UNIVERSITY OF OREGON

Accelerating Cooling System Performance at University of Oregon

By

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University of Oregon Chilled Water System

- Chiller Plant (2009) with 7,500 ton installed capacity, estimated to meet need until 2050
- 10 miles existing distribution piping
- Primary/ Secondary/ Tertiary (Some buildings only) pumping system.
- Some buildings isolated with Heat Exchangers
- Two sets of Secondary pumps with common header with different pump heads
- Cooling towers with space constraints
- Campus growing at a rapid pace

Some of the major issues

- Some buildings including the Athletic Arena designed with heat exchangers
  - Unable to maintain comfort conditions particularly during events
- Plastic Piping
  - Imposed operational pressure limits on system
  - Pipe failures Risk operation of entire system
  - Not enough pressure at certain buildings
- Installed Primary System booster Pump
  - Relocated pumping system

University of Oregon Chilled Water System – Summary of the issues

- Newly installed Chiller Plant and Existing system issues:
  - ✓ No overall guidance on how to design building systems
  - ✓ Many pumps in the plant, buildings and booster system
  - ✓ Pipe failures in the campus buildings
  - ✓ Lack of comfort condition in the athletic arena
- WM group provided free no obligation review
- Retained WM group to perform detail study and provide guidance based on the initial review

Initial review - Hemant

- I am a member of IDEA for over 40 years
- Now is the time to give back to the Industry
- Free review requires description of the existing design and copies of operating logs for two to three days per month for 12 months
- Free review provides quick guidance on the opportunities based on my 47 years of reviewing hundreds of facilities

Observation Based on Review of Data

- UO like many other universities is a victim of a poor plant design
- Your system design along with the design of building system with no guide lines to design consultant forces you to operate system very inefficiently
- Installing plastic pipes in some building has caused pipe failures
- Use of Heat Exchangers in some building and particularly for the Athletic center causes higher supply temperature and loss of comfort controls
- You have a major issue with the loss of operating capacity.
- Your total pumping head is 275 feet, yet you have installed booster pumps in the system. Your pumping head should not be more than 180 feet. Building pumps and primary pumps are NOT required

Observation Based on Review of Data

- Primary pumping is unitized, loss of a pump will prevent use of the chiller. Same for cooling tower cells
- Seven secondary pumps with different pump heads between the same suction and discharge headers cannot work together. Pumps 1 to 4 are way oversized and pumps 5 to 7 are undersized
- Fixing the building system controls can further reduce annual cooling requirements
- There are very cost effective opportunities to simplify your operation
- Your total plant efficiency can be reduced by over 30 percent with a payback to two to three years

Chiller Plant

- **5 chillers** with total capacity of **7,500 tons**

Chiller	Capacity (Tons)	CHW Flow (GPM)	ΔT	Compressor HP	Speed
CH-01	1,500	3,000	12	1,207	VFD
CH-02	1,500	3,000	12	1,207	VFD
CH-03	1,500	3,000	12	1,207	VFD
CH-04	1,500	3,000	12	1,207	VFD
CH-05	1,500	3,000	12	1,207	VFD
PFHX-01	400				N/A

- **Primary/ Secondary CHW** pumping system

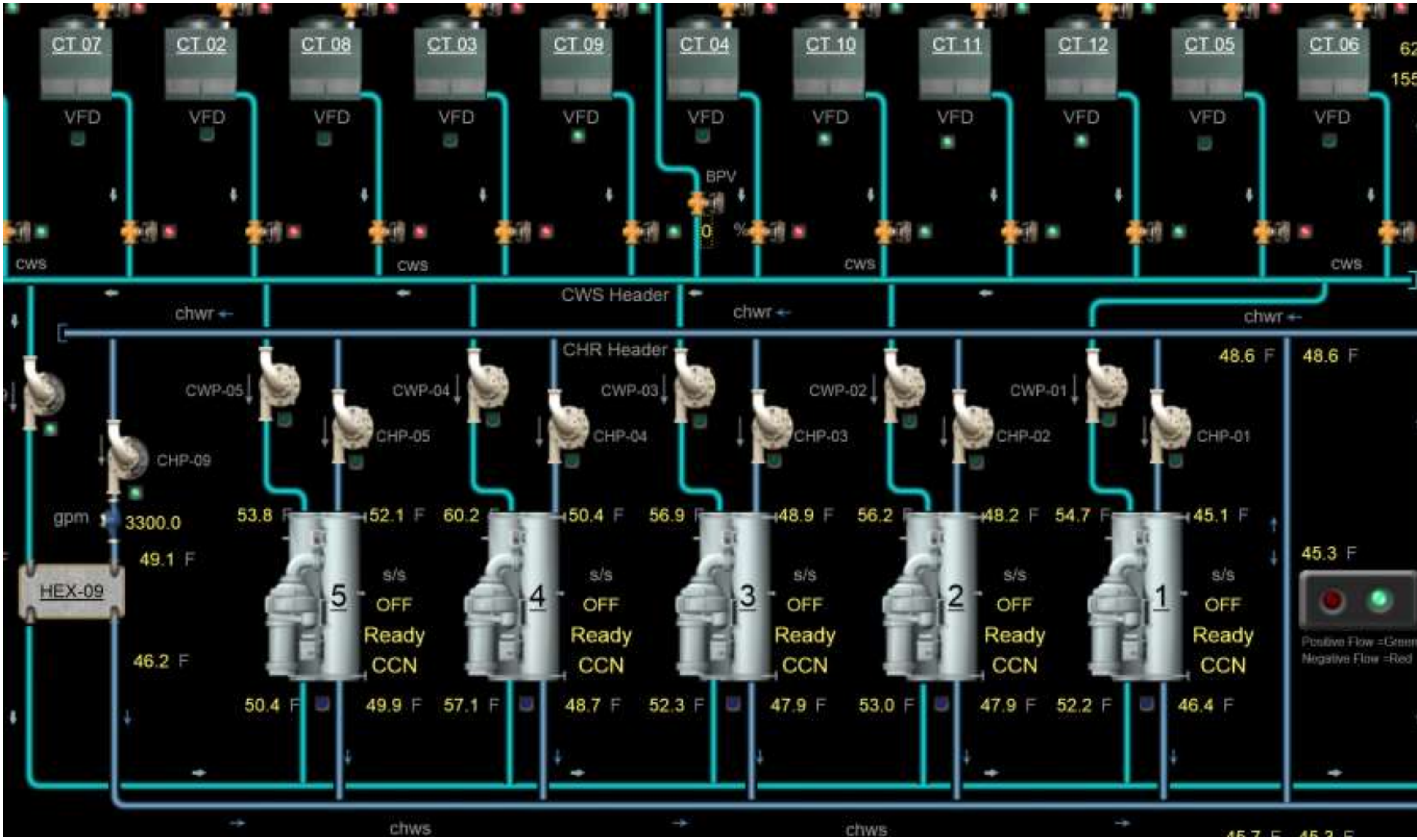
Pump	System	Capacity (GPM)	Pump Head (ft)	Motor HP	Speed
CHP-01	Primary Chilled Water	3,000	47	50	Constant
CHP-02	Primary Chilled Water	3,000	47	50	Constant
CHP-03	Primary Chilled Water	3,000	47	50	Constant
CHP-04	Primary Chilled Water	3,000	47	50	Constant
CHP-05	Primary Chilled Water	3,000	47	50	Constant
CHP-06	Primary Chilled Water	3,570	43	50	Constant
SCHP-01	Secondary Chilled Water	5,543	228	400	VFD
SCHP-02	Secondary Chilled Water	5,543	228	400	VFD
SCHP-03	Secondary Chilled Water	5,543	228	400	VFD
SCHP-04	Secondary Chilled Water	5,543	228	400	VFD
SCHP-05	Secondary Chilled Water			100	VFD
SCHP-06	Secondary Chilled Water			100	VFD
SCHP-07	Secondary Chilled Water			100	VFD

CHW Primary + Secondary Pump Head = **275 FT !**

Typical Pumping Head Loss

- **Plant = 45 – 50 ft.**
- **Building = 45 – 50 ft.**
- **Distribution = 80 – 100 ft.**
- **Total TDH <200 ft**

pumping system Unitized. Loss of a pump will inhabit chiller operation



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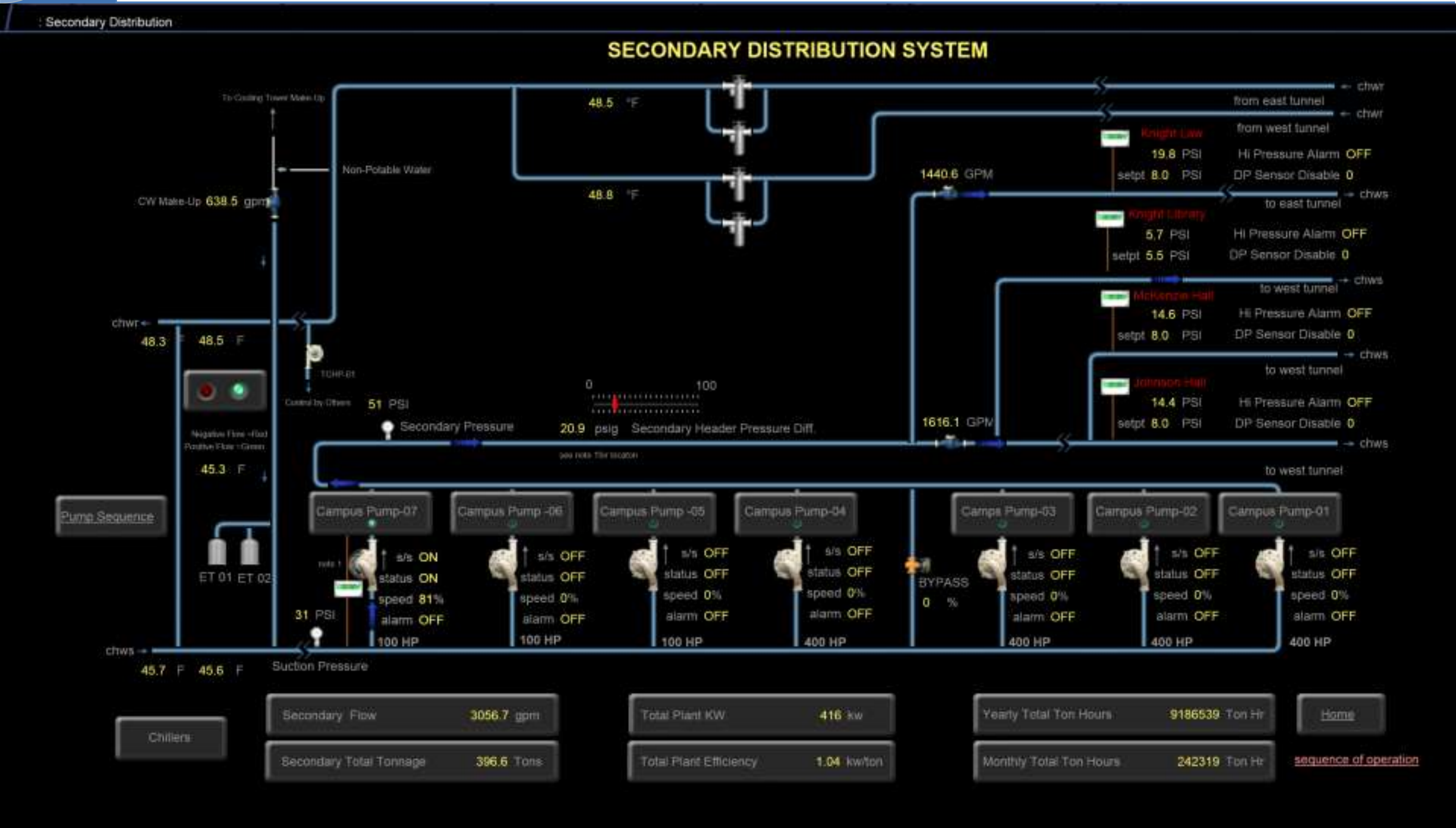
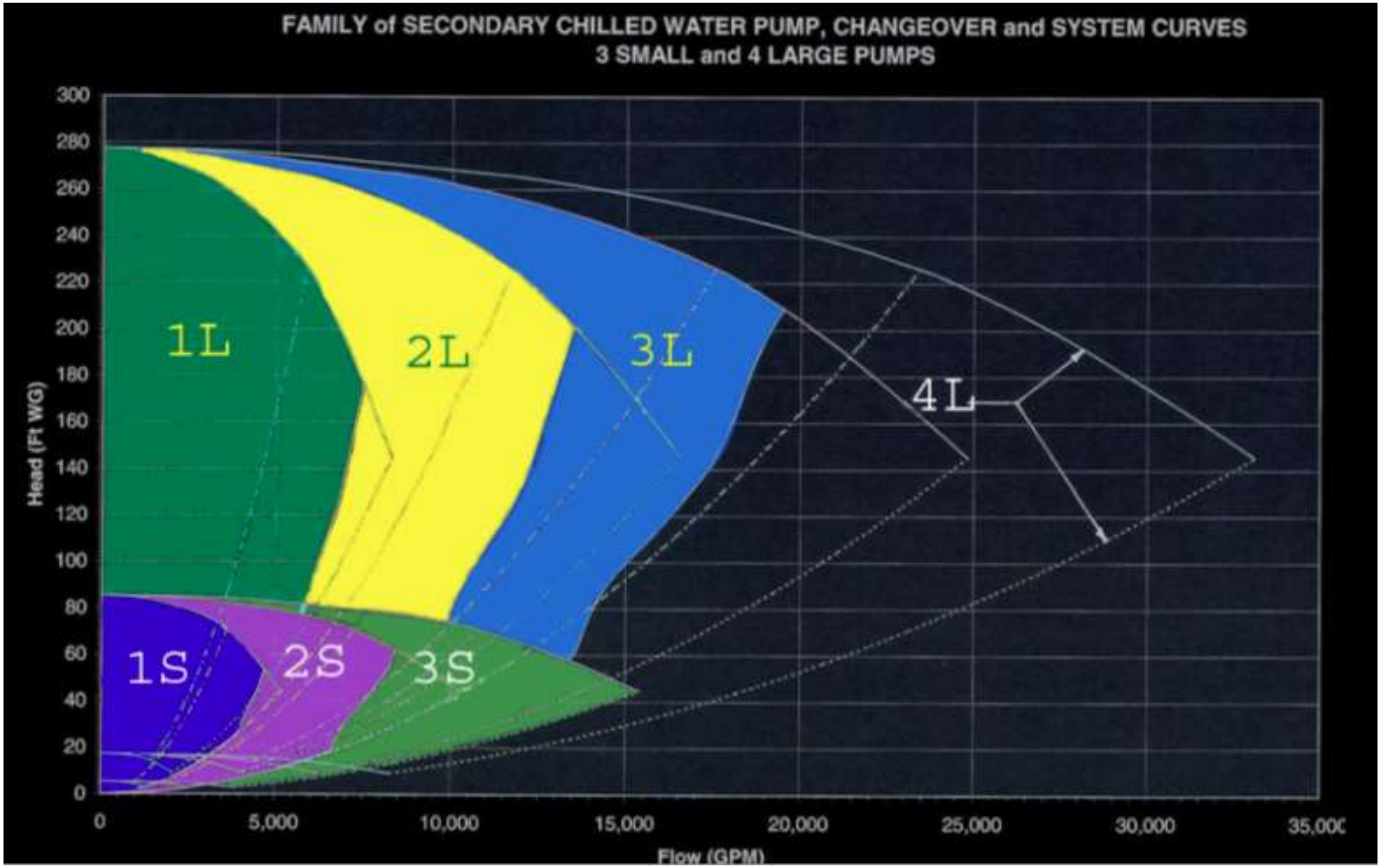
1. Pumps 1to 4 cannot work with pumps 5 to 7
2. Pumps 1 to 4 are way oversized and pumps 5 to 7 are undersized



Complex Operational Strategy



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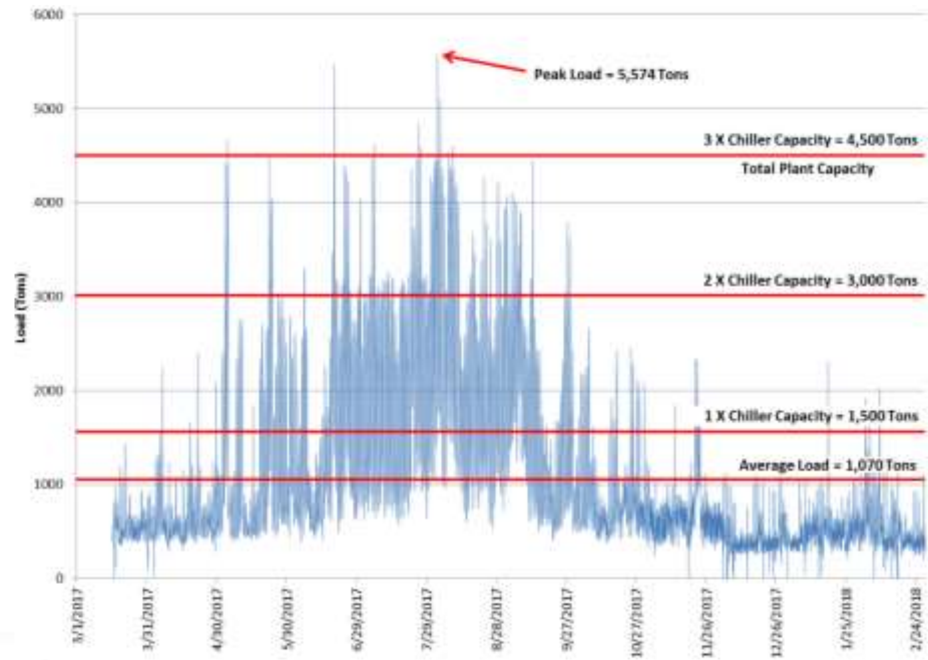
Cooling Load Profile – Low humidity most of the time

- Profile from March 1, 2017 through February 28, 2018
- Peak load of **5,574 Tons**
- Avg. Load = **1,070 Tons**
- No. of CH @ peak load = **4**
- **CH design capacity = 1,500 tons**



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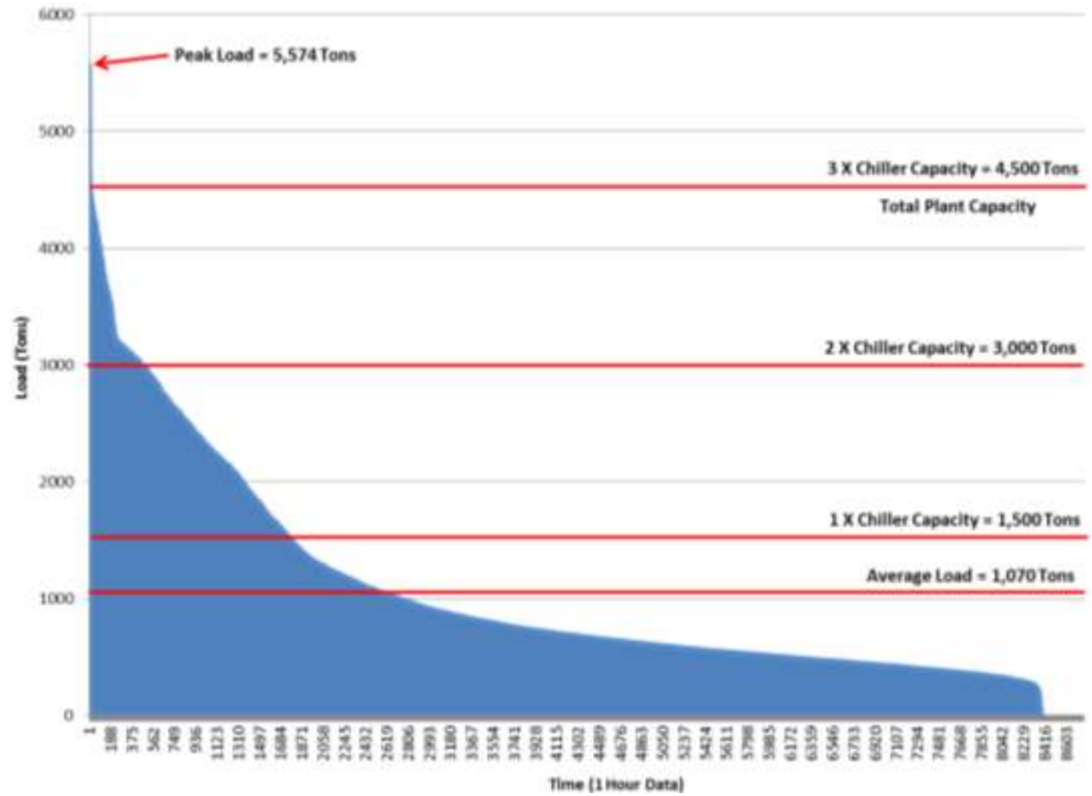
Cooling Load Duration Curve

- Profile from March 1, 2017 through February 28, 2018
- Cooling **load below 1,000 tons for 65% of time**
- **2 CH** operation for **90% of time!**



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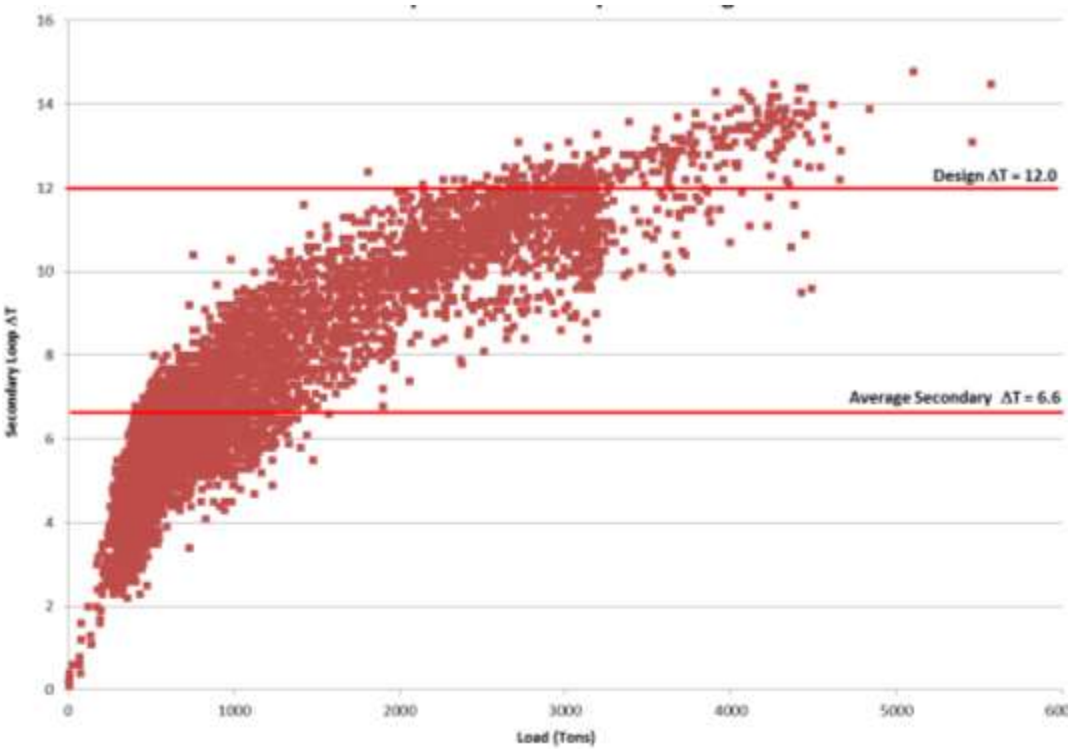
Observation – CHW ΔT

- CHW Plant Design Capacity = **7,500 Tons @ 12ºΔT**
- Your **annual secondary CHW average ΔT is 6.6º**
- ΔT increases with load. Most **money is lost** during **inefficient part load operation**
- **Actual ΔT** approached **design ΔT** of 12 or more for **around 713 hours** annually
- Coils are sized for peak load. Consequently, **oversized during Spring and Fall season**
- **ΔT should be better during shoulder season compared to peak season**



Plant Secondary Chilled Water ΔT

Months	0 - 300	300 - 600	600-900	900-1200	1200-1500	1500-1800	1800-2100	2100-2400	2400-2700	2700-3000	3000-3300	3300-3600	3600-3900	3900-4200	4200-4500	4500-4800	4800-5100	5100-5400	5400-5700	Avg
Jan	**3.5**	**5.0**	**6.3**	**7.9**	**7.2**	**9.6**		**11.1**												**5.2**
Feb	**3.2**	**4.4**	**6.3**	**7.4**	**7.7**	**8.5**	**8.4**													**4.8**
Mar	1.3	5.6	6.3	7.6	7.7															3.0
Apr	2.5	5.7	6.3	7.2	7.5	8.6	9.4	10.6	11.3											6.1
May		5.5	6.2	6.6	7.4	8.8	9.4	10.1	10.8	11.1	10.9	11.6	12.1	12.3	12.5	12.9				7.2
Jun		5.4	6.6	7.0	7.9	8.6	9.5	10.2	10.6	10.9	10.8	11.2	11.3	12.5	11.5				13.1	8.0
Jul		6.7	7.2	7.6	8.2	9.4	10.0	10.3	11.1	11.2	11.3	12.0	12.5	13.4	12.9	13.6	13.9			9.5
Aug		6.1	7.1	8.2	8.9	9.7	10.3	11.0	11.3	11.6	11.6	12.5	12.5	13.4	13.6	12.7		14.8	14.5	10.3
Sep		6.3	6.7	7.6	8.9	9.4	10.0	10.6	10.4	11.1	11.4	12.4	12.1	13.1	14.4					8.7
Oct		5.9	6.2	6.6	7.5	8.7	9.7	10.1	10.2											6.5
Nov	1.8	5.2	6.2	6.8	7.4	7.9	8.7	10.2												5.9
Dec	3.1	4.1	6.0	8.1	10.0															4.3
Average	**3.1**	**5.0**	**6.4**	**7.3**	**8.2**	**9.2**	**9.9**	**10.5**	**10.9**	**11.3**	**11.3**	**12.1**	**12.3**	**13.2**	**13.1**	**13.1**	**13.9**	**14.8**	**13.8**	**6.6**

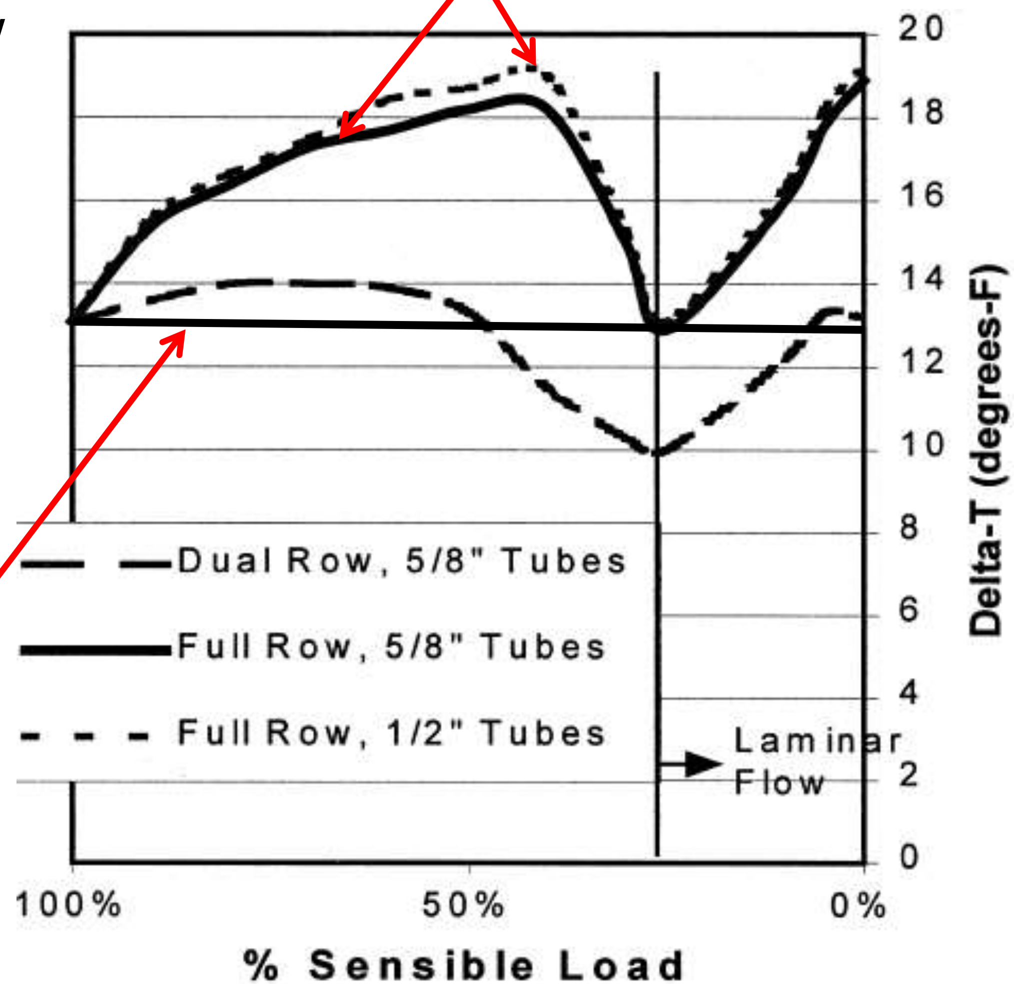
- Table shows **average annual ΔT** for Plant at various load range
- Maximum **average ΔT** of 14.8
- Minimum **average ΔT** of 1.3
- **Chiller design ΔT is 12.0**
- **Annual Average ΔT is 6.6**

Part Load Chilled Water ΔT

- ΔT should be **higher during part load**
- Poor ΔT can by improved by
  - ➢ **Retro-commissioning**
  - ➢ **Controls improvement**
- Most of our clients get **over 18º ΔT** during low load conditions

Coil Part Load ΔT @ various load

Coil Design ΔT = 13º



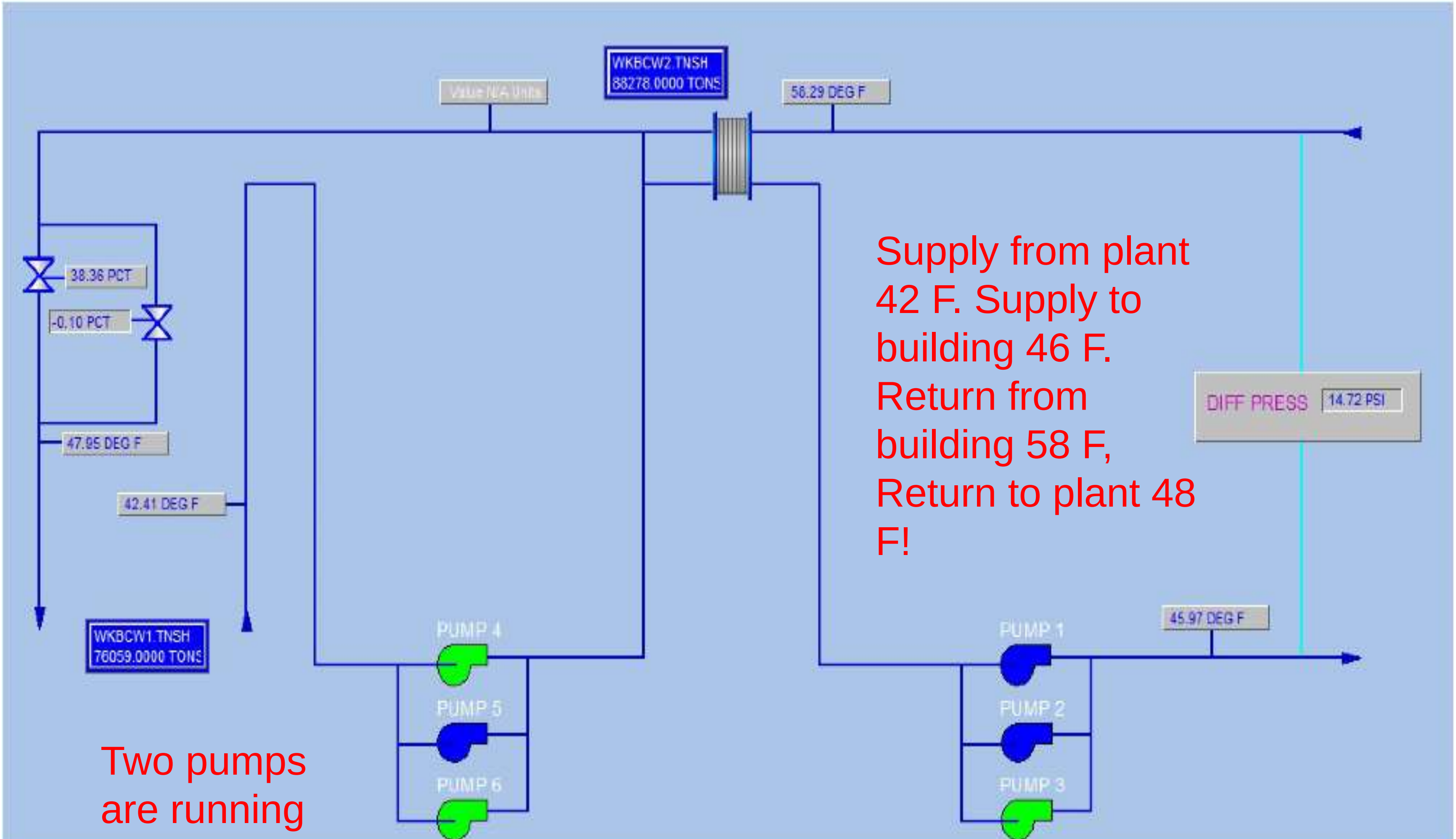
The above discussion was based on Free review

- University retain us to study the following items
  1. Sports Arena Cooling issues
  2. Not adequate pressure at certain buildings
  3. Over pressurization of building piping
  4. Zero and/or low cost recommendations to improve the system

1. Sports Arena Cooling Issues

- building system piping necessitated use of
  - Large Plate Type Heat Exchanger
  - Primary and Secondary pumps
- Building experiencing inability to properly cool spaces during events
- High Flows with Low **ΔT**
- Control Valve Failure
- Replaced control valves as well as booster pumps. Why?
- Control valves decreases pressures and pump increases pressure!

Sports Arena Cooling Issues



Supply from plant 42 F. Supply to building 46 F. Return from building 58 F, Return to plant 48 F!

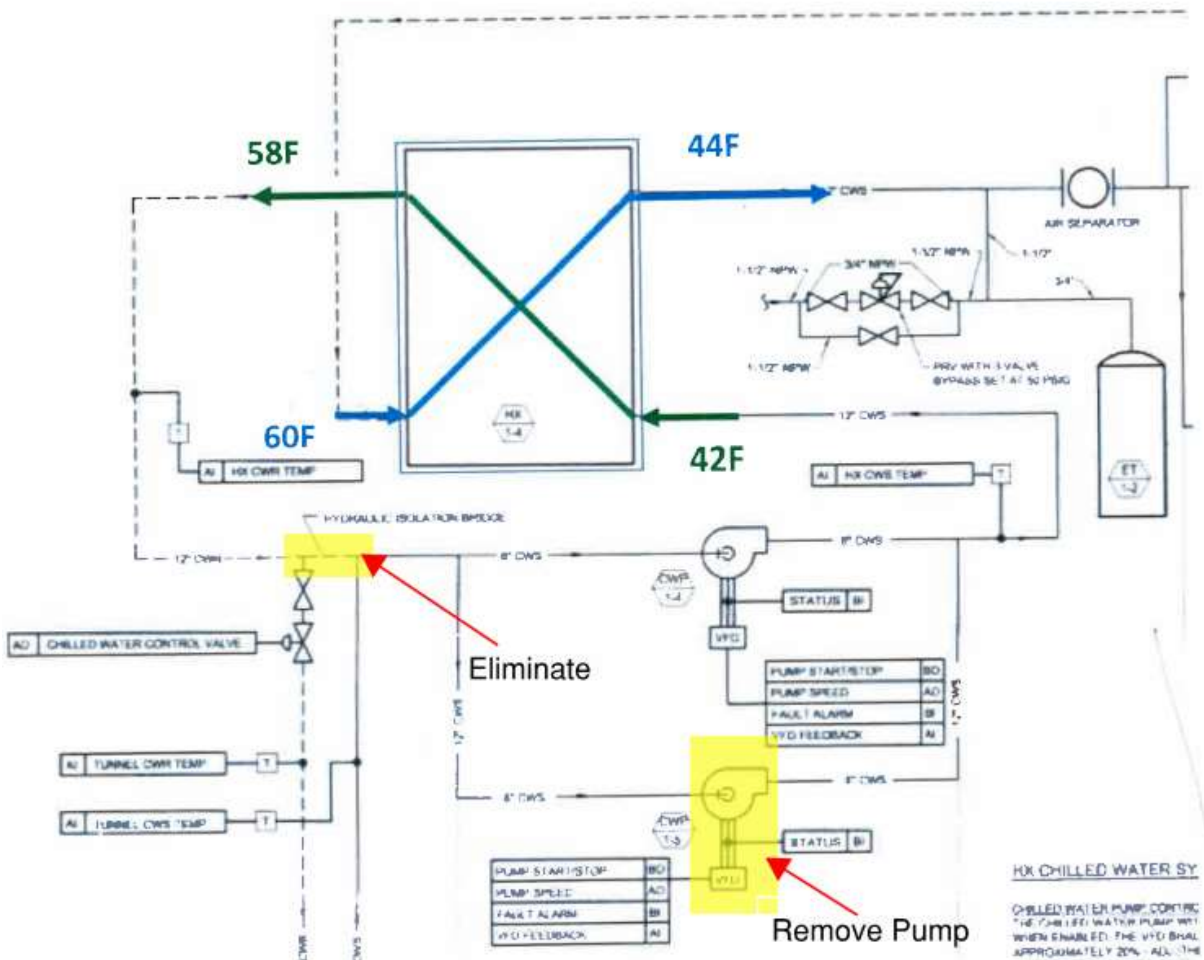
Two pumps are running and control valve is 38% open

Athletic Center Design requirements

- Many Athletic Center fail to meet comfort conditions during an event
- Why?
  - Humidity Stupid☺
- Needs colder water. Heat exchangers increases supply temperature
- AT UO HX were required due to plastic pipe on building side

Matthew Knight Arena
Our recommendations

- Eliminate the Hydraulic Isolation Bridge
- Remove the middle pump on the primary side and provide spool pieace to by-pass pumps
- Change control sequences
- Long term – eliminate heat exchanger once the plant pressure issue is fixed



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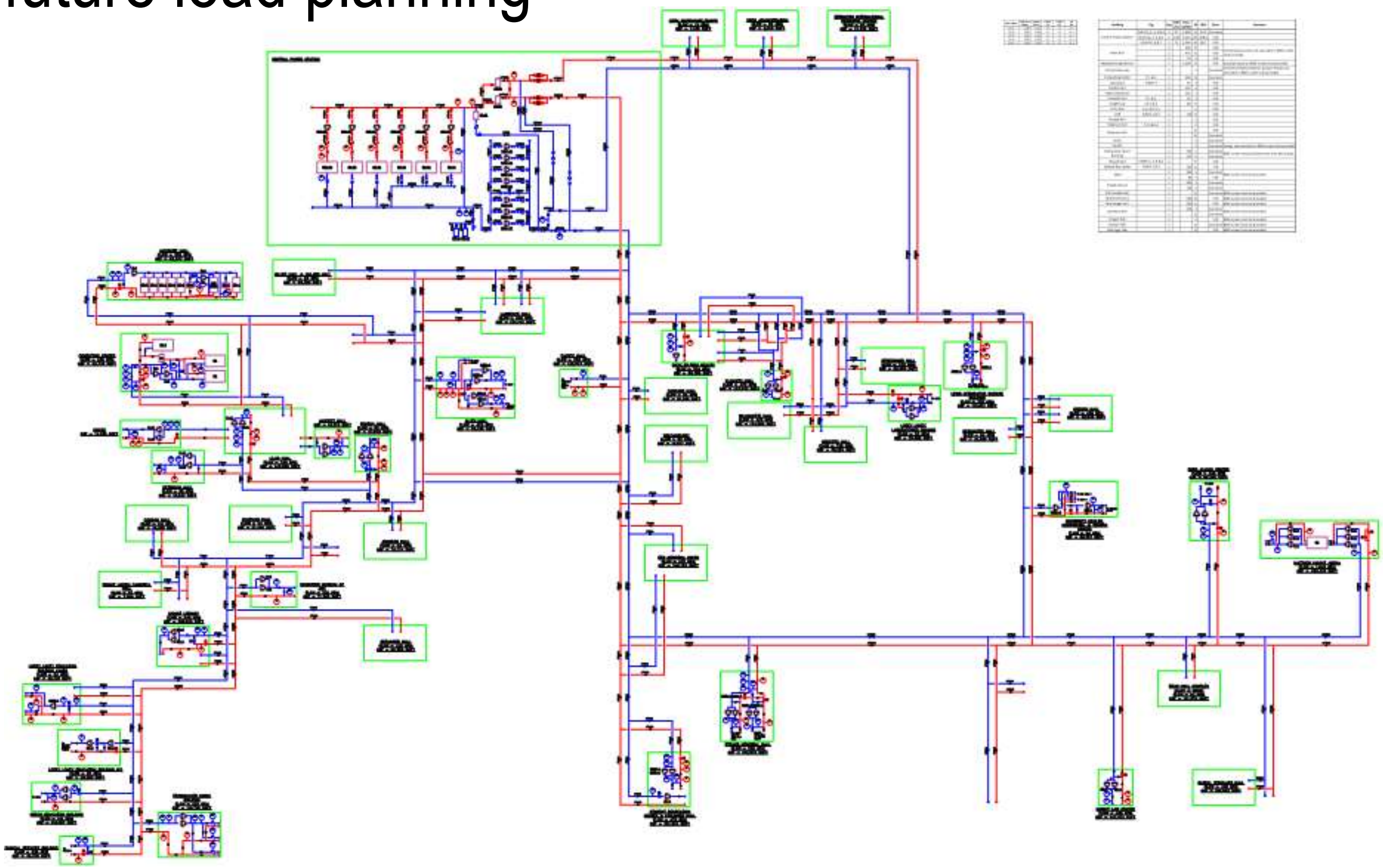
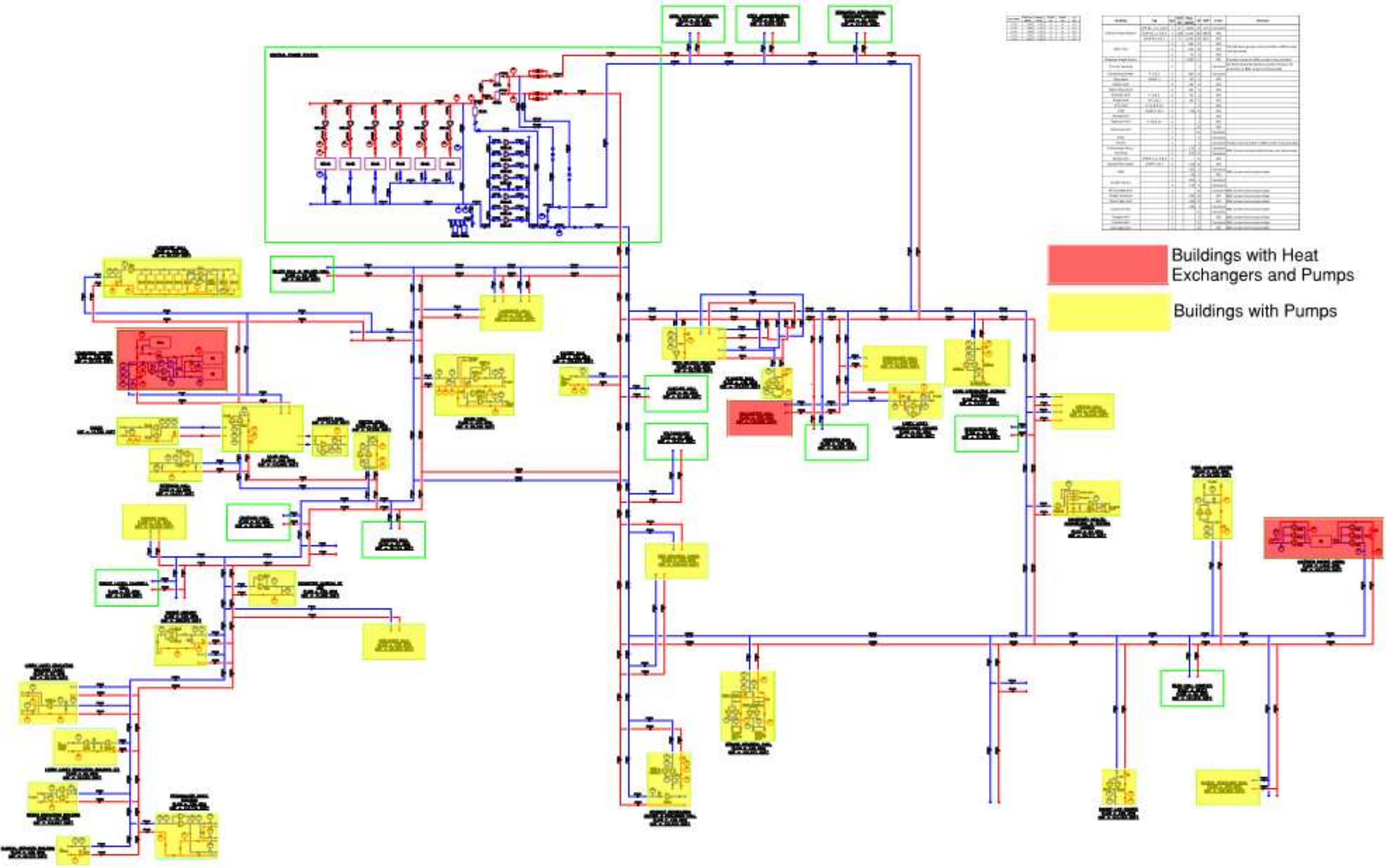
2. Not Adequate pressure at certain buildings

- First step - Composite One Line Dwg
- Provides knowledge of the system
- Guide for what to avoid for other consultants
- Helps for future load planning

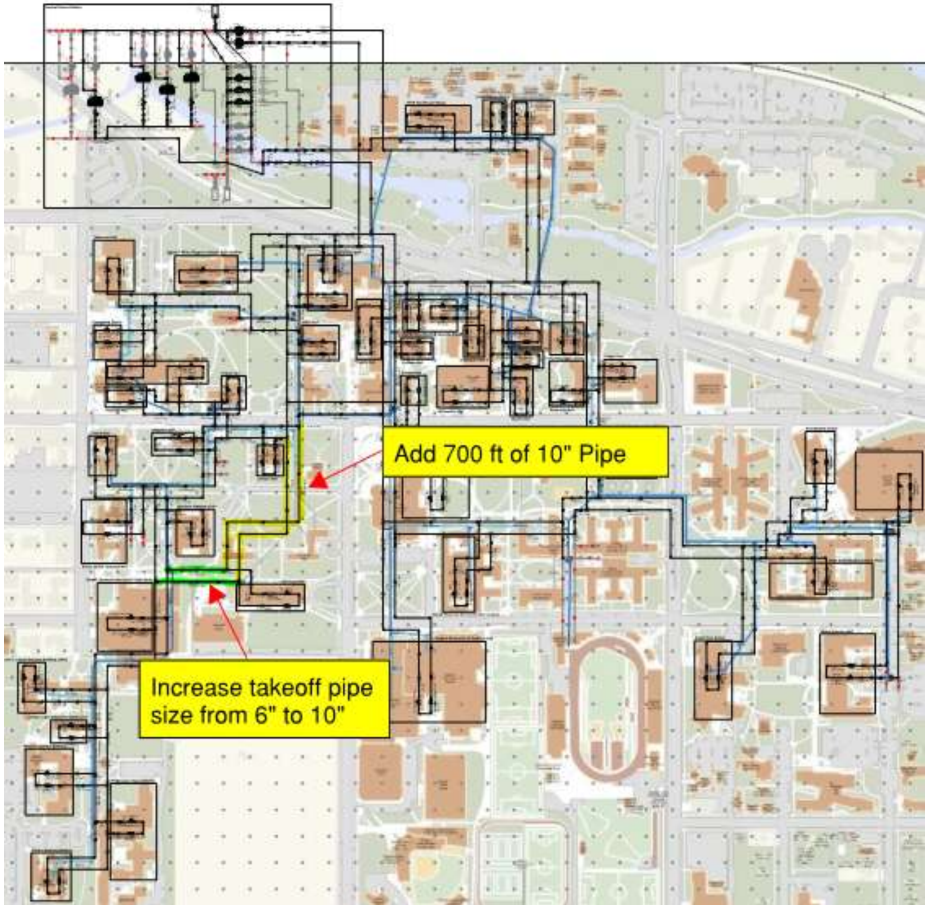


Composite One Line Dwg



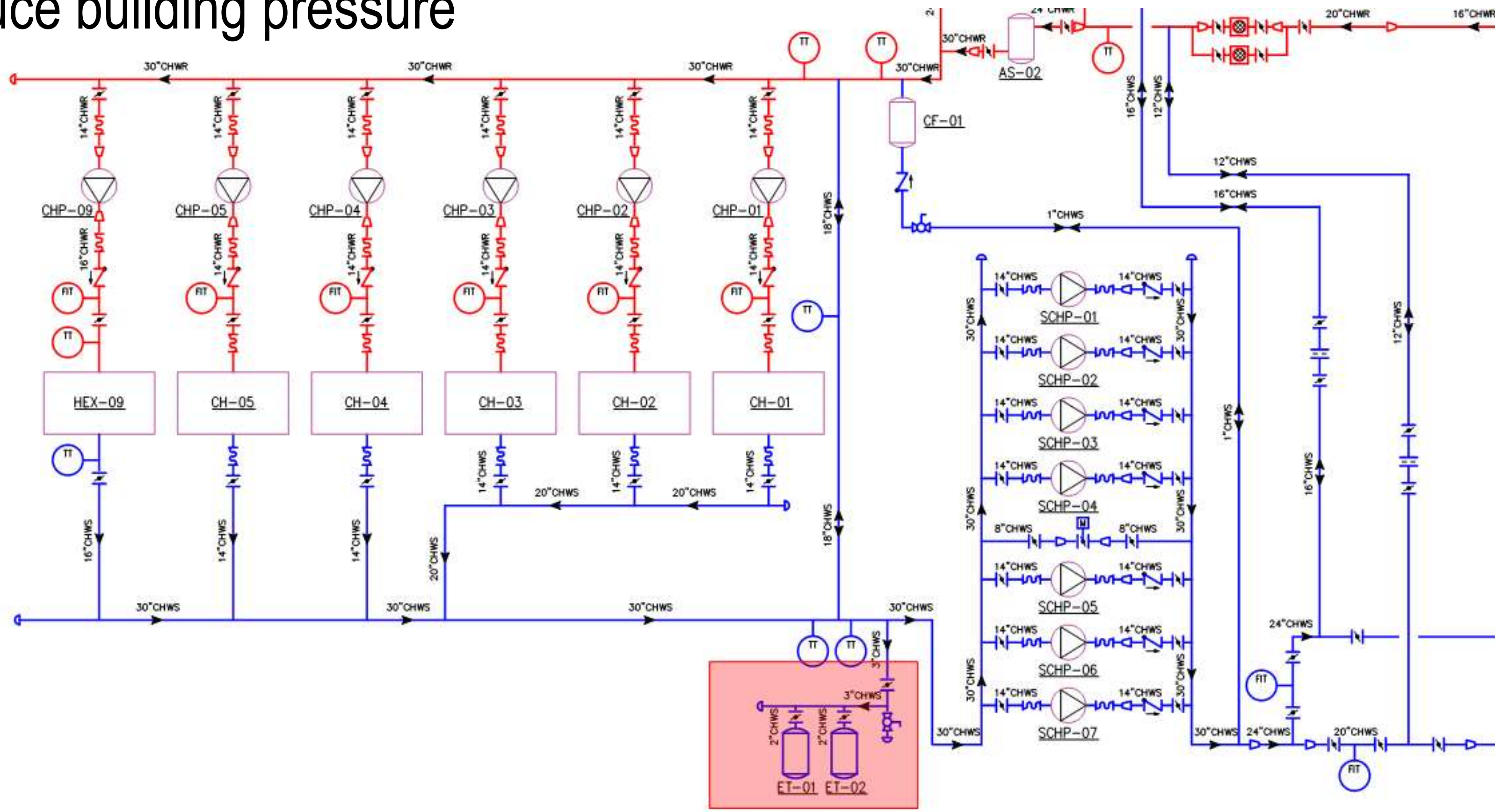
Hydraulic Model Sensitivity Analysis

- We ran additional option in the hydraulic model to see if pump head required for peak load can be reduced
- Added 700 ft of 10” pipe between Johnson Hall and Gerlinger Hall
- Increase takeoff pipe size for Gerlinger Hall from 6” to 10”
- **Pump head reduced from 219 ft to 168 ft**



3. Solutions for Over pressurization of building pipes

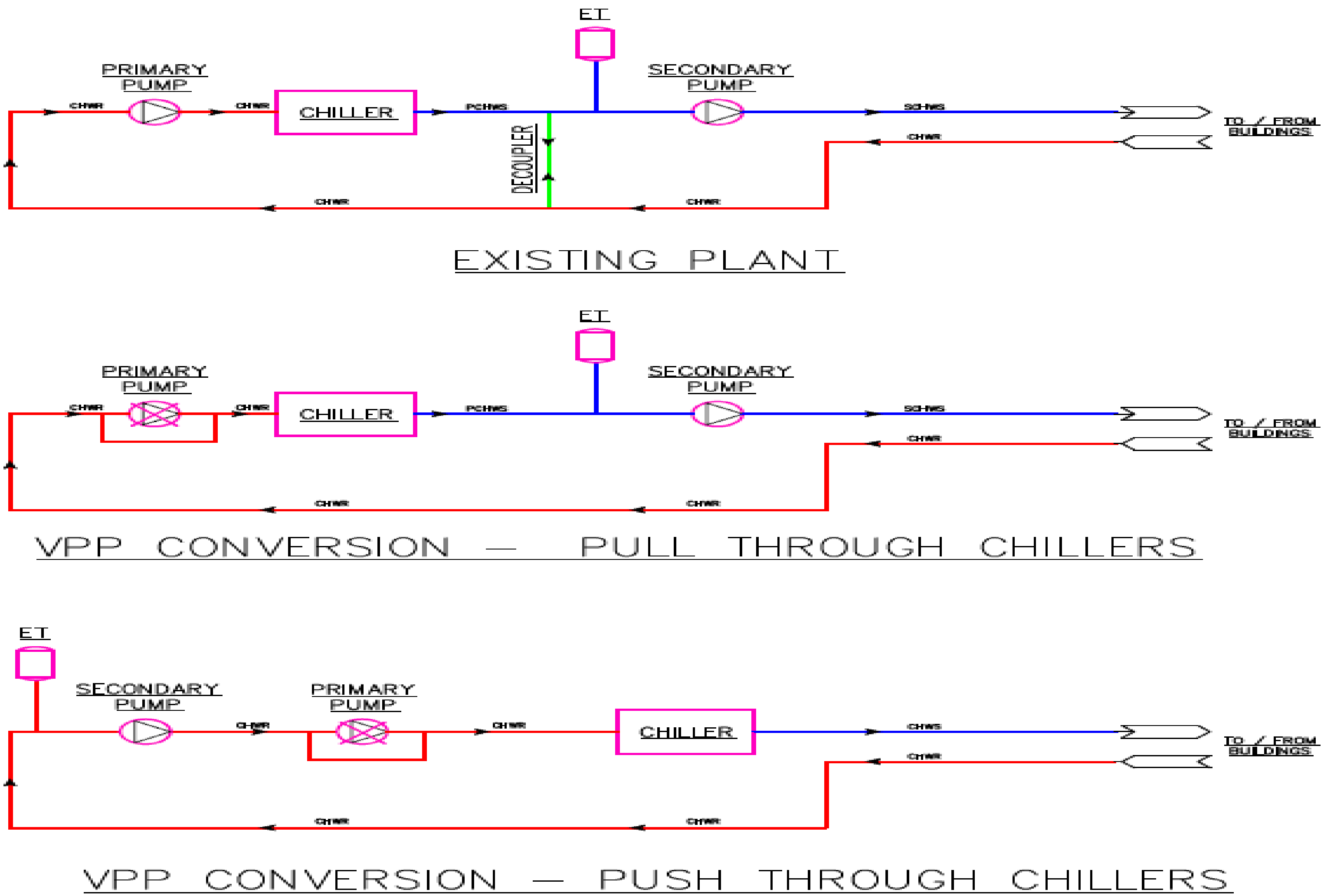
- Discharge pressure to buildings limited to 90 psi to protect HDPE pipes
- Limited pressure causes inadequate flow for the buildings
- Lower the expansion tank pressure during the peak summer session to reduce building pressure



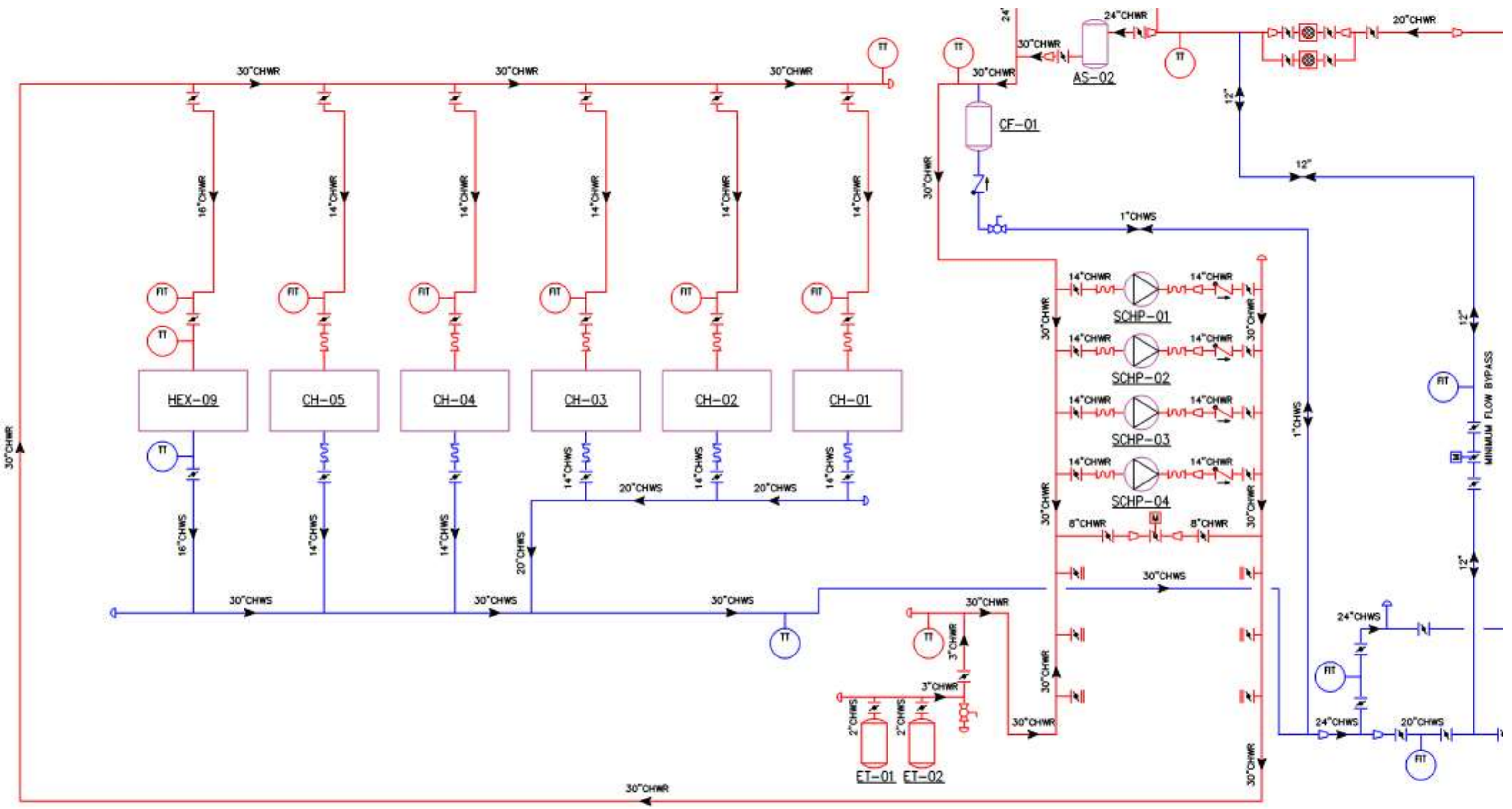
Recommendation to fix over pressurization

- Lowering expansion tank pressure and providing controls to vary pressure to ensure no penetration of air in the system
- Removal of all primary pumps and by passing all building pumps and heat exchangers
- Removing building pumps and HX once FEAR of operation is gone by running the system below 90 psig.
- Converting plant piping to the push through configuration of the Variable Volume Primary Pumping System:

How to reduce plant discharge pressure



Recommendation to fix over pressurization – Proposed flow schematic

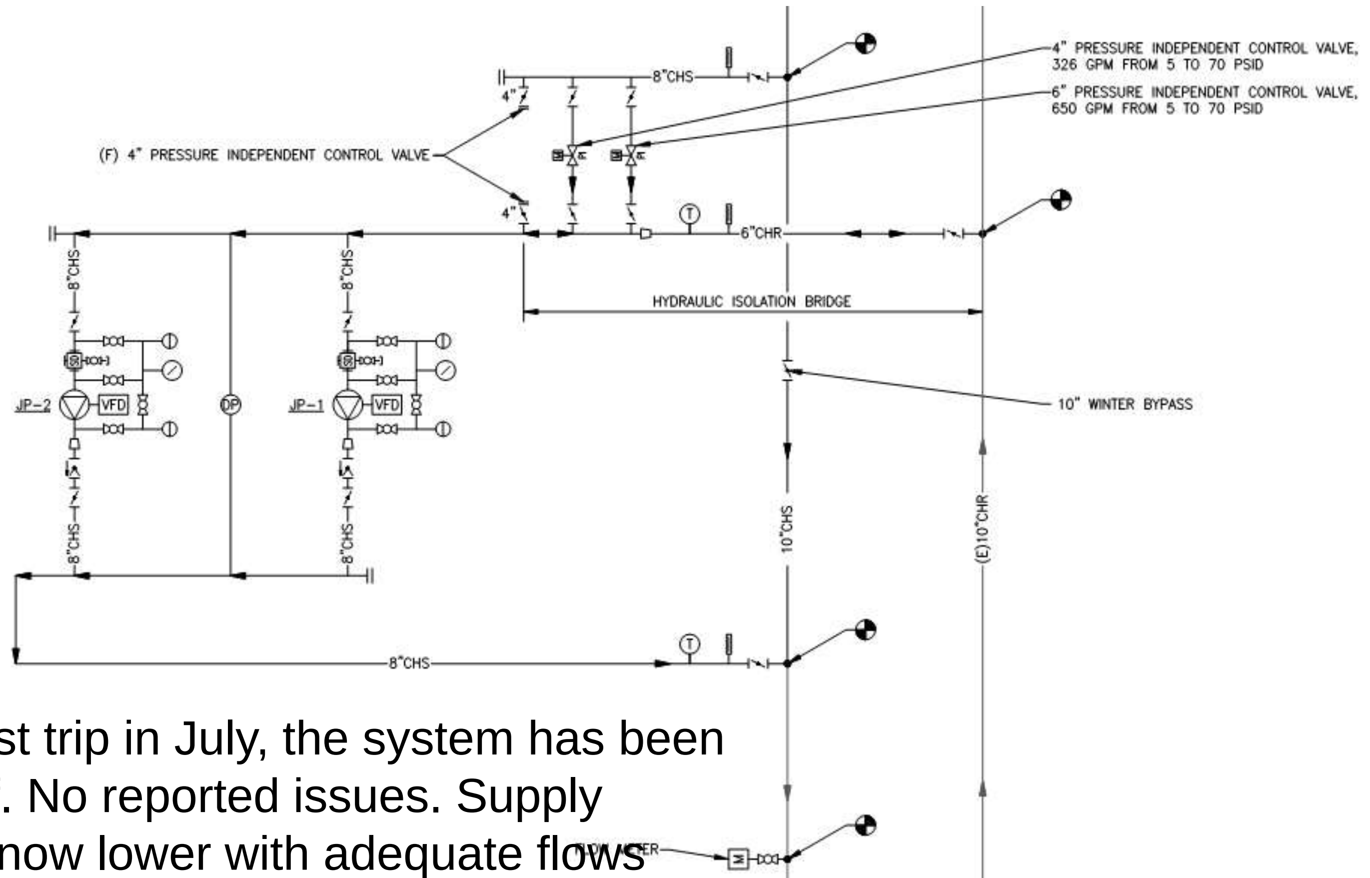


4. Zero/Low Cost Savings

- Quite often during the site survey for the study phase, guiding the operators can save energy & simplify operation
- Recommended measures:
  - ✓ Discontinue Booster Pump P-17
  - ✓ Low cost solution for Matthew Knight Arena
  - ✓ Pump operation to get lower discharge pressures
  - ✓ Identify issues with cooling towers

Elliminate Booster Pump P-17

- Once you connect to return, the pressure is controlled by return pressure
- Two control valves have no useful purpose



During my last trip in July, the system has been command off. No reported issues. Supply temperature now lower with adequate flows

Thank You!

WM Group Services

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