Industrial Cooling

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Why we need to pay attention

- **Cooling systems are often the least understood by plants**
  - Magic machines make chilled water
- **Cooling systems are often the least understood by our assessment teams!!!**
  - Magic machines make chilled water
- **We are often able to save 25%+ in plants which burn stuff**
  - Lucky to get 10% if energy consumption is mostly electric
- **There are many significant opportunities in industrial cooling**

Process Cooling

- **Purposes Conditioned spaces**
  - Process temperature control
  - Quenching operations
  - Control of chemical reactions and processes
  - Refrigeration, Freezing, and/or Cold Storage
  - Humidity control
- **Cooling achieved by**
  - Cold water
  - Ammonia (for subfreezing temps)
  - Liquid Nitrogen

Chilled Water Systems

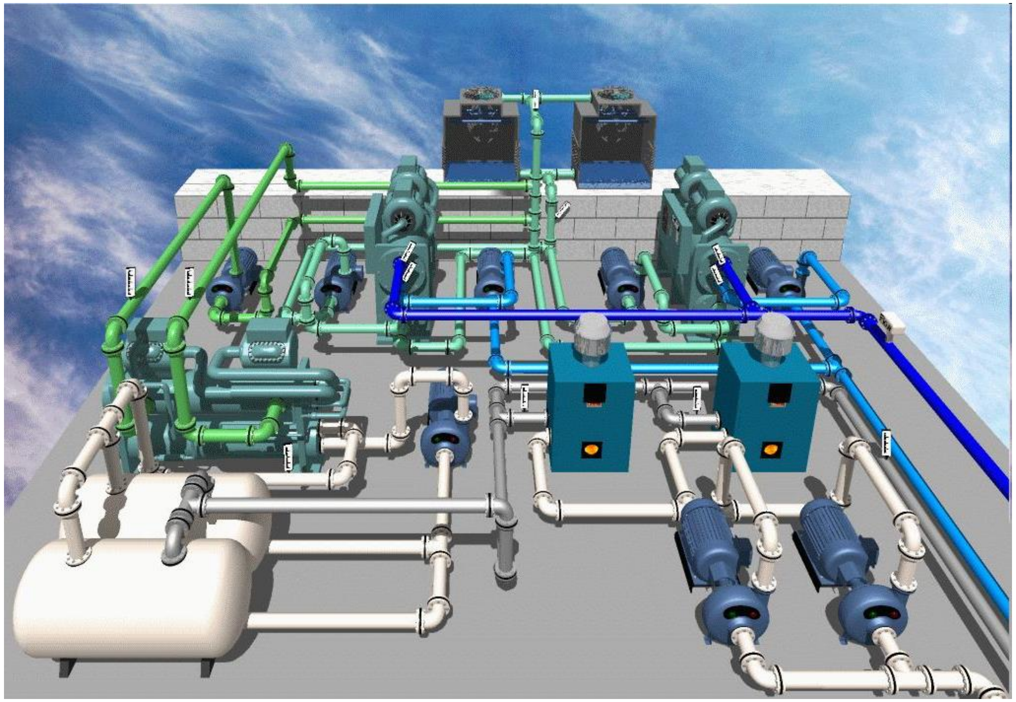
- **Water is chilled and then circulated**
  - Clearly desired temperatures must be above freezing

Low hanging fruit

- **Containing cold**
  - Insulation
  - Keeping sources of heat away from cooled areas/systems
- **Using it properly**
  - Set back timers
  - Cool only necessary things
  - Make sure nonoperating chillers are isolated from system
  - Don’t use cooling to control humidity or dew point
- **Distribute in efficient ways**
  - Move cold water/air/other fluid
  - Move refrigerant (DX – or direct expansion systems)
  - Move electricity – multiple small sized units

Chilled Water Systems can be very complicated

- **Sometimes it is just too much for us to do!!**
- **Search for In-house Info**
  - Use what’s on file
  - Update If necessary
  - Make it clear
- **Audit**
  - Sketch out a diagram
  - Identify Flow Directions
  - Heights and Lengths

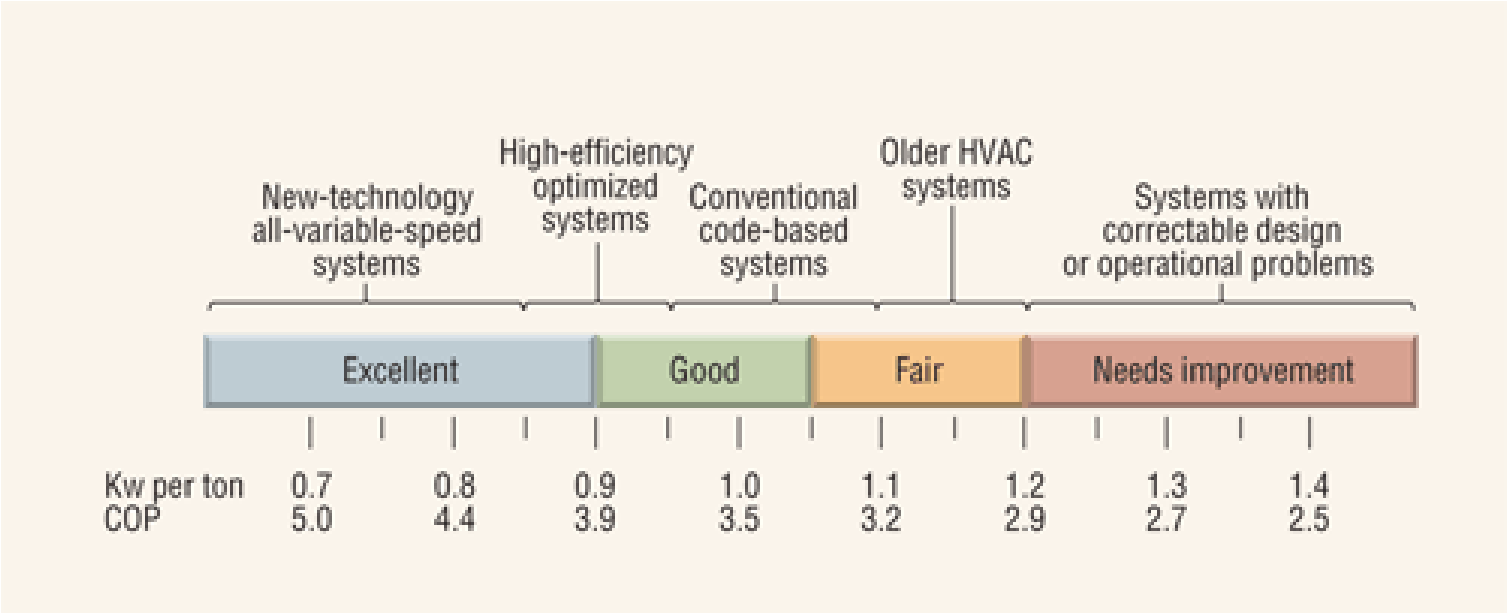


Chilled Water Systems

- **Determine how chilled water systems adjust to different loads**
  - Chillers need to operate at their optimal load
    - Higher or lower greatly reduces efficiency
  - Matching loads becomes the challenge
    - Helped by chillers of varying sizes

Old versus New

- **Major opportunity to improve performance with upgrades**
  - Adding additional chillers
  - Using rebates
- **Finding out how old a chiller is can be important**



Old versus New

- **From Trane: (data is available!!!)**

Chilled Water Plant Costs Estimated

Water chillers (with starters)		
Centrifugal:		
300 to 600 tons		$250/ton
600 to 1400 tons		$240/ton
1500 to 2500 tons		$230/ton
Absorption		
1 stage	90 to 1600 tons	$350/ton
2 stage	350 to 1000 tons	$500/ton
direct-fired	100 to 1100 tons	$525/ton
Rotary Screw		
water cooled	70 to 130 tons	$300/ton
water cooled	150 to 450 tons	$240/ton
air cooled	70 to 400 tons	$420/ton
Setting, rigging, installation		$60/ton
Add 4160 volt motor		$25/kW
Add 0.035 tubes		$7/ton
Add Gas Engine		$450/kW - $500/kW

Pumps (not including VFD or starter)	$200/HP - $300/HP
Cooling Tower	
Normal	$20/gpm - $40/gpm
Permanent	$40/gpm - $75/gpm
Piping	see chart
Controls	$30/ton - $60/ton
Electrical	$130/kW - $360/kW
Plate and Frame Heat exchanger	
unit only	$30/ton - $60/ton
complete installation with piping and simple auto control	$80/ton - $140/ton

Note: These prices are typical construction costs for normal access applications. For total project cost, add fees, testing and contingiencies.

Off Load Operation

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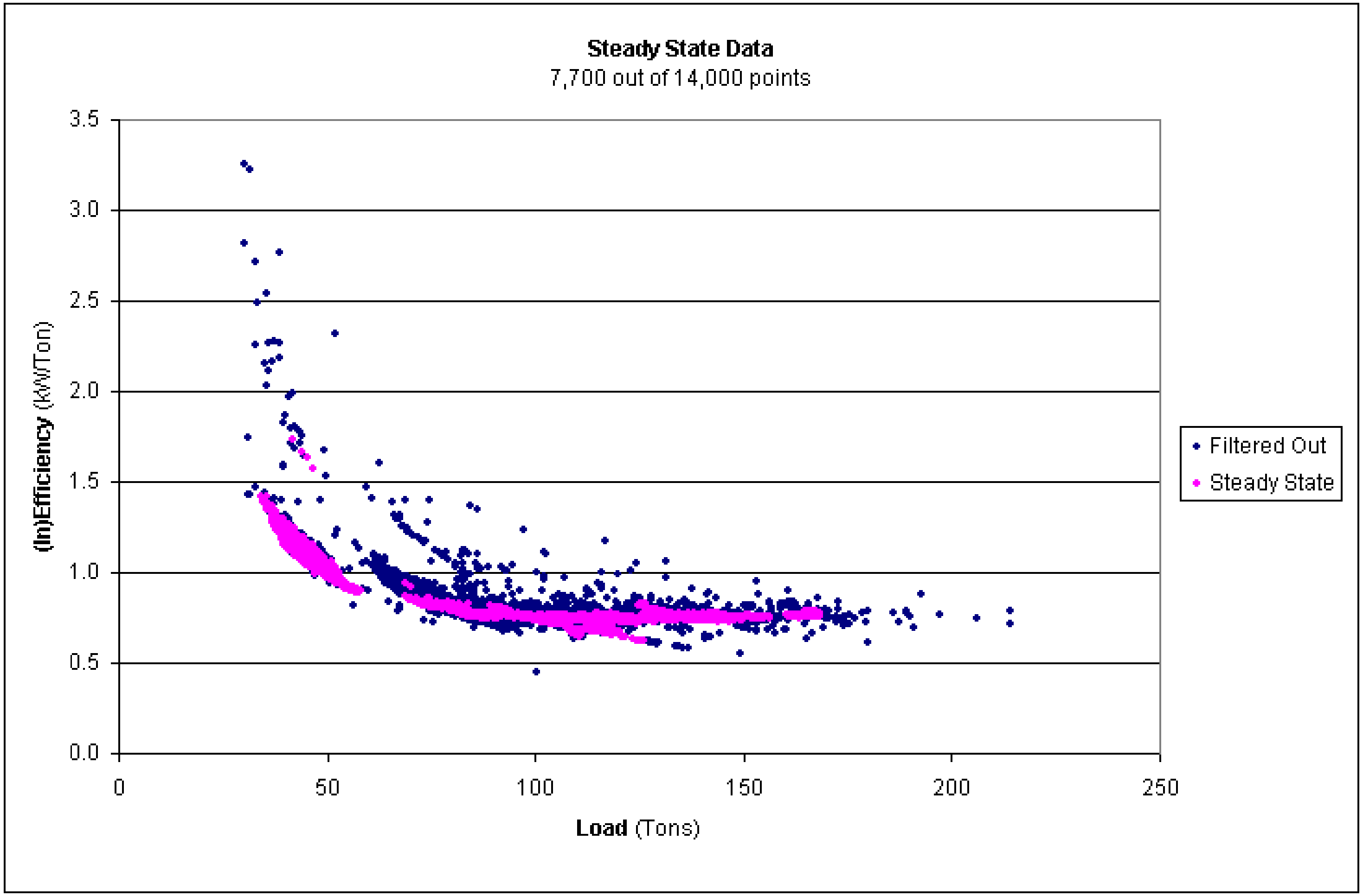
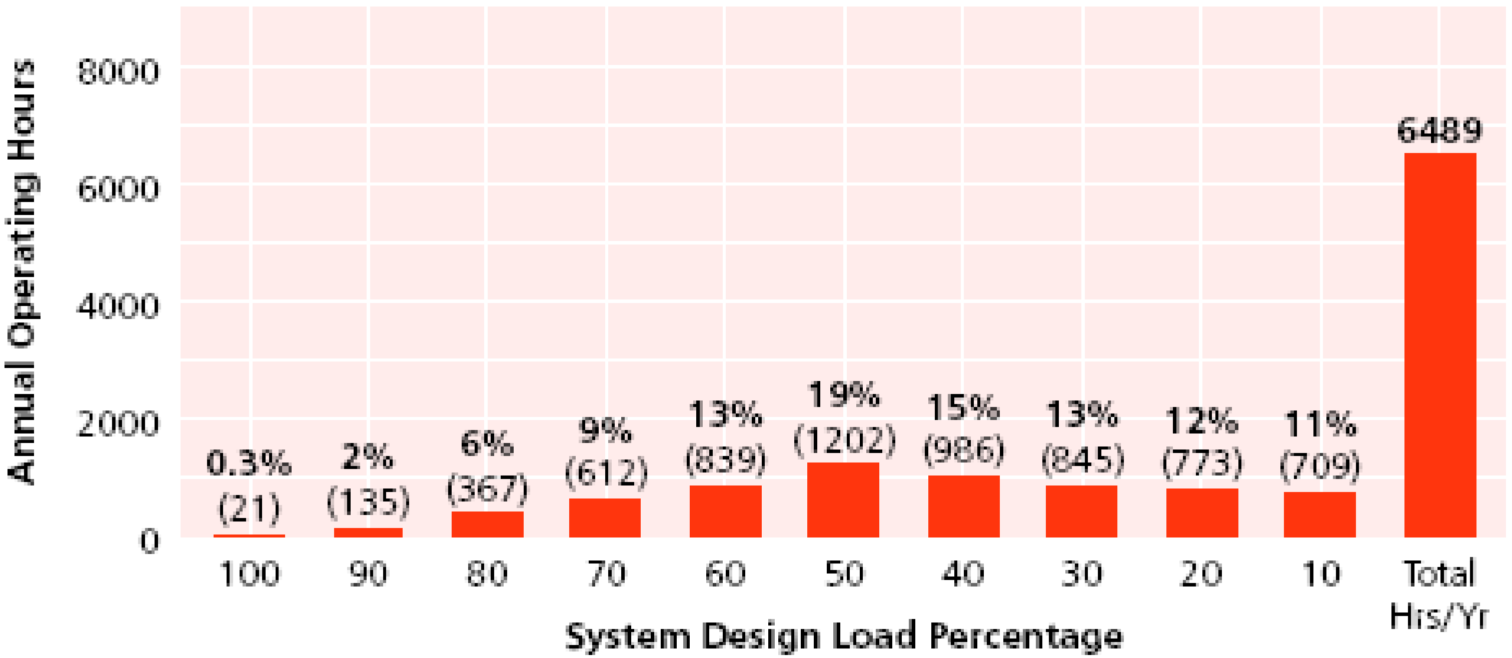
Off Load Operation

- **228 ton chiller**



Off Load Operation

- **Since chillers systems are designed for worst-case, most of the time they will be lightly loaded**



Off Load Operation

- **With single chiller, off load performance issues simply presents the recommendation of adding another, smaller chiller**
- **However, 80% of industrial plants with chillers have more than one**
  - Better when run well, worse when run poorly
  - 5% savings found in CA when two 200-ton centrifugal chillers operating simultaneously at 45% load were changed to a single chiller at 90% load
  - Annual energy savings would be about 34,500 kilowatt-hours (kWh), or about $2,800 per year at $0.08 per kWh.

Off Load Operation

- **We need to be able to determine real time loading**
  - Load can be read off of some new chillers – go through displays
  - Older chillers you need both chilled water flow rate and kW consumption which are difficult to get
  - kW draw is a good thing to datalog, but you may have to shut the chiller down to hook up the meter

Seasonal Issues

The rationale

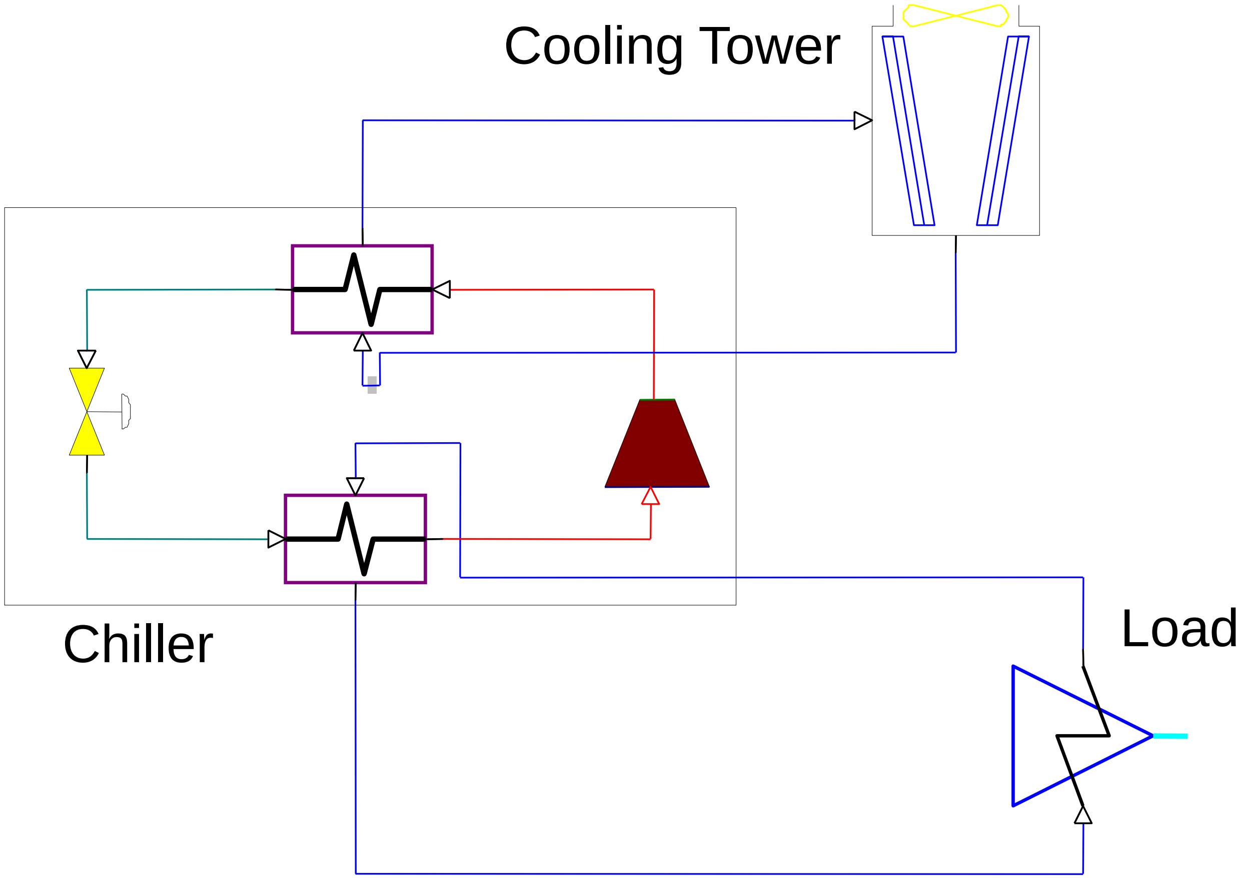
- **Industrial cooling for process normally includes operation during non-summer months**
  - Commercial buildings normally shut chilled water systems down from October to April
- **Chillers set up to operate in August are not running optimally in January**
- **Sometimes it is cool enough outside that running a chiller does not make sense**
- **Our assessments need to determine seasonal use patterns for cooling (space versus process)**
  - Sometimes space cooling continues during the winter because process heating is dominant
  - Data centers generate year-round cooling needs

What about winter time?

- **Computer rooms bring us much more operations of chilled water systems in the winter**
- **Can “free cooling” be used?**
  - If needed cold water temps can be achieved by cooling towers alone
    - Chillers are often set up only to reduce condenser temperatures (and improve chiller efficiency)
  - Inclusion of a second loop, where the cooling tower can directly chill the cool water loop
    - Called “water side free cooling”
  - Lots of applications with data centers – cooling year round
  - Some system redesign can save big $$
    - Paybacks can be 1-2 years!

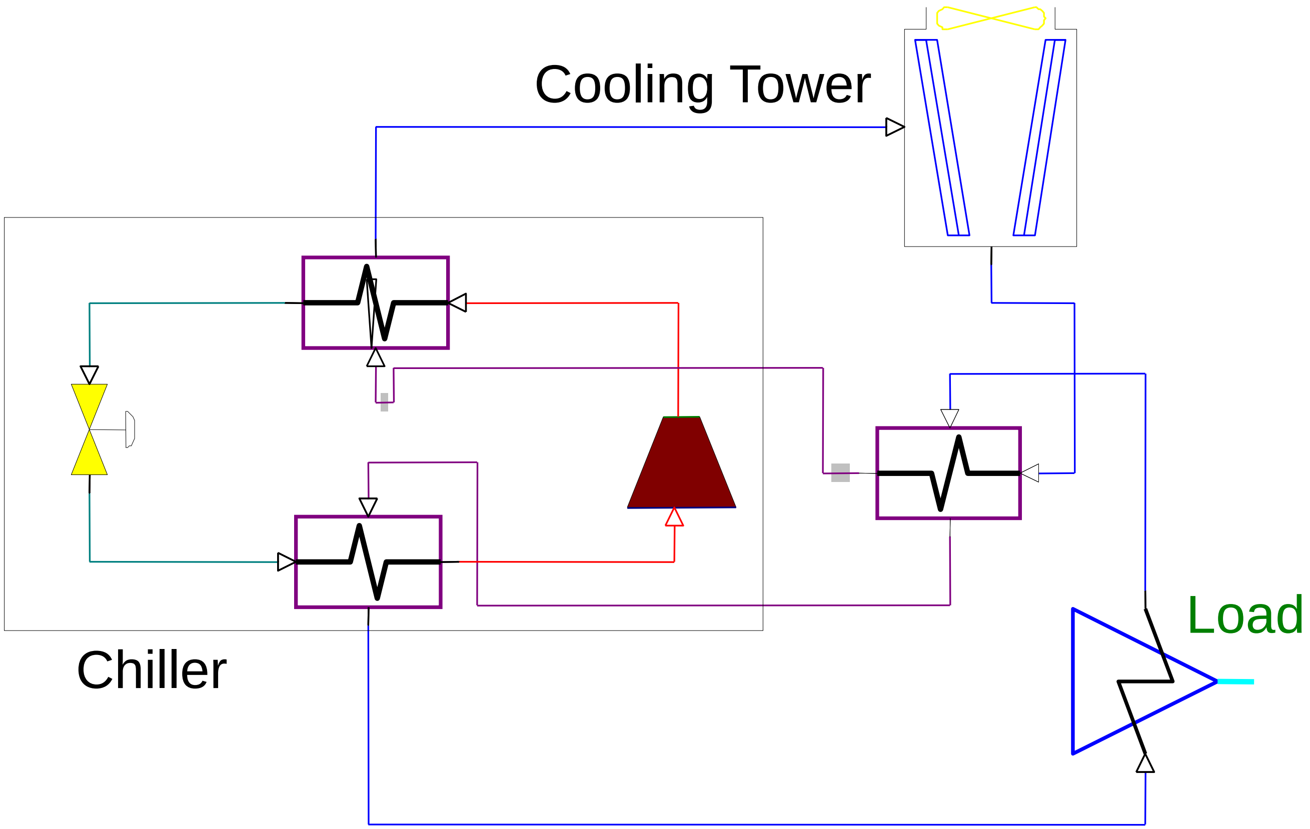
Chiller System Without Free Cooling

- **Two water loops**



Chiller System With Free Cooling

- **Extra heat exchanger and cutout logic**



Floating Head Pressure

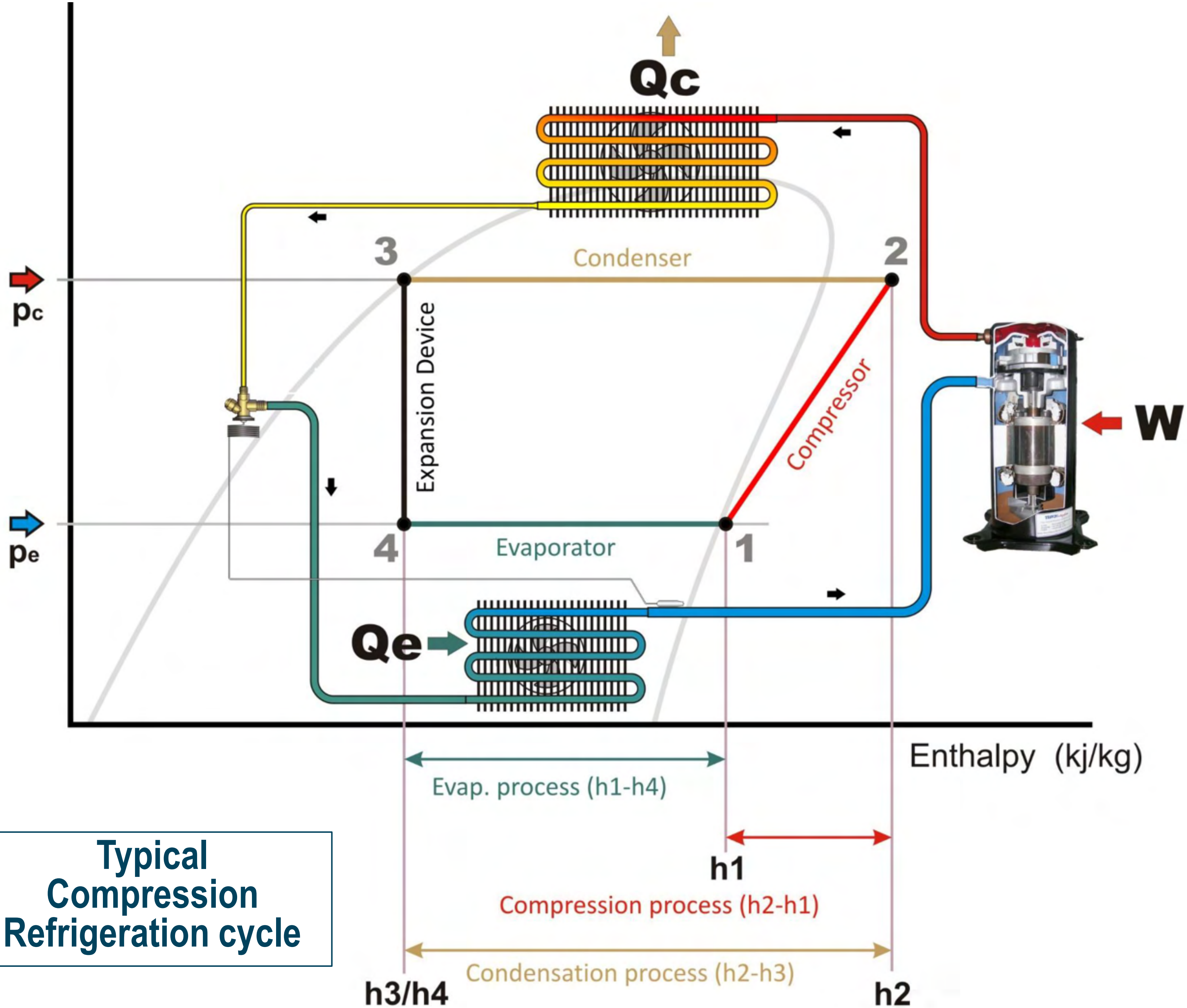
- **Also called “head pressure control”**
- **Chillers have condensers which operate at large pressures. However, when temperatures outside are low, increased efficiency can be obtained by lowering this pressure**
  - Normally this is done by floating the pressure

Discharge Pressure	Capacity	Input Power	COP
15 bar	75.5kw	27.1kw	2.78
10 bar	92kw	21.7kw	4.23

- COP = 3.516/(kW/ton)

Retrofits

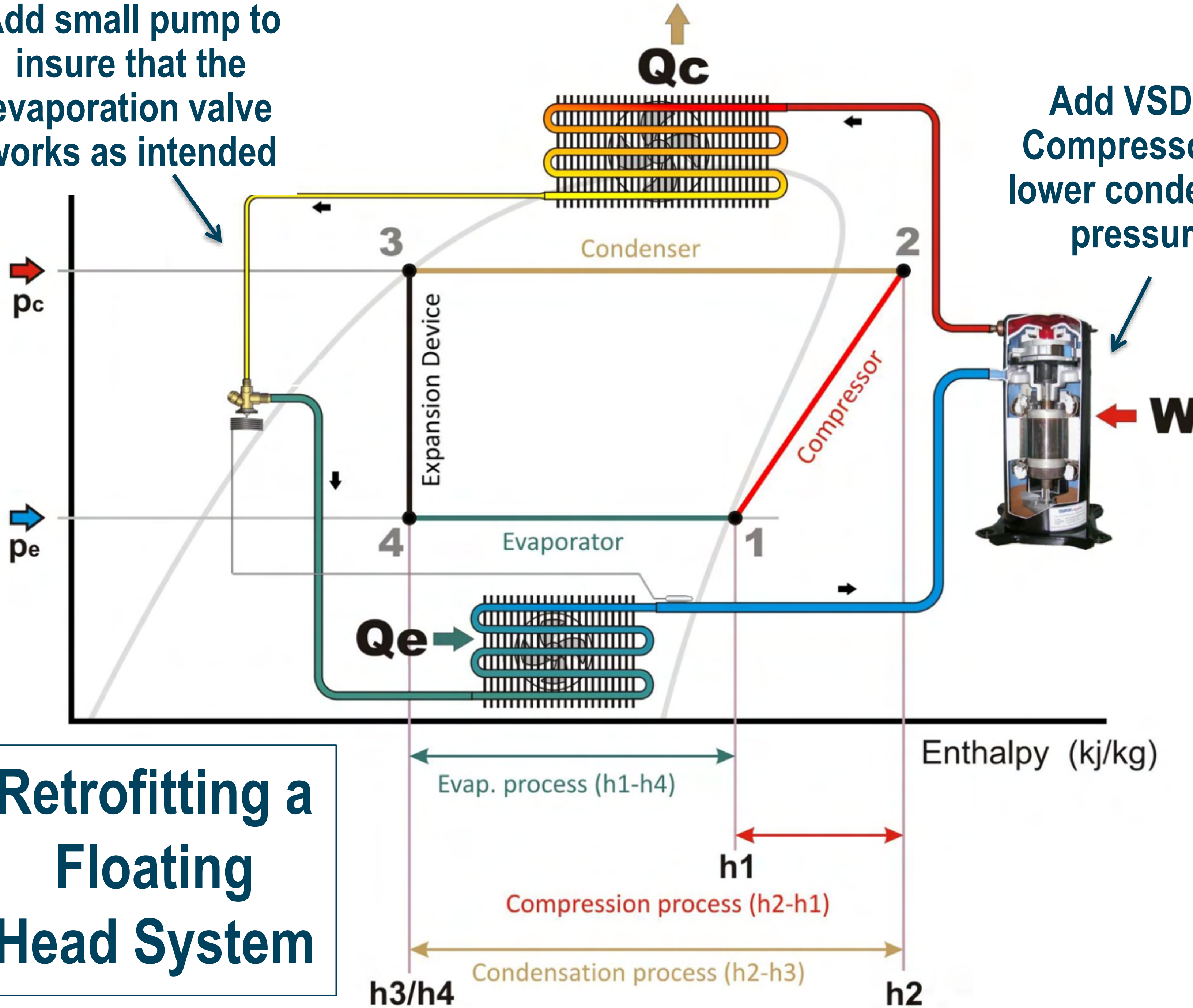
- **Retrofits are working better**
- **Lowering compressor pressure can mess up the valve performance**
  - Use a liquid pressure amplifier to make condensed liquid have normal pressure



Typical Compression Refrigeration cycle

Add small pump to insure that the evaporation valve works as intended

Add VSD to Compressor to lower condenser pressure



Retrofitting a Floating Head System

Floating Head Pressure

- Energy is saved in two ways:
  - 1. Compressor power.
    - It takes less power to compress the refrigerant to lower pressure
  - 2. Efficiency.
    - The cooler liquid refrigerant has more cooling capacity. At lower pressure the system thermodynamic efficiency and the compressor volumetric efficiency
- Actual case studies for grocery refrigeration systems show savings of 27%

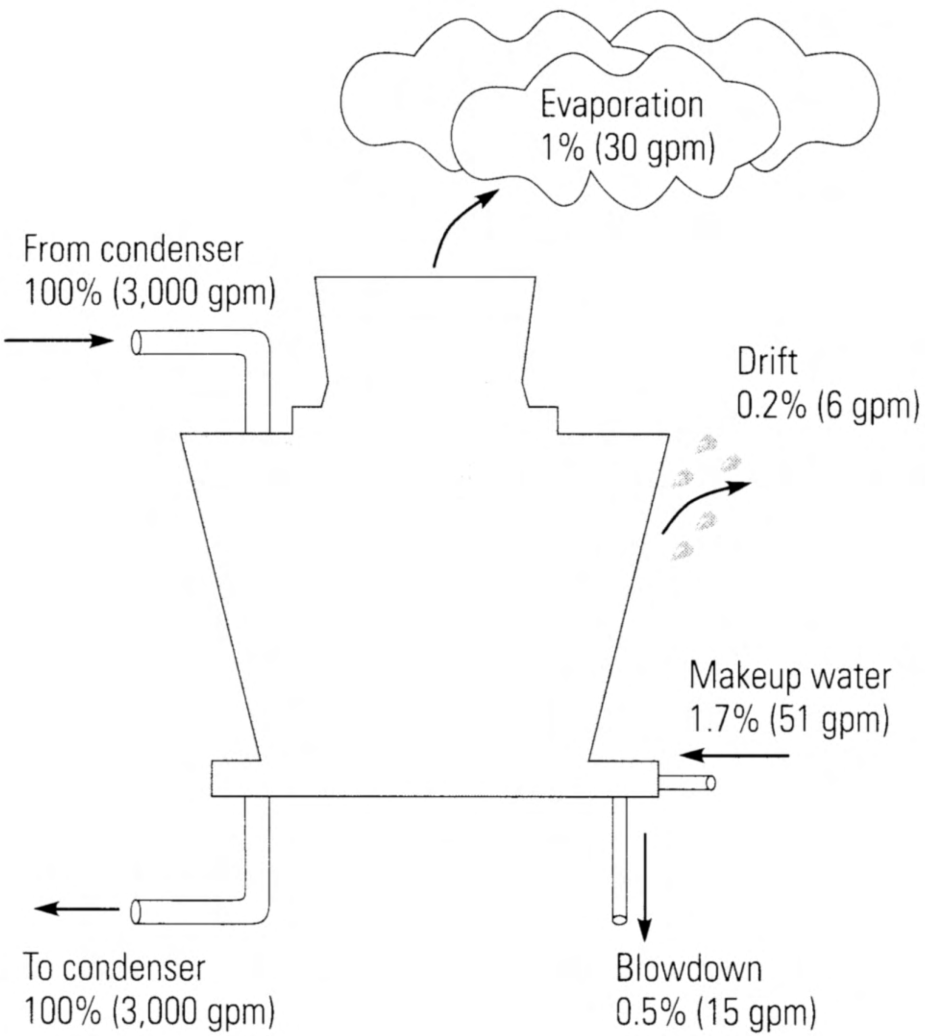
Cooling towers

- **Critical for efficient operation of chillers**
- **Main energy use (and focus usually) is on the fans pushing air through the cooling tower**
  - Multi-speed fans and adjustable speed drives can match needs and minimize fans energy
  - Measurement and logging of return temps
  - Adjust speed to maintain an *approach** between 8 and 14 °F

***Difference between cooled-water leaving tower and ambient wet-bulb temperature**

Cooling towers

- **Evaporation means loss of some water**
  - Makeup is small (nominally 2%)
- **Larger losses means leaks or excess drift**
- **Savings is energy and water!!!**



Cooling towers

- **Towers are outside and out of view by management**
  - Often in great need of maintenance
- **Damaged fill**
- **Leakage**
- **Broken access doors**

Cooling towers

- **Add a tower? Move a tower? All very cheap compared to working your chillers harder**
  - Do look where wet exhaust is going!!!
  - Into other cooling towers? Or into an air compressor?
- **Tower efficiency is also dependent upon the physical placement and orientation of cooling tower cells at the facility.**

Cooling tower performance

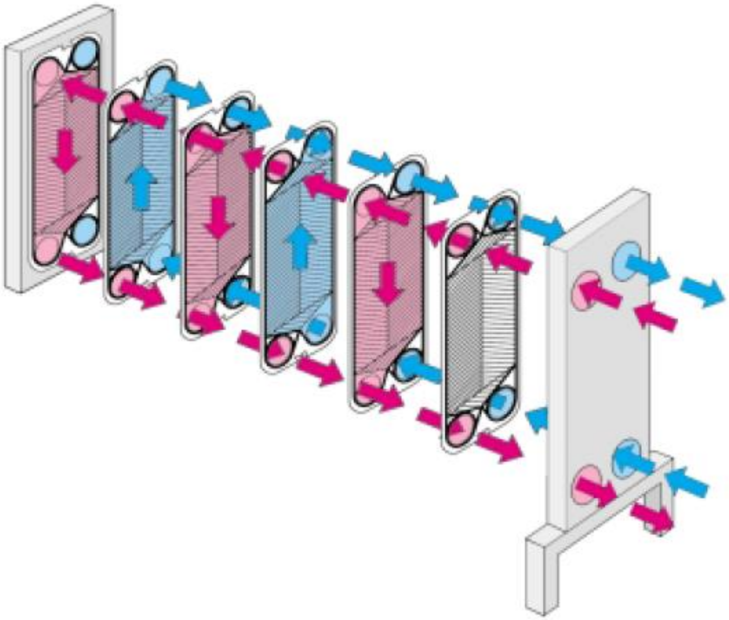
- Icing is a problem
  - many towers which have a closed loop use antifreeze
  - some towers operate dry in winter (use dry bulb instead of wet bulb temps)
- Water issues are significant
  - Dry cooling can be the rule if treatment costs are high (California)

Heat exchangers

- **Large area for easy savings**
  - They work quietly and transparently –
  - But if they start working poorly?
    - Change in desired output temperature results
    - Often there is a secondary system – chiller, say, that can make up for loss of heat recovery
- **Are delta T's being checked on heat exchangers?**
- **What maintenance program is in place?**

Maintenance Levels

- **Backflushing**
  - Good for removal of loose solids
- **Cleaning-In-Place**
  - Chemical cleaning primarily to remove scale
  - Nitric acid, citric acid, sodium polyphosphates, etc.
- **Disassembly**
  - Mechanical cleaning



Thermal Storage

- Utilize more efficient generation-side power
- Avoid peak use
- Choice between water and or ice

Table 1.
Monthly Demand Savings of Using Thermal Storage to Shift Chiller* Use to Night-time

Utility Demand Rate	Cost Per Ton Hour of Cooling	Monthly Demand Savings
$6/kW	$4.20	$1,008
$12/kW	$8.40	$2,016

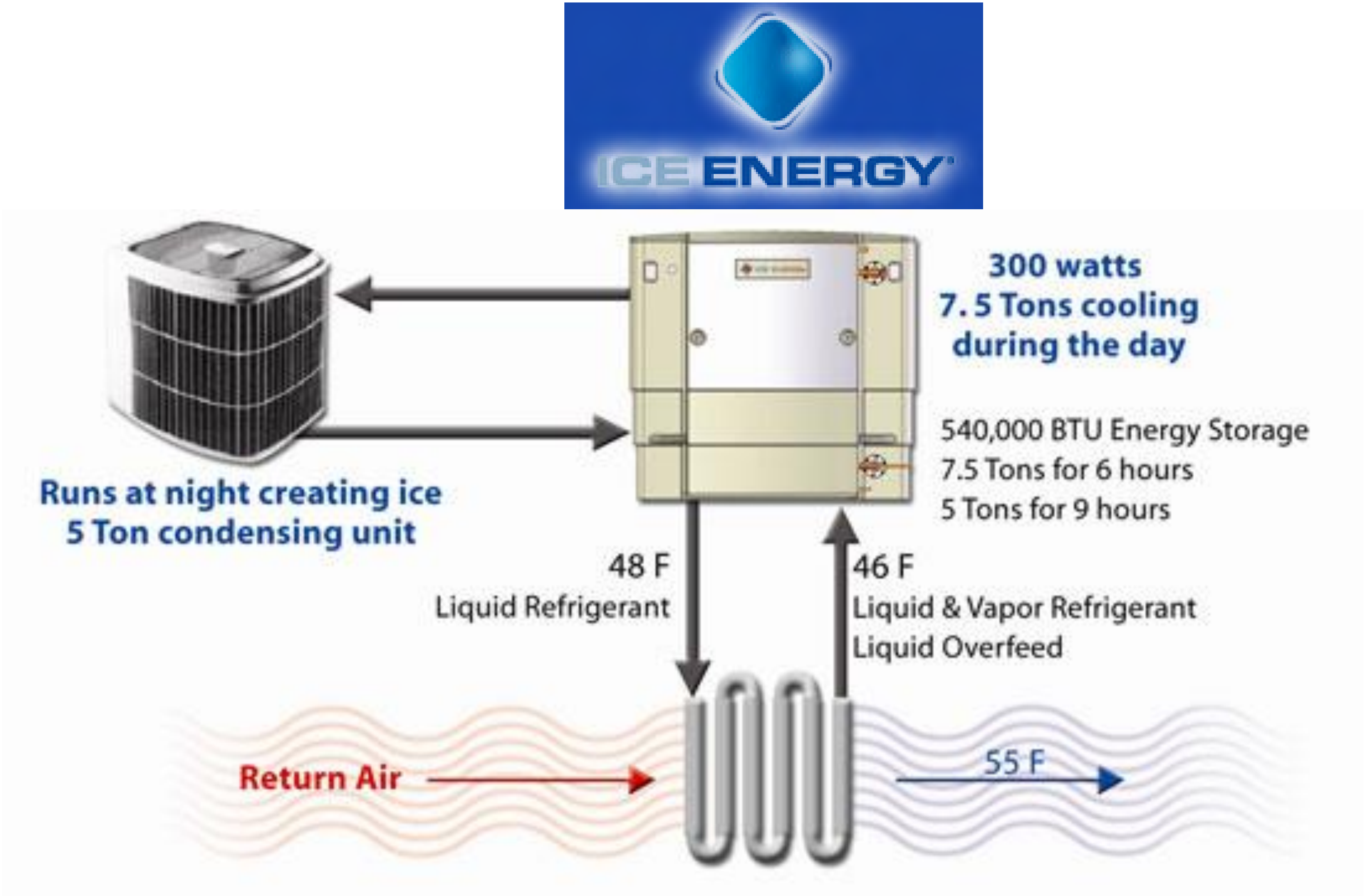
**Assumes 300-ton chiller operating at average load—80% of full load, or 240 tons. Chiller efficiency assumed at 0.7 kW/ton. Chiller operation assumed to operate at night when building is unoccupied so that peak demand is not increased by chiller operation.*

Table 2.
Comparison of Thermal Storage Media

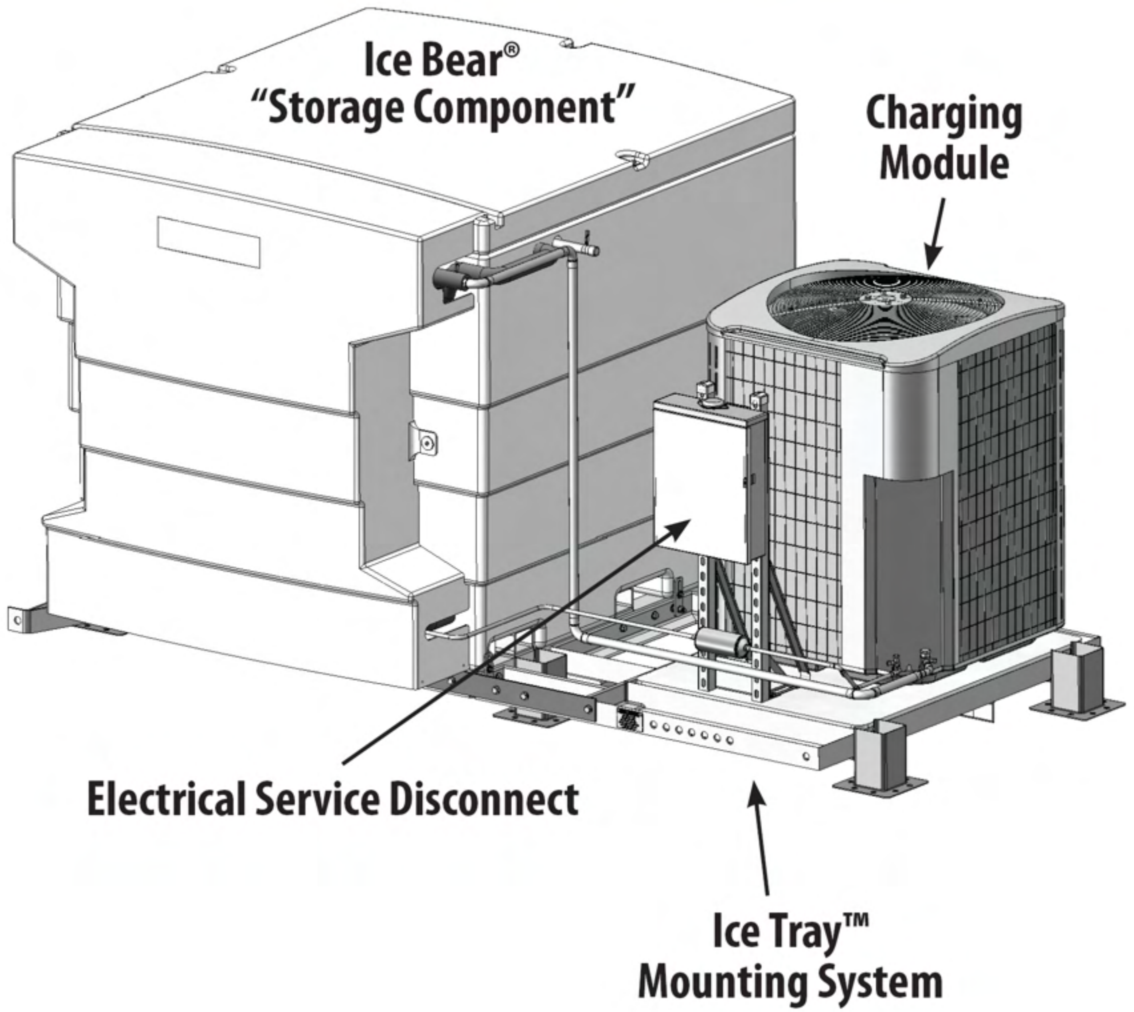
	Chilled Water	Ice
Chiller Cost	200-300 $/ton	200-1,500 $/ton
Storage Tank Cost	30-150 $/ton-hr	20-70 $/ton-hr
Storage Volume	6-20 ft^3/ton-hr	2.5-3.3 ft^3/ton-hr
Chiller Efficiency	5-6 COP	2.7-4 COP

Ice for Thermal Energy Storage

- **Mechanical refrigeration is used to make ice when electric rates are lower.**
  - For reasonable paybacks, chillers which can freeze water should already be present
- **When cooling is needed water is circulated through the ice storage area**
- **An ice storage system can reduce chilled water flow requirements by half.**
  - A traditional chilled water system using 44 $^{\circ}$F supply and 54 $^{\circ}$F return will require 2.4 gallons per minute (gpm) of chilled water for each ton-hour of refrigeration.
  - An ice storage system can supply chilled water at 34 $^{\circ}$F reducing the required chilled water flow to 1.2 gpm.

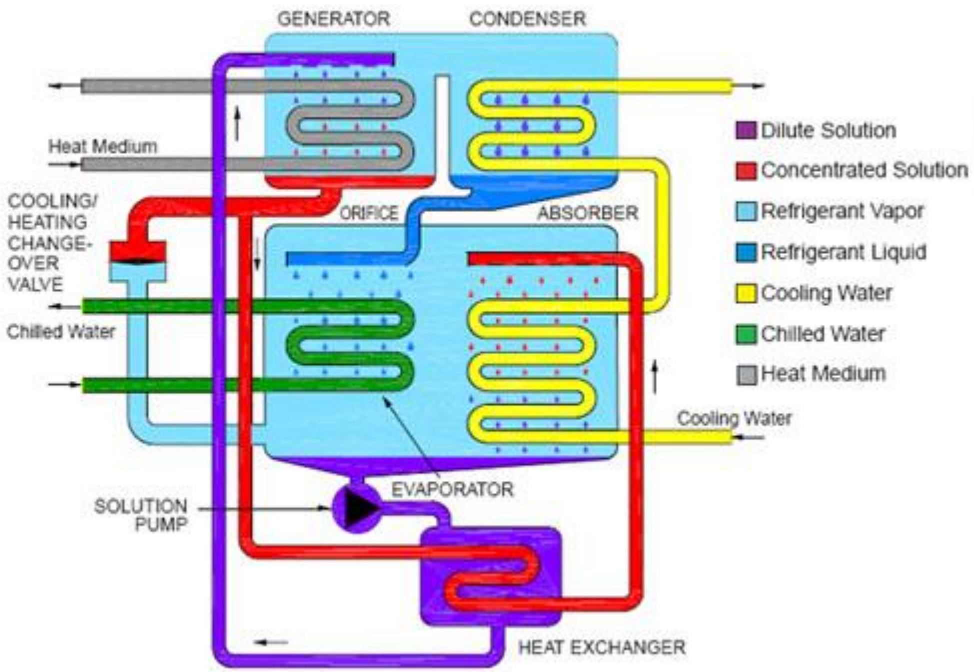

ICE ENERGY
300 watts
7.5 Tons cooling
during the day
540,000 BTU Energy Storage
7.5 Tons for 6 hours
5 Tons for 9 hours
Runs at night creating ice
5 Ton condensing unit
48 F
Liquid Refrigerant
46 F
Liquid & Vapor Refrigerant
Liquid Overfeed
Return Air
55 F

Ice Used to support Air conditioning



Additional Cooling Methods

- **Absorption Chiller**
  - Only effective when there is a viable waste heat source that would otherwise be rejected
  - Replaces the compressor with a more efficient pump



Cool only where necessary

- **Often cooled areas can be efficiently separated from areas where cooling is not needed**
- **Cooling is also used to control humidity**
  - There are other ways (dessicants) to handle this especially if there is waste heat around
- **For hot spots compressed air can be used for spot cooling**
  - Vortex tubes