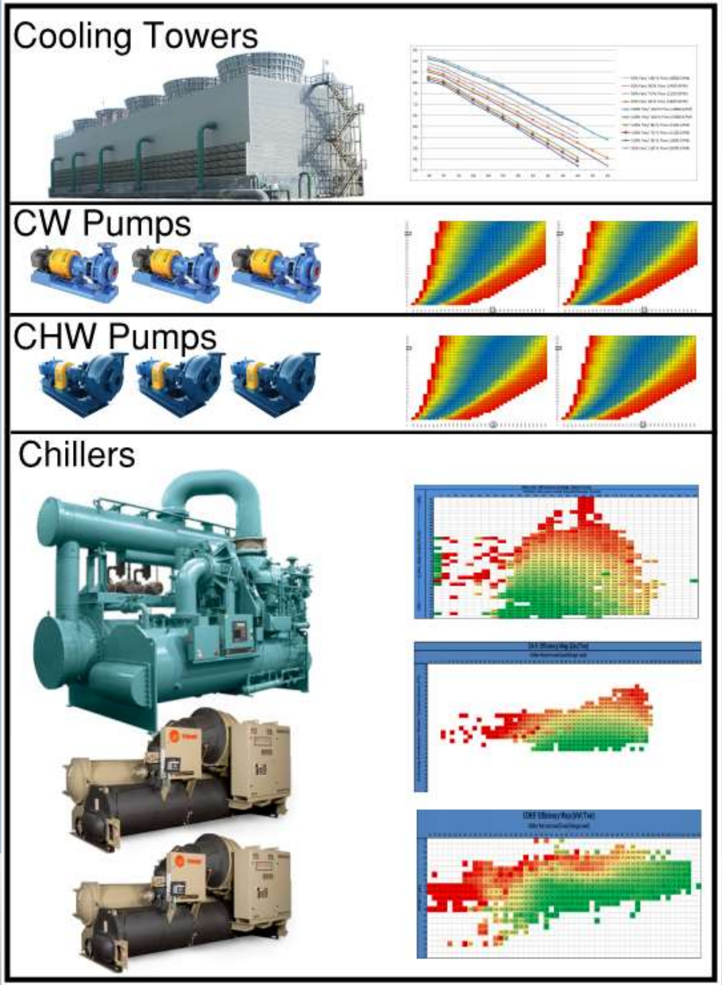
Flipping Chilled Water Optimization: Train Operators First

Princeton and MIT Case Studies

CHILLED WATER PLANT OPTIMIZATION



- **Chilled Water plant optimization finds lowest energy balance of all components**

- **Typically training occurs at end of project**

- **We recommend <u>training first</u>**

WHY TRAIN FIRST?

REASON #1: MUST UNDERSTAND THE SYSTEM

- **Most often simple issues keep system from working properly, that can only be found through survey**

- **Tribal knowledge can be key to success**

- **Training facilitates dialogue between operators**

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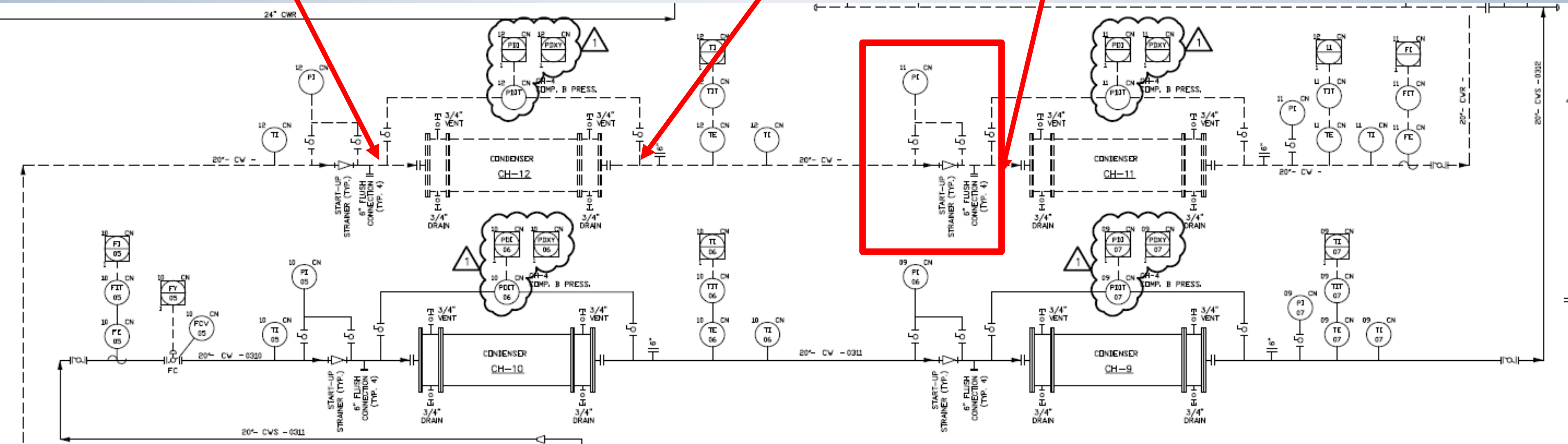
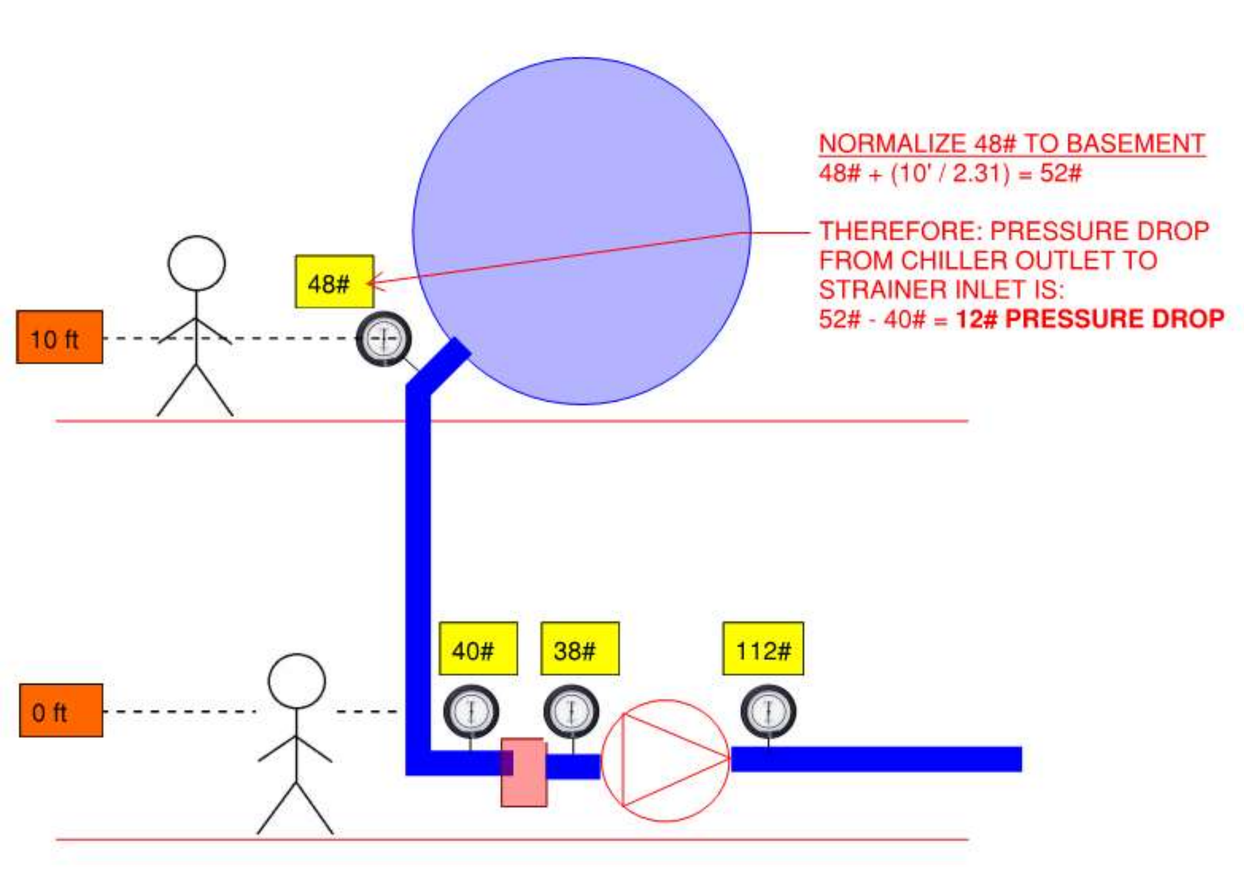
EXAMPLE: MIT SYSTEM BOTTLENECKS

CLOGGED START-UP STRAINER



MORE CLOGGED STRAINERS

READING PRESSURE GAUGES AT ELEVATION



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REASON #2: COMPLEX PLANTS PARTIAL AUTOMATION

- Many plants do not want full automation

- Especially plants with mix of steam and electric assets

- Steam turbine chillers

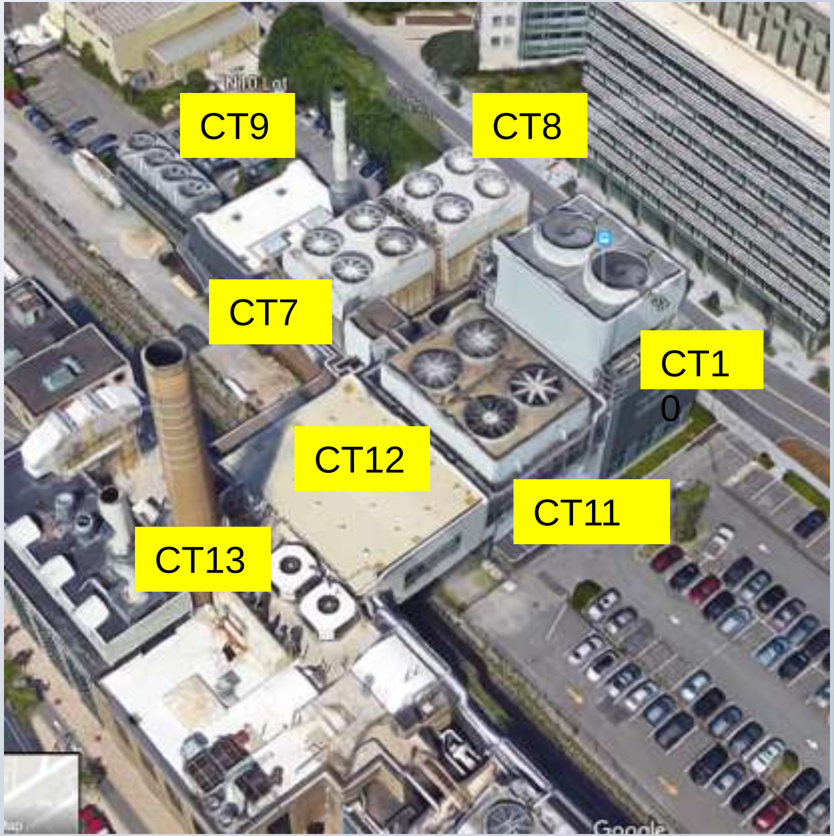
STEAM TURBINE CHILLERS

MIT: 5000 Ton York OM500

Princeton: 4500 Ton Carrier 17DA

EXAMPLE: MIT COOLING TOWERS

- **Uneven cooling tower basin levels**



REASON #3: GAIN OPERATOR'S TRUST AND ADDRESS MISCONCEPTIONS

- **If operators do not trust the optimization, THEY WILL OVERRIDE IT**

- **There are common misconceptions that are counter to principles of optimization**

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EXAMPLE: CW TEMPERATURE ON TRANE CHILLERS

PU CW Operation – CW Control Valve – CH-2

TRANE

Guidelines for CenTraVac Chillers with Tracer AdaptiView Controls

Operating Recommendations

All chillers require a minimum pressure difference between the condenser and evaporator refrigerant circuits to assure proper management of oil and refrigerant, as well as hermetic motor cooling (when applicable).

Following are specific guidelines for CenTraVac™ condenser refrigerant pressure with Tracer AdaptiView controls.

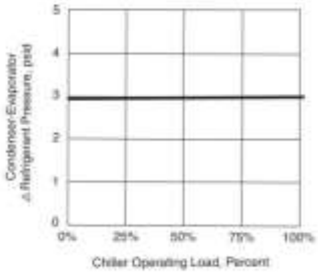
At start-up ...

- The chiller should reach the required minimum pressure differential within 15 minutes of starting the chiller. This means that the entering condenser water can be very cold at the start (e.g., –40°F–50°F). The chiller can start in an inverted mode where the condenser water is colder than the evaporator chilled water temperature.
- Running the chiller continuously for 30 minutes at the required minimum refrigerant pressure differential will assure that the oil returns to the oil tank via the oil reclaim system.

When running ...

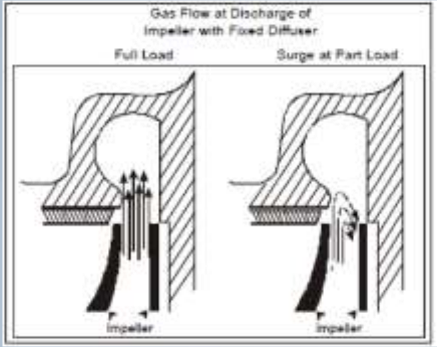
- The chiller can run steady state with very cold entering tower water. It is important to maintain a minimum 3 psid (20.7 kPaD) pressure differential as shown in Figure 2. The 3 psid (20.7 kPaD) minimum at all loads is nominally equivalent to a 15°F differential between leaving chilled water temperature and leaving condenser water temperature. For example, a chiller running at 40°F chilled water could operate with an entering condenser water temperature below 50°F, as long as the leaving condenser water temperature is greater than or equal to 55°F. If you have chillers with older controls, refer to previous revisions of this bulletin for pressure differential minimums.

Figure 2. Minimum condenser-evaporator refrigerant pressure differential



An optional signal is available from the chiller that can be used to maintain the 3 psig pressure differential. Once the signal option is chosen, there are two different control signal pathways available for use. The first pathway is the *direct option*. In this case, the signal from the chiller can be set up to go directly to the bypass valve or variable speed drive (see "Direct Tracer AdaptiView Signal," p. 8). The second pathway is the *indirect option*. In this case, a raw signal from the chiller is provided and an intermediate controller must be used prior to the external bypass valve or variable speed drive (see "Indirect Tracer AdaptiView Signal," p. 17).

EXAMPLE: CHILLER SURGE



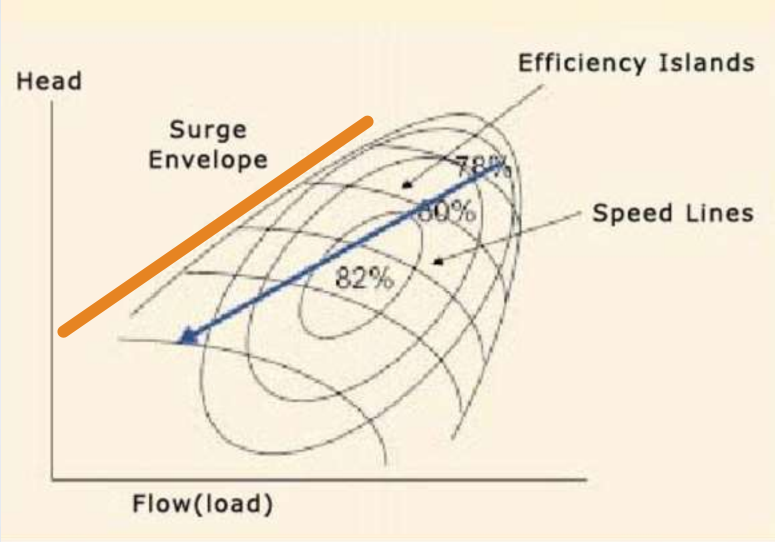
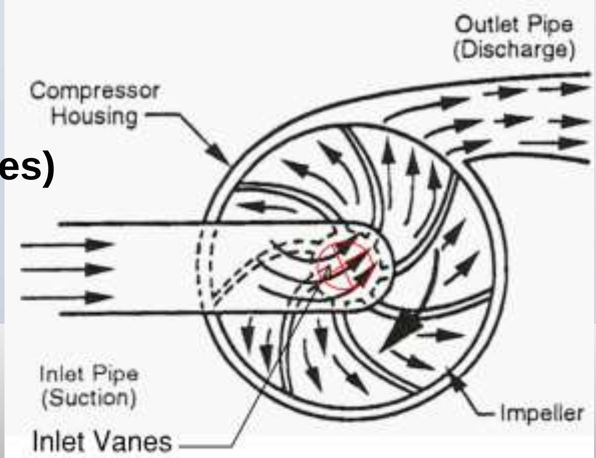
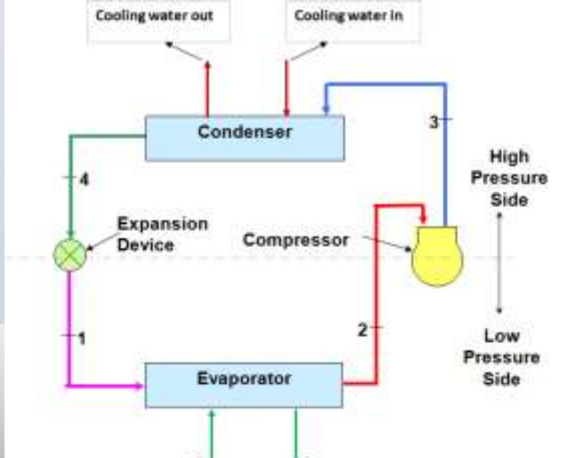


Figure 3 : Centrifugal compressor map

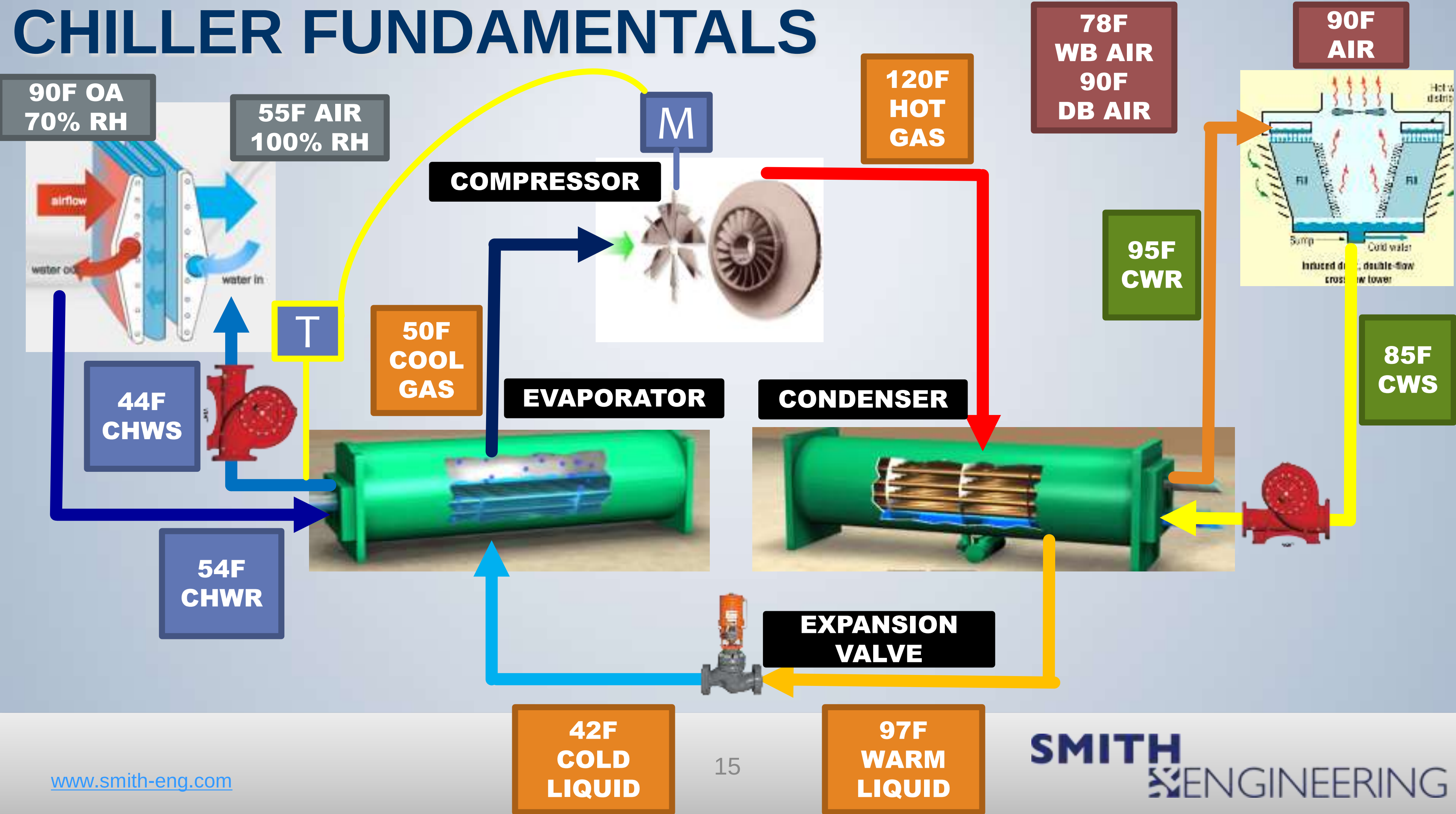
Ways to get out of surge:

1. **Increase CW Flow**
2. **Lower CWST**
3. **Increase Evap Flow**
4. **Raise CHWST (sometimes)**

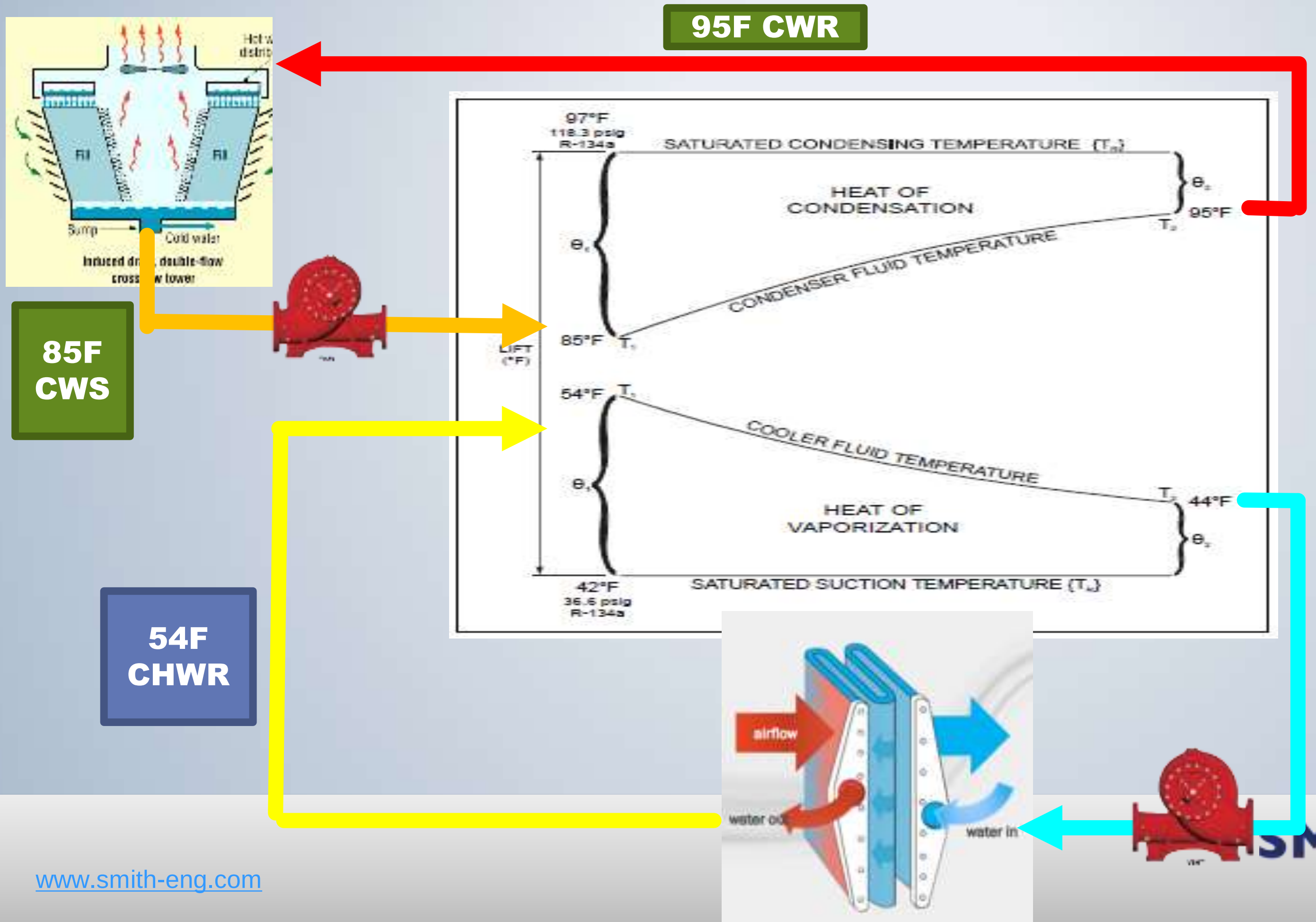




CHILLER FUNDAMENTALS



CHILLER FUNDAMENTALS – APPROACH AND LIFT



Cond Approach = Cond Refrig Temp - Leaving CW Temp

97F-95F = 2F

Evap Approach = Leaving CHW Temp -Evap Refrig Temp

44F – 42F = 2F

Lift =

Cond Pressure – Evap Pressure

118.3 – 36.6 = 81.7psig

Or

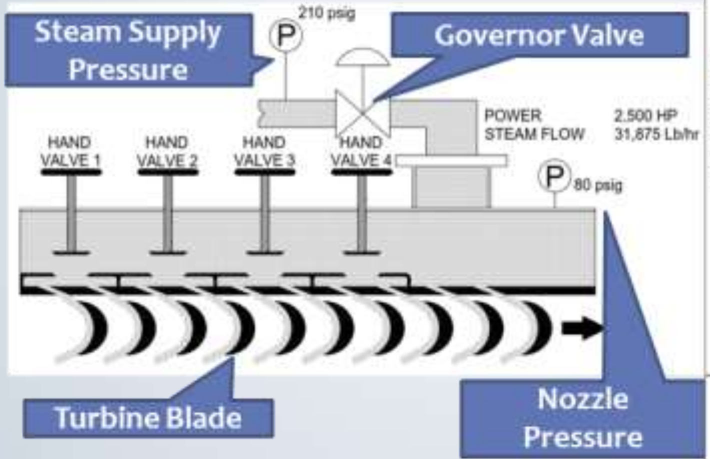
Cond Temp – Evap Temp

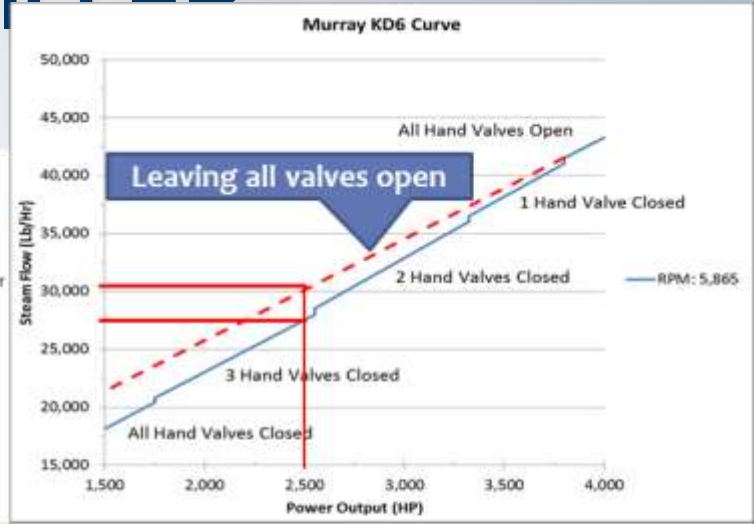
97F – 42F = 55F

EXAMPLE: MIT HAND VALVE OPTIMIZATION

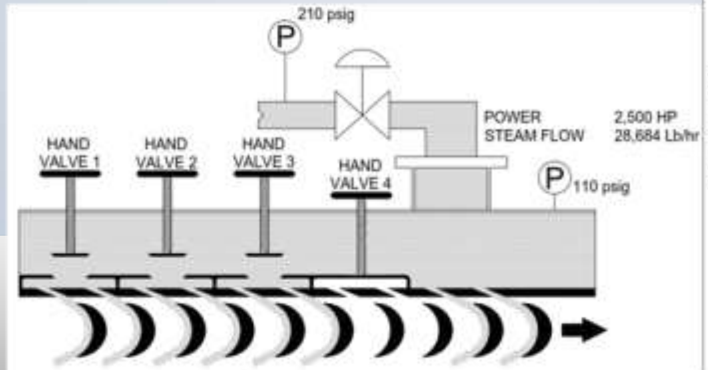
OPTIMIZATION – STEAM CHILLER

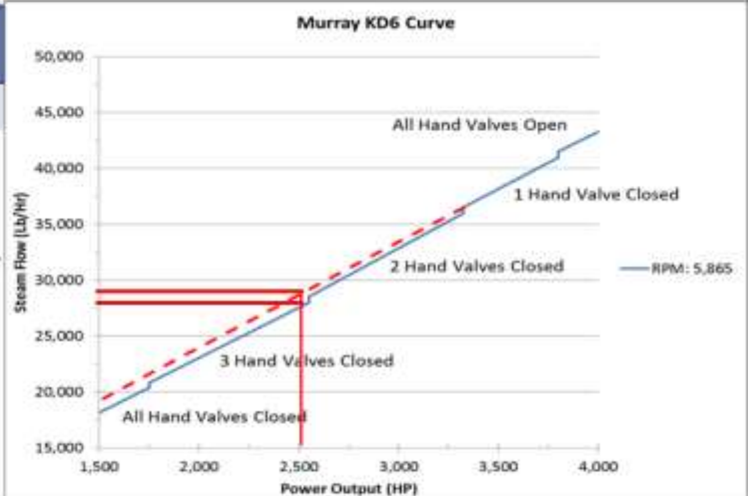
All hand valves open: Inefficient





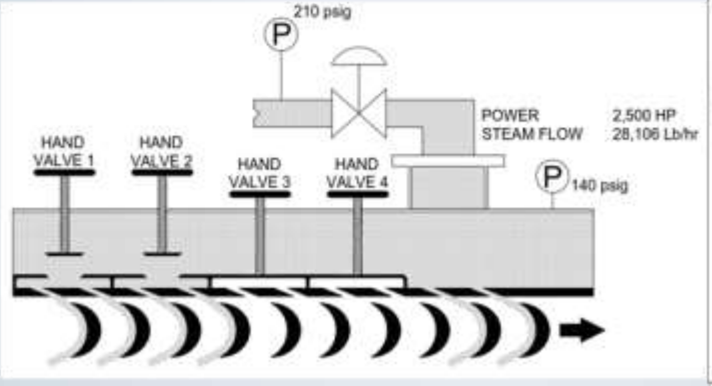
One hand valve closed: Better

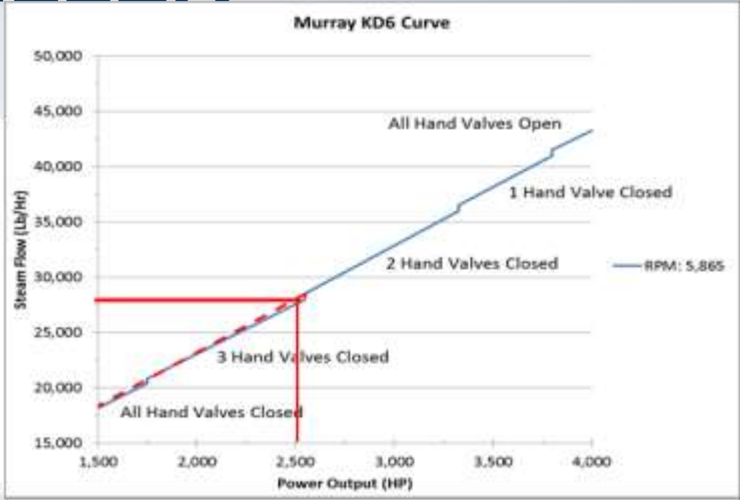




OPTIMIZATION – STEAM CHILLER

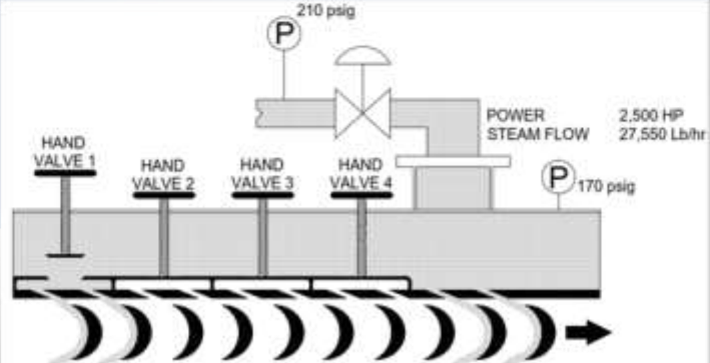
Two hand valves closed: Even Better

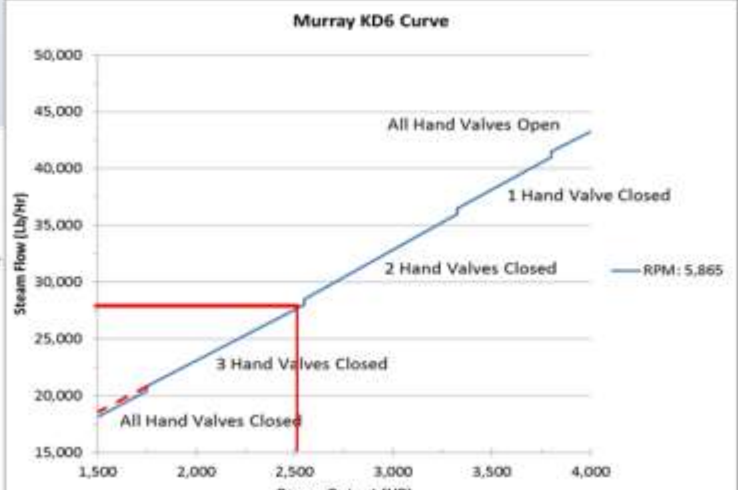




Three hand valves closed: Best

Over 3,500 lb/hr reduction





OPTIMIZATION – STEAM CHILLER

The hand valves cannot be used as throttling valves. They should be either fully opened or fully closed. A valve that is partly open will soon have a damaged seat due to steam erosion. This condition is better known as "wire drawing". However, when putting the unit into operation, do not close a valve tightly until the turbine is up to operating temperature and all parts are evenly heated.

REASON #4: GET SAVINGS WITH PARTIAL OPTIMIZATION

- **An operator "Cheat Sheet" can often get you half the way to fully optimized**

Massachusetts Institute of Technology

CUP Chilled Water Plant Operating "Cheat Sheet"

Condenser Water Temperature Reset

Outside Air Wetbulb (°F)	Condenser Water Supply Temperature Setpoint (°F)	
	If Steam Chiller is Running	Else
36	Engage Free Cooling (CWST SP= 38 F)	
38	Disengage Free Cooling	
less than 50 F	65	55
52	65	57
54	65	59
56	65	61
58	65	63
60	65	65
62	67	67
64	69	69
66	71	71
68	73	73
70	75	75
72	77	77
74	79	79
76	81	81
78	83	83

Notes:
1) Minimum temperatures for steam chillers can be further reduced based on additional engineering review.

Cooling Tower Cell Staging

Run as many CT cells as possible down to minimum Tower Flow		
Minimum CW GPM Per Cell (Min GPM per Fan)		
Tower	IF OA WB (F) is greater than 25F	IF OA WB (F) is less than 25F
CT-7	1,900	2,200
CT-8	1,900	2,200
CT-10	3,400	3,800
CT-11	4,800	5,200
CT-12	4,800	5,200
CT-13	4,800	5,200

Notes:
1) Confirm minimum flows by observing if "dry spots" appear in the falling water.
2) Monitor towers for ice build up in winter and increase flow if necessary

Chilled Water Pump Control

	1 Pump	2 Pumps	3 Pumps	4 Pumps
CHWPs	GPM Range			
1,2,3,4	0-7500	7,500-12,000	12,000-18,000	18,000 and up
5,7,8,9	0-8,000	8,000 to 15,000	15,000 to 21,000	21,000 and up
10,11	One Pump Per Chiller			
12,13,14	0-11,000	11,000-22,000	22,000 and up	

Notes:
1) CHWP staging is based on normal CHWP operating differential pressures in range of 50-65 (depending on pump set)
2) If pumps cannot meet flow setpoint at full speed, start another pump

Misc. Notes

Ways to Get out of Surge:
(1) Lower tower condenser water supply temperature setpoint
(2) Increase flow through chiller condenser
(3) Increase flow through chiller evaporator

Steam Turbine Hand Valves: Steam turbine chest hand valves should be "open" or "closed", not throttled

Tube "Approach": Monitor evap and condenser "approaches" (difference between refrigerant and leaving water temperatures) should be less than 3 degrees. If more, then tubes could be fouled (or other issues)

*The above operating guidelines are taken from a a system optimization strategy training session performed by Smith Engineering in June 2017. The above guidelines are based on a cursory review of the plant equipment, current operating strategies and describe good practice optimization strategies. These are not meant to be taken as "operating rules", and operators must use their experience with equipment and operating judgment to monitor and control the plant according to established MIT operating practices. We are available to update the above sheet based on operator feedback.

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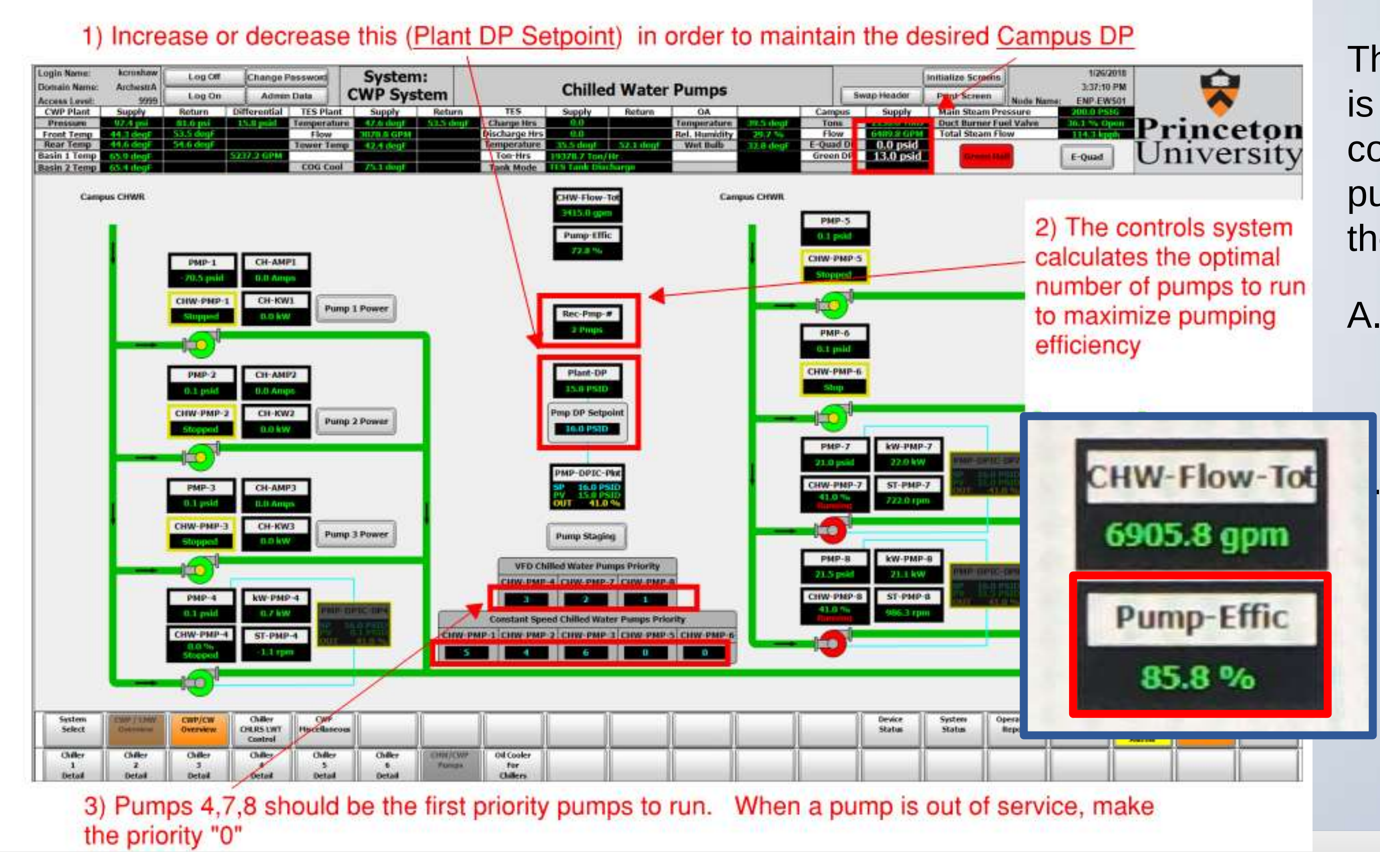
REASON 5: OPERATOR INTERFACE MUST HAVE BUY-IN



The pump control sequence is designed to automatically control the number of running pumps and the speed that the pumps run to:

A. Maintain the differential pressure at the plant wall, and

Stage the number of pumps running so that the pumps are close as possible to their best efficiency point

REASON #6: POST OPTIMIZATION DRIFT

- **Systems <u>change over time</u>. Operators must know how to respond**

- **Getting operator buy-in so that they see the process and understand, allows them to**

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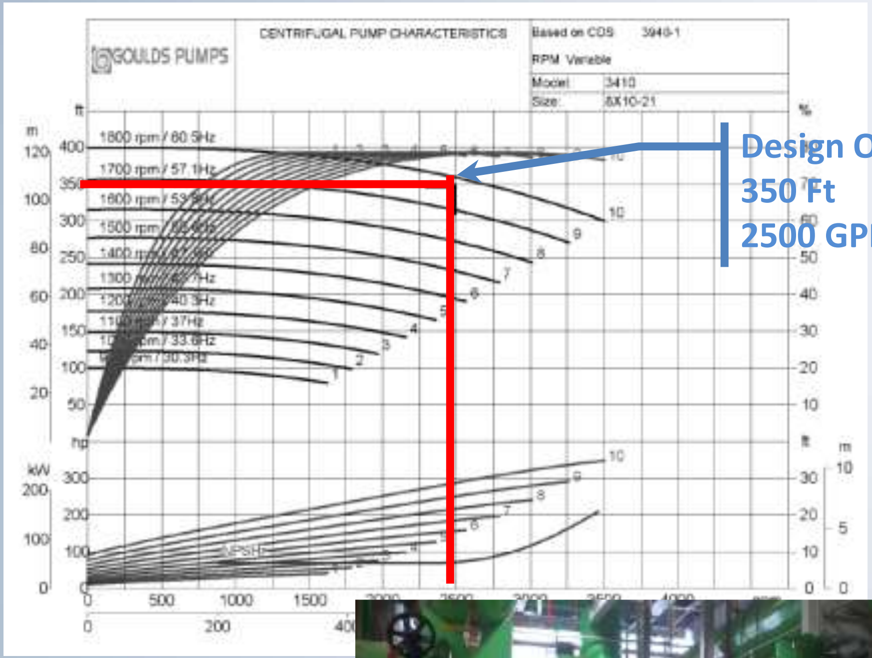
EXAMPLE: PRINCETON PUMP STAGING

PUMP PRINCIPLES



Design Operation
350 Ft
2500 GPM

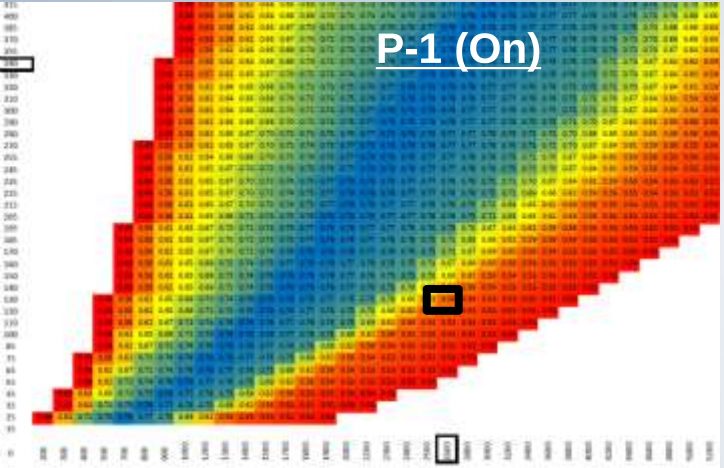
LARGE CAMPUS CHILLED WATER PUMP

$$HP = \frac{Flow\ x\ Head}{3960\ x\ \eta}$$

1. Flow: Campus dictates ΔT and thus flow
2. Head: Too many valves to poll to perform DP reset; therefore hydraulically remote DPT determines pump head
3. η can never be greater than pump+motor+VFD **BEP** ~80%

3 CHW Pumps

TDH: 135’ FLOW: 2621 GPM η : 56%



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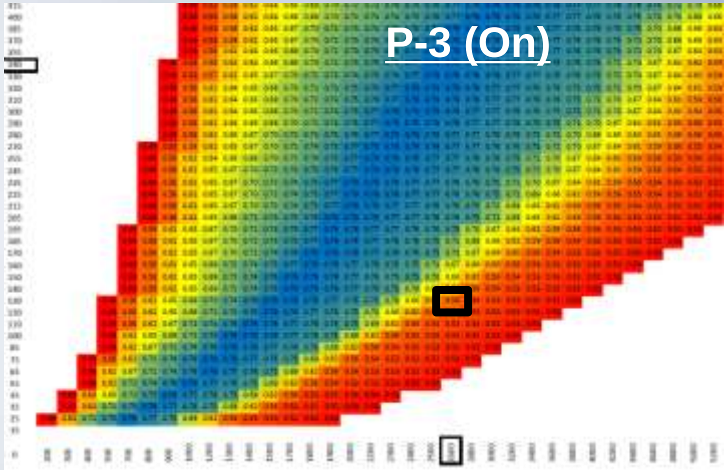
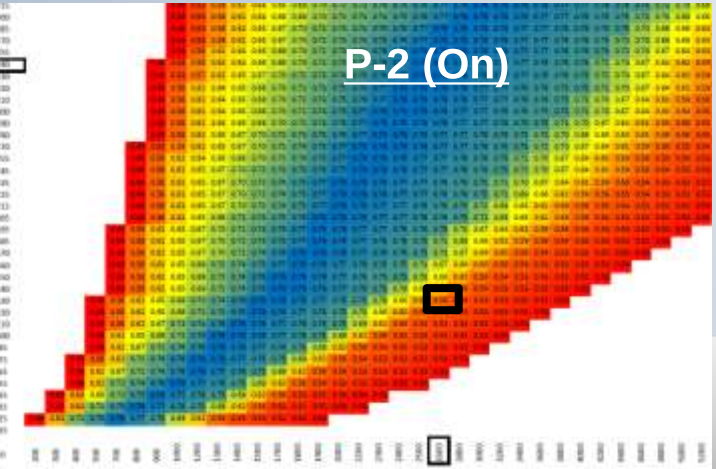
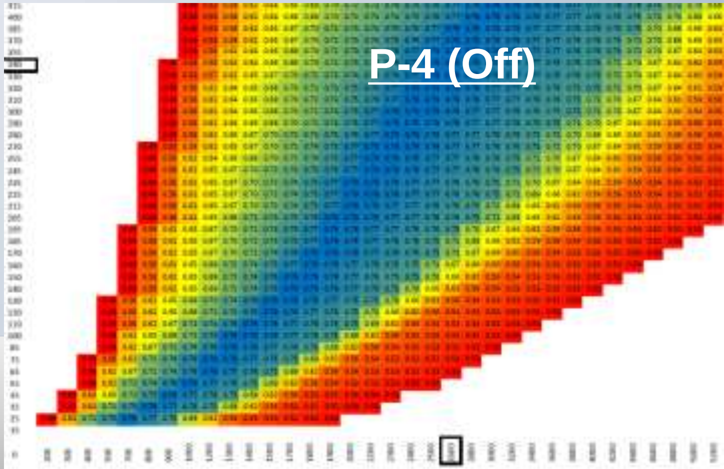


TDH: 135’ FLOW: 2621 GPM η : 56%



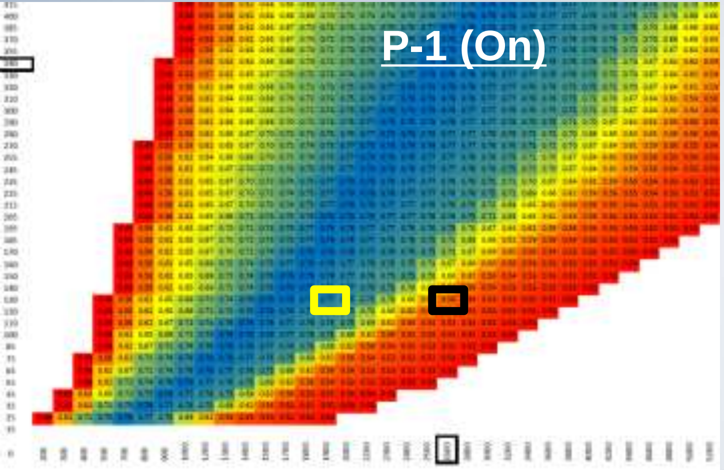
TDH: 0’ FLOW: 0 GPM η : 0%



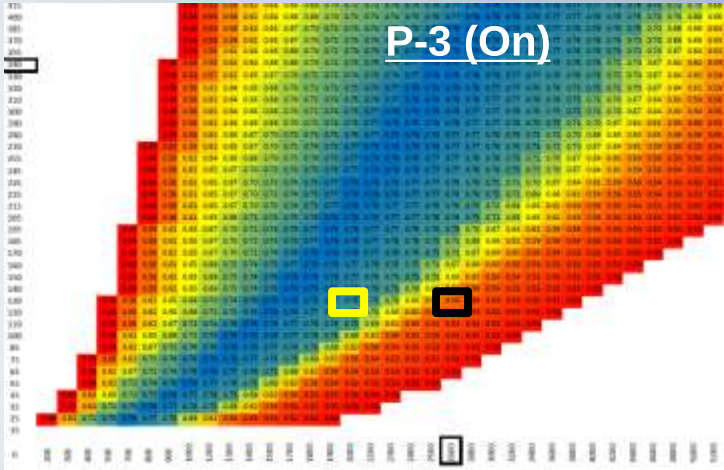
TDH:
135’
Total FLOW:
7,863 GPM
η:
56%
Total kW:
375

4 CHW Pumps

TDH: 133’ FLOW: 1965 GPM η : 76%



TDH: 133’ FLOW: 1965 GPM η : 76%



TDH:

133’

Total FLOW:

7,863 GPM

η:

76%

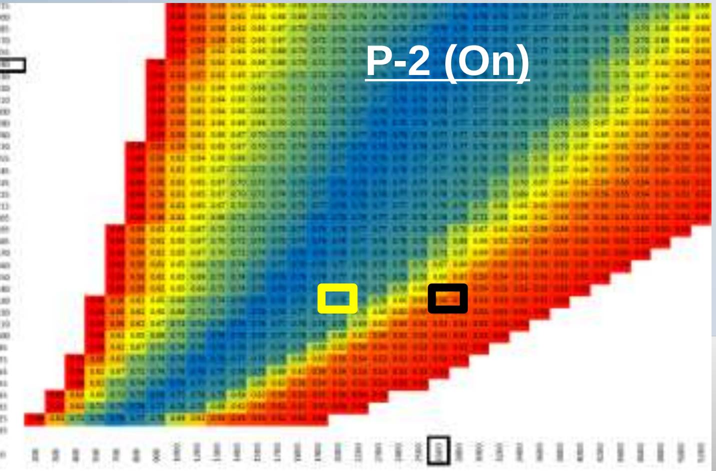
Total kW:

259

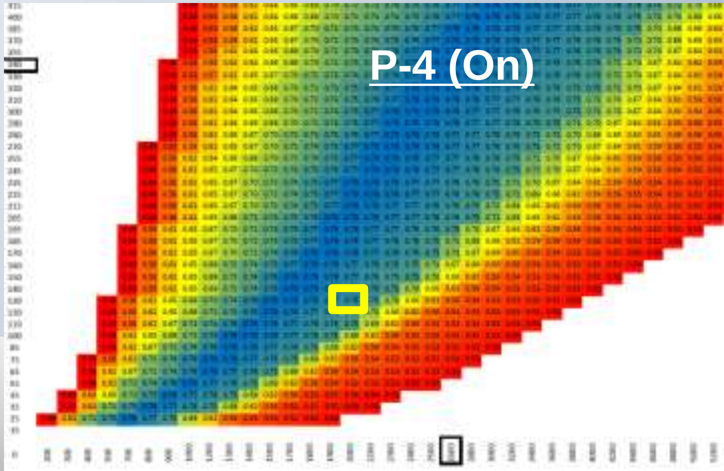
kW Reduction:

115

TDH: 133’ FLOW: 1965 GPM η : 76%



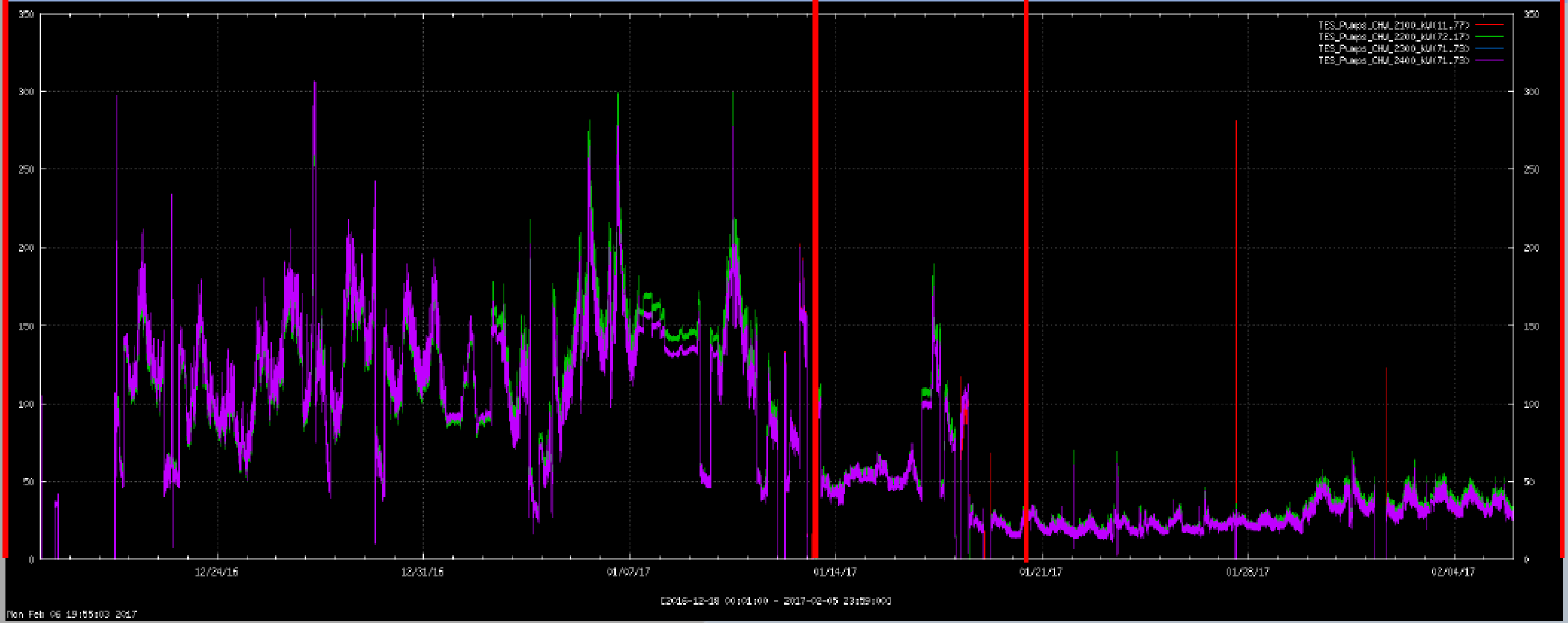
TDH: 133’ FLOW: 1965 GPM η : 76%



CHW PUMP OPTIMIZATION

Campus TES CHW Distribution Pumps – (4) 400hp Pumps

	Pre-Optimization	Cx and Operator Training	Stable Optimized Operation
Peak (kW)	609	350	215
Kwh Per day	7,701	4,583	2,525



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SUMMARY: WHY TRAIN FIRST?

1. Must understand the system and capture tribal knowledge
2. Complex plants likely do not want full automation
3. Process must gain operator's trust
4. Partial Optimization can be achieved with operator cheat sheet
5. Operator Interface must have operator buy-in and context
6. Optimization will drift if operators are not on board

Thank You