# IDEA 2016 – St. Paul, MN

# Chilled Water Plant Optimization Case Study

## Global Pharmaceutical Supplier R&D Campus

Presented by

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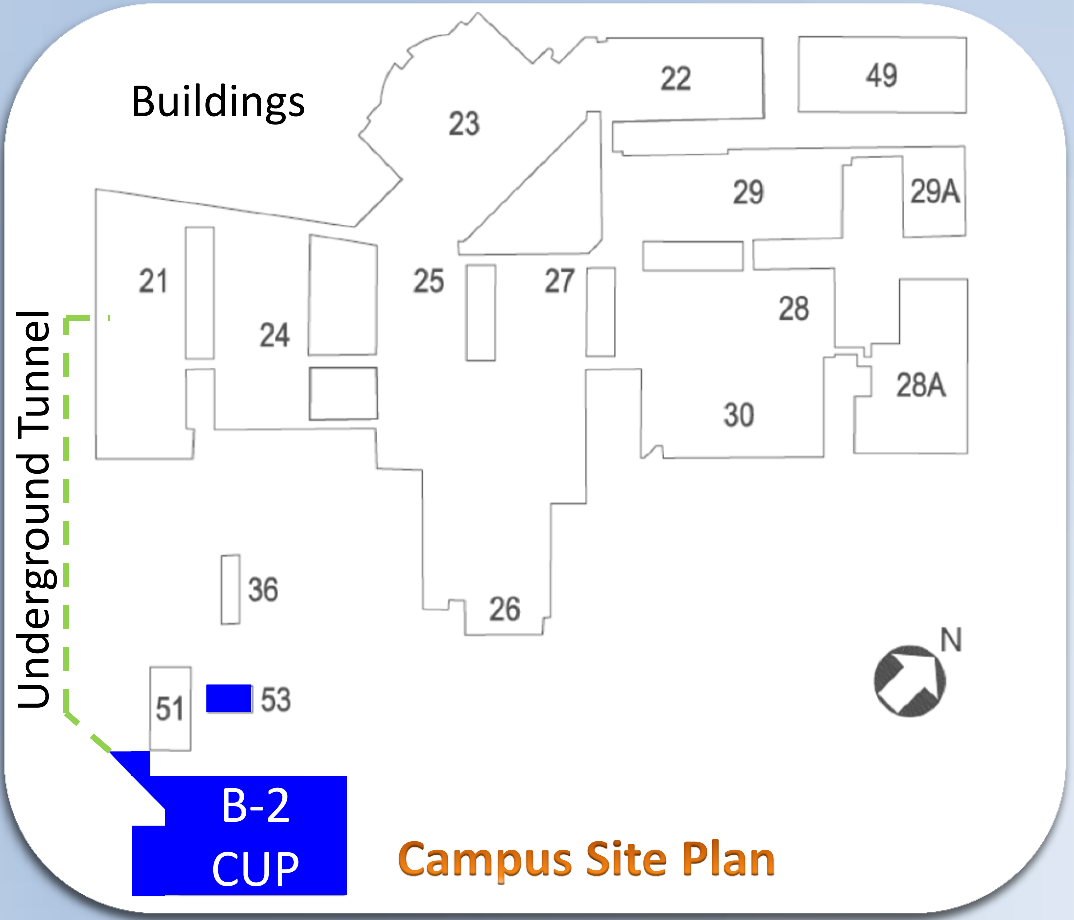
# Optimization Case Study Outline

- Project Goals
- System Overview
- Analysis
- Modifications
- Project Results
  - Energy & Cost Savings
  - Payback
  - Rebate

# Optimization Project Goals

1. Maintain Cooling Reliability.
2. Maintain Cooling Reliability.
3. Maintain Cooling Reliability.
4. Minimize Operation Disruption.
5. Optimize System Efficiency.
6. Obtain Utility Rebate.

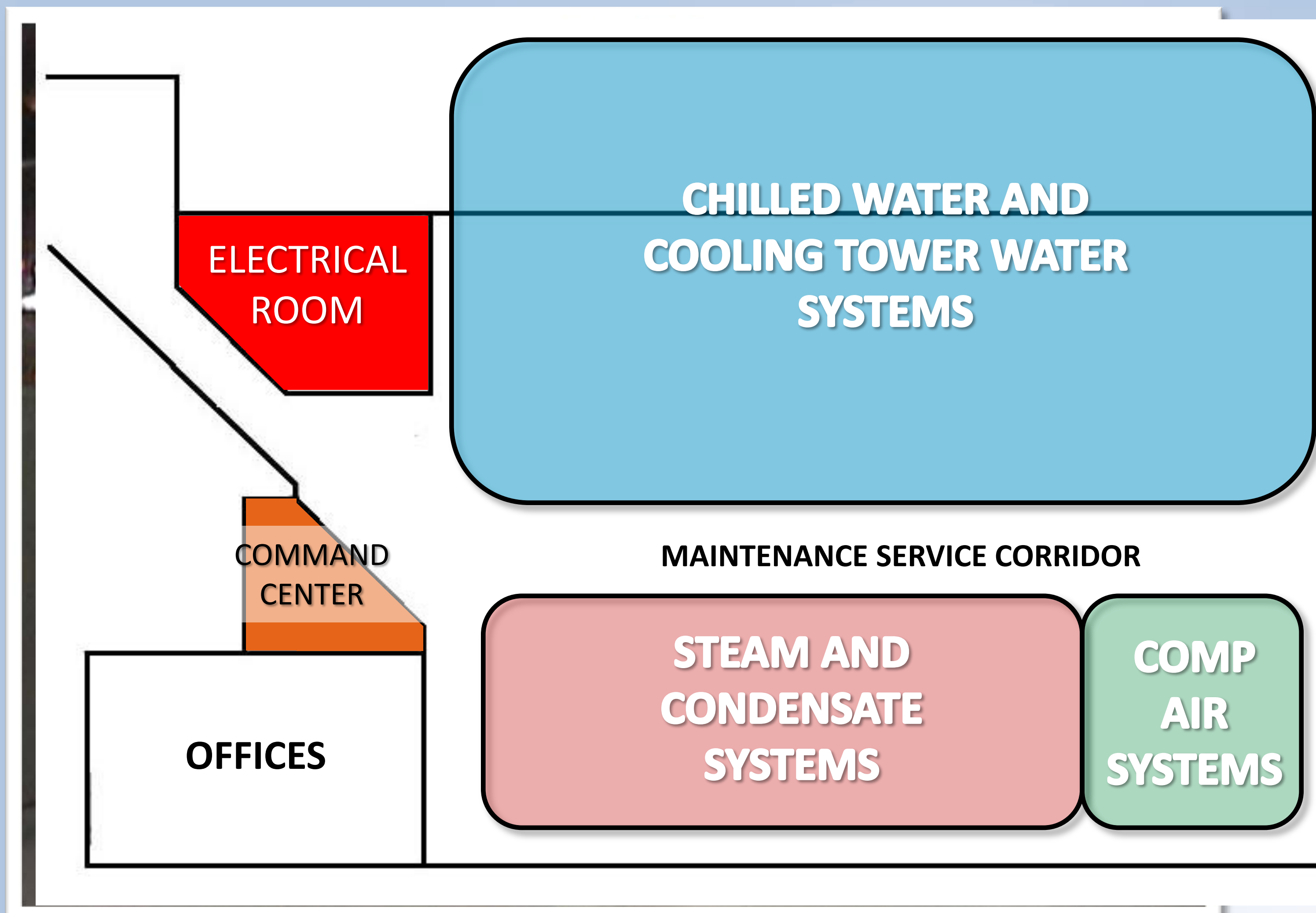
# Campus Map / Distribution System



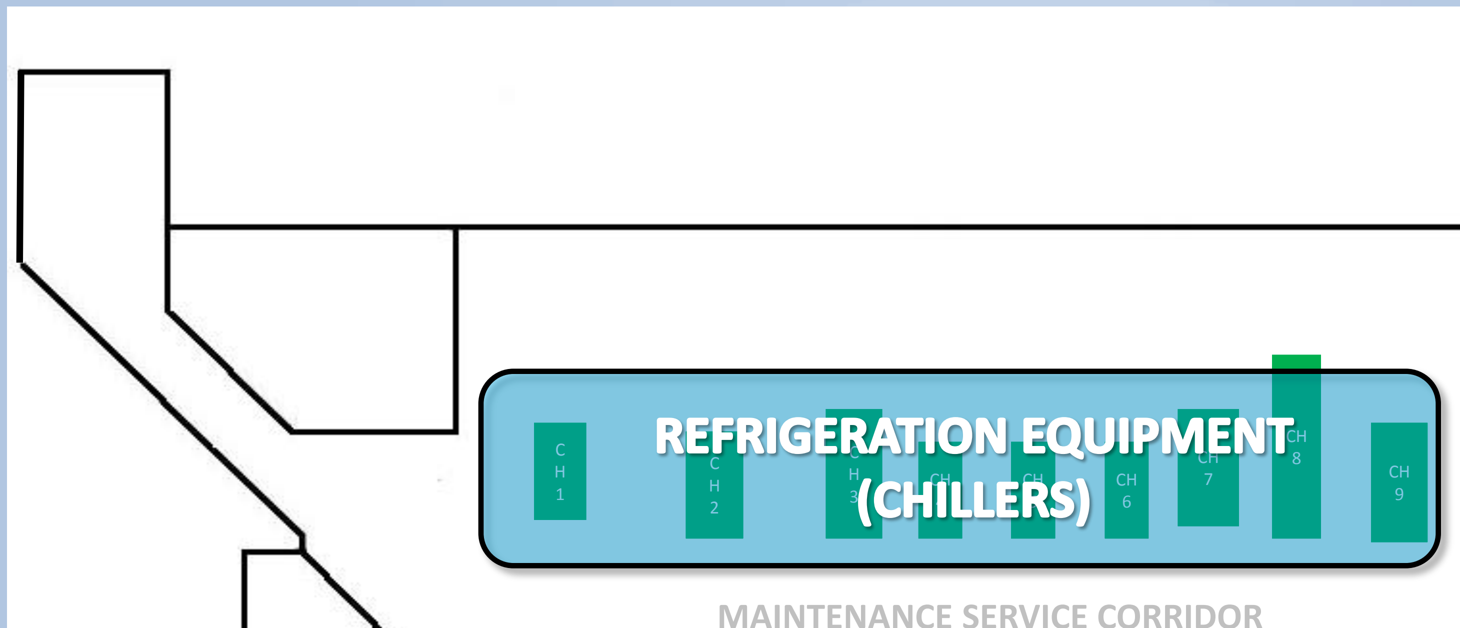

Cooling to:

- R&D Laboratories
- Datacenter
- Laboratory Animal Sciences (LAS)
- Sterile Suite
- Critical Manufacturing
- Offices

# Central Utility Plant

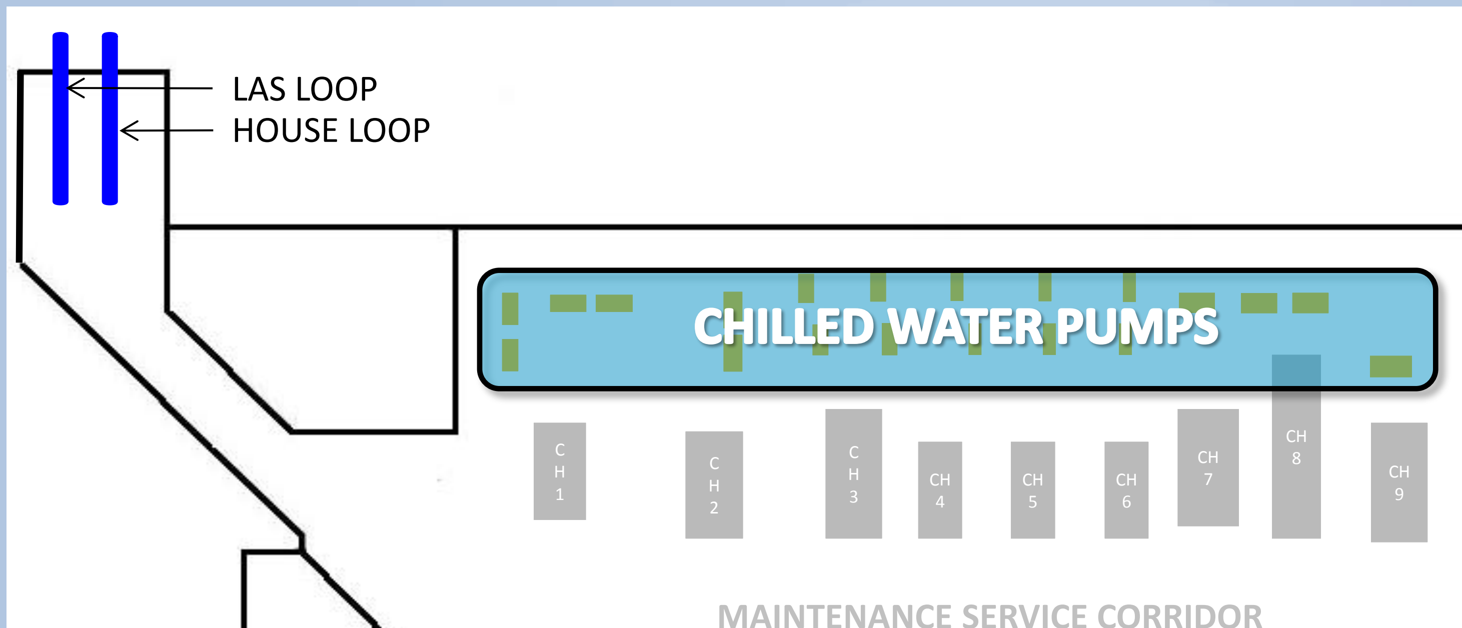


# Previous CHW Generation Scheme




| CHILLED WATER GENERATION | | |
|---|---|---|
| Eight (8) Water-cooled Elect. Centrif. Chillers<br>950 TR TO 2,000 TR<br>4160V Constant Speed Motors | One (1) Low Pressure Steam Absorption | Chiller design $\Delta T = 16°F$ |

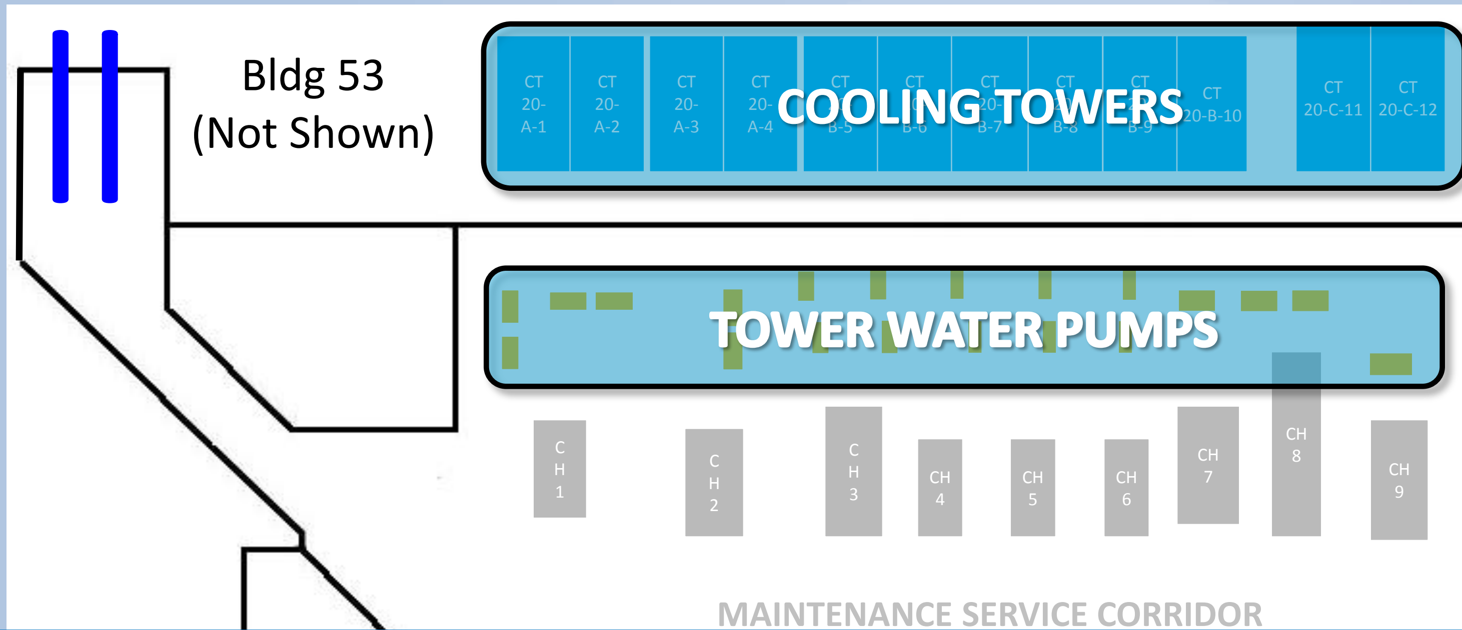
# Previous CHW Distribution Scheme




## CHILLED WATER DISTRIBUTION

| | | |
|---|---|---|
| Headered Primary Only Pumping Configuration | Ten (10) Centrifugal Pumps | Two (2) Interconnected Piping Loops<br>LAS And House Loops |

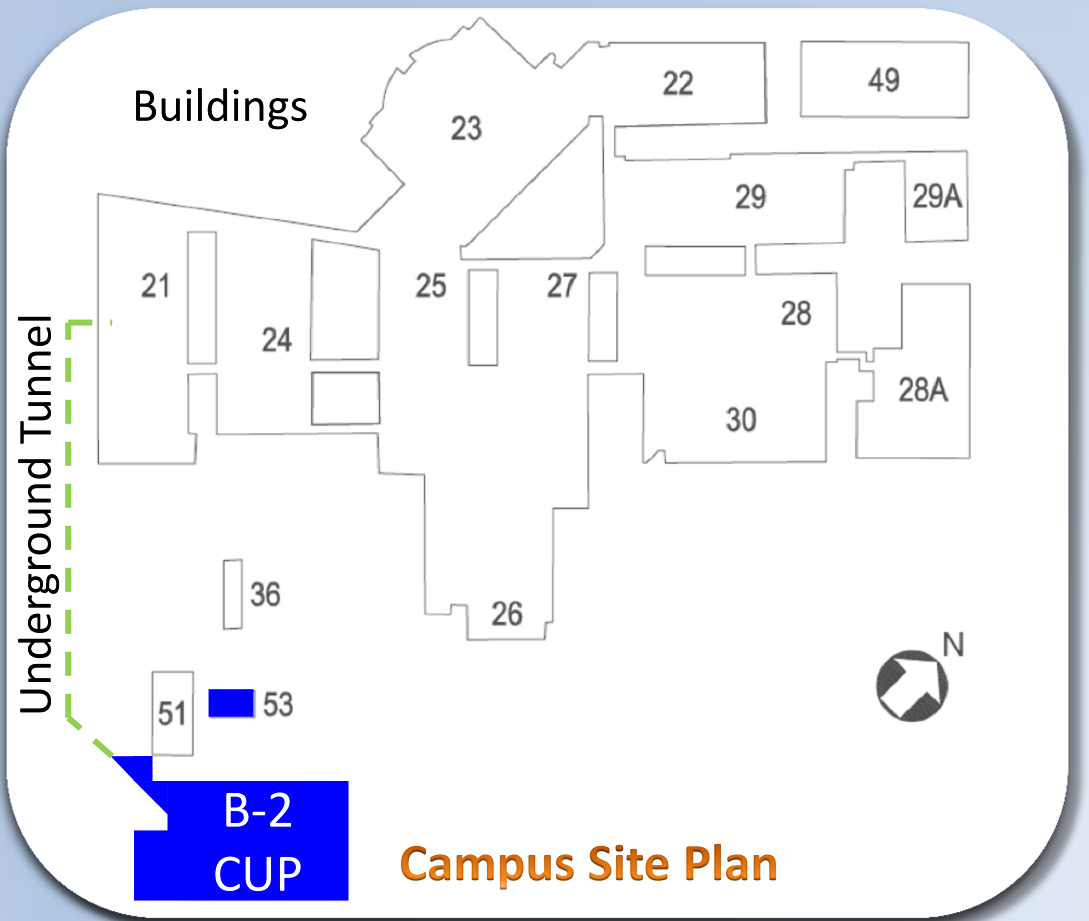
# Previous Tower Water System Scheme




## TOWER WATER SYSTEM

| | | |
|---|---|---|
| 4 Towers / 15 Cells<br>Induced Draft<br>Crossflow Type | VFD's On Cooling Towers<br>Fixed Condenser Water Supply Temperature | Headered Pump Config<br>12 Centrifugal Pumps<br>Constant Speed |

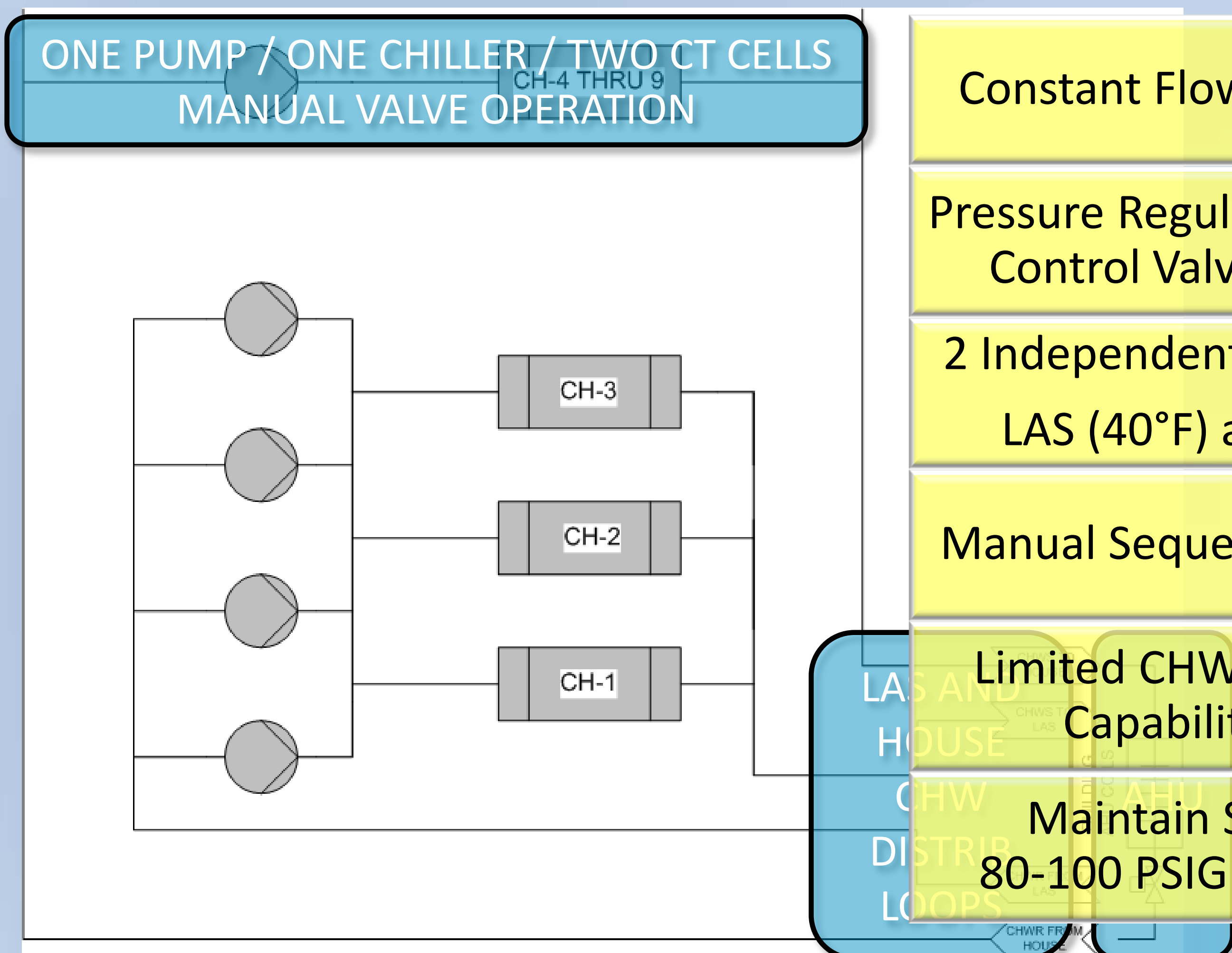
# Chilled Water Demand And Usage




B-2 CHW SYSTEM
DEMANDS
9,980 Tons

B-2 CHW SYSTEM
CAPACITY
10,635 Tons

# Previous CHW Plant Operation




Constant Flow Primary Pumping

Pressure Regulating / 2-Way / Flow Control Valves in Distribution

2 Independent Distribution Loops

LAS (40°F) and House (44°F)

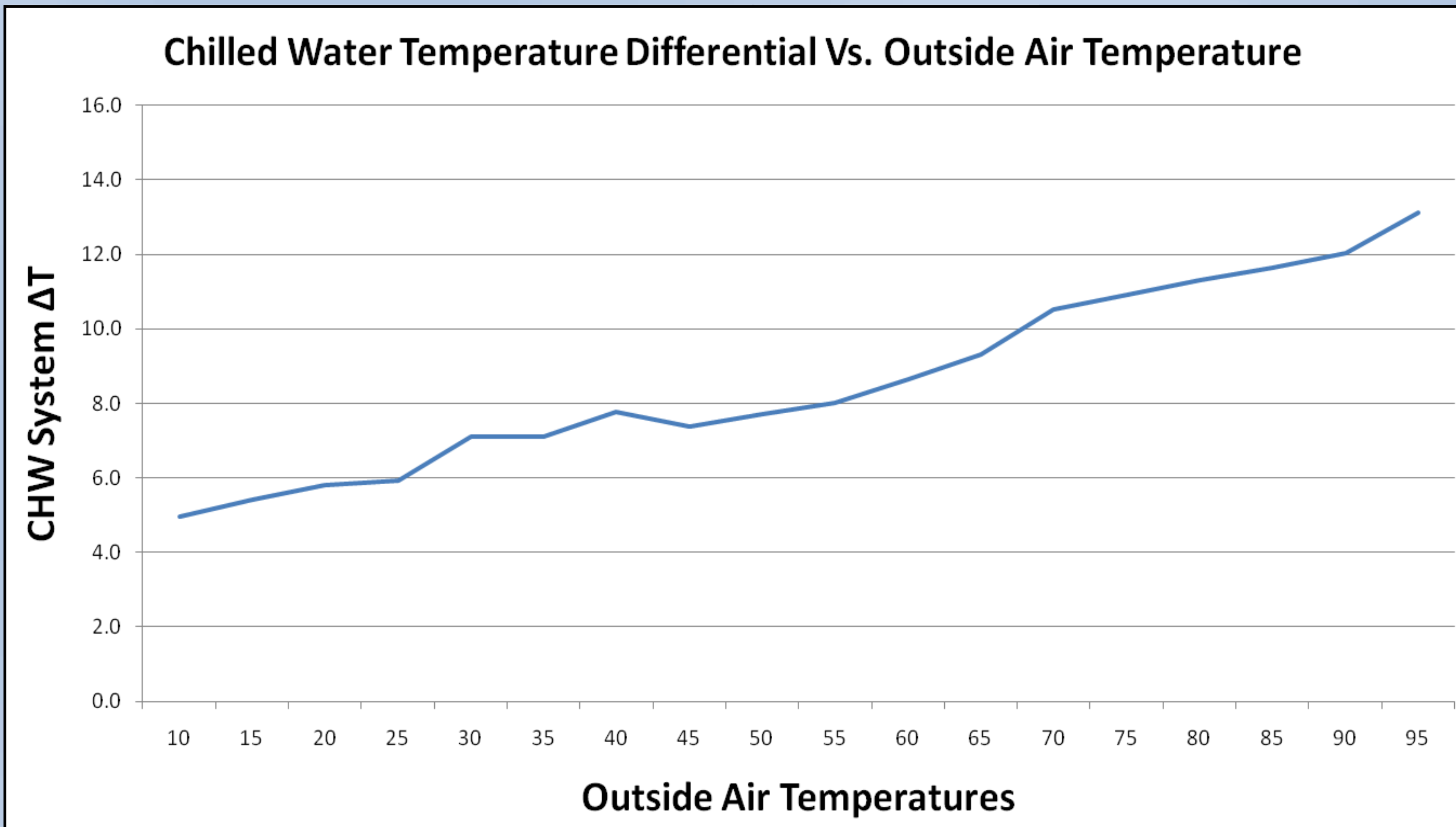
Manual Sequencing of Equipment

Limited CHW Plant Monitoring Capabilities to BASem

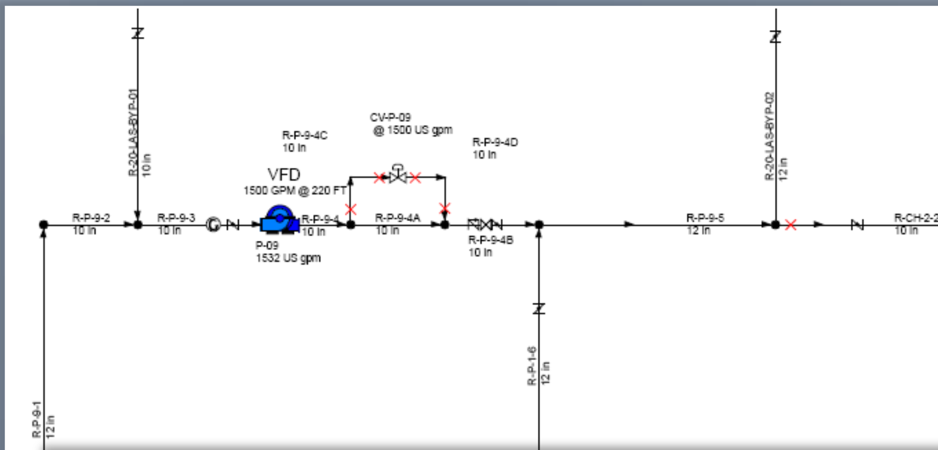
Maintain Supply Pressure 80-100 PSIG (ΔP = 30-50 PSID)

At Building Risers

# Previous Plant Performance Issues



# System Hydraulic Model & Evaluation

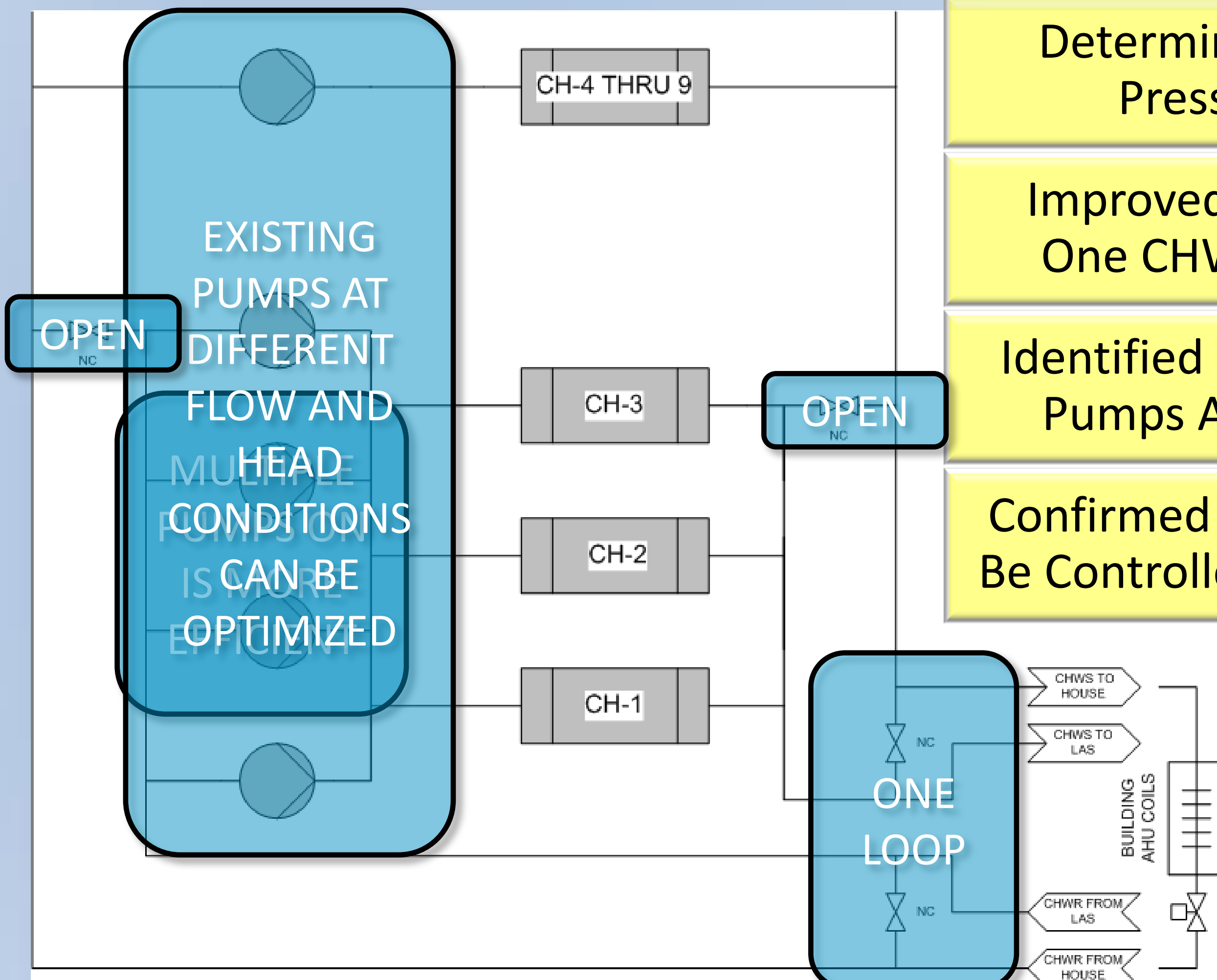



| CHILLER SUMMARY | | | | | |
|---|---|---|---|---|---|
| Chillers | Device DP (PSI) | Calculated Flowrate (GPM) | Design Flowrate (GPM) | Minimum Flowrate (GPM) | Maximum Flowrate (GPM) |
| CH-1 | 0 | 0 | 1420 | 1340 | 4090 |
| CH-2 | 0 | 0 | 1420 | 1340 | 4090 |
| CH-3 | 4.602 | 1720 | 1500 | 1240 | 3910 |
| CH-4 | 5.905 | 1968 | 1800 | 1240 | 3850 |
| CH-5 | 5.878 | 1963 | 1800 | 1240 | 3850 |
| CH-6 | 5.862 | 1961 | 1800 | 1240 | 3850 |
| CH-7 | 5.194 | 1874 | 1725 | - | - |
| CH-8 | 0 | 0 | 1500 | - | - |
| CH-9 | 10.72 | 4302 | 4000 | 3000 | 5925 |
| Plant Totals | | 13788 | 16965 | | |

Partial Pipeflo Hydraulic Model

- Surveyed CHW and TW Systems
- Entered Equipment and Component Information
- Analyzed Results Based on PI Trending Flow Rates
- Results Linked To Excel for Further Calculations

# System Hydraulic Evaluation Summary




Determined Minimum CHW Pressure Differential

Improved Pumping Efficiency One CHW Distribution Loop

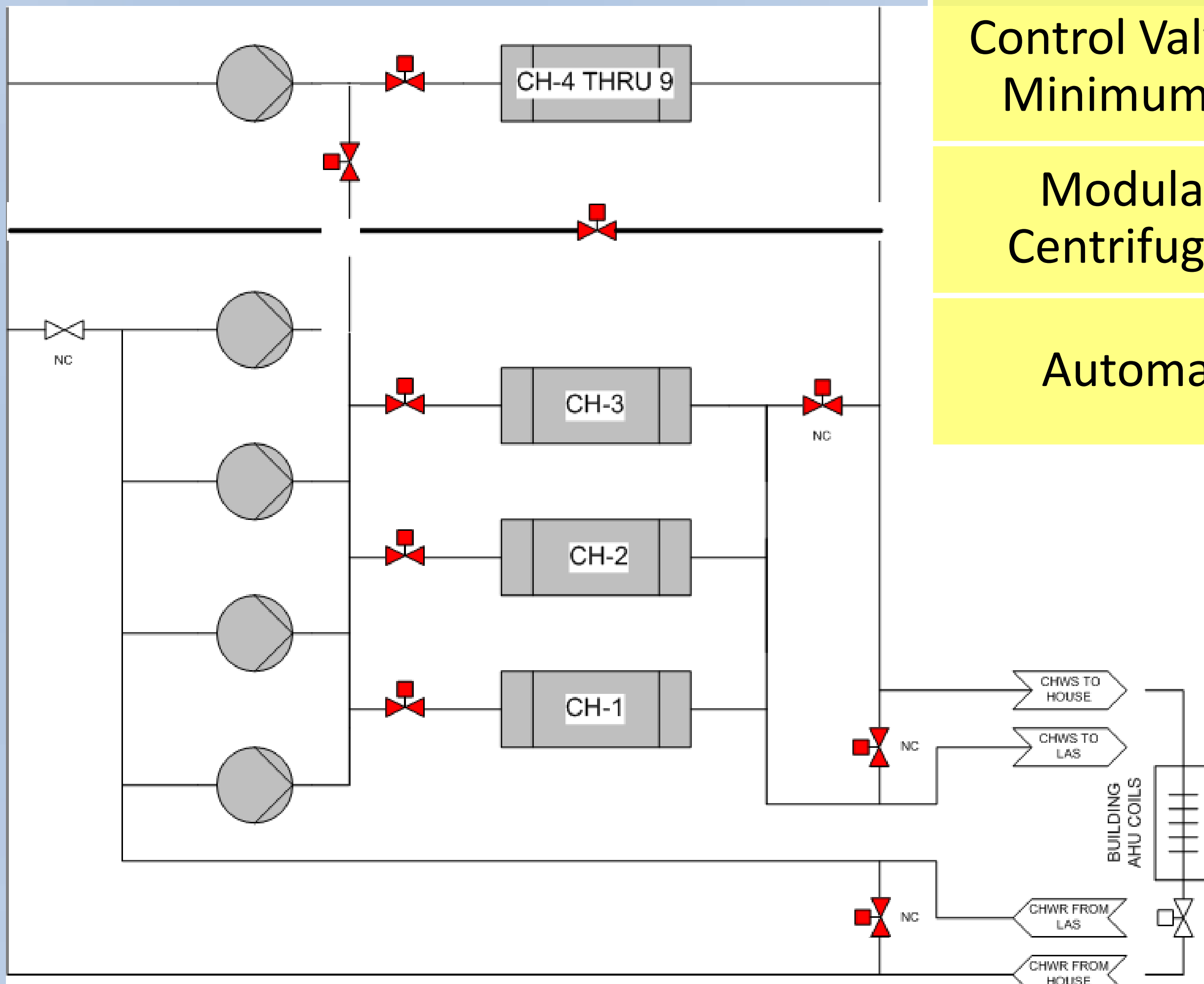
Identified Optimum Number Of Pumps At Varying Demands

Confirmed Headered Pumps Can Be Controlled Effectively on VFD's

P

System DP To Satisfy All Demands is approx. 5-35 PSID

# Hydronic / Mechanical Modifications

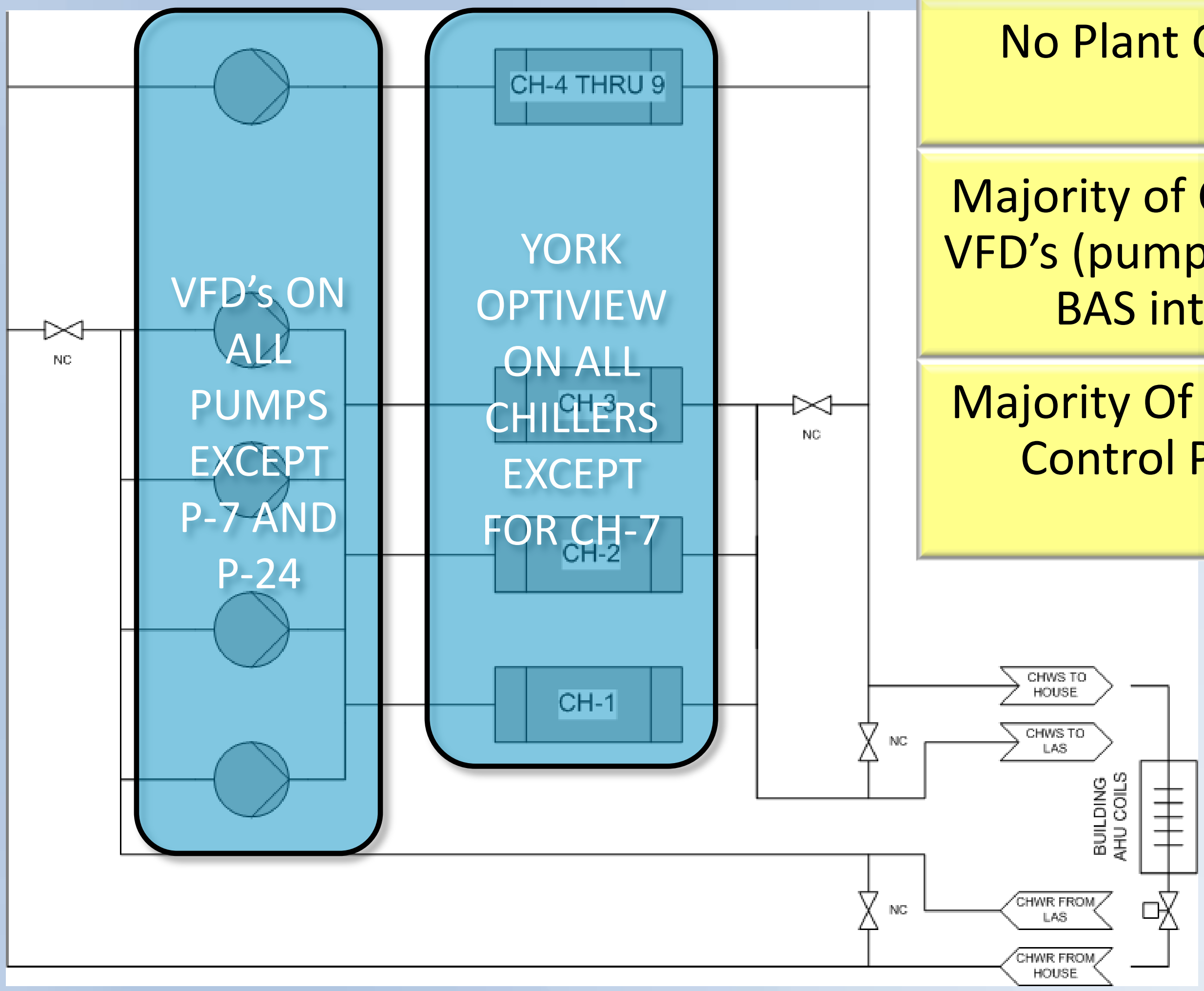



Control Valve Bypass To Maintain Minimum Flow At The Chillers

Modulating Valves At Each Centrifugal Chiller Evaporator

Automatic Isolation valves

# Previous Control System Evaluation

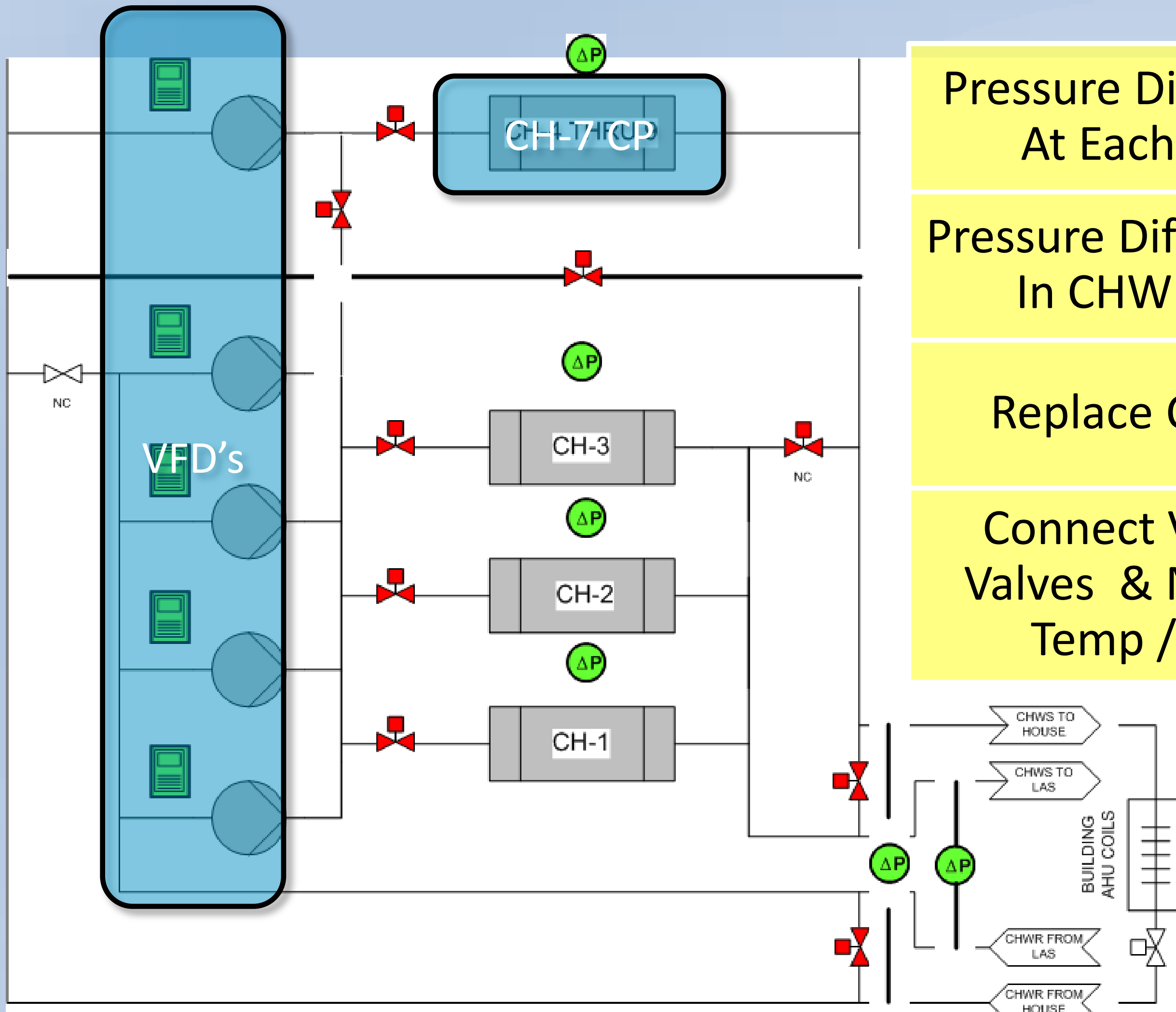



No Plant Control Automation Installed

Majority of CHW equipment have VFD's (pumps and towers) with no BAS interface or control

Majority Of Chillers Have Modern Control Panels with no BAS interface

# Instrument & Field Device Modifications




Pressure Differential Transmitters At Each Chiller Evaporator

Pressure Differential Transmitter(s) In CHW Distribution Loops

Replace Chiller Control Panel

Connect VFD's, Chiller Panels, Valves & Miscellaneous Press / Temp / Flow Instruments

P T F

BYPASS PT
CHW S AND R TT's
DPS, HOA, S CV POSITIONS

# Summary: Issues & Recommendations

| Issue | Recommendation |
| --- | --- |
| Low ΔT's, High CHW Flows, Chillers Operating when Not Required | Convert To Variable Primary Flow (VPF) operation |
| Inefficient Operation with Two CHW Distribution Loops | Operate With Only One CHW Distribution Loop |
| Inefficient Operation of Equipment/Plant – Manual Mode | Fully Automate Operation |

**Automatic Operation ≠ Optimized Operation**

Solution: Control Based Optimization

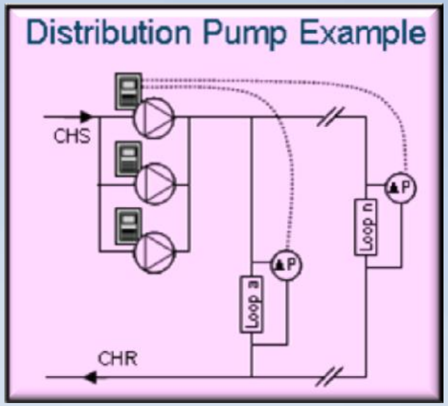
Integrated Local Control and Optimization

# Control Based Optimization

- Standard Control System Design Goal: auto control to make enough cold water on a design day.
- Control Based Optimization Design Goal: control to meet demand *every* day at the lowest kW/ton.
- Utilize real-time values to control operation *and* maximize energy efficiency: flow / ΔT / ΔP / ***kW***.
- Automatic, incremental adjustments to operation in real-time to minimize kW/ton.

# Control Based Optimization: Distribution Pumps

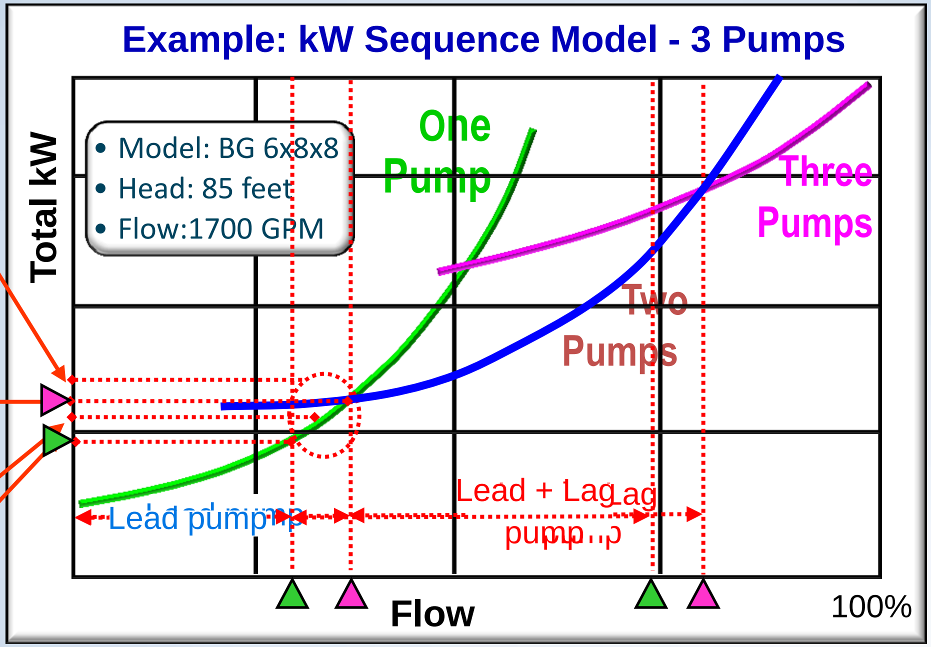
- Pump speed regulated to demand (remote DP.)
- # of pumps to run for lowest pump power?
- *Pump kW Sequence Model* – based on specific hydronic system and affinity laws.
- Adaptive algorithm auto resets setpoint to minimize pump power.




kW evaluated after each lag pump sequence operation

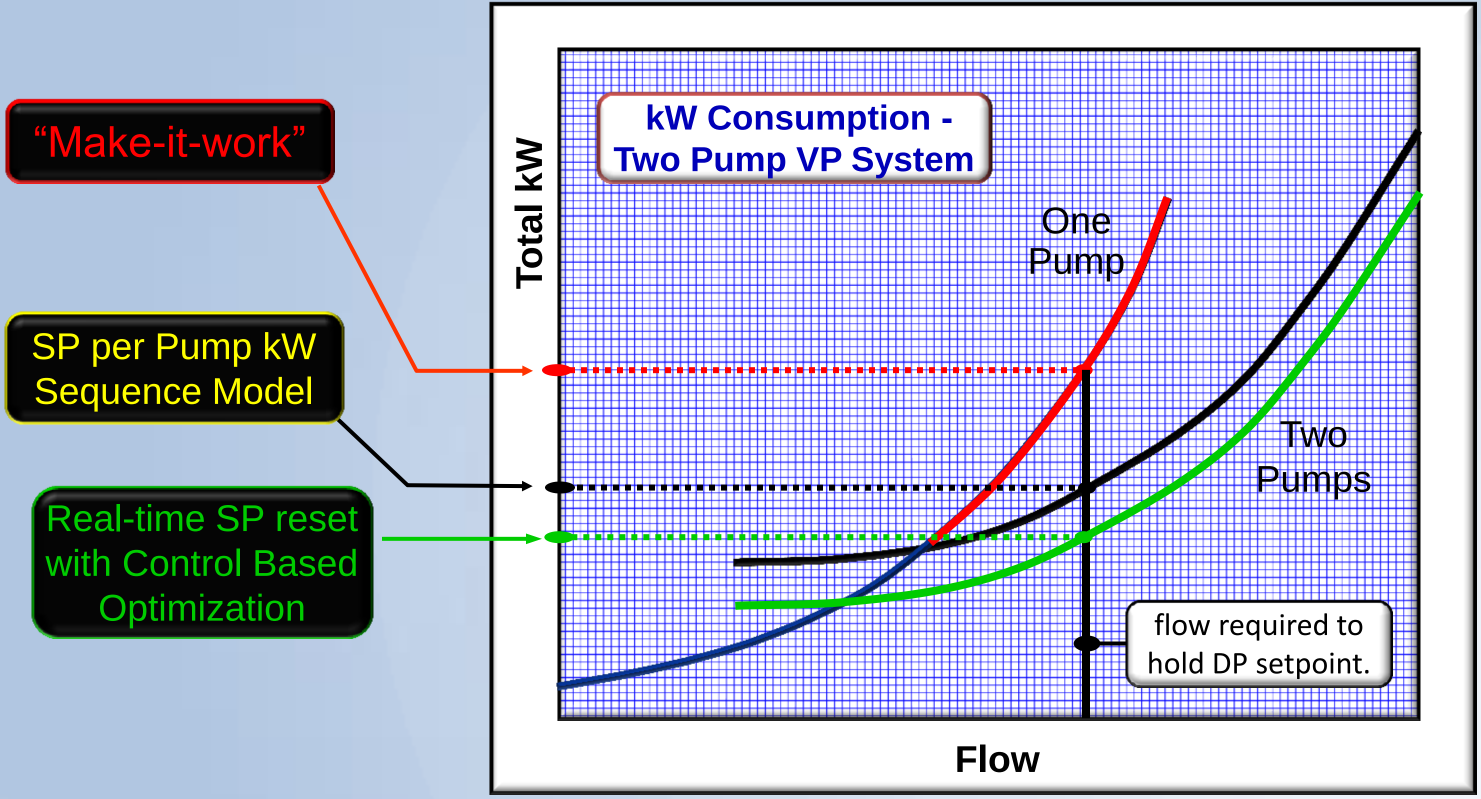
ON setpoint for 1st sequence operation using model

ON setpoint for next operation using adaptive algorithm



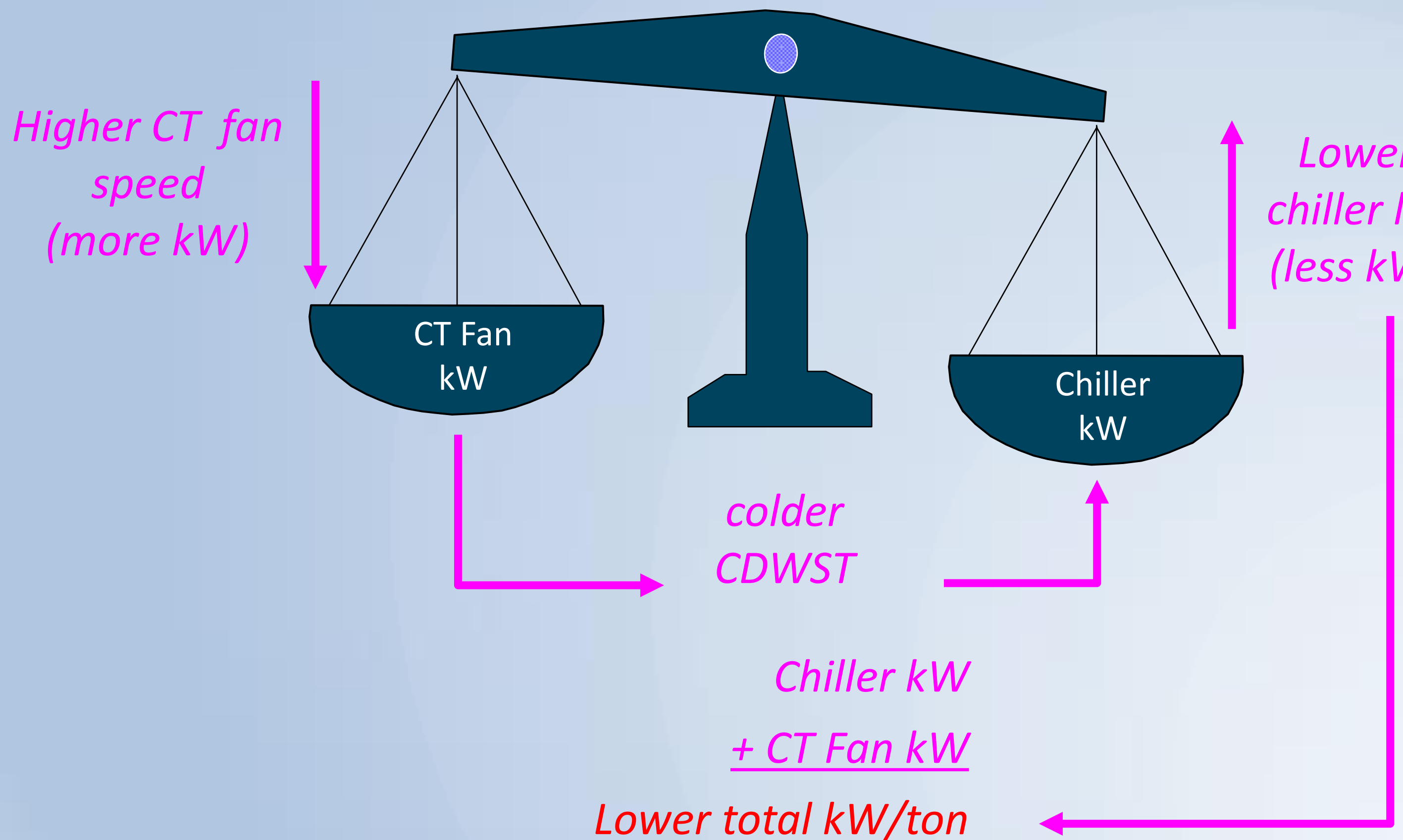
# "Make-it-work" Control vs. Model/Tweak Optimization vs. Control Based Optimization

From standard consultant spec: "… sequence ON lag pump after lead pump operates at 90% of rated speed for 1 minute."

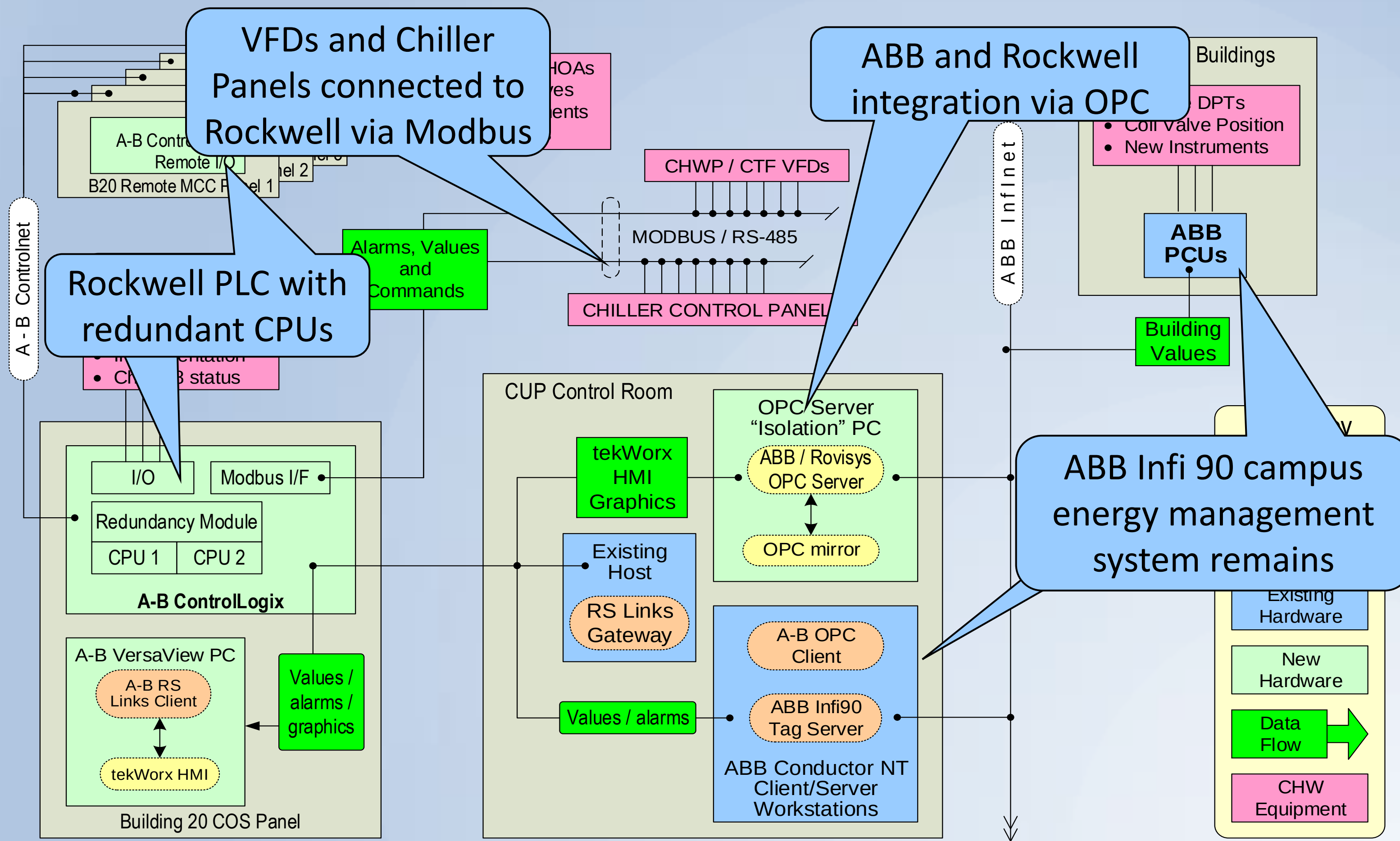


# Control Based Optimization: CDW Temperature

- Goal: Minimize <u>total</u> kW of chiller <u>and</u> tower.
- Control Strategy: balance CT fan speed vs. chiller lift.



# New Control System Architecture



# Energy/Cost Savings Projections

| Baseline | |
|---|---|
| Annual Production: | 19,875,000 ton-hours |
| Plant Average Low Load: | 435 Tons @ 4.5 °F ΔT |
| Plant Average High Load: | 6,725 Tons @ 11.7 °F ΔT |

| Projected Savings | |
|---|---|
| Efficiency Improvement: | 0.23 kW / ton |
| Reduced Power Usage: | 4,600,000 kWh |
| Cost Savings: | $410,000 |

# Energy/Cost Savings M&V

| Month | Savings (9¢/kWh) | |
|---|---|---|
| | kWh | $ |
| Total | 369,146 | $401,782 |
| JAN | 152,450 | $13,721 |
| FEB | 162,039 | $14,584 |
| MAR | 234,295 | $21,087 |
| APR | 247,410 | $22,267 |
| MAY | 415,550 | $37,400 |
| JUN | 550,700 | $49,563 |
| JUL | 615,967 | $55,437 |
| AUG | 687,850 | $61,907 |
| SEP | 562,150 | $50,594 |
| OCT | 466,683 | $42,002 |
| NOV | 172,344 | $15,511 |
| DEC | 196,801 | $17,712 |

# Project Payback

- Total Project cost  $ 2,175,000
- Utility Rebate: $385,000
- Annual projected savings: $402,000 (blended average cost: 9¢/kWh)
- Simple Payback:
  - Without rebate: 5.3 years
  - With rebate: 4.3

# IDEA 2016

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# Questions and Discussion

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