How to optimize campus chilled water system

Diagnostics and treatment to make your cooling & heating system fit and sustainable.

Presentation to

Healthcare Facilities Management Society of New Jersey
And
US Green Building Council of New Jersey

by

Hemant Mehta, PE

WM Group Engineers
Smart solutions that work.

April 18 2013

Introduction

- U.S. buildings consume *400% more energy* than European buildings
- One Btu of *cooling costs 2.5 times* as much as a Btu of heating
- Chilled water cost is typically 35% to 40% of annual fuel and power costs

WM Group Engineers
Smart solutions that work.

Causes of System Inefficiency

- *Master Planning by young inexperience engineers*
- *Poor and/or Signature Design*
- *Lack of Peer Review*
- *Fear*
- *Lack of Training*

WM Group Engineers
Smart solutions that work.

Let's discuss how to optimize

- *Process for a project*
  - *Master Plan*
  - *Detail design*
  - *Construction and Commissioning*
  - *Operators training*

WM Group Engineers
Smart solutions that work.

Master Plan

- Definition of Master Plan
  - master plan *n* (1929): "a plan giving overall guidance"

WM Group Engineers
Smart solutions that work.

Master Plan periods

Master plan leading to optimum solution for:

- Near Term (1 – 2 years)
- Short Term (2 – 5 years)
- Long Term (5 – 20+ years)

WM Group Engineers
Smart solutions that work.

Utilities

- High voltage electrical
- Low voltage electrical
- Steam/hot water
- Chilled Water
- Condenser water
- Fuel oil
- Natural gas
- Storm water
- Sanitary water
- Fire water
- Domestic water
- Domestic hot water
- Nitrogen
- Communication & life safety
- Laboratory waste

WM Group Engineers
Smart solutions that work.

Approach to Master Planning

- On-site team
- Existing systems assessment
- Benchmarking
- Development of load projections
- Infrastructure alternatives
- Optimization modeling
- Life cycle cost analysis
- Near-term, short-term & long-term solutions
- Prioritization of projects

WM Group Engineers
Smart solutions that work.

Deviating from normal approach can harvest big savings with

- One of the major tasks of the master plan is the site survey
- Engineers collect data of the existing system for the remaining life of the equipment, utility load etc.

WM Group Engineers
Smart solutions that work.

What our experience brings us

- While performing site survey, if the engineering team includes well-experienced team members, they can identify many improvements for your immediate benefit during the survey with *Immediate payback*

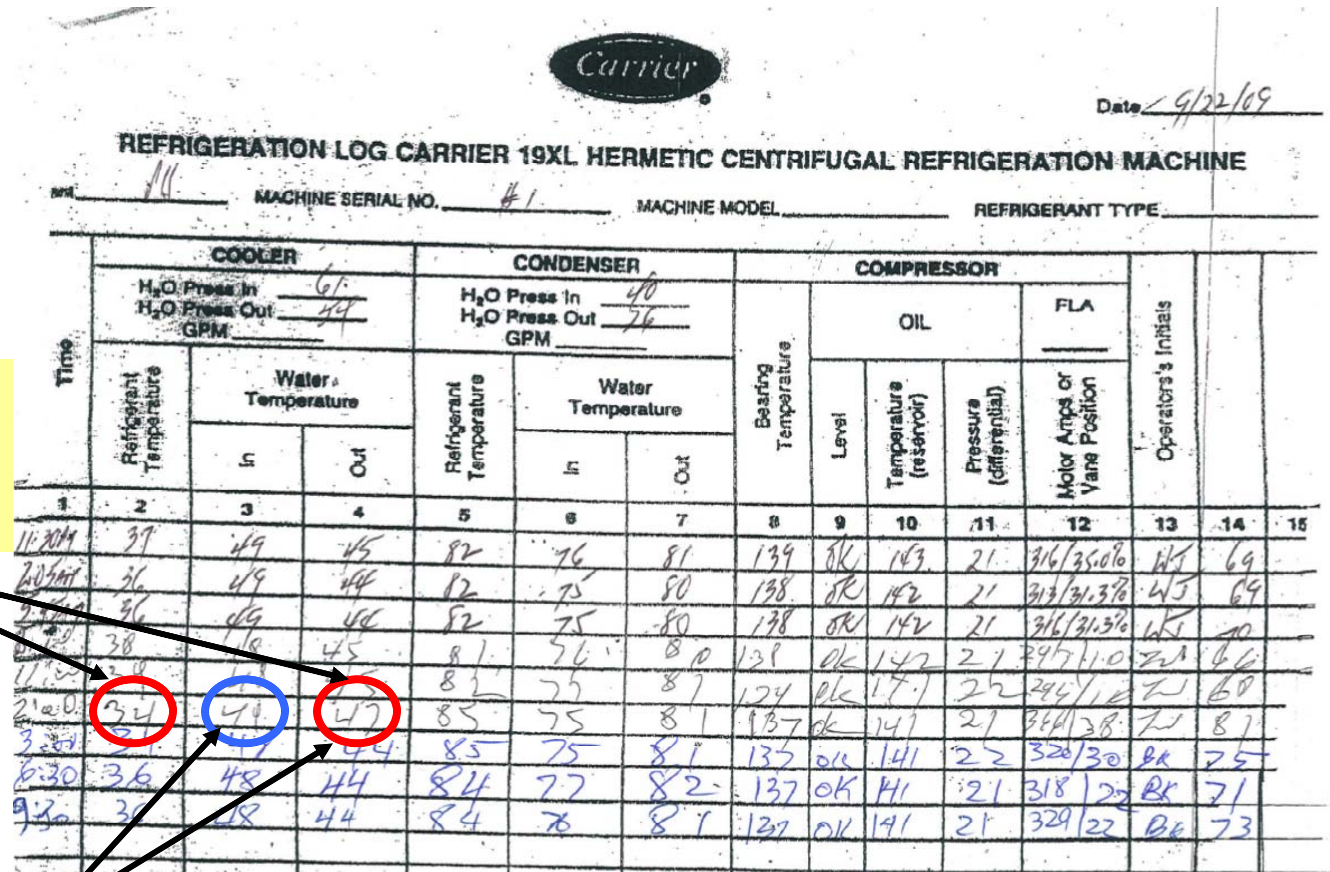
- Let's review some of the case histories

WM Group Engineers
Smart solutions that work.

Chiller Review – Excessive Approach Identified

- Inefficient evaporator

Evaporator approach: 47 – 34 = 13ºF. (>>2ºF)



Chilled Water Delta T: 49 – 47 = 2ºF.

WM Group Engineers
Smart solutions that work.

Chiller Review – Excessive Approach Resolved

Sent: Wednesday, June 30, 2010 2:58 PM
To: Barber, Ernest (ehb5d); Martin, Edward (esm3e)
Cc: Hemant Mehta
Subject: UVA Chiller Plant Performance

Ernie/Scott,
Per the attached Plant Graphic snap shot from 6-23-10, we calculated the kW/ton of the chiller to be over 30% greater than the rated energy use This may be due to:

- low refrigerant charge
- fouled condenser water tubes
- excess oil in the evaporator
- low condenser water flow

Please have Trane take a look at the machine to determine the cause.....

Andre Pearson, PE, LEED AP, CEM
Senior Associate

WM Group Engineers, P.C.
370 Seventh Avenue, Suite 701
New York, NY 10001

From: Martin, Edward (esm3e) [mailto:esm3e@eservices.virginia.edu]
Sent: Friday, October 22, 2010 11:23 AM
To: Andre Pearson; Barber, Ernest (ehb5d)
Cc: Hemant Mehta; Gomez, Cheryl (clg9y)
Subject: RE: UVA Chiller Plant Performance

All,

Additional work on this issue revealed:

- Chiller #1 was 400lbs low on refrigerant charge and;
- Chiller #2 was 100lbs low on refrigerant charge

Bill Kirby informs me that the approach on both machines is now what we should expect.

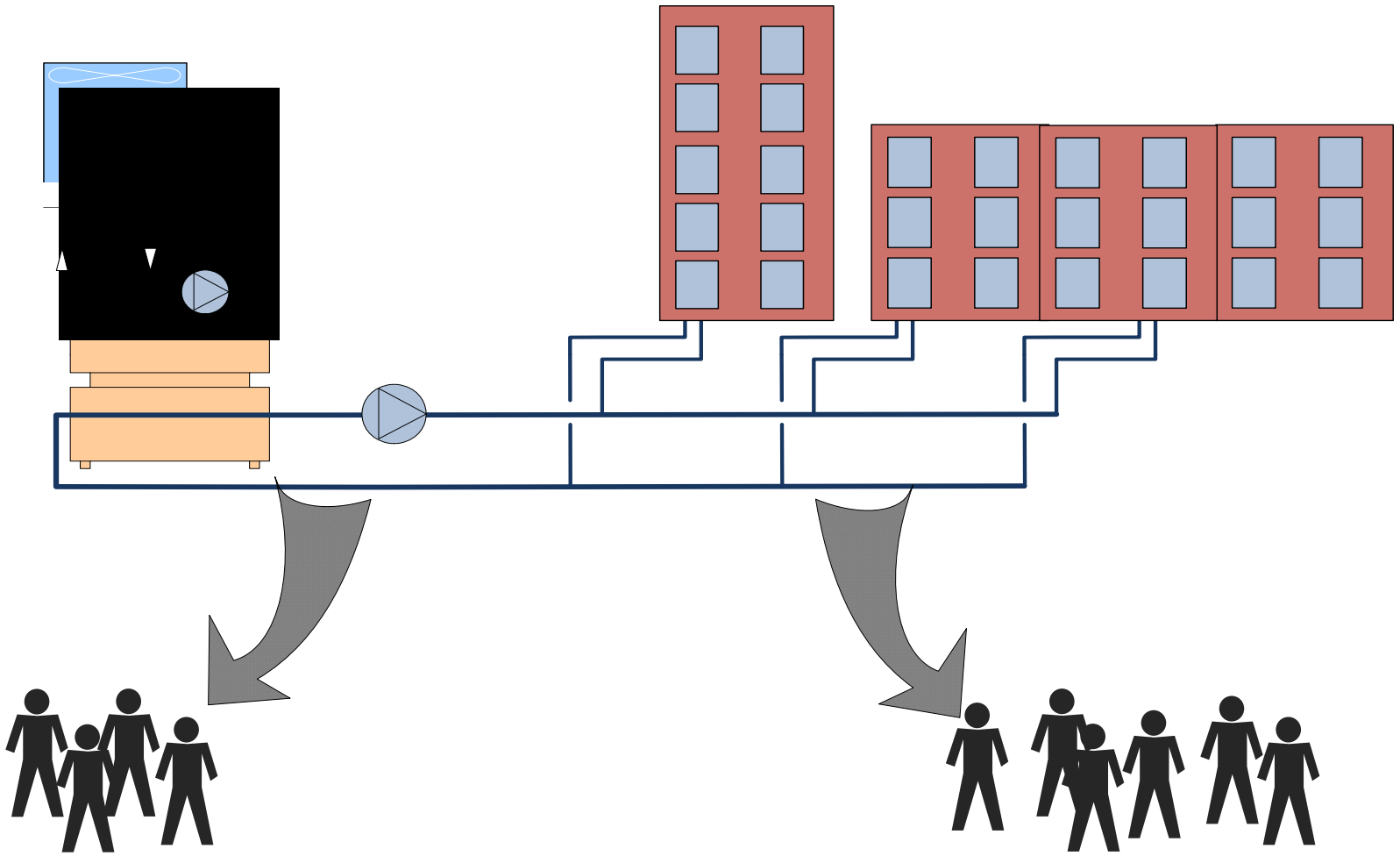
US Capitol

- While performing site survey we noticed that the last building on the distribution system Amtrak building was imposing additional pressure drop of 23 feet on the whole system of 46,000 gpm

- We could eliminate this pressure drop by simply opening a valve

WM Group Engineers
Smart solutions that work.

Division of Responsibility



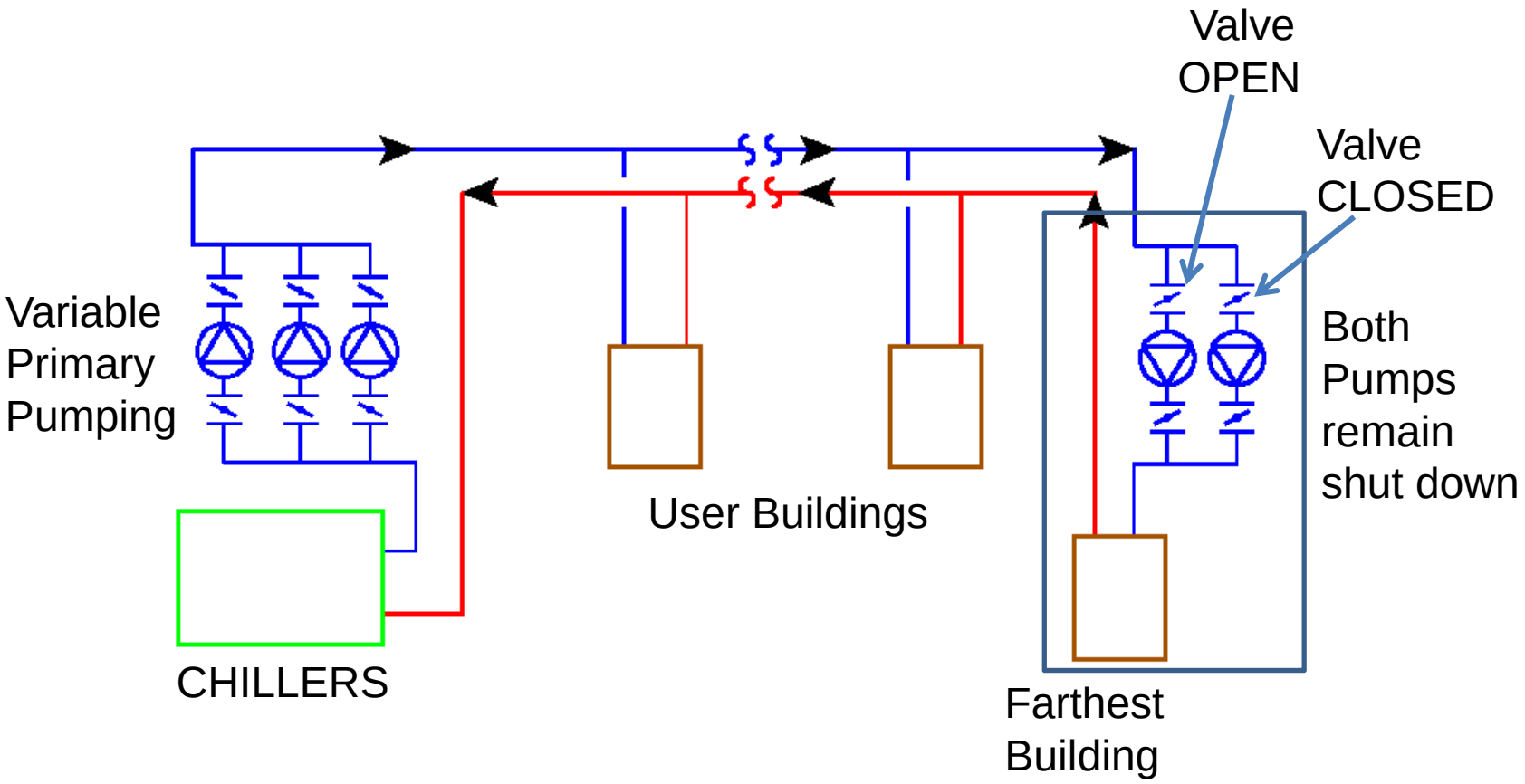
Generation

Utilization

WM Group Engineers
Smart solutions that work.

US Capitol - Division of Responsibility

- *Chilled water pressure being utilized improperly at buildings…*



WM Group Engineers
Smart solutions that work.

US Capitol

Building connections: Chilled water pressure being utilized improperly at buildings.

Chilled water flowing through non-operating pump.

Pressure drop:10psi
Head Loss: 23 ft.

At peak load flow of 46,000 GPM, additional power required for Pumps at Chiller Plant is

46000*23/(3960*.8)
= 335 HP or 250.2 kW

With equivalent 4000 full load hours, annual energy loss is 1,000,883 kWh
At $0.0912/kWh, annual loss is **$91,281**

WM Group Engineers
Smart solutions that work.

US Capitol

Uneven Water Flow in Tower

Supply flow was below the allowable range, and there was also clogging in tower fill

After observations, operators ran towers at higher flow and replaced the fill to fix problems

WM Group Engineers

Smart solutions that work.

Story of Six Different Consultants 2012

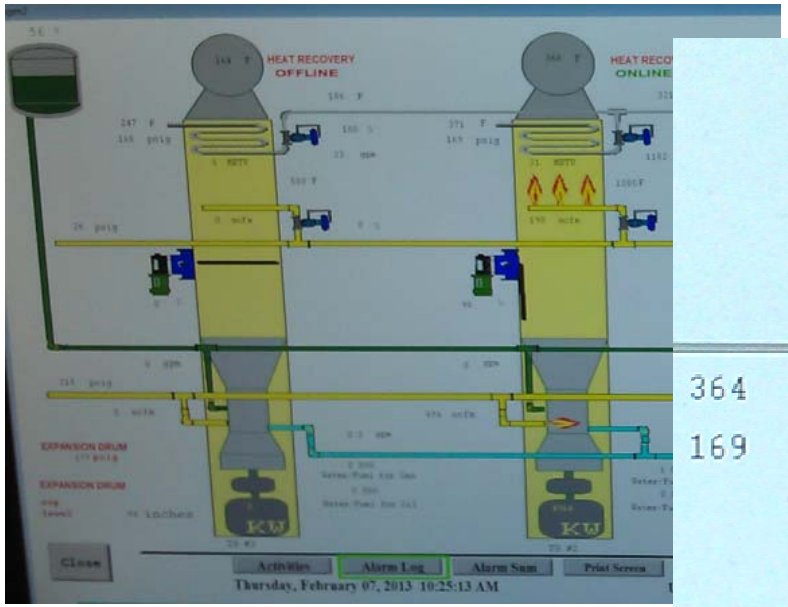
World Trade Center

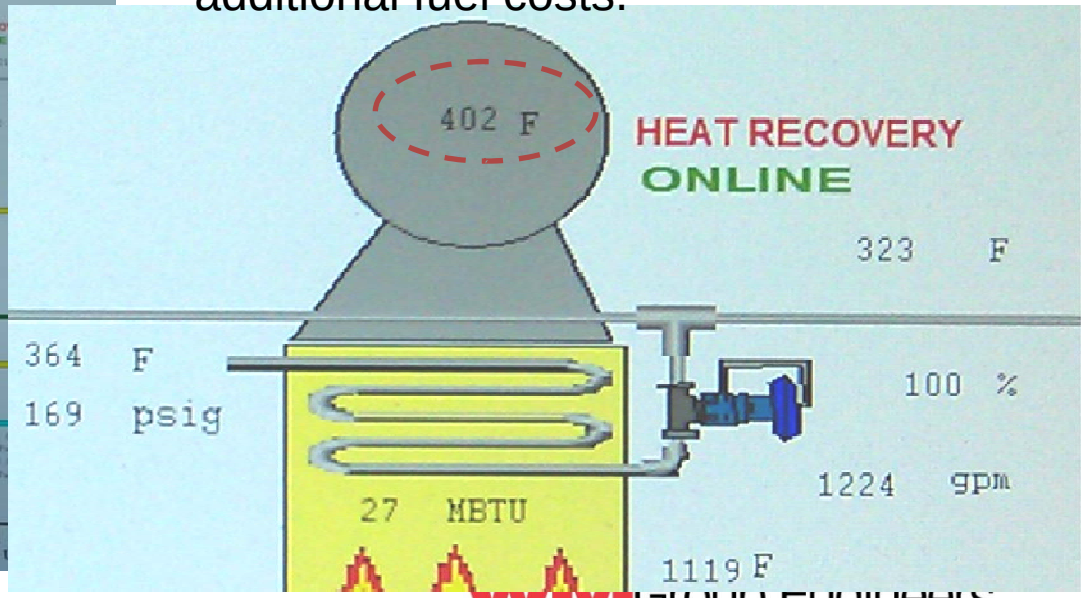
- Central CHW Plant & River Water Systems Design
  - 12,500-ton central chiller plant and distribution system serving multiple buildings
  - River cooling water system and river water pump house restoration
- *Six different consultants* design inter-connections to buildings in different ways…
- Memorial Building consultant installs secondary pumps one story below machine room!
  - We will get paid to correct this and remove the unnecessary pumps!

WM Group Engineers
Smart solutions that work.

New Jersey University

Return HTHW temp is 270 F. Flue gas after heat recovery should be less than 300 F, but because of mixing of return water and possible issues with heat exchanger, flue gas leaving temperature is 400 F, i.e. 100 degrees of heating is thrown away. Contributes to significant additional fuel costs.

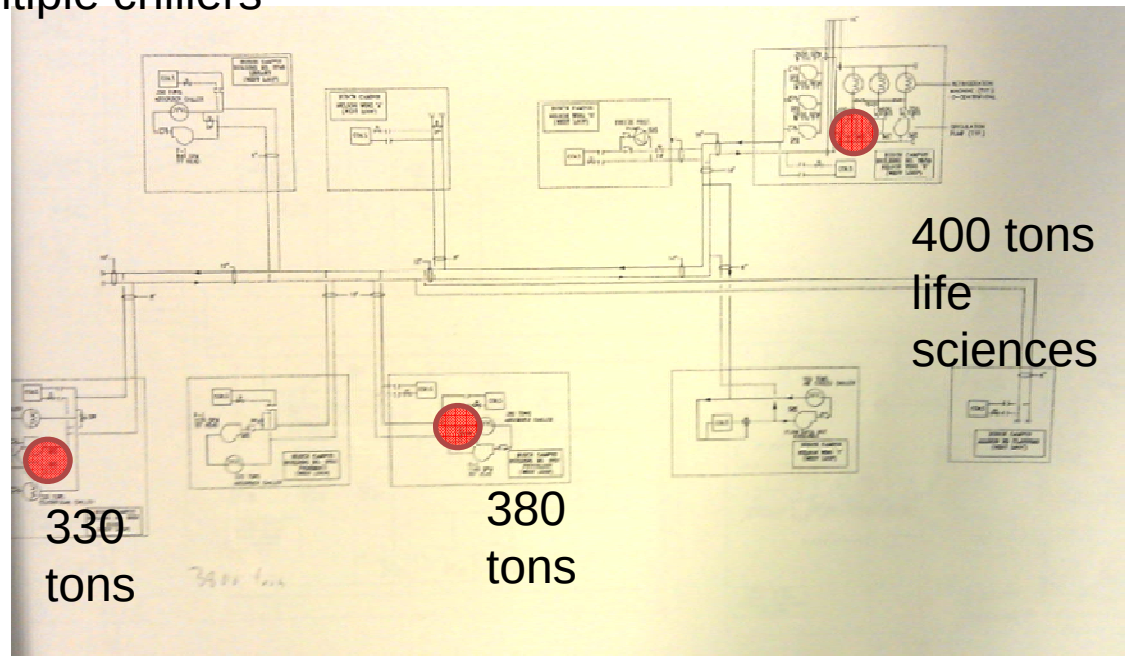




WM Group Engineers
Smart solutions that work.

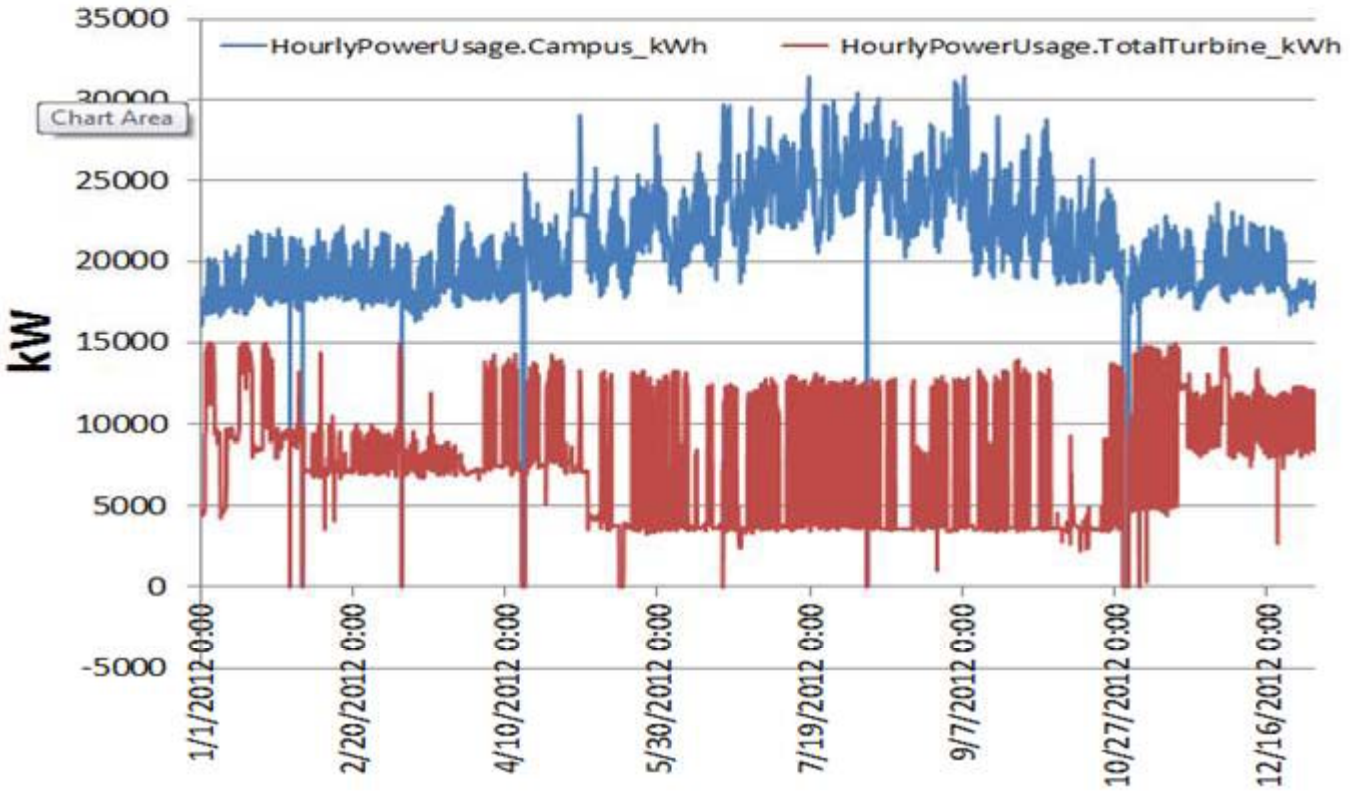
New Jersey University

Chillers are running on 30 degree day. Free cooling heat exchangers are not being used. Likely simultaneous heating and cooling in the spaces, as well as lost efficiency by running multiple chillers



WM Group Engineers
Smart solutions that work.

Review of the winter electrical demand indicates heavy winter cooling load



WM Group Engineers
Smart solutions that work.

New Jersey University

Cooling tower supply temperature setpoint is not reset from the design temperature, adding 20% to chiller energy use. Estimated energy cost of at least $150,000

CDW Supply temp of 78 on a 30 deg WB day

WM Group Engineers
Smart solutions that work.

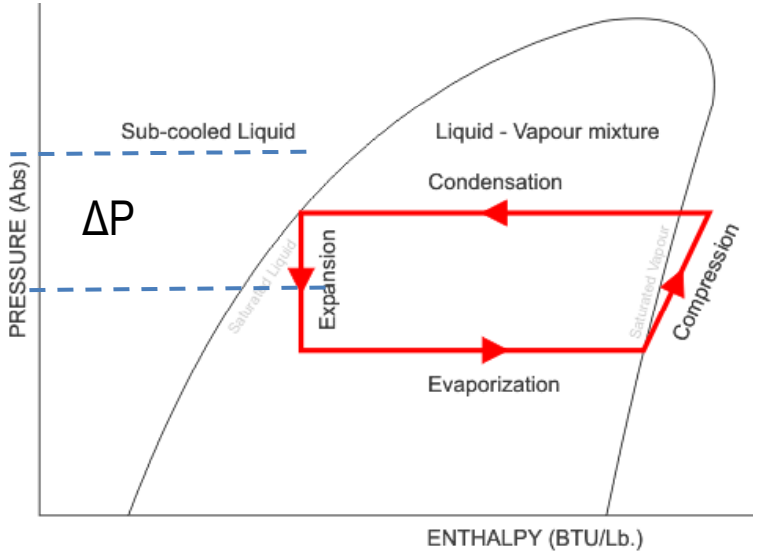
How does delta T and condensing temperature affect Power?

- Compressor Energy (Ce):

$$Ce = \dot{m}\Delta P$$

- Refrigerant mass flow:

$$\dot{m} = \frac{200}{RE}$$



- RE: Refrigerant effect increases as ΔT increases.
- Mass flow rate decreases with increase in ΔT
- Hence compressor power decreases with increase in ΔT.
- Low ΔT reduces chiller capacity and more chillers need to be operated.

WM Group Engineers
Smart solutions that work.

Rutgers Newark HTHW System- Consequence of master plan performed by an inexperienced engineer

- Rutgers sent RFP to expand the boiler plant for cost of $5 million, based on master plan
- Master plan must have been prepared by a smart but young engineer with no supervision
- review of logs revealed operating temperatures were 360ºF supply and 300ºF return, while system design was 400ºF supply and 250ºF return temps.
- The poor delta T reduced the operating capacity by 60/150 = 40%
- Conclusion: No new boiler was required.
- Saved over 5 million dollars in investment.

WM Group Engineers
Smart solutions that work.

Amgen California Consequence of master plan performed by an inexperienced engineer

- Site had two chillers plants interconnected but operated independently
- Recommended new (third) chilled water plant
- A quick two hours review indicated that there was no need for the third plant
- Savings of over Ten million dollars

WM Group Engineers
Smart solutions that work.

System Optimization

"We expect to save millions of dollars in capital and O&M costs in the next 10 years."

Dave Callahan
Senior Project Manager

Amgen, Inc.

Thousand Oaks, CA

Chilled Water Hydraulic Study and Plant Interconnection

- **Creation of computerized hydraulic model of existing chilled water plant and distribution system.**
- **Identification of bottlenecks in system flow, evaluation of existing capacity for present and future loads.**
- **Two plants interconnected: Single plant operation for most of the year, second plant used for peaking.**

Annual Energy Cost Savings: $ 500,000

WM Group Engineers
Smart solutions that work.

Experience

AMGEN - from Client

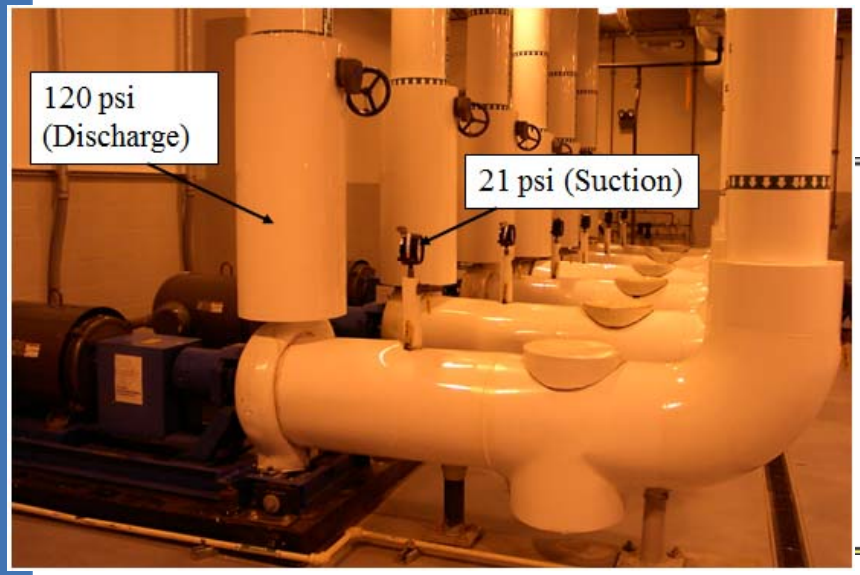
Location	HP	Voltage	Kw	Description	Hours per Year	KwH per Year	Price per KwH	Power Factor	Annual Savings
B29	100	480	74.6	B29 P-01	8760	653,496	0.12	0.85	$ 92,258
	100	480	74.6	B29 P-02	8760	653,496	0.12	0.85	$ 92,258
	100	480	74.6	B29 P-03	8760	653,496	0.12	0.85	$ 92,258
B25	40	480	29.84	B25 P-01	8760	261,398	0.12	0.85	$ 36,903
	40	480	29.84	B25 P-02	8760	261,398	0.12	0.85	$ 36,903
	40	480	29.84	B25 P-03	8760	130,699	0.12	0.85	$ 18,452
B30	150	480	111.9	B30 P-5251	8760	980,244	0.12	0.835	$ 140,873
	150	480	111.9	B30 P-5252	8760	980,244	0.12	0.835	$ 140,873
	150	480	111.9	B30 P-5253	8760	490,122	0.12	0.835	$ 70,437
B38	30	480	22.38	B38-08-P1	8760	98,024	0.12	0.85	$ 13,839
	30	480	22.38	B38-08-P2	8760	98,024	0.12	0.85	$ 13,839
B27	20	480	14.92	B27-01	8760	130,699	0.12	0.85	$ 18,452
	20	480	14.92	B27-02	8760	130,699	0.12	0.85	$ 18,452
B14	50	480	37.3	B14-CW-P0001	8760	326,748	0.12	0.83	$ 47,241
	50	480	37.3	B14-CW-P0002	8760	326,748	0.12	0.83	$ 47,241
B15	60	480	44.76	B15 -P001	8760	392,098	0.12	0.85	$ 55,355
	60	480	44.76	B15 -P002	8760	392,098	0.12	0.85	$ 55,355
B33	7.5	480	5.60	B33 -P01	8760	49,012	0.12	0.83	$ 7,086
	7.5	480	5.60	B33 -P02	8760	49,012	0.12	0.83	$ 7,086
B32	40	480	29.84	B32-P001	8760	261,398	0.12	0.902	$ 34,776
	40	480	29.84	B32-P002	8760	261,398	0.12	0.902	$ 34,776
	40	480	29.84	B32-P003	8760	261,398	0.12	0.902	$ 34,776
Total	1,325					7,841,952			$ 1,109,488

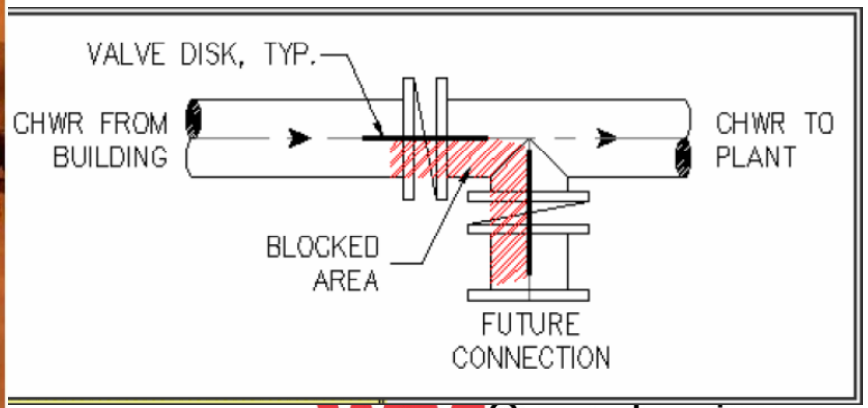
WM Group Engineers
Smart solutions that work.

Question what you see

Identification of Bottlenecks

- Two close valves created the blocked area which increases the increased in pump head.
- Identification and elimination of bottlenecks reduced thousands of dollars in operating cost.





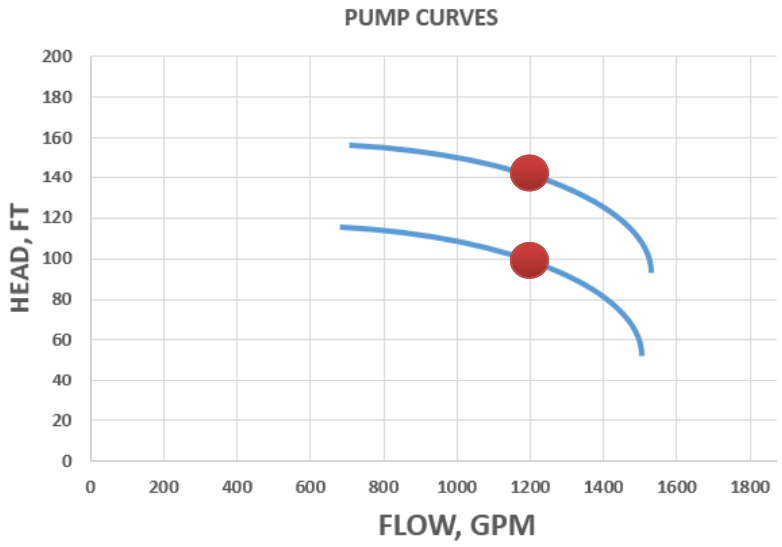
WM Group Engineers
Smart solutions that work.

New Jersey University

CHW Pump Size Disparity

EE Building Plant Chilled Water Pumps:

140 ft. and 1200 gpm
And
100 ft. and 1200 gpm
The disparate pressures lead to fighting pumps and incorrect supply flows.



WM Group Engineers
Smart solutions that work.

NY HospitaL

Uneven Water Flow in Tower

Weir dams in towers intended to distribute flow over fill. However dams were installed sideways, making flow *more* uneven. Contributed to $25,000 of additional chiller energy use costs due to ineffective heat rejection at towers.

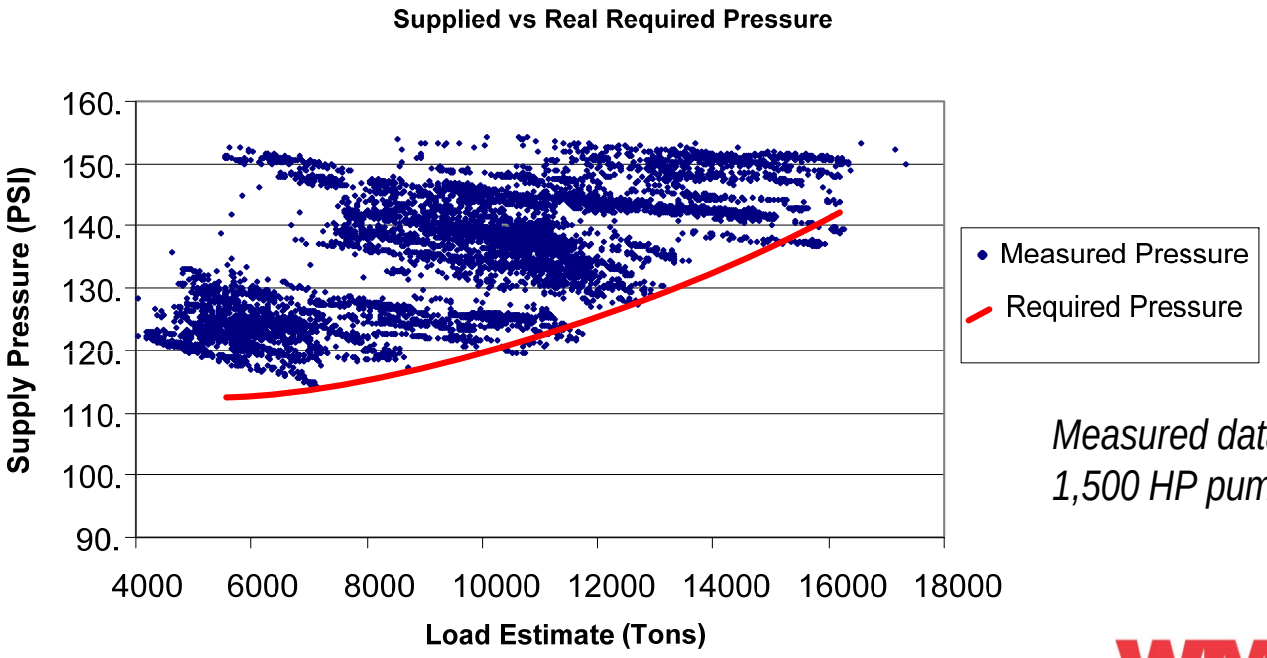
RECOMMENDED DISTRIBUTION

WM Group Engineers
Smart solutions that work.

MIT site Survey

High System Pressure (no dP reset)

- Excess water pressure gets eaten up by control valves, which throttle down the flow

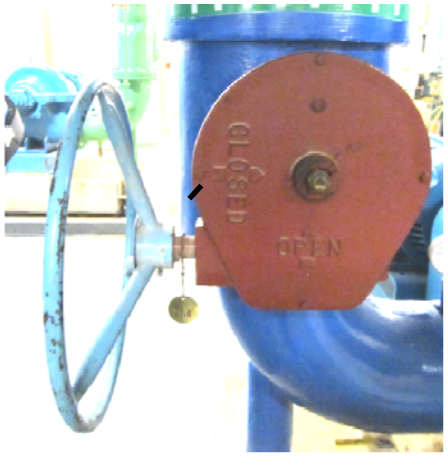


Measured data for a system with four 1,500 HP pumps

WM Group Engineers
Smart solutions that work.

Bronx Hospital

Chiller have balancing valves half closed, eating up pressure drop so that VFD's are 100% on to try to meet demand pressure. Estimated energy cost of $26,000



WM Group Engineers
Smart solutions that work.

NY Hospital

Pumps themselves have triple duty balancing valves half closed, eating up pressure drop so that VFD's have to run at higher pressure to meet demand. Estimated energy cost of $20,000

WM Group Engineers
Smart solutions that work.

Pennsylvania State Capitol Building Complex

Harrisburg, PA

PENNSYLVANIA DEPARTMENT OF GENERAL SERVICES

Chilled Water Systems Upgrade

- **Optimization of the system pumping**
- **Improvement of chilled water system temperature differential**
- **Conversion of the existing chilled water system from a primary/secondary/tertiary pumping system to an all-primary, variable volume system.**

Annual Projected Energy Savings: $ 320,000 per year Estimated

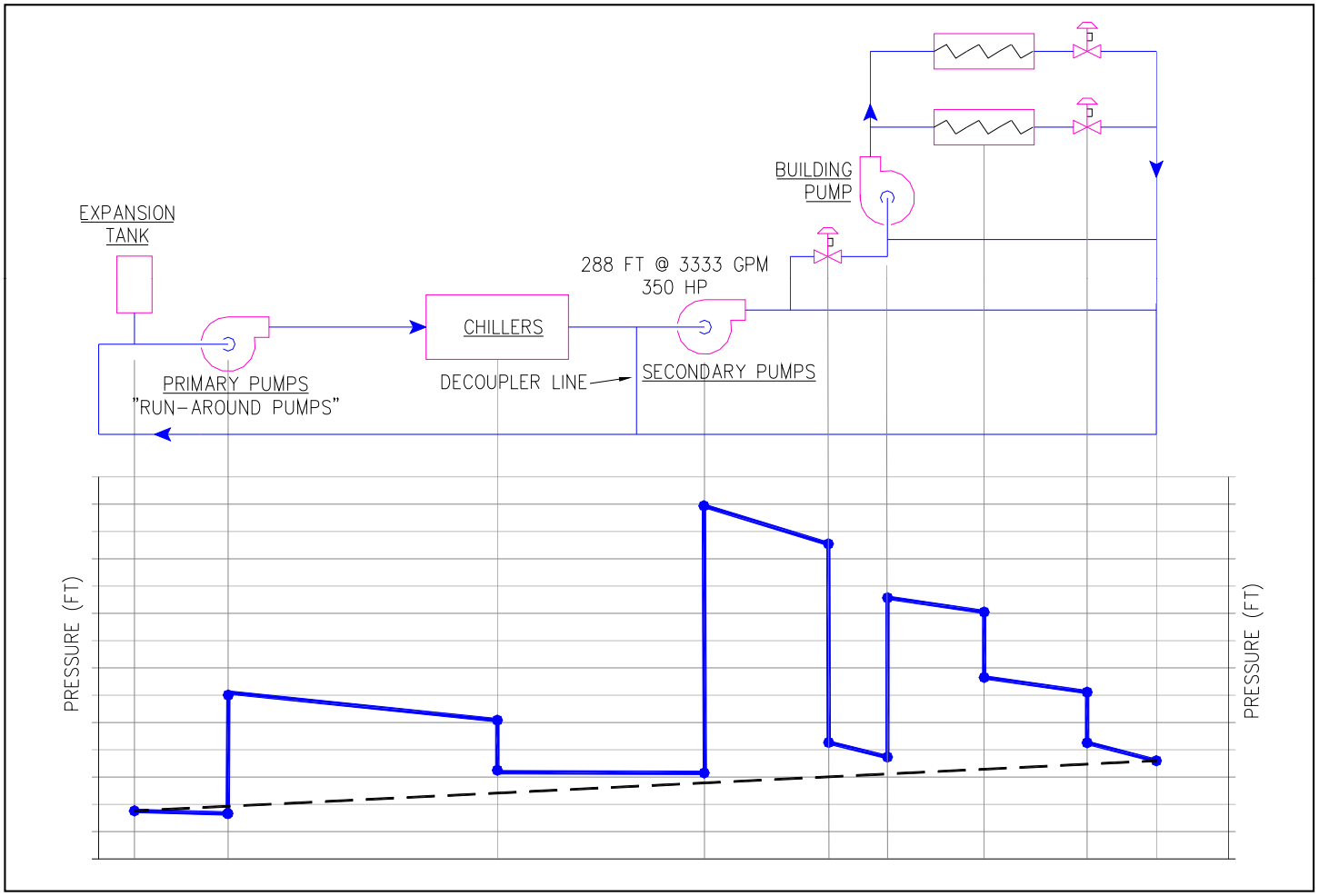
Implementation Cost: $ 825,000

Simple Payback: 2.6 years

WM Group Engineers

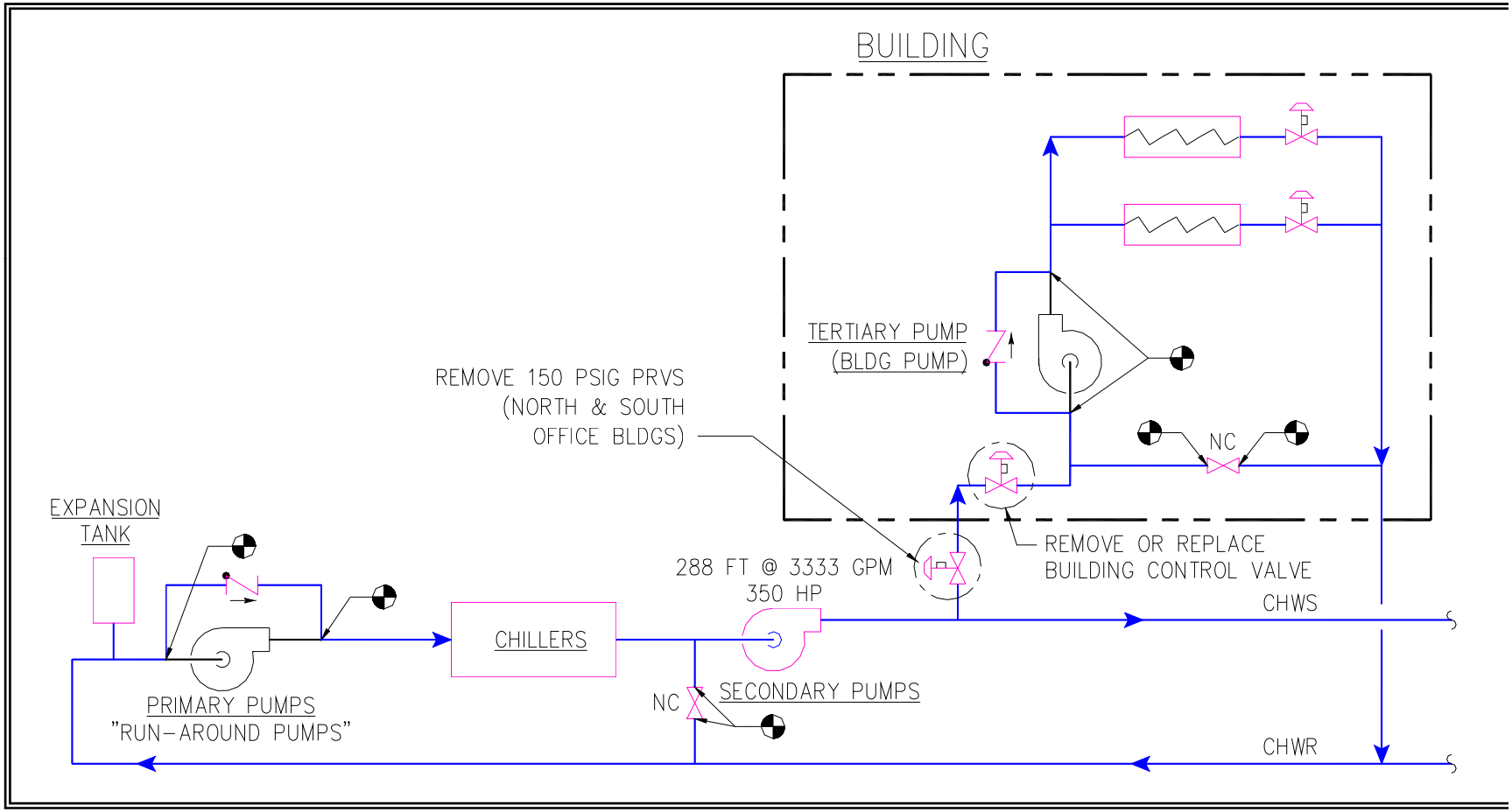
Smart solutions that work.

Pressure Distribution Diagram



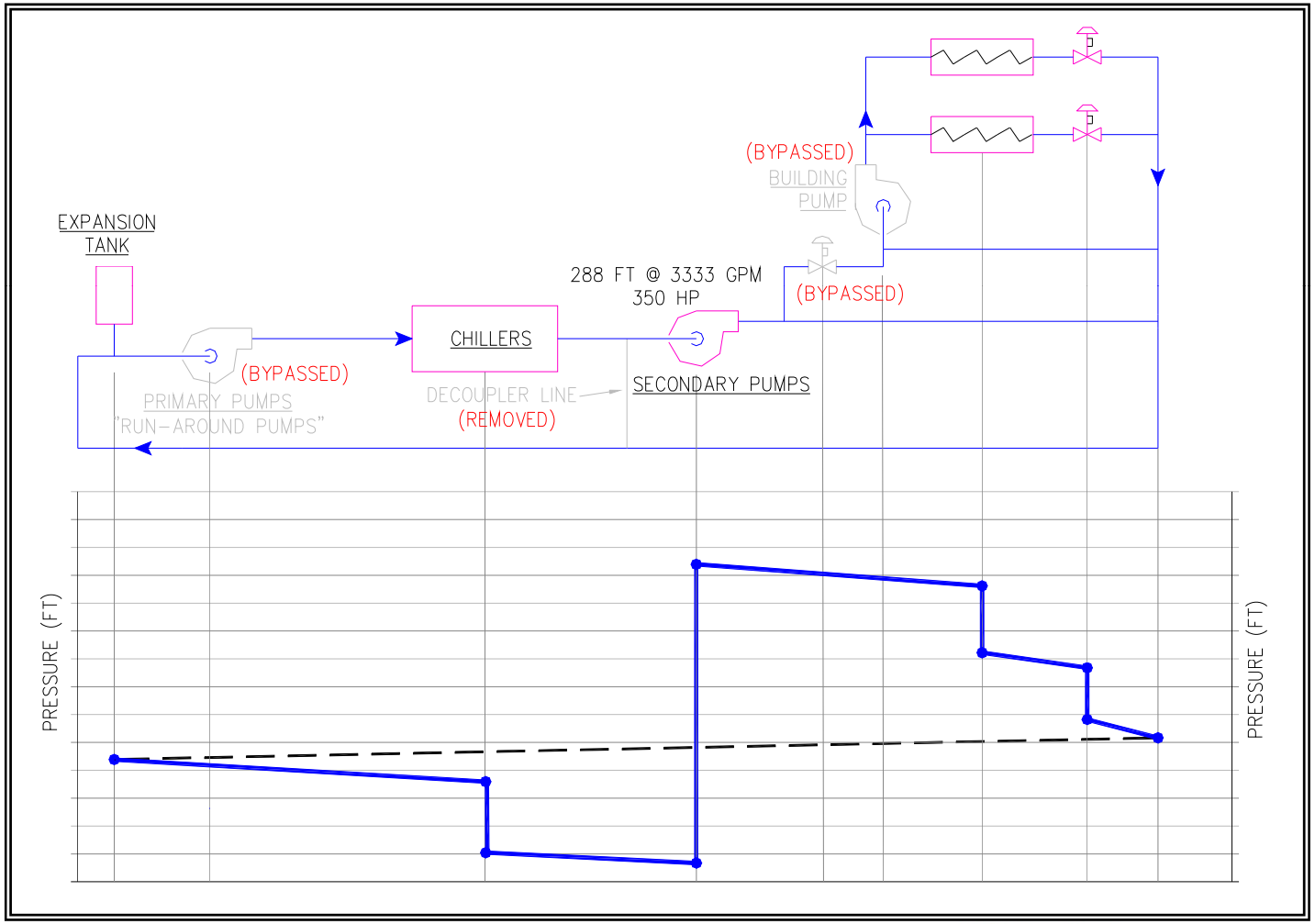
WM Group Engineers
Smart solutions that work.

Our Solution for Immediate Implementation



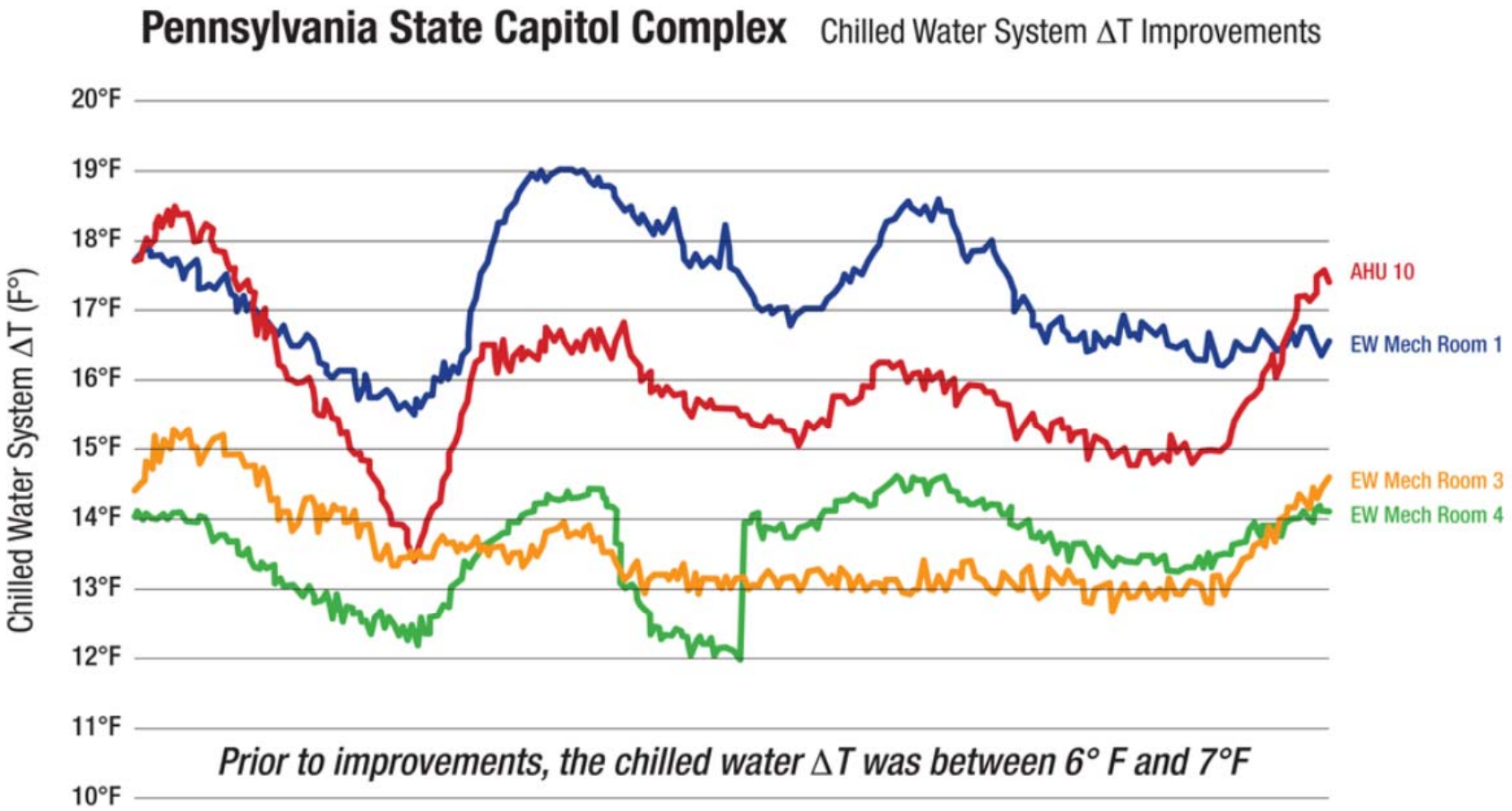
WM Group Engineers
Smart solutions that work.

New Pressure Distribution Diagram



WM Group Engineers
Smart solutions that work.

PA State Capitol – Process Control



WM Group Engineers
Smart solutions that work.

Poor and/or Signature Design:

- Many Engineering firms have one design concept they feel comfortable with
- So regardless of what is best for the particular project they imposed the so called signature design.
- Many times I can just walk into the plant and name design consultant
- With no peer review requirements in our industry client pays penalty.

WM Group Engineers
Smart solutions that work.

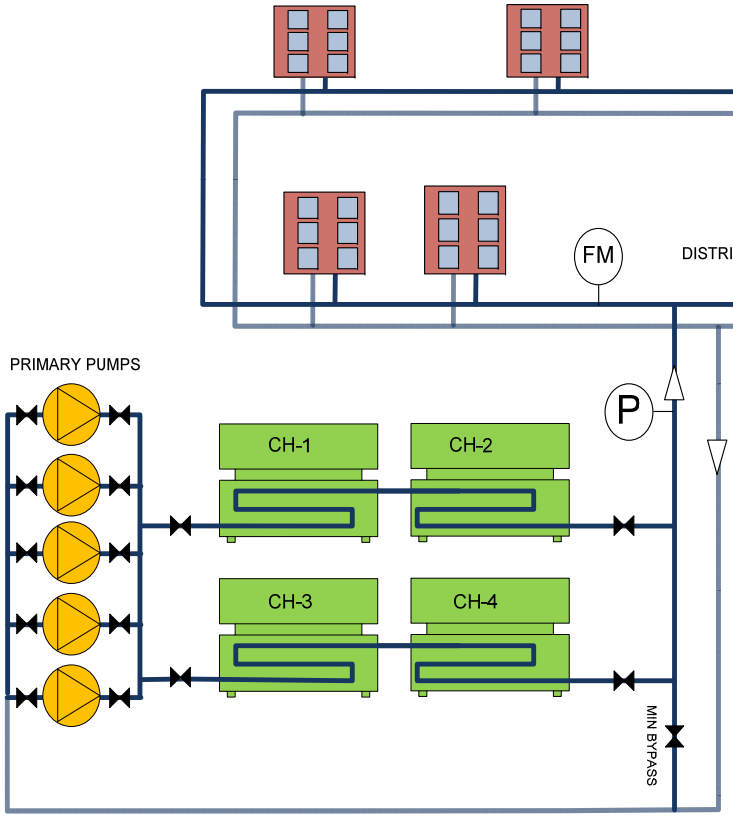
Poor and/or Signature Design:

- Deviation from the normal Master Planning approach with experienced engineers on site survey team provides immediate benefit from improvements that could have been overlooked.
- Almost on all master plan projects we worked on we were able to save more than our engineering fees after the completion of site survey task.
- Discussing improvements with plant operators provides the training and empowers them as well.

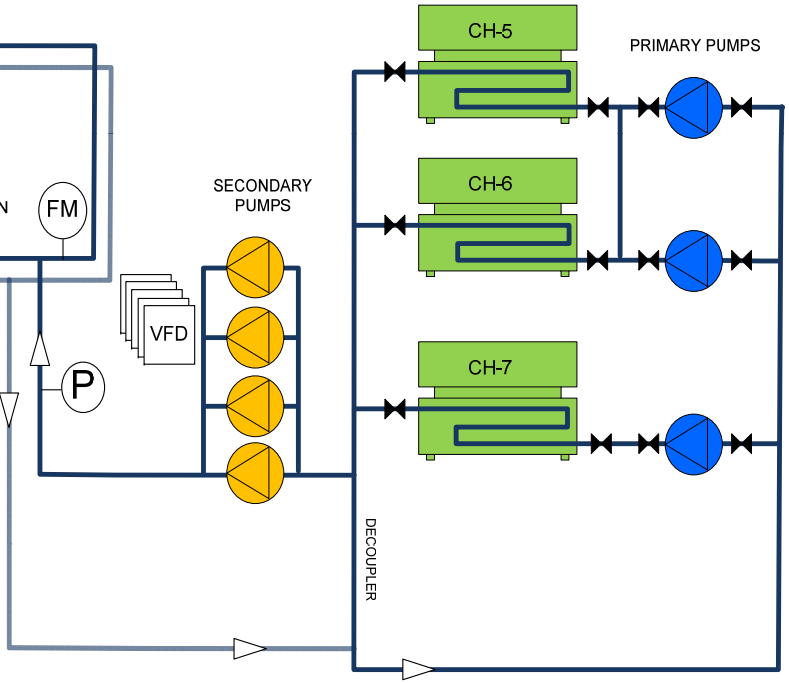
WM Group Engineers
Smart solutions that work.

Consequence of Signature Design "Cut and Paste"

- *Incompatible additions…*



Primary-Constant Speed

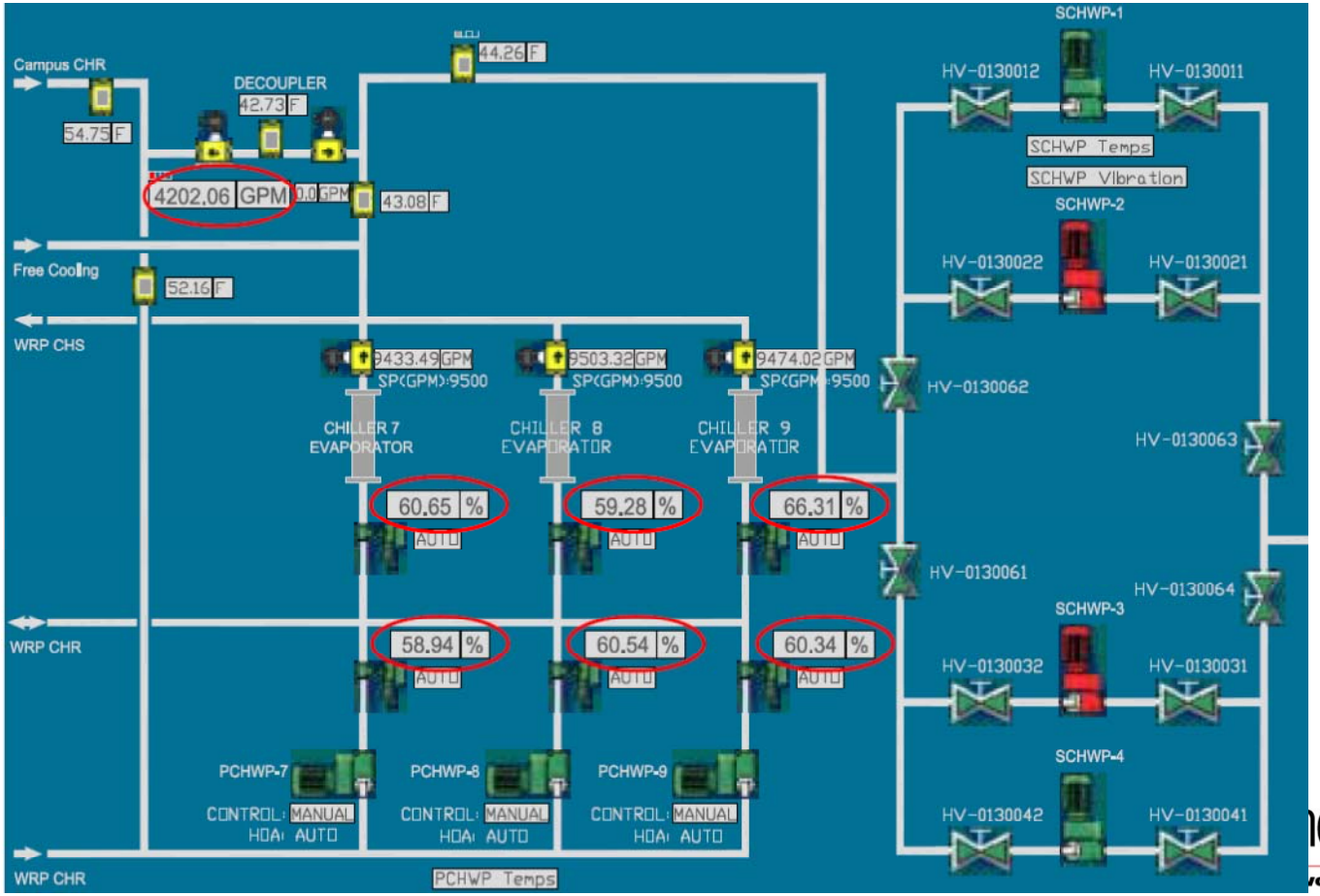


Primary/Secondary Variable

WM Group Engineers
Smart solutions that work.

Consequence of signature design "Cut and Paste"

- *Oversized pumps* causing valves to throttle at ~60%
- Flow above 4,000 GPM routed through decoupler



Benefit of Peer Review

Duke University Project

- Plant #1 built in 2000
- Final bid docs for Plant #2 were being prepared for construction
- Our client from Yale asked that we review the Duke project
- Our peer review reduced cost by over $2 million

- As money was already funded, used to redesign Plant #1…

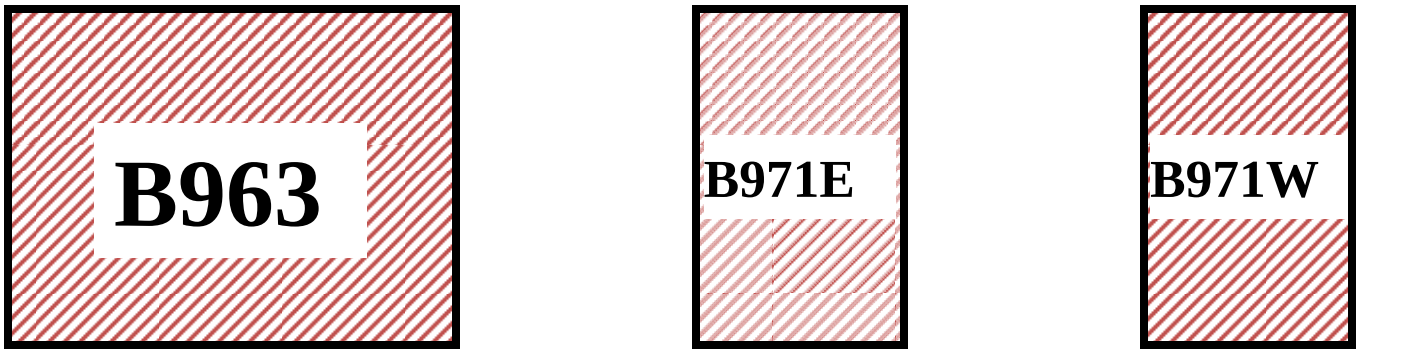
Dark blue pipes replaced old primary pumps

WM Group Engineers
Smart solutions that work.

Benefit of Peer Review
IBM – Burlington, Vermont

WM Group Engineers
Smart solutions that work.

Existing System



Boiler & Chiller Plant

Chiller Plant

Chiller Plant

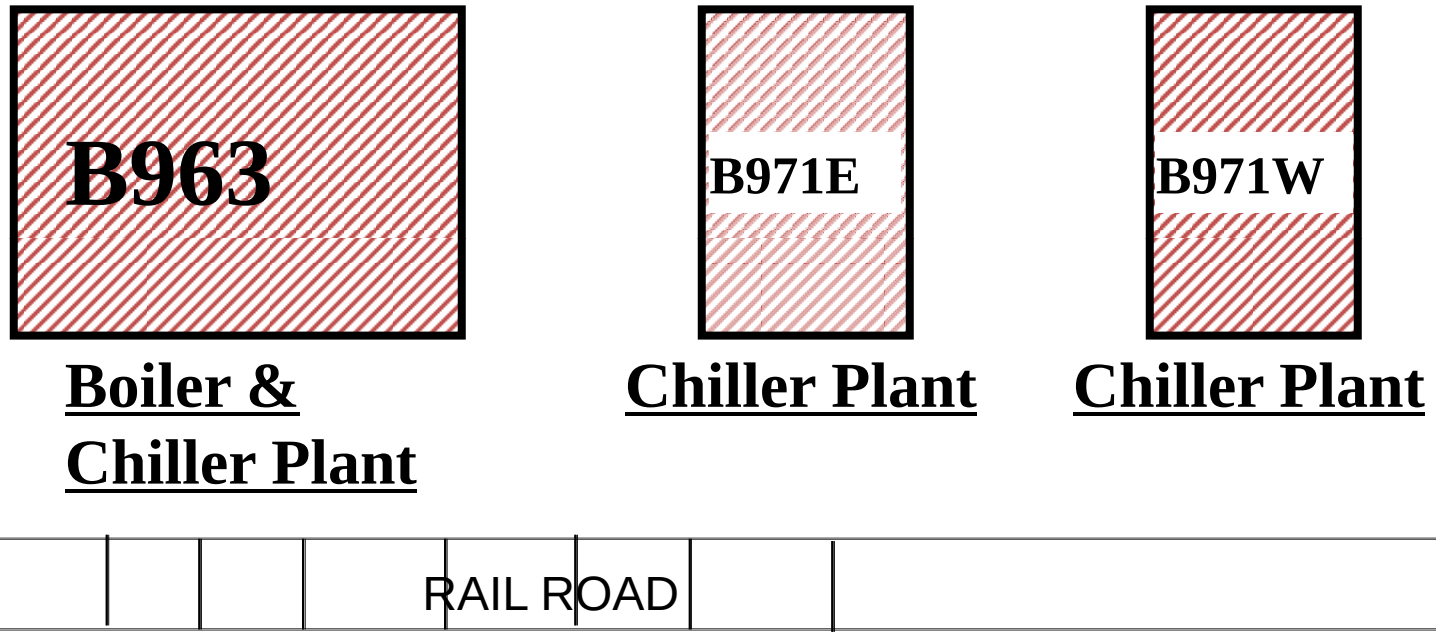
WM Group Engineers
Smart solutions that work.

Task

- **New Fabrication building**
- **Substantial growth of the heating and cooling load**
- **No room for expansion in the existing plants**
- **Proposed solution: Build a new $42 million plant**

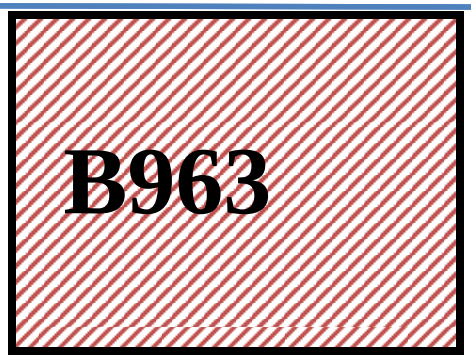
WM Group Engineers
Smart solutions that work.

Proposed System

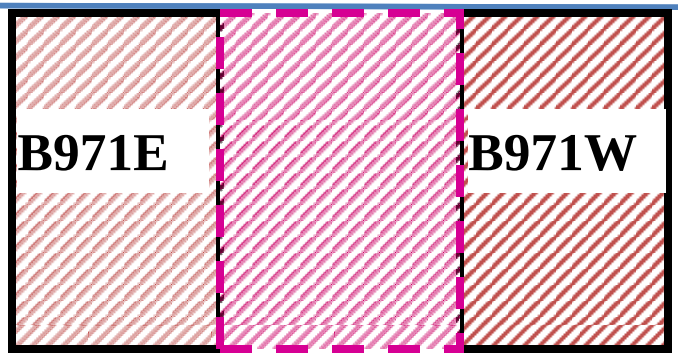


WM Group Engineers
Smart solutions that work.

Out-of-the-Box Solution



Central Boiler Plant

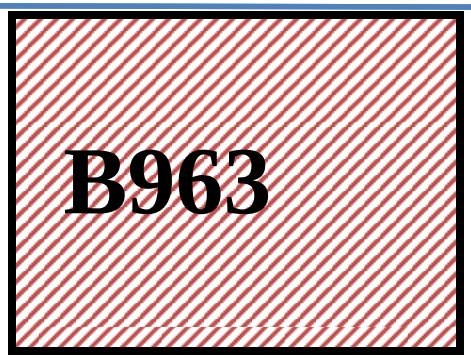


Central Chiller Plant

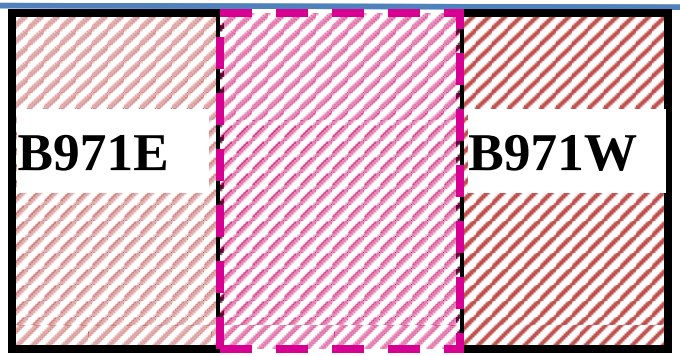
1. **Remove Chillers from Plant B963.**
2. **Install additional HTHW Boilers for the increased load in Plant B963.**
3. **Relocate Chillers from Plant B963 and install new Chillers in new Central Chiller Plant to meet increased load.**

WM Group Engineers
Smart solutions that work.

Out-of-the-Box Solution – Cont'd



Central Boiler Plant



Central Chiller Plant

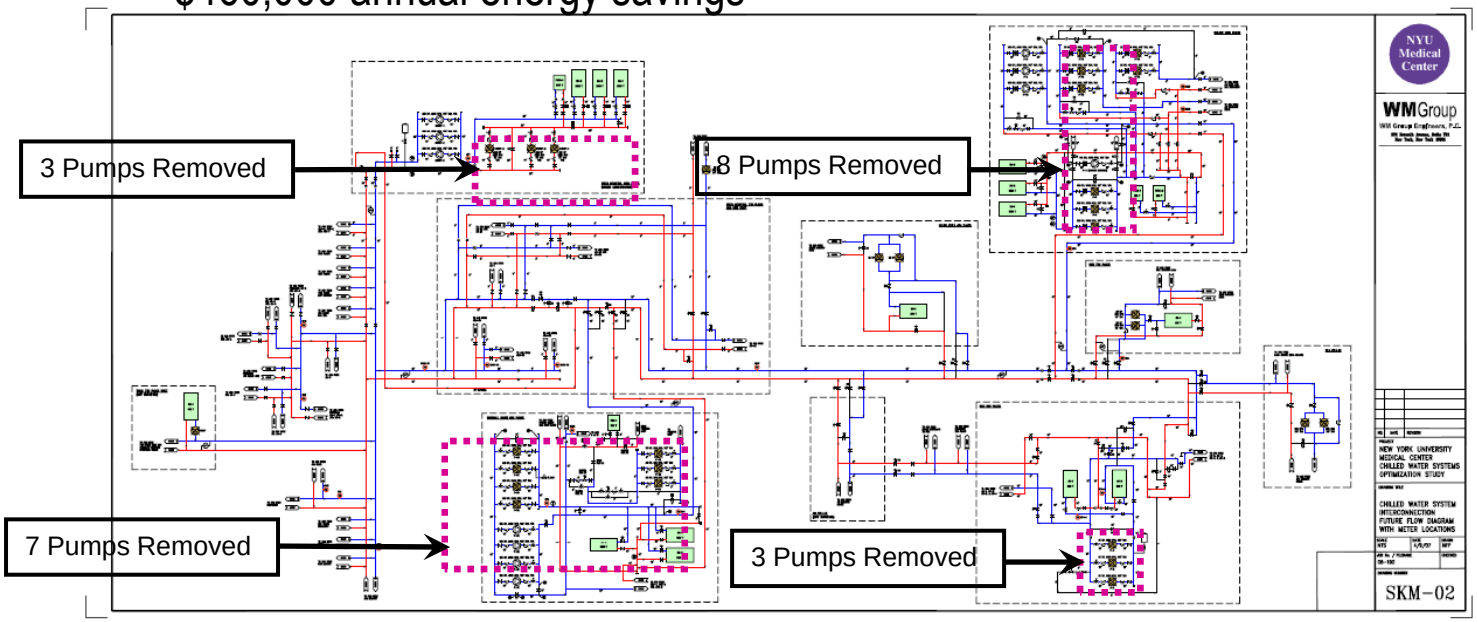
4. **Results:**
   - **Central Boiler Plant**
   - **Central Chiller Plant**
   - **$12 Million construction cost**
   - **$30 Million Savings over original concept**
   - **Over 20% energy cost reduction**

WM Group Engineers
Smart solutions that work.

Virtual Central Plant Regains 3600 tons of Additional Capacity

NYU Medical Center (2007)

- Plant survey and hydraulic model indicated unnecessary pumps
- 1,300 horsepower of pumps are being removed, including 11 pumps in two brand new chiller plants
- $300,000 implementation cost
- $460,000 annual energy savings

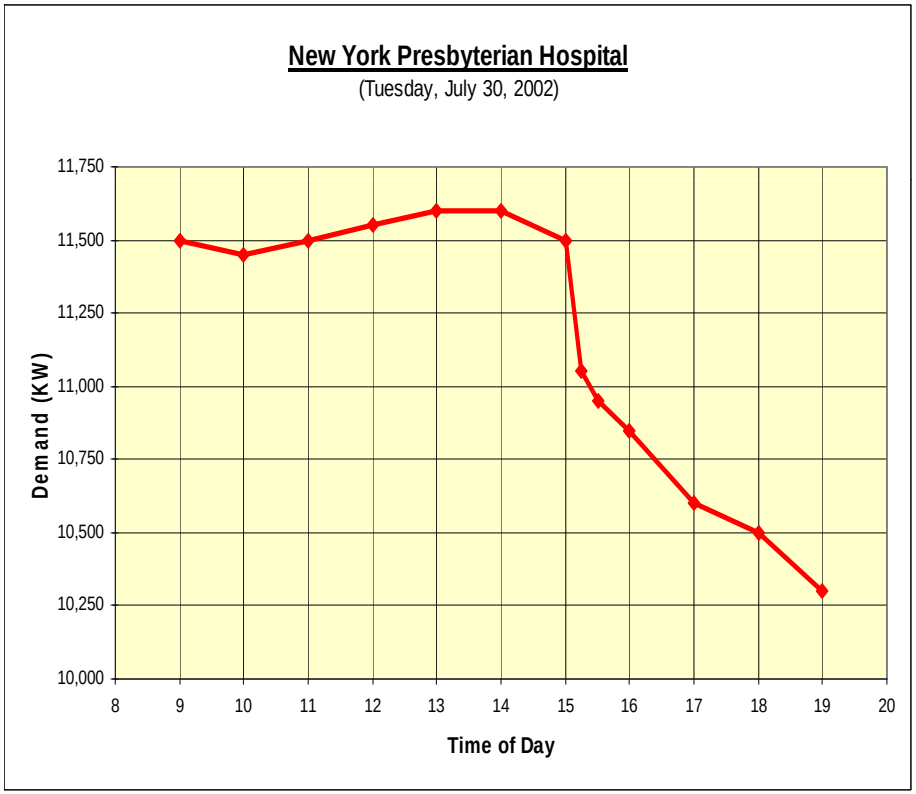


WMGroup Engineers
Smart solutions that work.

Teach operator to run a system not machines

New York Presbyterian Hospital

- Uptown and Downtown Facilities
- Chilled water system optimization
- ~650 kW peak demand savings
- Saved over $500,000 per year
- *Now peak cooling demand is met by 4 chillers rather than 6 chillers prior to modification*

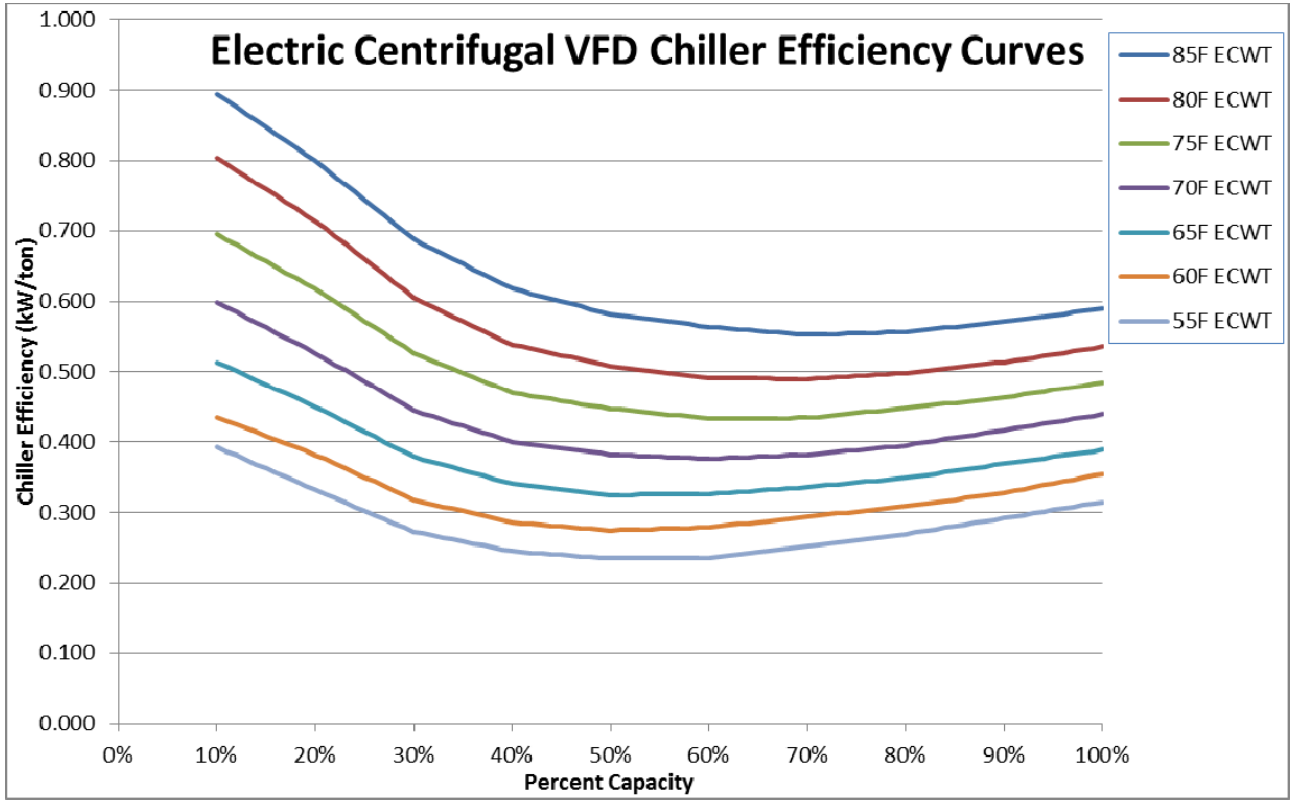


WM Group Engineers
Smart solutions that work.

Remove Operators Fear by educating

Constant Chilled Water and Condenser Water Temperatures…

- VFD-equipped chillers can achieve ***exceptional part-load efficiency*** *IF* they take advantage of *condenser water temperature relief/reset*



Remove Operators Fear by educating

Constant Chilled Water and Condenser Water Temperatures…

Before Tower Reset

Month	Total ton-hr	Chiller Energy (kWh)	Cooling Tower Energy (kWh)
Jan	0	0	0
Feb	0	0	0
Mar	11,182	4,644	70
Apr	35,668	14,742	273
May	160,925	72,611	1,755
Jun	403,521	181,786	6,719
Jul	426,127	191,492	6,089
Aug	412,393	186,241	7,407
Sep	311,018	139,943	5,097
Oct	53,085	22,043	476
Nov	32,745	13,723	283
Dec	0	0	0
Total		827,226	28,168

After Tower Reset

Month	Total ton-hr	Chiller Energy (kWh)	Cooling Tower Energy (kWh)
Jan	0	0	0
Feb	0	0	0
Mar	11,182	3,190	268
Apr	35,668	10,461	1,012
May	160,925	54,750	5,658
Jun	403,521	152,057	15,808
Jul	426,127	156,383	16,034
Aug	412,393	159,696	15,520
Sep	311,018	117,641	11,769
Oct	53,085	16,135	1,774
Nov	32,745	10,040	910
Dec	0	0	0
Total		680,351	68,753

Remove Managers Fear by educating

Pfizer

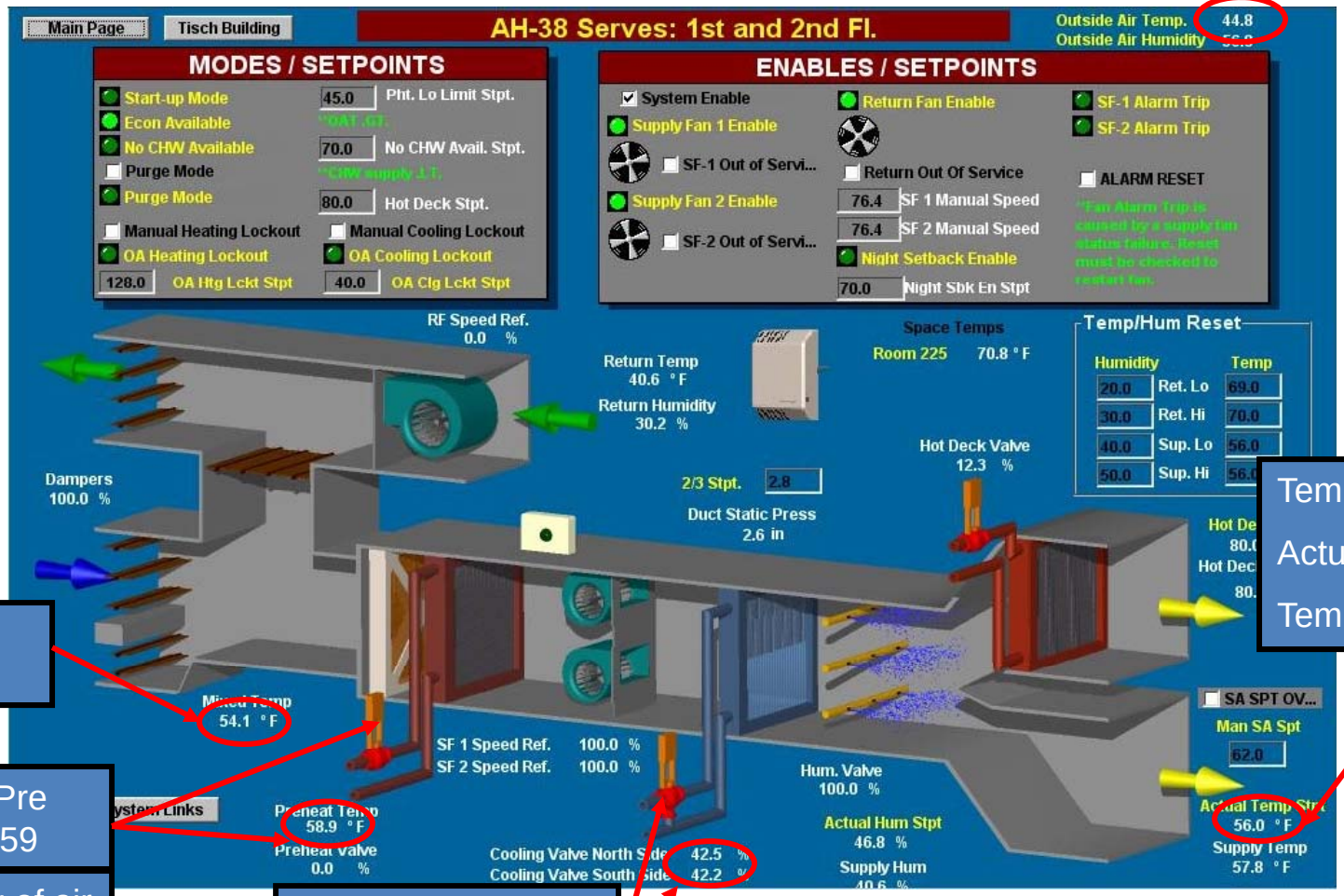
- "…*changes had always been viewed as too risky*… During winter months, one 2,000-ton chiller was supporting only about 300 tons of a very critical manufacturing process load."

- A hydraulic analysis showed, however, that this plant could safely be shut down, with the load transferred to another plant. The site has operated in this manner for two years now, saving significant amounts of energy.

- "Had WM Group not instilled the confidence in our operators to overcome the fear of failure, the savings would never have been realized."
  - Bill Geiling, CEM, Manager of Plant Engineering and Maintenance, Chiller Plant Operations.

WM Group Engineers
Smart solutions that work.

Results of Lack of Training



OAT: 45

Temp Set: 56

Actual

Temp: 58

Mixed Air Temp: 54

Valve leak, Pre heat temp: 59

Overheating of air

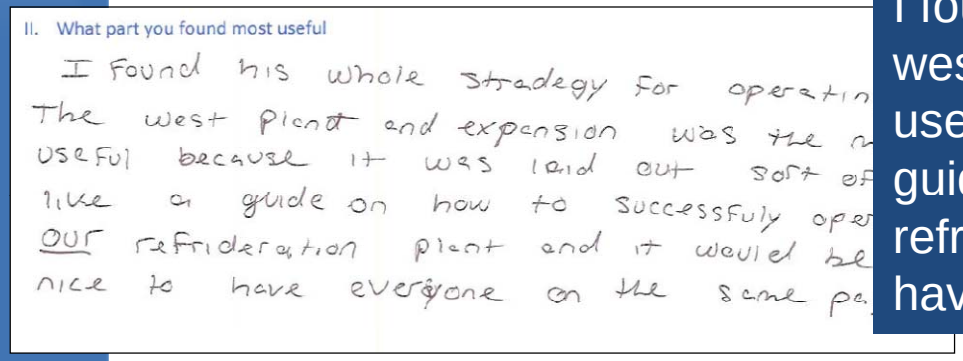
Cooling Valve: 42% open to cool air to set temp.

WM Group Engineers

Smart solutions that work.

Lack of Training

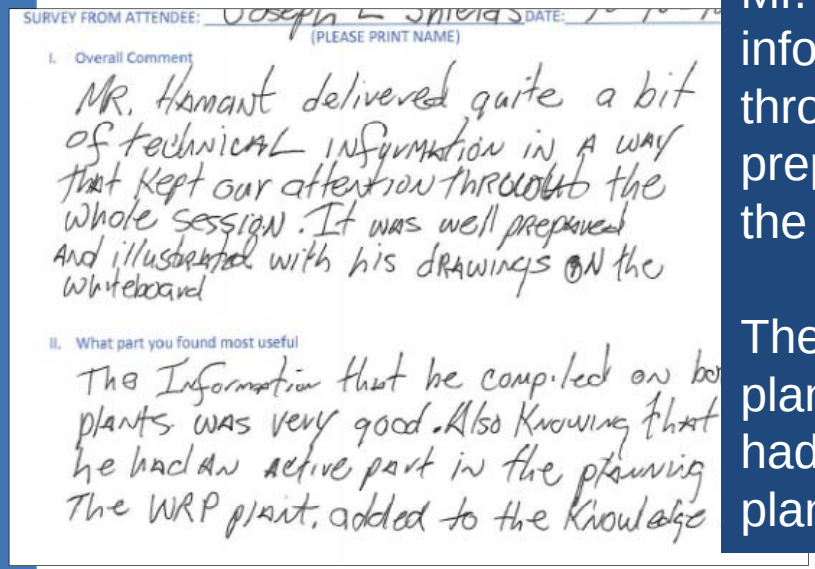
Training Session Feedback…



II. What part you found most useful

I found his whole stradegy for operatin
The west plant and expansion was the
useful because it was laid out sort of
like a guide on how to successfuly oper
our refrideration plant and it would be
nice to have everyone on the same pa

I found his whole strategy for operating the west plant and expansion was the most useful because it was laid out sort of like a guide on how to successfully operate our refrigeration plant and it would be nice to have everyone on the same page.



SURVEY FROM ATTENDEE: Joseph L Shields DATE:
(PLEASE PRINT NAME)

I. Overall Comment

MR. Hamant delivered quite a bit of technical information in a way that kept our attention through the whole session. It was well prepared and illustrated with his drawings on the whiteboard

II. What part you found most useful

The Information that he compiled on bo
plants was very good. Also knowing that
he had an active part in the planning
The WRP plant added to the knowledge

Mr. Hemant delivered quite a bit of technical information in a way that kept our attention through the whole session. It was well prepared and illustrated with is drawings on the whiteboard.

The information that he compiled on both plants was very good. Also knowing that he had an active part in the planning of phase 1 plant added to the knowledge base.

Optimum Design Concepts
Virtual Variable Primary System. Educate client to make the bold move

WM Group Engineers
Smart solutions that work.

Pump Cemetery

Memorial Sloan-Kettering Cancer Center

Chilled-water system optimization results:
-- a total of 19,000 tons of chilled water production capacity was interconnected, providing additional redundancy and flexibility for demand response;
-- a total 32 pumps were bypassed and 23 pumps were demolished (many shown here);
-- summer peak demand reduced by 600 kW on Main Campus, 400 kW at Rockefeller Research Lab;
-- projected pumping horsepower reduced 1,600; and
-- $1 million in projected annual energy savings.

MSKCC received $662,000 from NYSERDA for peak shaving.

WM Group Engineers, P.C.
Seven Penn Plaza
370 Seventh Avenue, Suite 701
New York, NY 10001

Phone (646) 827-6400
Fax (646) 827-6401

www.wmgroupeng.com

19,000 tons CHW production capacity interconnected

32 pumps bypassed
23 pumps demolished

$1 million in projected annual energy savings

$662,000 NYSERDA funding

WM Group Engineers
Smart solutions that work.

Summary:
How To Keep Your System in Shape

1. Keep *operating logs*; have logs reviewed by an expert

2. Don't be afraid of change; use *state-of-the-art technology*
3. *Educate managers to remove their fear*

4. Provide *system training* to operators

5. Interchange operating personal between plant and buildings, or *"cross training"*

6. Convert HVAC controls to *process controls*

WM Group Engineers
Smart solutions that work.

Summary:
Believe in our education

- We are engineers with power to make our planet Green
- Please stop and think before you jump into design
- Yes, “cut and Paste” design will make little extra money in short term but it is a loss in long term

WM Group Engineers
Smart solutions that work.

Thank You

Hemant Mehta, PE

President

WM Group Engineers, P.C.

(646) 827-6400

hmehta@wmgroupeng.com

www.wmgroupeng.com

WM Group Engineers

Smart solutions that work.