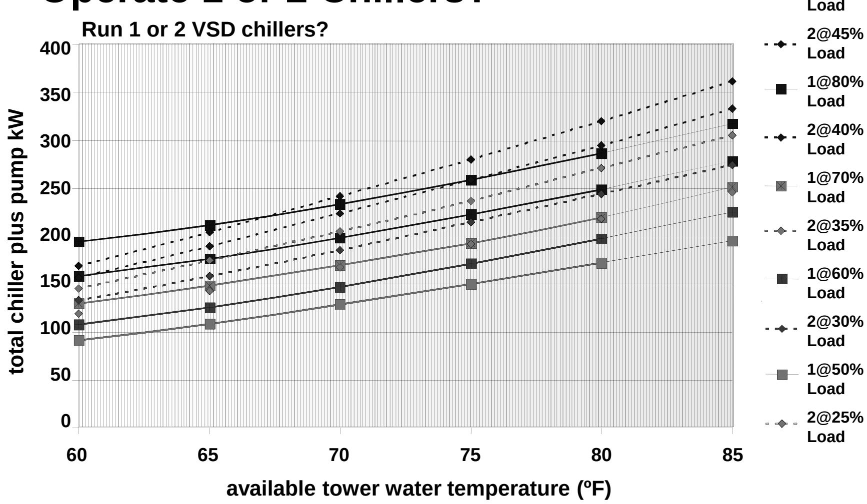
# Operate 1 or 2 Chillers?

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## Operate 1 or 2 Chillers?

- 45% plant load: one chiller until tower temperature is < 65°F
- 40% plant load: one chiller until tower temperature is < 60°F
- 35% plant load and below: one chiller

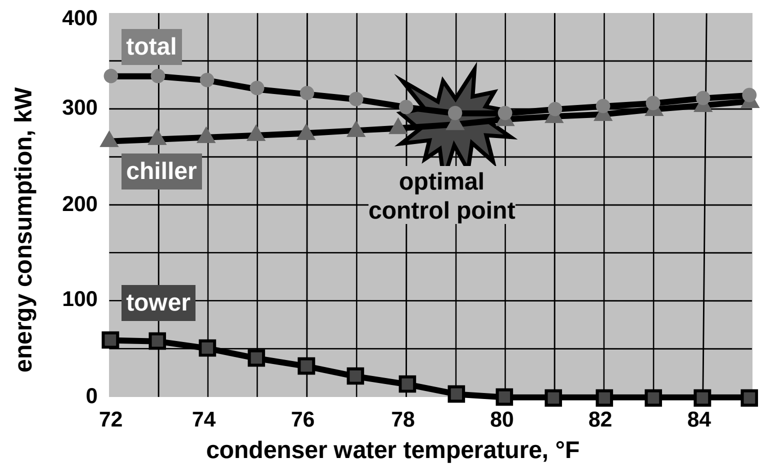
chiller–tower optimization
## Documentation

- Braun, Diderrich: ASHRAE Transactions (1990)
- Schwedler, Hage, Dorman, Stiyer (1993)
- Schwedler: ASHRAE Journal (July 1998)
- Hydeman, Gillespie, Kammerud: PG&E CoolTools™ program (2000)
- Cascia: ASHRAE Transactions (2000)
- Crowther, Furlong: ASHRAE Journal (July 2004)

optimal condenser water control

## Chiller-tower Interaction



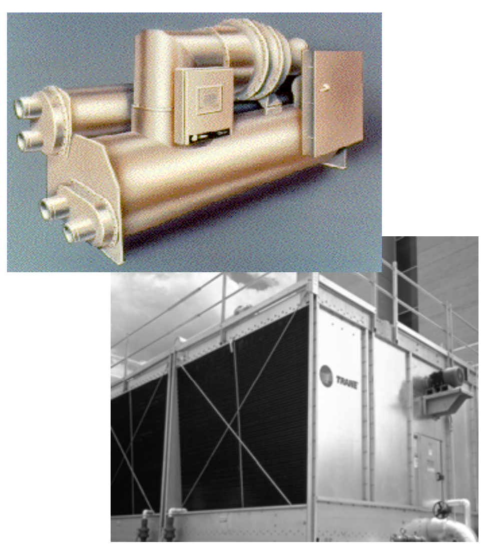




chiller-tower optimization

## Dependent On?

- Chilled water plant
  - Tower design
  - Chiller design
    - Centrifugal
    - Helical rotary
    - Variable speed drive
    - Absorption
  - Changing conditions
    - Chiller load
    - Ambient wet bulb



chiller-tower optimization

## Estimated Savings

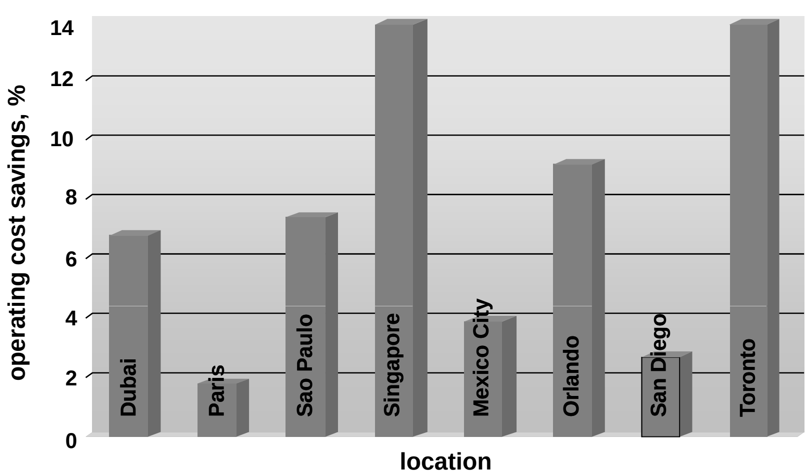
- Crowther & Furlong
  (“Optimized” vs. driving water to 65°F)
  - Chicago: 5.4%
  - Las Vegas: 2.6%
  - Miami: 8.5%

**Based on chiller+tower annual energy consumption**




chiller–tower optimization

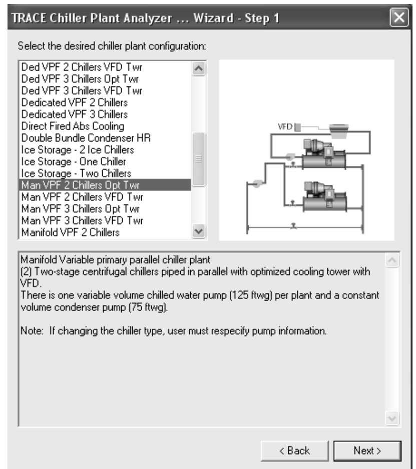
## Operating Cost Savings



chiller–tower optimization

## How Do You Calculate Savings?

- TRACE Chiller Plant Analyzer
- System Analyzer™
- TRACE® 700



## How Many Cooling Tower Cells Should Be Operated?

- For this discussion: assume condenser water pump speed is constant
- Simple answer: as many as allowable
  - More heat exchange surface
  - Closer tower approach temperature
  - Lower airflow to achieve tower setpoint
  - Reduced airflow = lower tower fan power

example
## Operating More Cooling Tower Cells

- Design conditions
  - Two 500-ton chillers
  - Each
    - 1000 gpm condenser water flow rate
    - Two tower cells (each)
      - 99/85/78
      - 40 hp
- Operating conditions
  - 200 ton load
  - One chiller
    - Condenser water flow rate: 1000 gpm
    - Condenser water ΔT: 5.6°F




example
## Operating More Cooling Tower Cells

| | One cell | Two Cells |
|---|---|---|
| Total flow (gpm) | 1000 | 1000 |
| Flow per cell (gpm/cell) | 1000 | 500* |
| Tower setpoint (°F) | 65 | 65 |
| Wet bulb temperature (°F) | 60 | 60 |
| Approach (°F) | 5 | 5 |
| Range (°F) | 5.6 | 5.6 |
| Fan speed (%) | 100% | 39 % |
| Total fan power (bhp) | 40.0 | 23.4 |
| **Tower fan power savings (bhp)** | **0** | **16.6** |

***Stay above tower cell minimum water flow rate**

issues

## Reducing Tower Cell Water Flow Rates

- Poor water distribution over the tower fill
- Dry spots in the cooling tower
  - Poor heat transfer
- Scale on fill
  - Poor heat transfer
  - Increased maintenance
- During winter, icing concerns

## VSD on the Condenser Water Pump

- Ensure pump motor is compatible with a drive
- Balance the flow
  - Open triple duty valve
  - Set pump speed to balance to design flow
  - Save condenser water pump energy
- Use the VSD for head pressure control
- Vary condenser water flow?
  - Savings are possible
  - It's complicated
  - Minimum pump speed

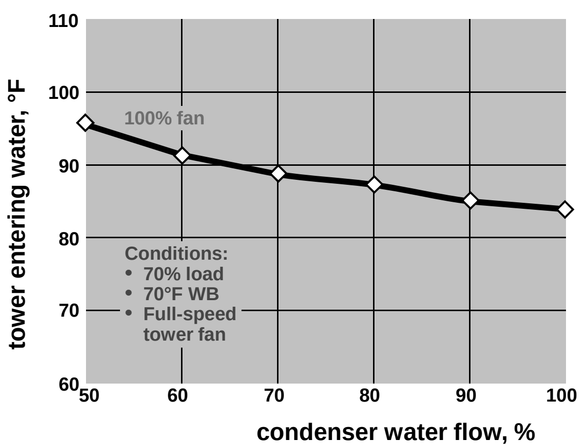
## VSD on the Condenser Water Pump

- Pump minimum speed dependent on one of the following
  - Minimum allowable chiller condenser flow
    - – maintain good heat transfer and control
  - Minimum speed to achieve tower static lift
    - – Open portion of condenser loop, from the tower sump to the top of the tower
  - Minimum allowable tower water flow
    - – Maintain proper distribution over fill
      - » Avoid dry spots in tower
      - » Reduce possibility of scaling
      - » Maintain good heat transfer

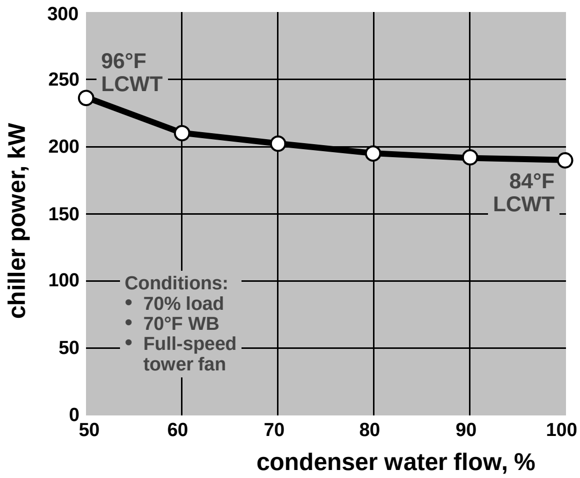
**CONFIRM WITH TOWER PROVIDER!**




variable condenser water flow
## Effect on Tower

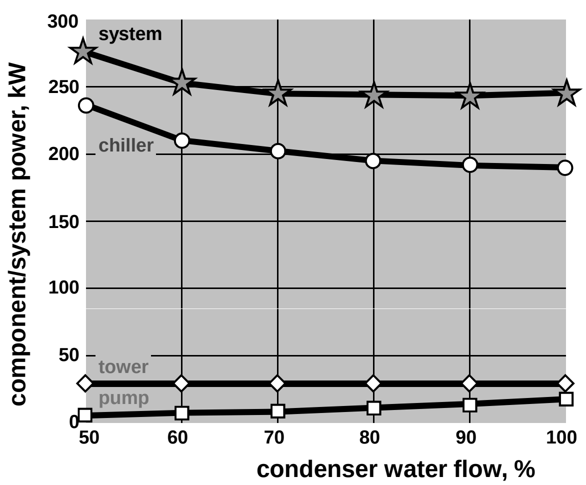


## variable condenser water flow
# Effect on Chiller



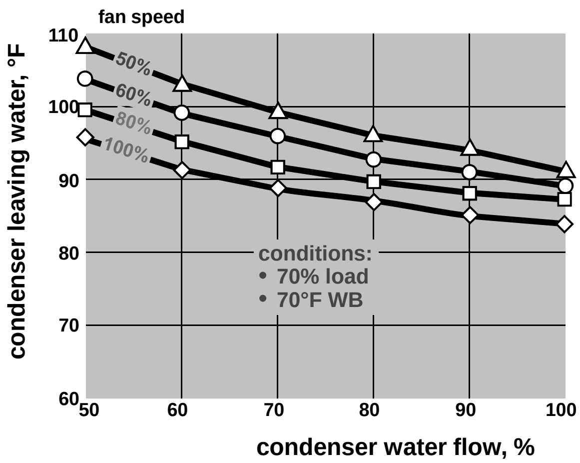

 

## variable condenser water flow
# Effect on System



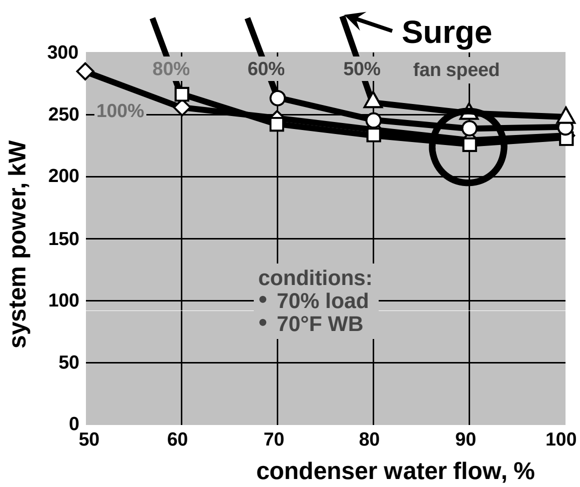

 

## reducing flow & fan speed
# Effect on Tower



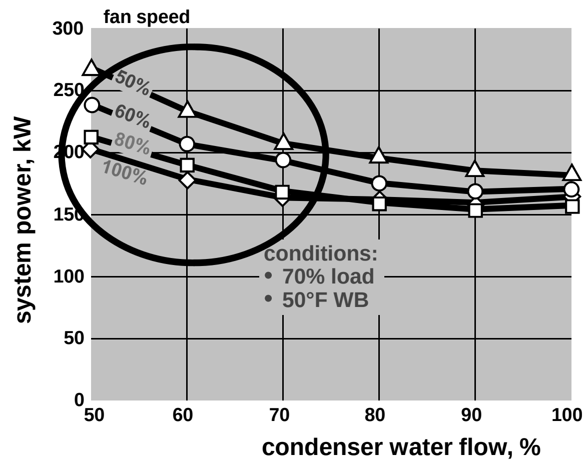

 

## reducing flow & fan speed
# Effect on System



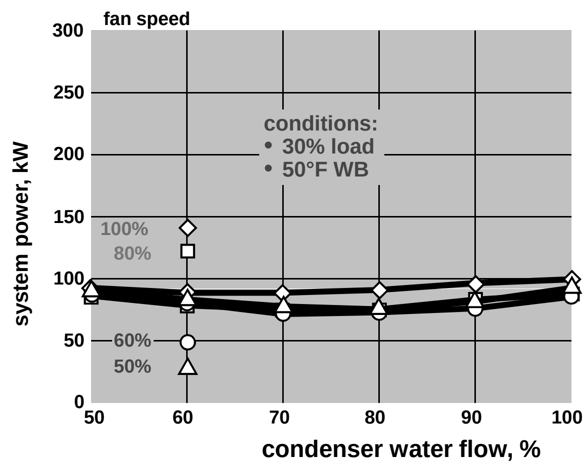
## reducing flow & fan speed
# Effect on System







## reducing flow & fan speed
# Effect on System



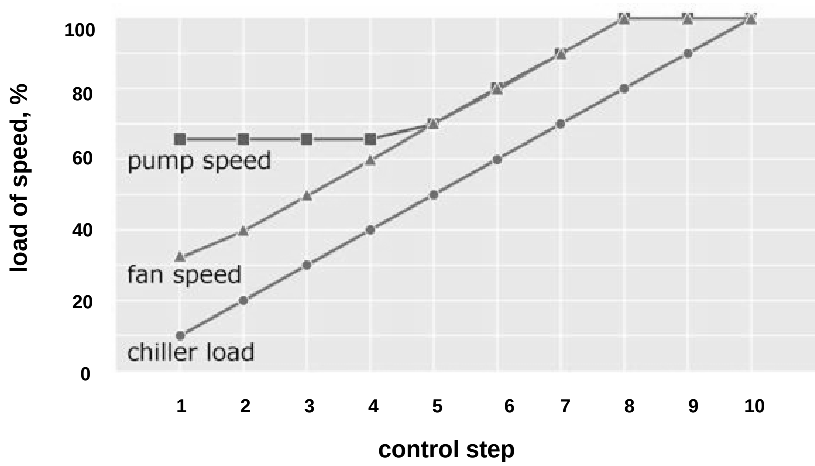
## Varying Condenser Water Flow and Cooling Tower Fan Speed

| % Chiller Load | Outdoor Wet Bulb Temperature (°F) | Condenser Water Pump Speed (%) | Cooling Tower Fan Speed (%) |
|---|---|---|---|
| 70 | 70 | 90 | 90 |
| 70 | 50 | 90 | 80 |
| 30 | 50 | 70 | 60 |

- These are only three points in time
- What about the rest of the year?




## Varying Fan and Pump Speed Together



variable condenser water flow
## Summary

Determine what savings, if any, are possible

- Are pumps already low power?
- Can reducing tower-fan speed achieve most of the savings?

variable condenser water flow
## Summary

If you decide to reduce flow:

- Find minimum condenser-water flow rate
- Examine system at various loads and wet-bulbs, as well as chiller/tower combinations
  - keep chiller out of surge
- Document the sequence of operation
- Help commission the system

variable condenser water flow
## Guidance

- Can provide savings
  - Finding proper operating points requires more time, more fine-tuning
- Two-step process:
  1. Reduce design pump power
  2. Is variable condenser-water flow still warranted?

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## References


- Schwedler, "*Upgrading Chilled-Water Systems*," *ASHRAE Journal*, November 2009
- Baker, Roe, Schwedler, "*Prescription for Chilled Water Plants*," ASHRAE Journal, June 2006.


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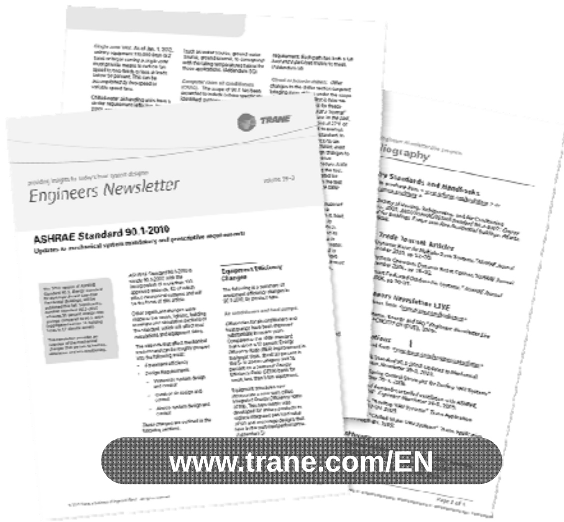
references for this broadcast

## Where to Learn More

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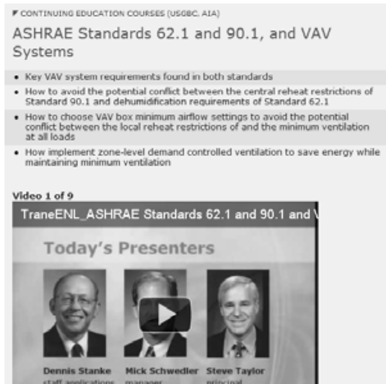
- Insightful topics on HVAC system design:
  - Chilled-water plants
  - Air distribution
  - Refrigerant-to-air systems
  - Control strategies
  - Industry standards and LEED
  - Energy and the environment
  - Acoustics
  - Ventilation
  - Dehumidification

EDUCATION PROVIDER

## Continuing Education

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## Engineers Newsletter Live 2011

- **June**
  - High Performance VAV Systems
- **October**
  - Dedicated Outdoor Air Units

 

## Upgrading Existing Chilled-Water Systems

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