

Presentation Goals?

- Explore Multiple Application Opportunities
- Expand your tool kit
- Maximize Questions
- Minimize Answers
- Prove Nothing
- Encourage personal exploration and discovery (while at work!)

Presentation Goals

- **No LCCA Analysis (accurate or misleading) Provided Here**
- **Every job has unique considerations that can dramatically effect results**
 - Proximities
 - Load matching
 - etc
- **You need to prove it out on your specific project**

Heat Recovery Chillers Consider This

- A Heat Recovery Chiller's primary purpose may be cooling but.....
- A Heat Recovery Chiller's primary purpose may be Heating

Consider This

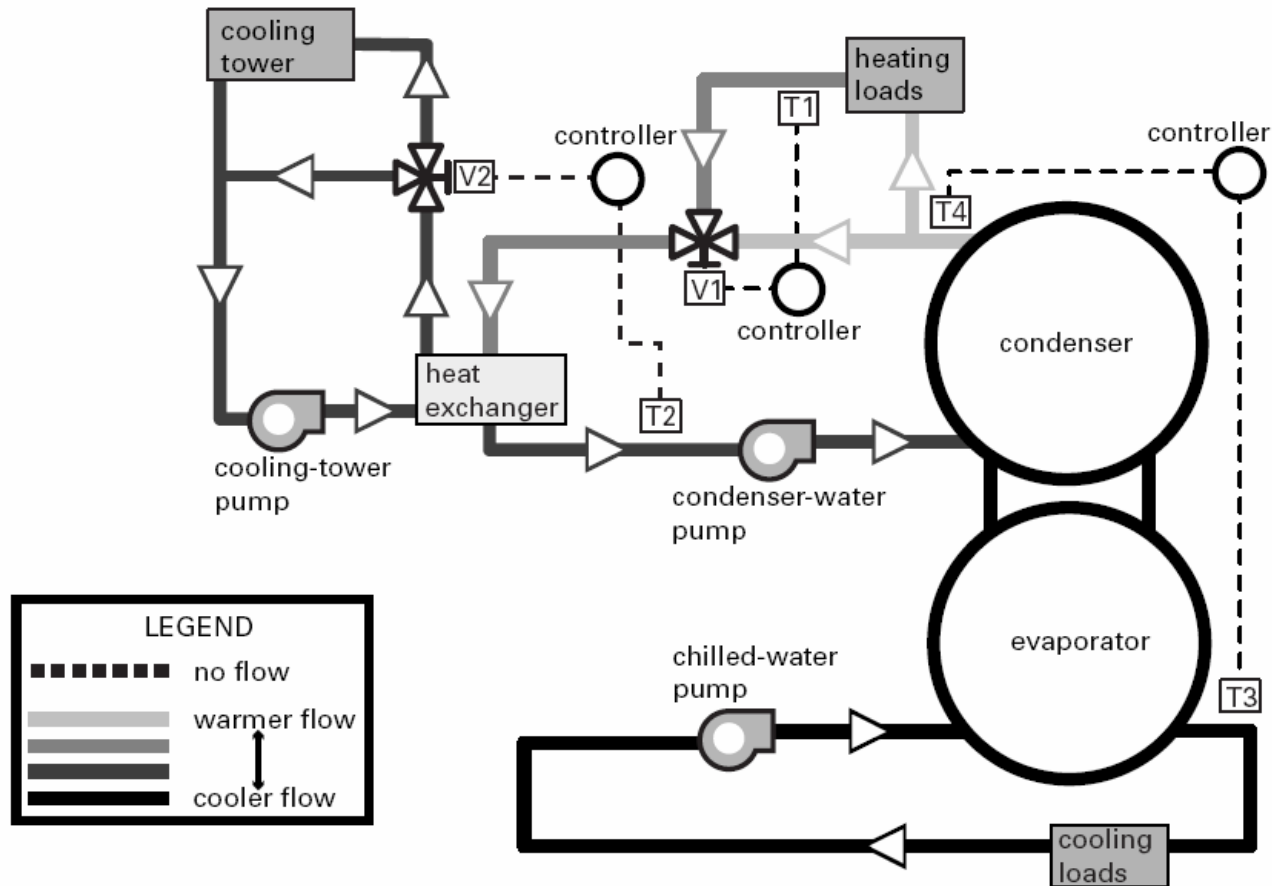
- When conceiving of application opportunities think of these not as Chillers but as alternatives to Boilers
- A Heat Recovery Chiller can generate heat more efficiently than a boiler.
- But.....There must be coincident cooling load. As long as we have cooling load that we can pick up with chilled water, we can generate heat more efficiently than a boiler.
- We are on a quest to find heat leaving the building through other than skin conduction.

And.... Consider This

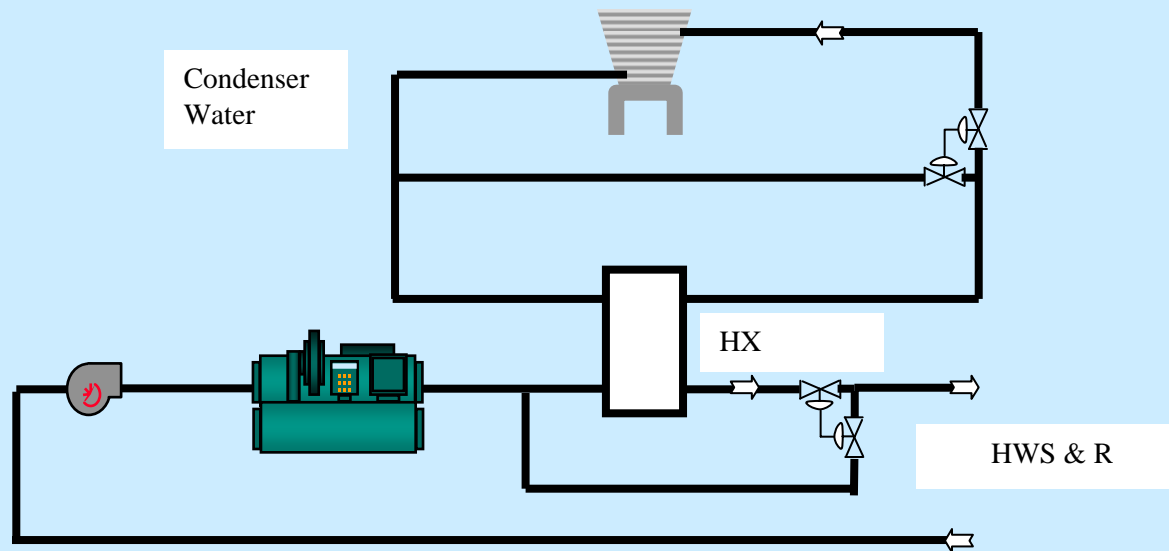
It's a bonus if the Chilled Water produced can actually be utilized simultaneously for useful cooling.

Single Bundle Heat Recovery

Figure 14. Single-bundle leaving-water-temperature control

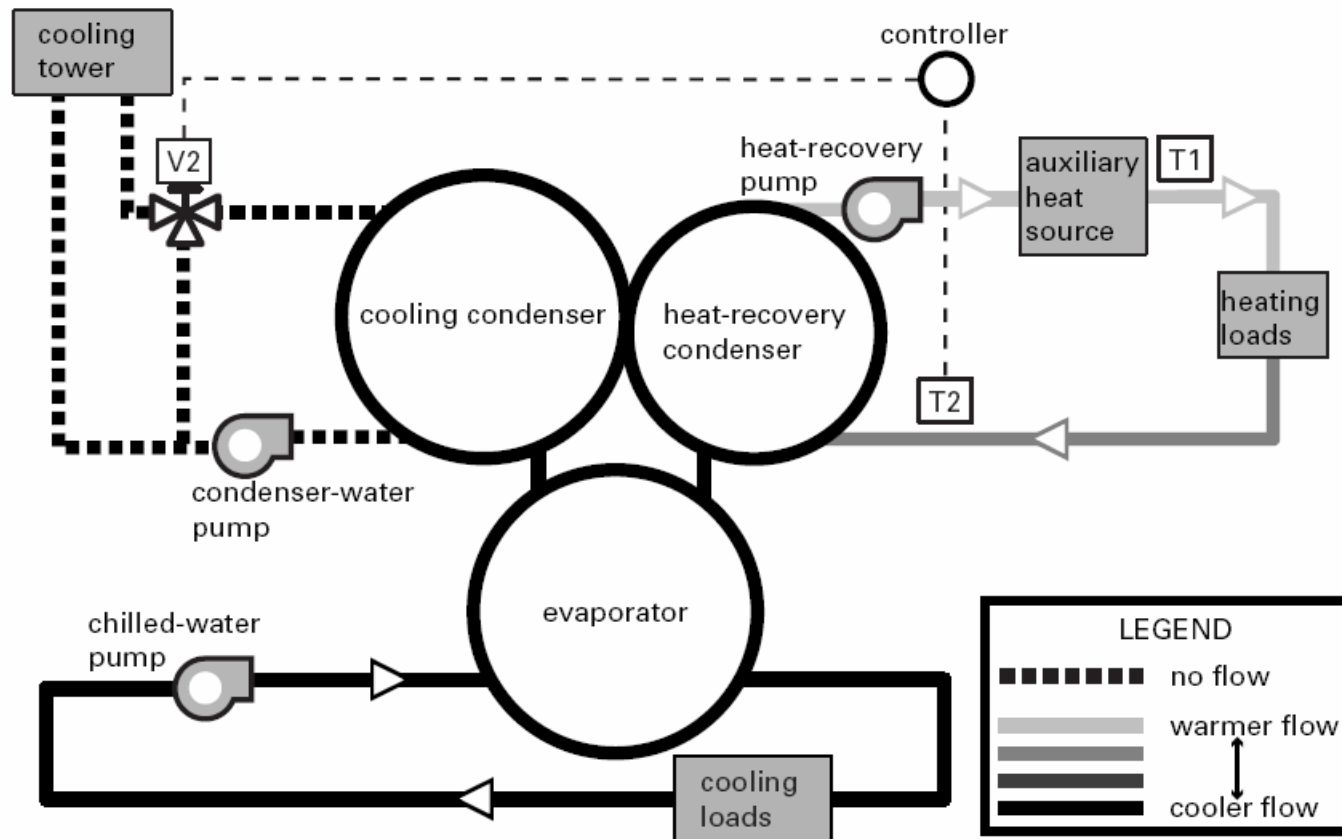


Single Bundle Heat Recovery



Double Bundle Heat Recovery

Figure 15. Double-bundle heat-recovery control: all heat to load



Efficiency Discussions

What is COP?

Coefficient of Performance:

- $COP = \text{Btuh out} / \text{Btuh in}$

Efficiency Discussions

What is Boiler Efficiency?

Same Thing!

- **Boiler Efficiency = Btuh out / Btuh in**

High Efficiency Boiler Curves

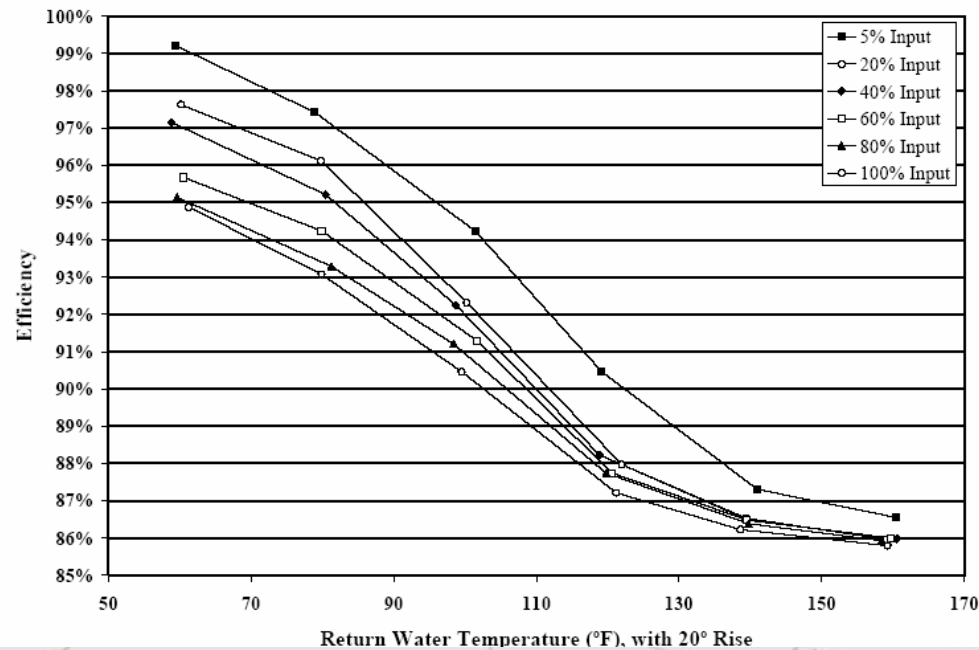
AERCO
International, Inc.

**Boiler Thermal Efficiencies
Benchmark 2.0 Low NOx**

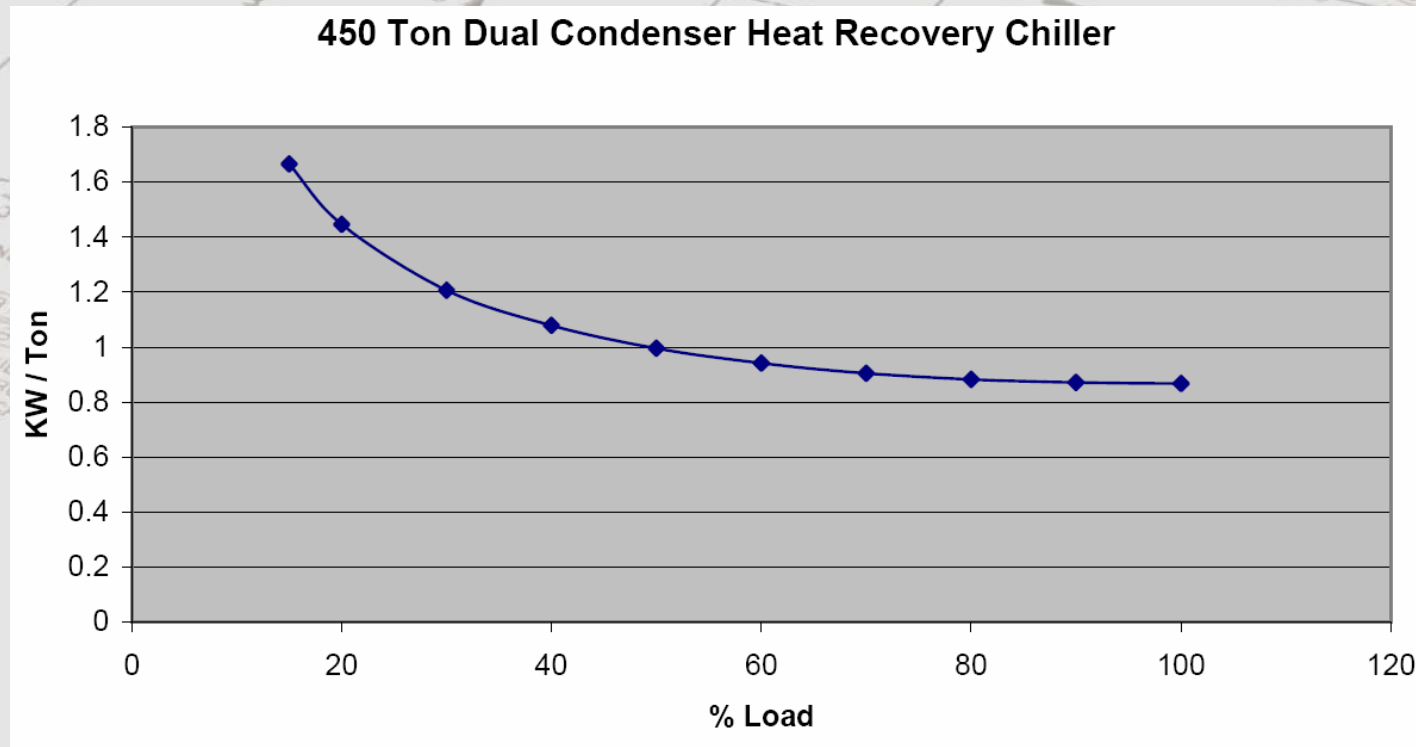
Benchmark 2.0 Low NOx Efficiency Curves

As a condensing boiler, the BMK2.0LN boiler maximizes operating efficiency when applied in a system that leverages cold return water temperatures. As pictured below, the colder the incoming water temperature, the greater the boiler's thermal efficiency.

Thermal Efficiency of BMK2.0LN



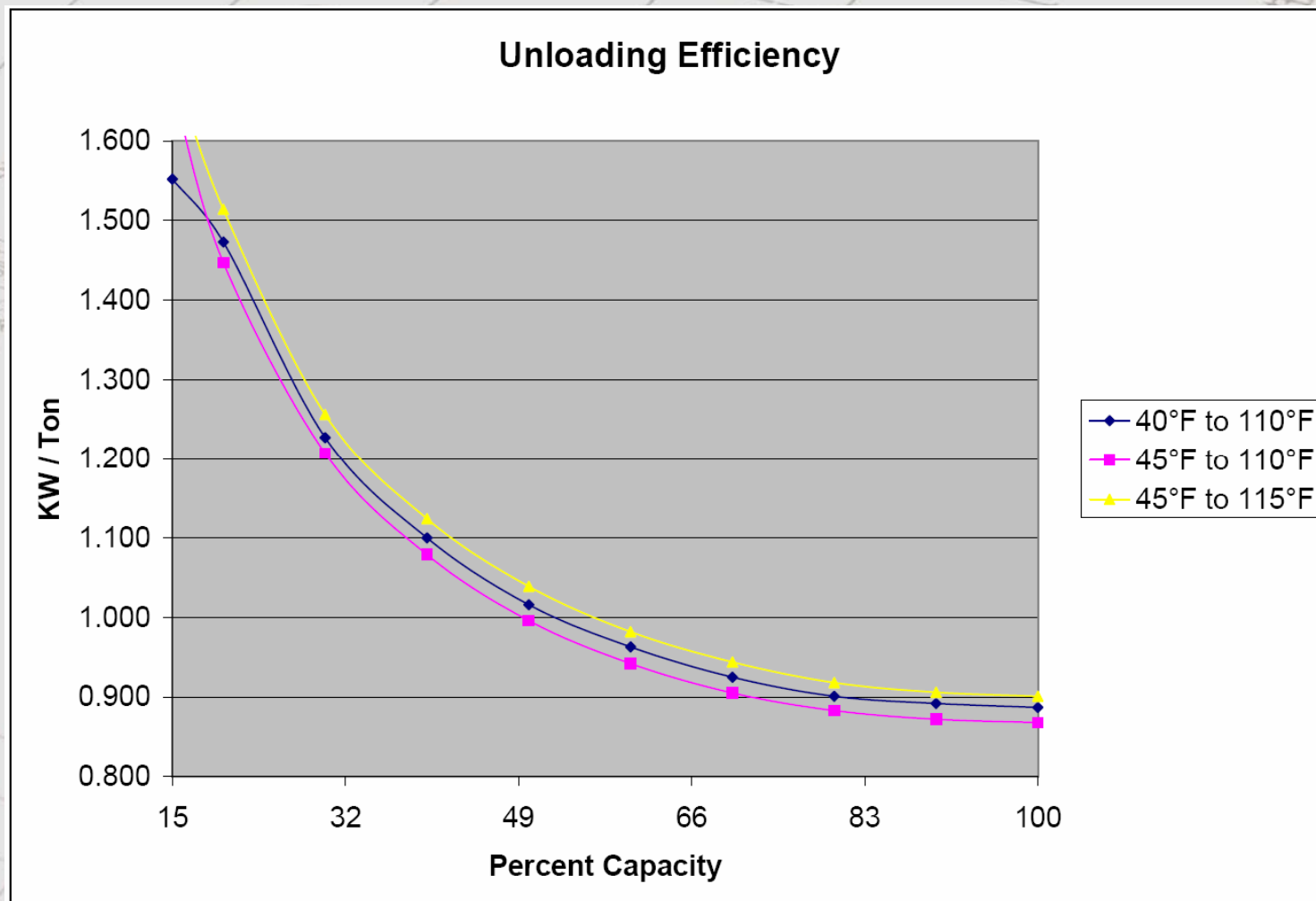
Heat Recovery Chiller Efficiency Multi Stage Centrifugal Sample unloading curve



Heat Recovery Chiller Efficiency

Multi Stage Centrifugal

Sample unloading curves



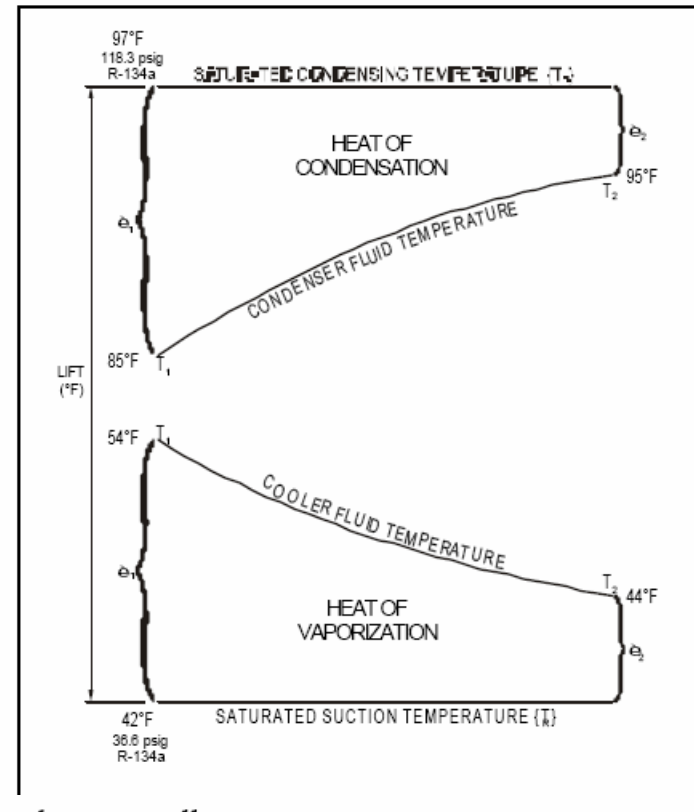
Chiller Efficiency

Refrigerant “Lift”

- Leaving Condenser °F – Leaving Evaporator °F
- Lower lift = Less Compressor Work = higher efficiency
- Approach between Leaving Chilled Water and Leaving Condenser Water sets the lift.

Centrifugal compressors differ from positive displacement compressors (such as scroll, reciprocating and screw). Centrifugals are aerodynamic or turbine type. They move gas by converting kinetic energy to pressure energy. Positive displacement compressors encase a quantity of refrigerant in a decreasing volume during the compression process. They provide excellent lift characteristics. The advantage of centrifugal compressors is their high flow rates capability and good efficiency characteristics.

Figure 3, Heat Exchanger Performance



Carrier 30HXC 206

- Recent downtown high rise office plant retrofit project
- 226 ton screw chiller selection
 - Cooling only NPLV Table 14-1L
 - 85°F to 95°F Condenser Water
 - Code requirement = 5.5
 - Actual = 8.63
 - Heating Mode making 120°F Heating Water
 - 105° to 120°F Heating Ready Condenser water
 - NPLV = 7.79

Compare Heat Recovery Chiller Efficiency to a Boiler

Boiler efficiency

- 0.95 COP
- 3.24 EER
- 3.70 kw /ton

Heat Recovery Chiller 50% Unloaded

- 1.0 kw / ton
- 12.0 EER
- 3.52 COP

Ground Source Heat Pump Heating Efficiency

- Code minimum efficiency with 50°F entering water
 - = 3.1 COP
 - = 10.6 EER
 - = 1.14 kw / ton
- Code minimum Boiler efficiency
 - = 0.80 COP
 - = 2.73 EER
 - = 4.40 kw /ton

Discuss: No beneficial cooling done while heating.

Heat Recovery Chiller Combined Heating and Cooling Efficiency

**VFD Chiller 50% Unloaded Plus
95% Efficient Boiler**

- 2.25 kw / ton
- 5.33 EER
- 1.56 COP

**Heat Recovery Chiller 50% Unloaded
Heating plus Cooling**

- 0.437 kw / ton
- 27.5 EER
- 8.05 COP

Heat Recovery Chiller Combined Heating and Cooling Efficiency



SAM HEAT RECOVERY CHILLER - EFFICIENCY SUMMARY

FULL LOAD SELECTION

Cooling Capacity (tons)	450.0
Cooling Capacity (btuh)	5,400,000
Heating Capacity (btuh)	6,581,100
Total Capacity (heating + cooling)	11,981,100
Total Power (kW)	344.1
Total Power (btuh)	1,175,163
COP (energy out / energy in)	10.20
Part Load Weighting	1%

50% LOAD SELECTION

Cooling Capacity (tons)	225.0
Cooling Capacity (btuh)	2,700,000
Heating Capacity (btuh)	3,309,650
Total Capacity (heating + cooling)	6,009,650
Total Power (kW)	193.3
Total Power (btuh)	660,154
COP (energy out / energy in)	9.10
Part Load Weighting	45%

75% LOAD SELECTION

Cooling Capacity (tons)	337.5
Cooling Capacity (btuh)	4,050,000
Heating Capacity (btuh)	4,925,740
Total Capacity (heating + cooling)	8,975,740
Total Power (kW)	262.6
Total Power (btuh)	896,826
COP (energy out / energy in)	10.01
Part Load Weighting	42%

25% LOAD SELECTION

Cooling Capacity (tons)	112.5
Cooling Capacity (btuh)	1,350,000
Heating Capacity (btuh)	1,880,960
Total Capacity (heating + cooling)	3,230,960
Total Power (kW)	193.4
Total Power (btuh)	660,496
COP (energy out / energy in)	4.89
Part Load Weighting	12%

Heat Recovery Part Load Value = (Full Load COP X 1%) + (75% Load COP X 42%) + (50% Load COP X 45%) + (25% Load COP X 12%)

Heat Recovery Part Load Value = 8.99

Chiller and Boiler Pricing

<u>450 ton Centrifugal</u>	<u>tons</u>	<u>base</u>	<u>high eff.</u>	<u>HE w/ VFD</u>	<u>Double Bundle HR</u>
	450	\$ 99,500	\$ 105,700	\$ 133,000	\$ 139,500
	\$/ton	\$ 221	\$ 235	\$ 296	\$ 310
	delta		\$ 14	\$ 74	\$ 89

<u>800 ton Centrifugal</u>	<u>tons</u>	<u>base</u>	<u>high eff.</u>	<u>HE w/ VFD</u>
	800	\$ 139,900	\$ 153,500	\$ 174,100
	\$/ton	\$ 175	\$ 192	\$ 218
	delta		\$ 17	\$ 43

<u>Multistack</u>	<u>tons</u>	<u>base</u>
	50	\$ 30,000
	\$/ton	\$ 600

<u>200 ton Screw</u>	<u>tons</u>	<u>base</u>
	200	\$ 53,000
	\$/ton	\$ 265

<u>High Efficiency Boiler</u>	1800 MBH Output	<u>tons</u>	<u>base</u>
		150	\$ 26,500
		\$/ton	\$ 177

<u>Code Efficiency Boiler</u>	1886 MBH Output	<u>tons</u>	<u>base</u>
		157	\$ 15,492
		\$/ton	\$ 99

Consider Other Operational and First Cost Issues

For Example:

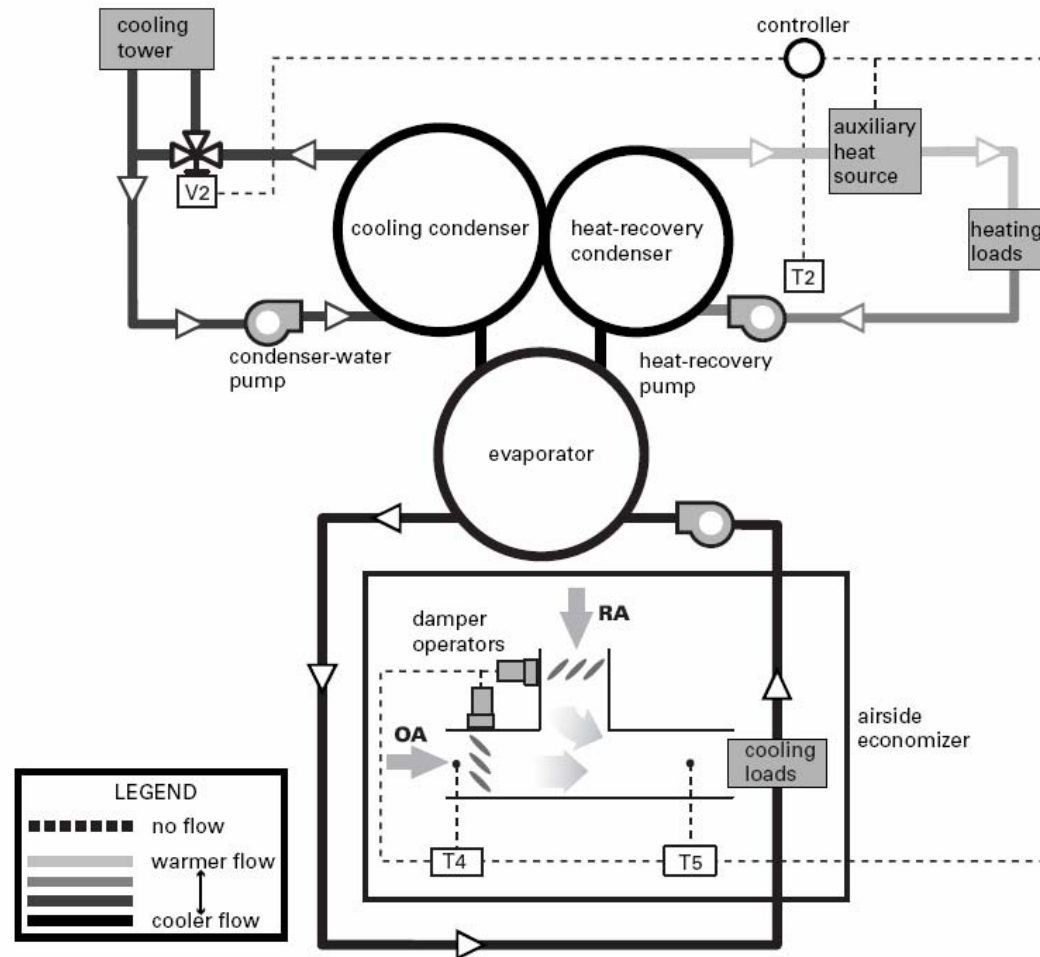
Low Temperature Heating Hot Water

- Additional Coil Rows
- Year Round Fan Energy Penalty

Must have coincident heating and cooling loads

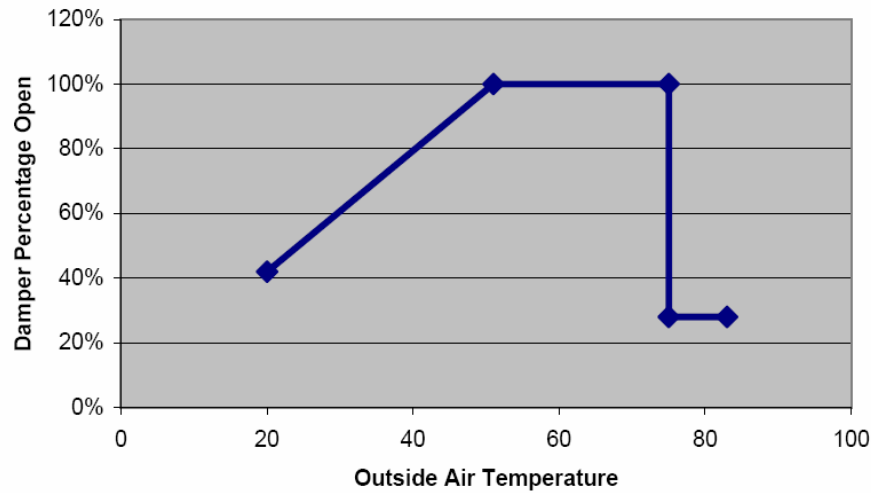
Load Shedding Economizer

Figure 22. Load-shedding economizer

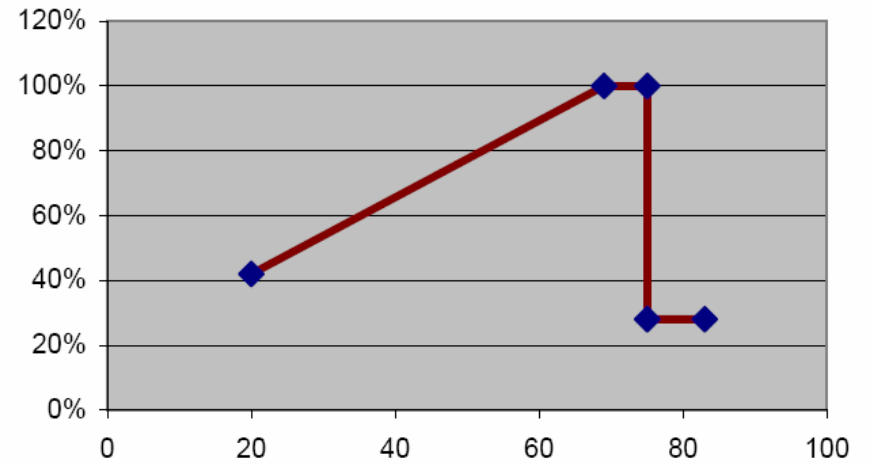


Load Shedding Economizer

Outside Air Economizer



Load Shedding Economizer



Load Shedding Economizer

Remember:

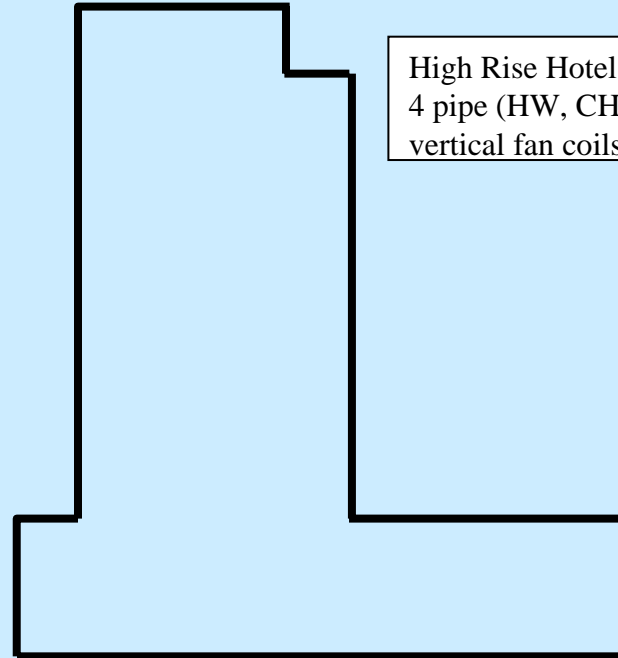
You are on a quest to find available heat that can be rejected / used elsewhere.

So.....If a building has air systems with outside air economizers then the typical strategy is to maximize free cooling with outside air.

But, (AH HA), we could use the heat recovery chiller to cool that air and recover the heat.

Load Shedding Economizer

Example:



High Rise Hotel:
4 pipe (HW, CHW)
vertical fan coils

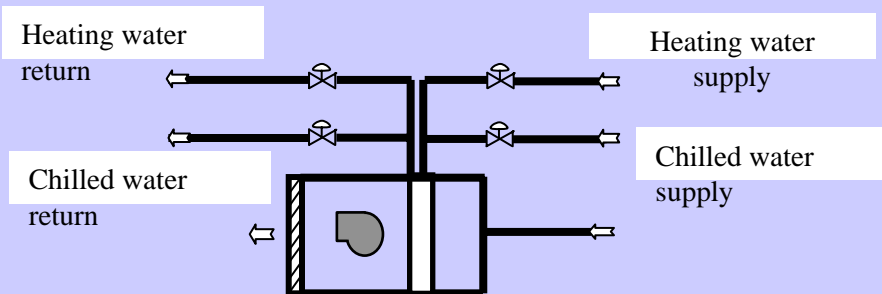
Podium level
ballrooms, meeting
rooms, Restaurant, etc.:
Air Handlers with
airside economizer and
CHW coils

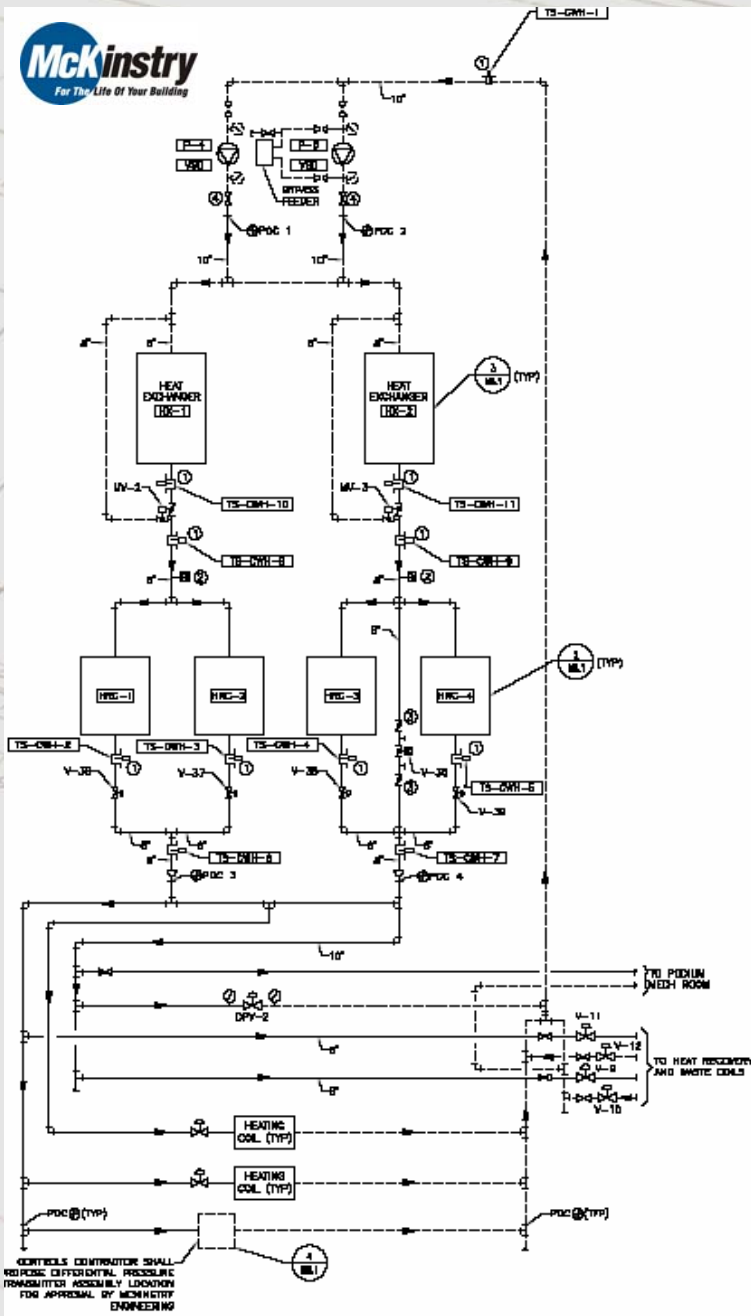
Where could recovered heat be used:

1. Hotel Domestic Water Preheat
2. Hotel Heating Hot Water
3. Restaurant Kitchen Domestic Water Preheat
4. Kitchen Makeup Air Preheat
5. Podium level heating hot water
6. Lobby radiant slab heating

“Waste Coil” Switchover Opportunity

- Relief air systems with chilled water coils can be used to capture heat from building exhaust air.
- Valves can be added to switchover the heating water into the exhaust stream coil which then acts as first stage of condenser water cooling when there is excess heat being produced.
- This can be used to reduce staging by allowing allow excess heat production in addition to saving cooling tower energy

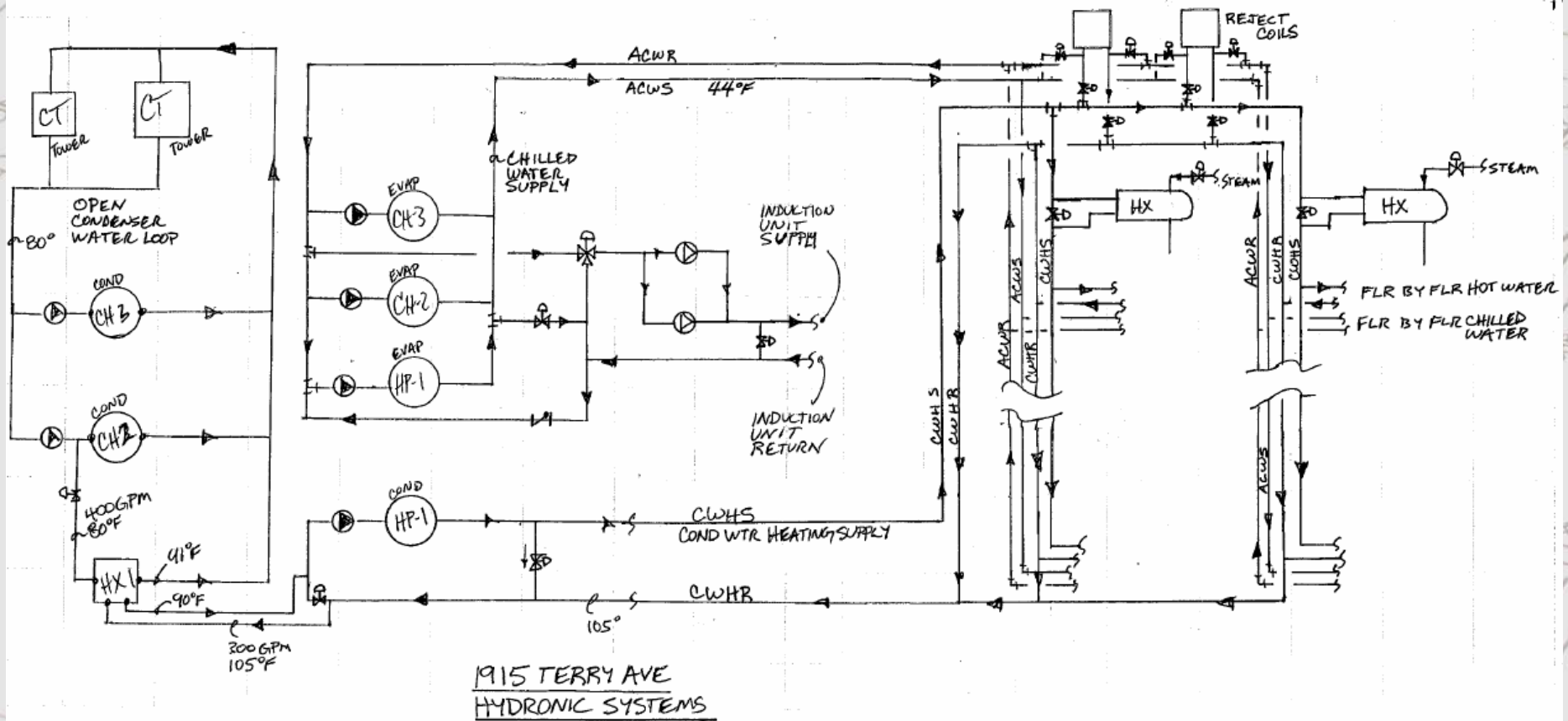




Another Project: Single Bundle with Heat Exchanger and “Waste” Coils with Switchover



Another Project with “Waste” Coils and Switchover



Seattle Art Museum Washington Mutual Center



SAM Project Data

Present Expansion

- *Up through 4th Floor*
- *Anticipated Cooling Load = 500 tons*
- *Anticipated Heating Load =*

Future Expansion

- *Up Through 12th floor*
- *Anticipated Cooling Load = 1400 tons*
- *Anticipated Heating Load = 19500 MBH*

SAM Plant Description

- *Water cooled chillers*
 - 50 ton Pony Chiller
 - 450 ton Heat recovery chiller
 - » Redundant Cooling Capacity
 - 450 ton High Efficiency VFD chiller
 - 450 ton High Efficiency VFD chiller Future
 - 450 ton High Efficiency VFD chiller Future
- *Seattle Steam Generated Hot Water*
 - 19500 MBH Steam to water HX
- *VAV Hot Water Reheat*
 - Minimum Airflow = 80% of Design Max
- *No Airside Economizer*
 - SEC 1433 Exception 4

SAM

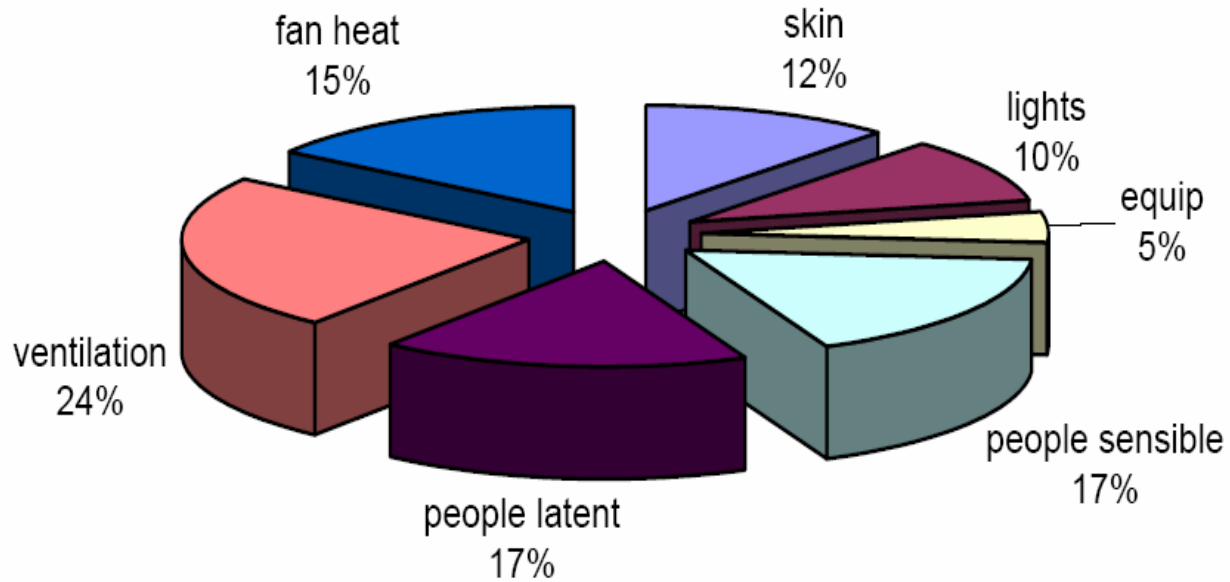
Design Build Mechanical Contractor



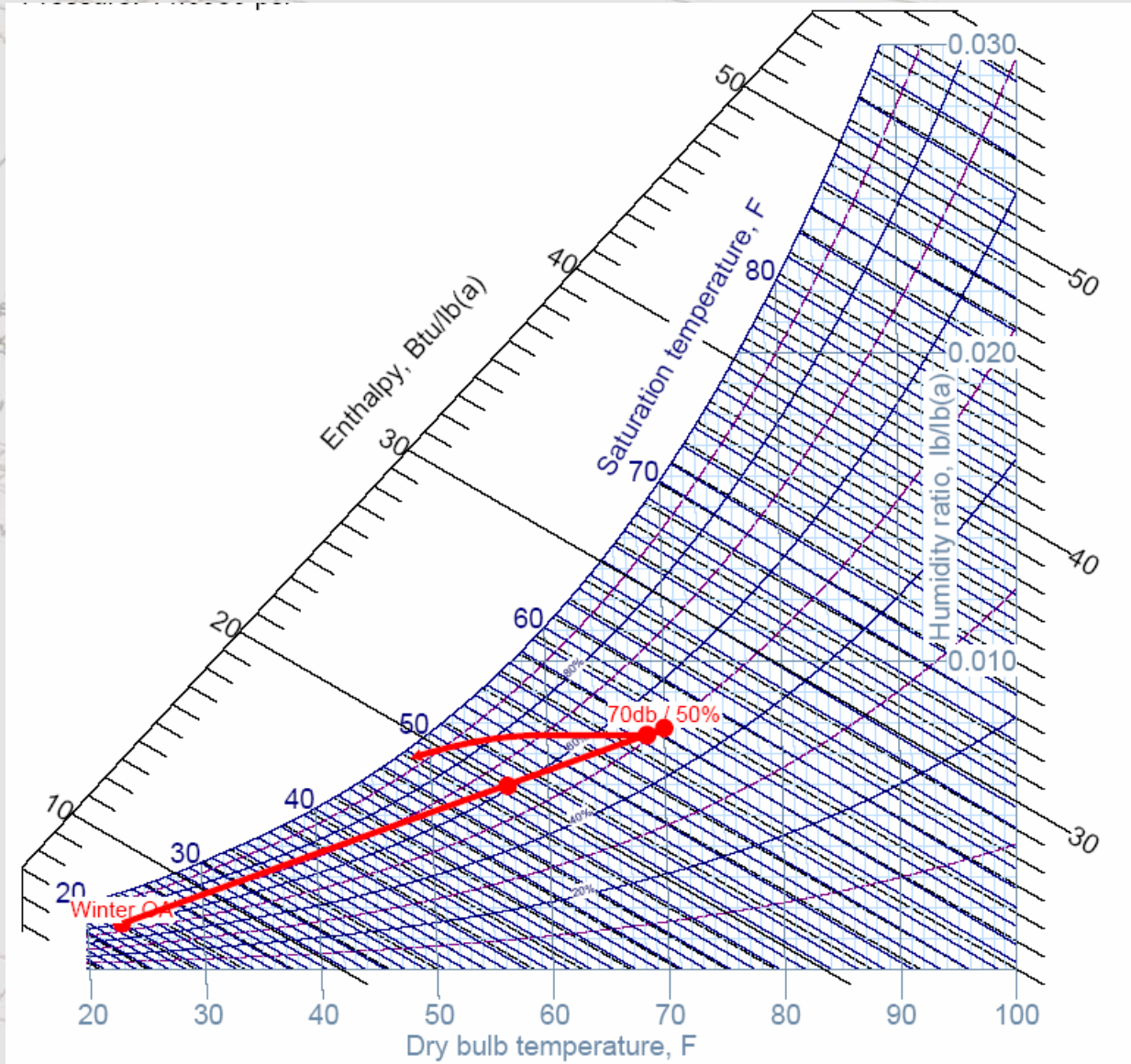
- *Primary Mechanical Engineers*
 - *Scott Rushing, PE (Engineer of Record)*
 - *Mark Gardner, PE*
 - *Michael Frank, PE*
 - *Douglas Holtan, PE*
 - *Eric Vander Mey, PE*
 - *Rae Anne Rushing, PE (Project Director)*

SAM More Stuff

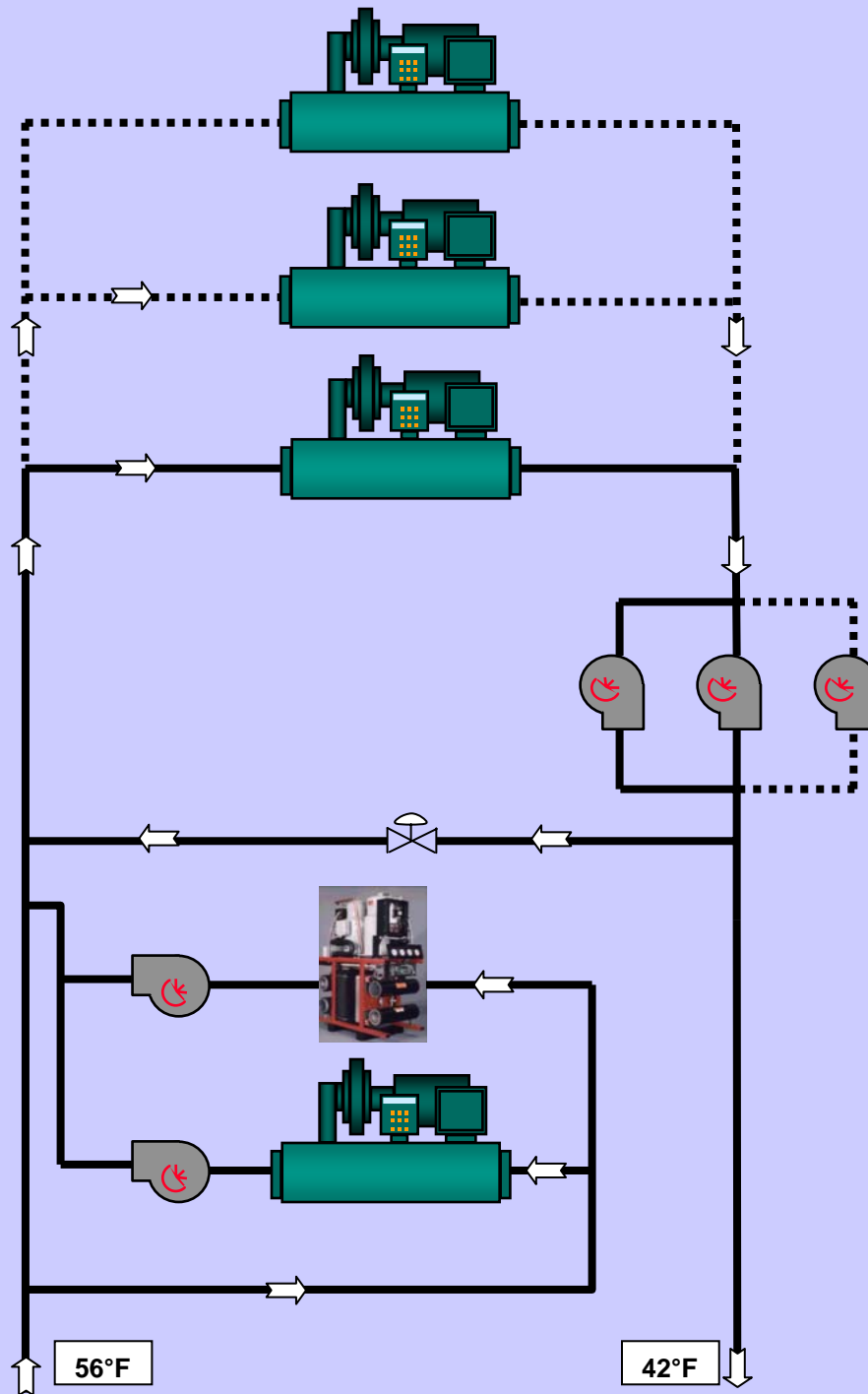
4th Floor Museum Special Exhibition Load Breakdown



Base Load Discussion



SAM Chilled Water Plant Schematic



Series Plant

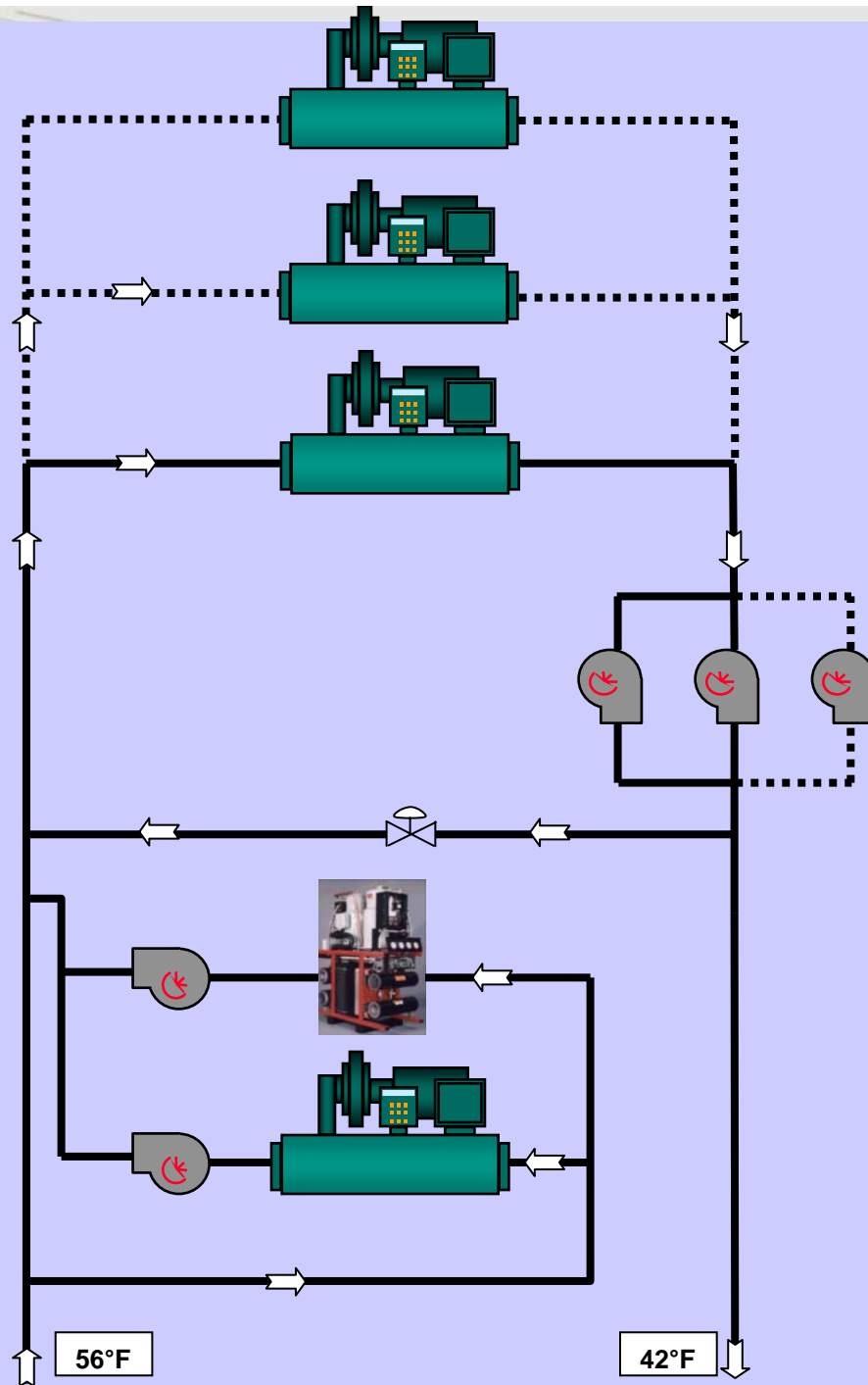
Allows Minimum Lift to
Maximize Efficiency

Lift = Condenser Leaving
Temp – Evaporator
Leaving Temp

Heat Recovery Chiller
(HRC) Entering Evaporator
Temp = CHWR = 56°F

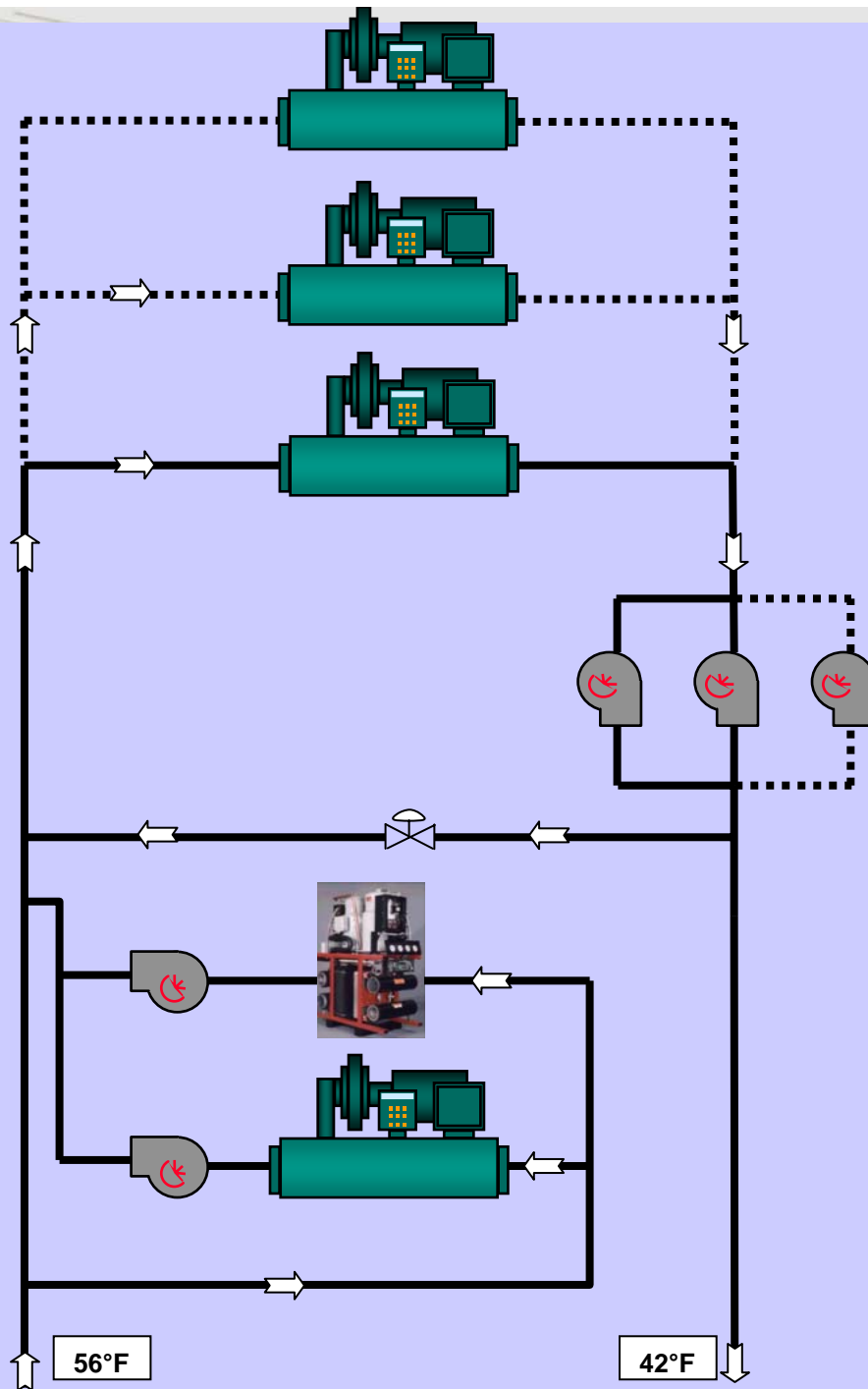
Control to the heating load
and HWS temperature

Do not worry about
leaving CHWS
temperature!

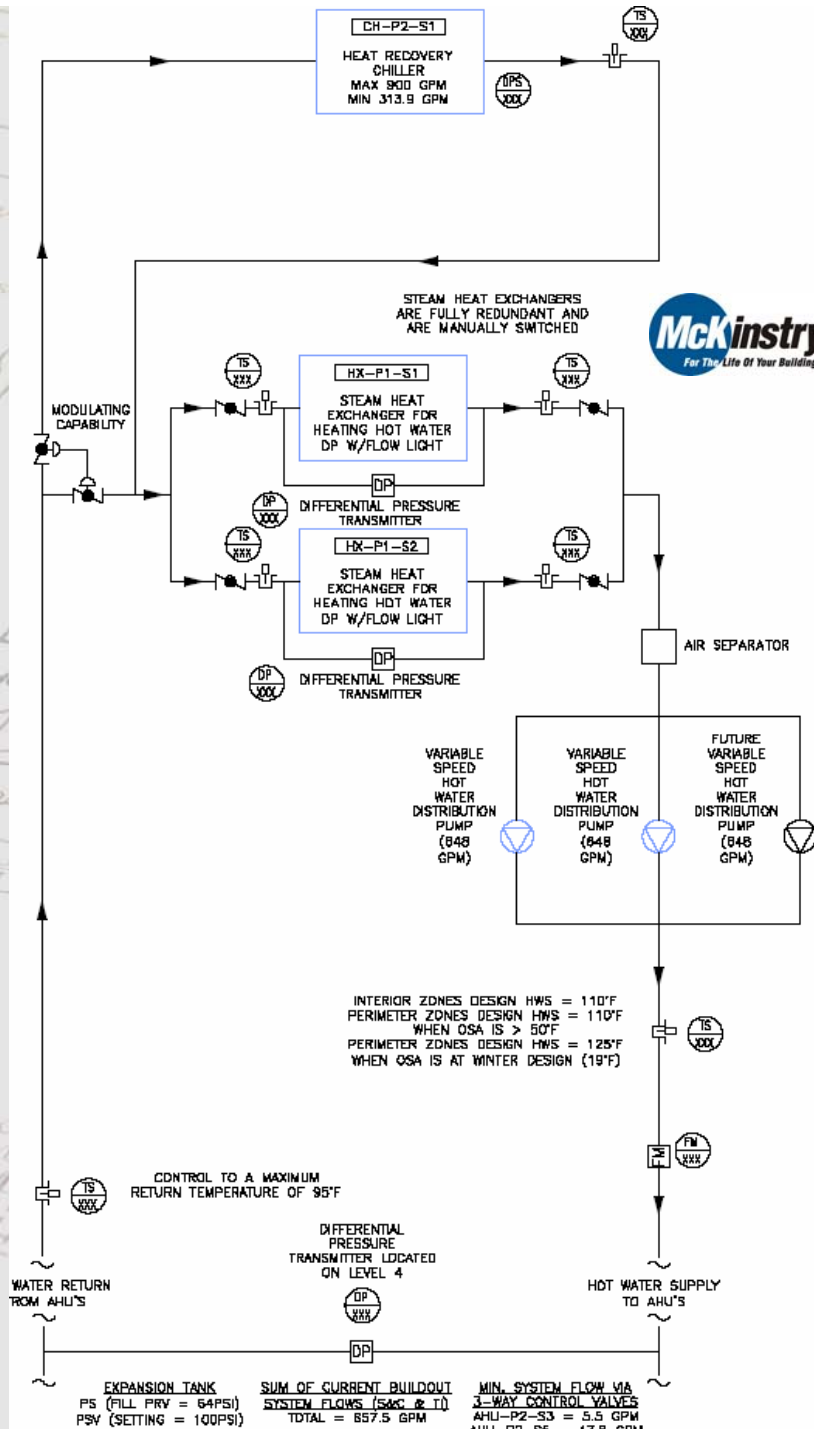


Series Plant

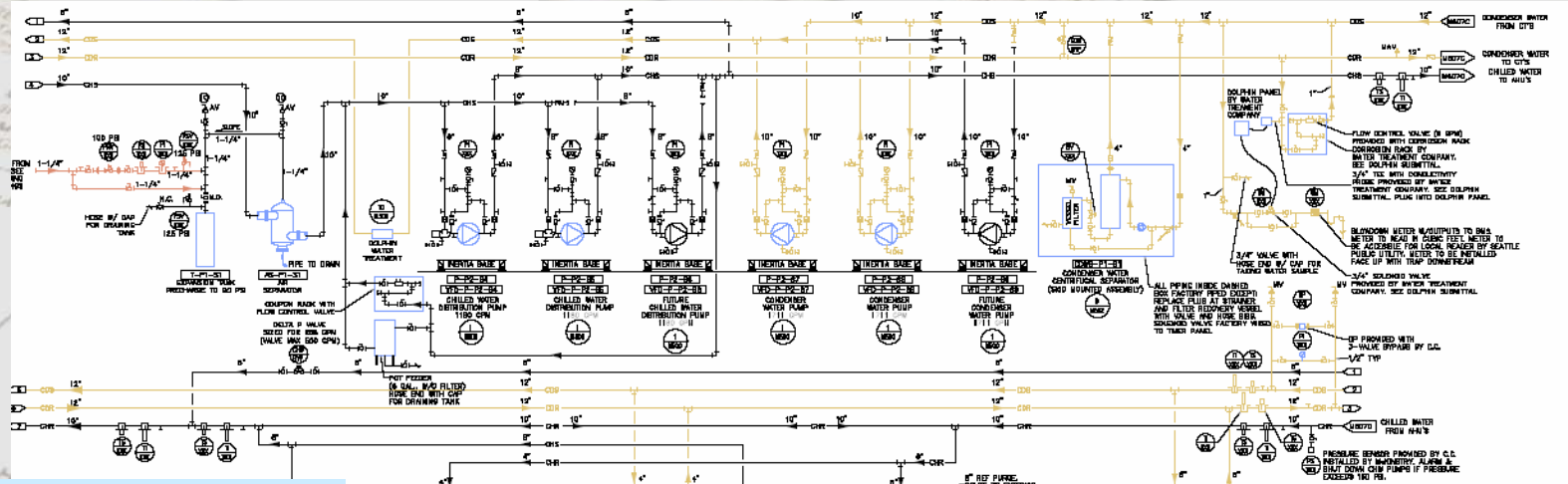
get trane newsletter tips here



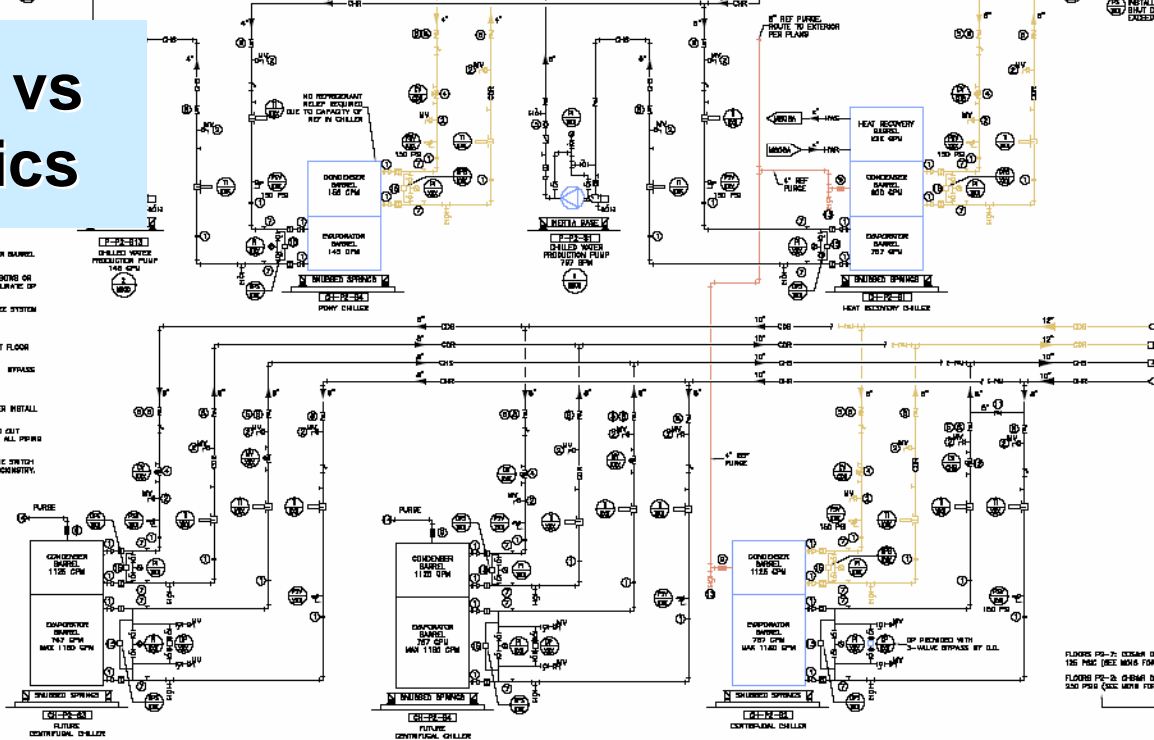
SAM Heating Plant



Block Diagrams vs Piping Schematics



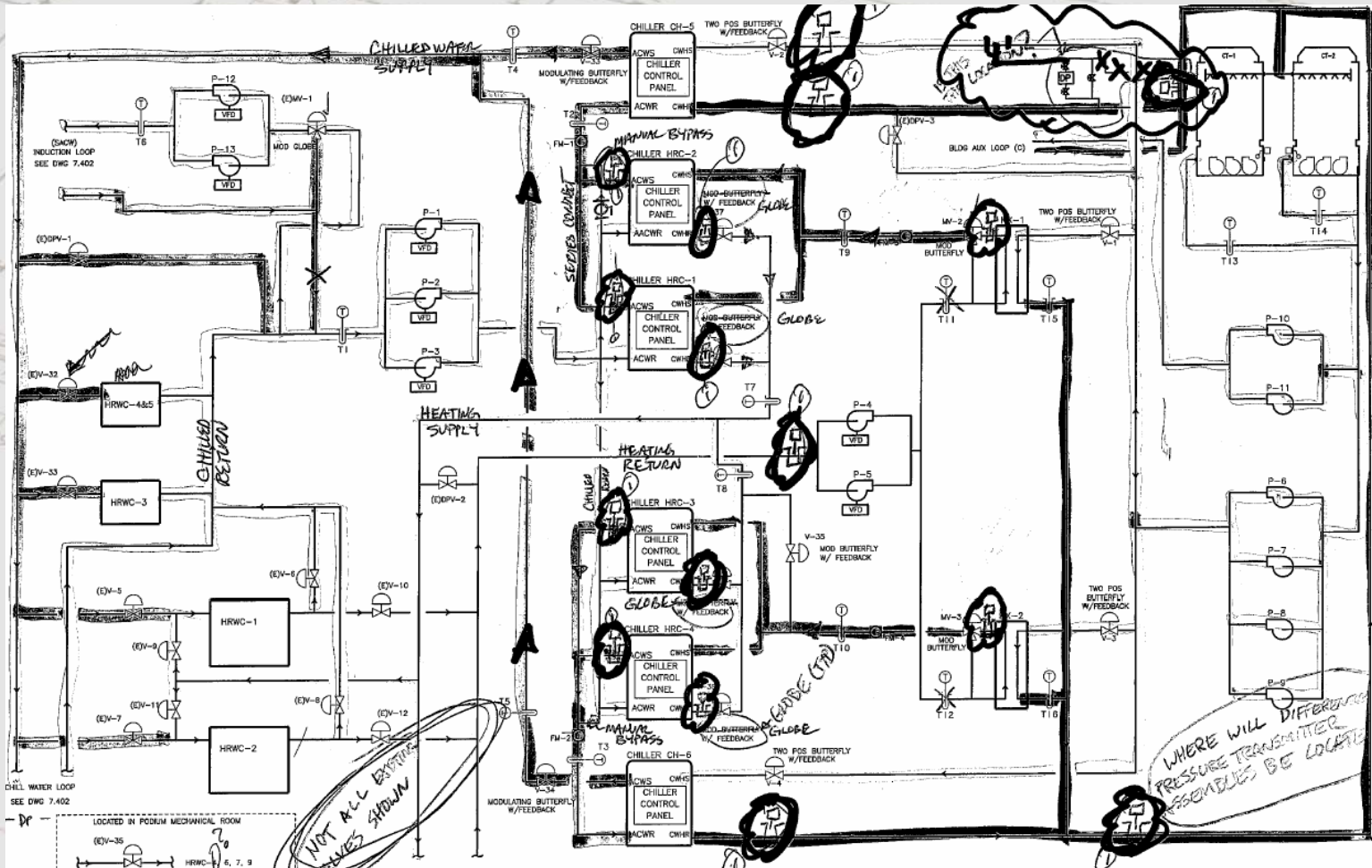
- > BUTTERFLY VALVE MANDATORY STOP.
- > ONLY ONE EQUAL SET TO 1 GPM TO HEED CONDENSER BARREL FLUSHING.
- > LOCATE P/T FIFTS SUCH THAT THERE ARE NO ELBOWS OR VALVES BETWEEN P/T FIFTS AND BARREL FOR ACCESS/IF REQUIRED.
- > LOCATE ELBOW TO SLOPE PIPE FLANGE TO MINIMIZE SYSTEM LOAD DURING INTERNAL DRAIN DOWN.
- > STAINLESS STEEL FLEX CONNECTION.
- > PIPE DISCHARGE FROM AUTO AIR VENT TO NEAREST FLOOR DRAIN.
- > VALVE TO BE CLOSED DURING NORMAL OPERATION. SPINNAE PROVIDED FOR DRAILER MAINTENANCE.
- > TRAP FLANGE CONNECTION DC.
- > PROVIDE 1/4" (1.6M) AFT DRAIN VALVE. SEE CHILLER INSTALL MANUAL FOR DETAILS.
- > FUTURE CHILLER RESTRICTION VENT TO BE ROUTED OUT SEPARATE FROM EXISTENT CHILLER RELIEF VENTS. ALL PIPES TO BE FINISHED IN OUTSIDE.
- > LIMITED ELECTRIC CONTROLS DIFFERENTIAL PRESSURE SWITCH MAX 100 PROVIDED WITH CHILLER INSTALLED BY MCKINSTRY. WED BY G.C.



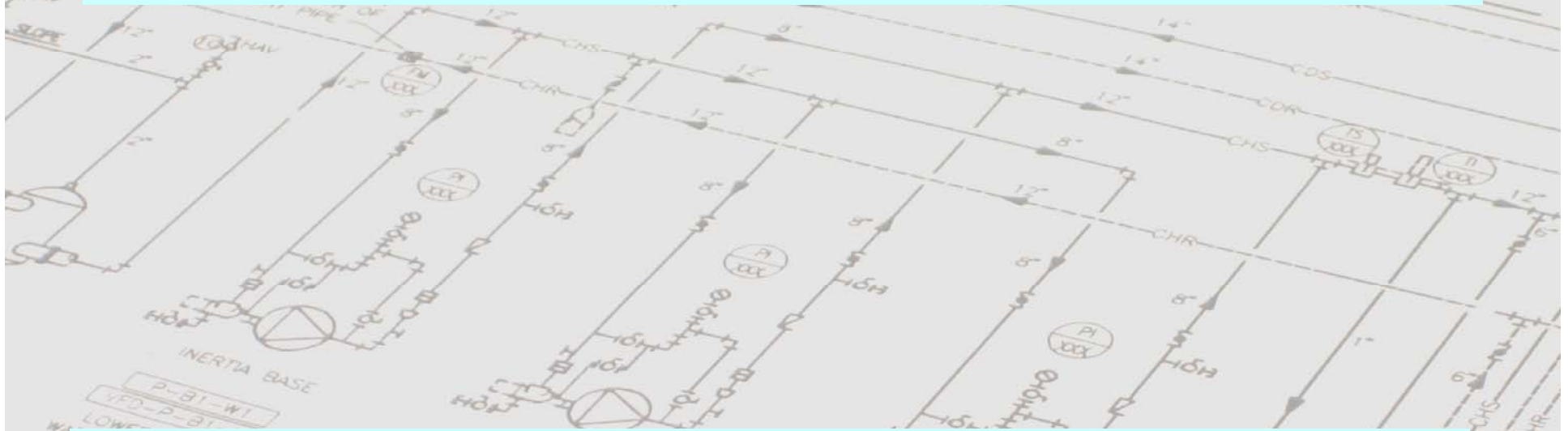
FLOOR PS-7: CLEAN ROOM PRESSURE = 125 PSIG (SEE M06 FOR DETAILS)
 FLOOR PS-3: CLEAN ROOM PRESSURE = 200 PSIG (SEE M06 FOR DETAILS)



Controls Challenges



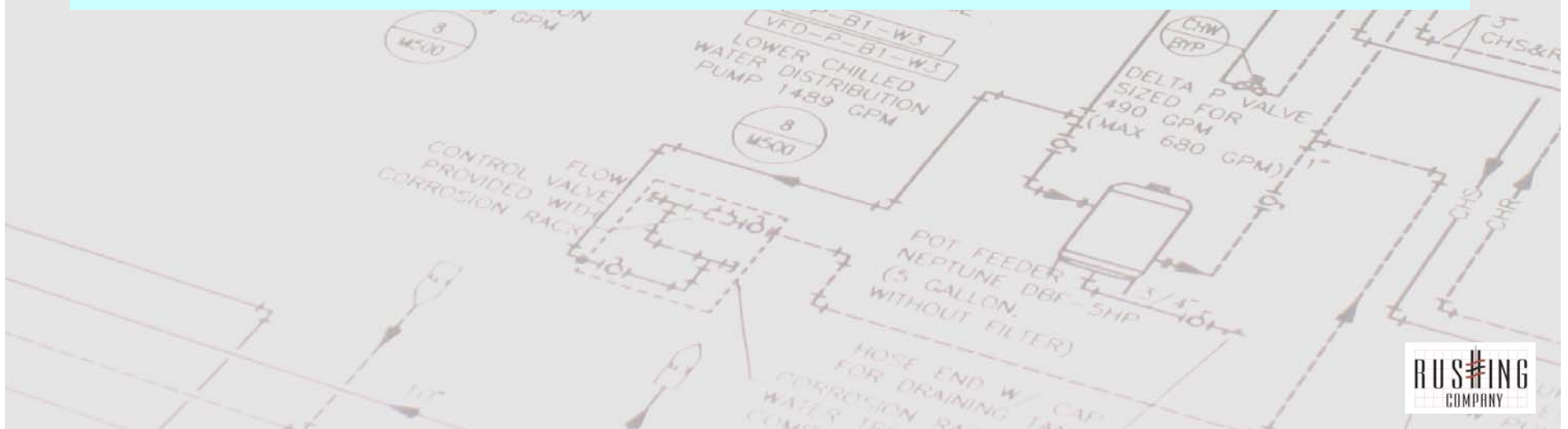
Controls Sequence of Operations



crobat Documer

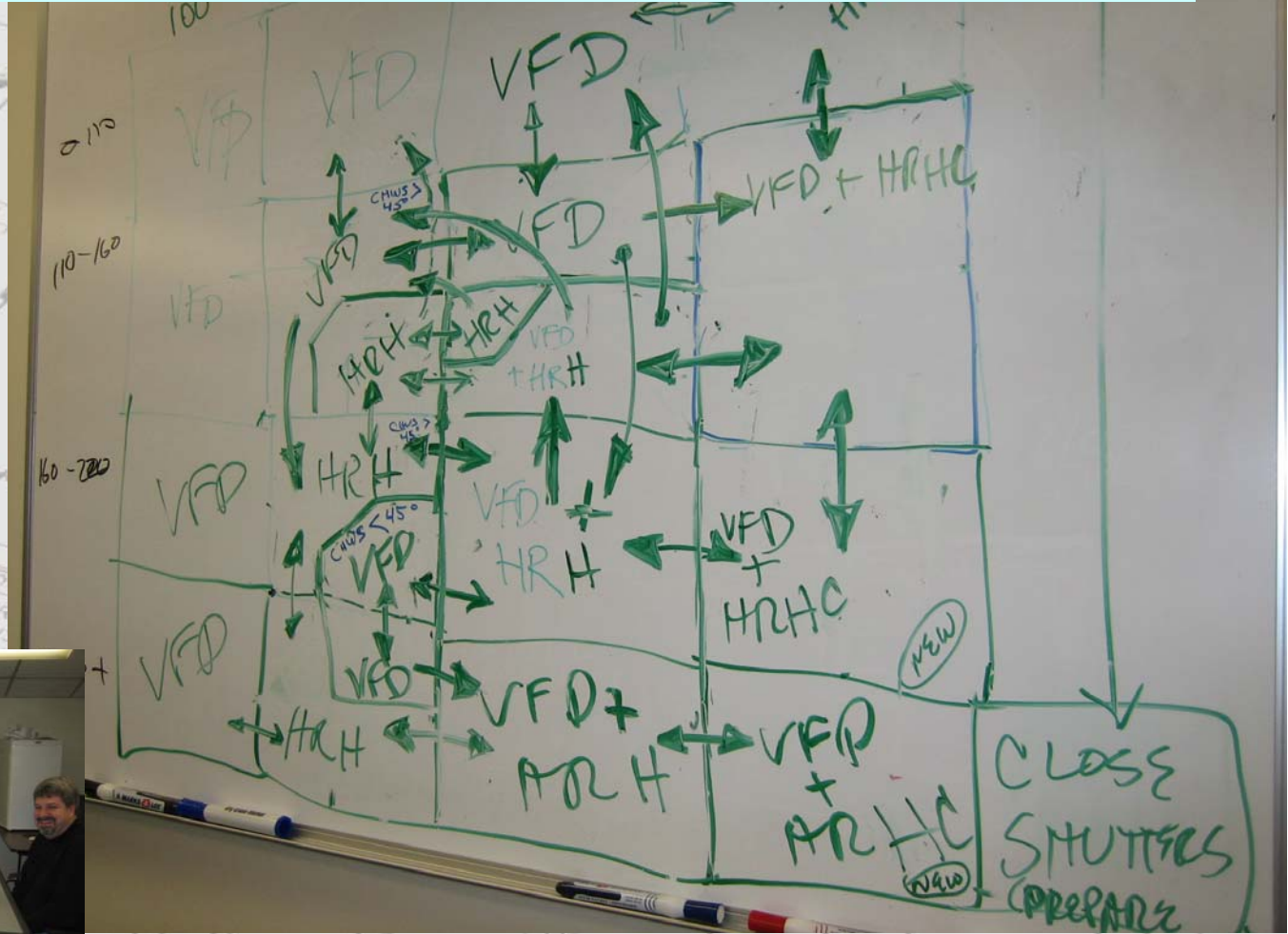


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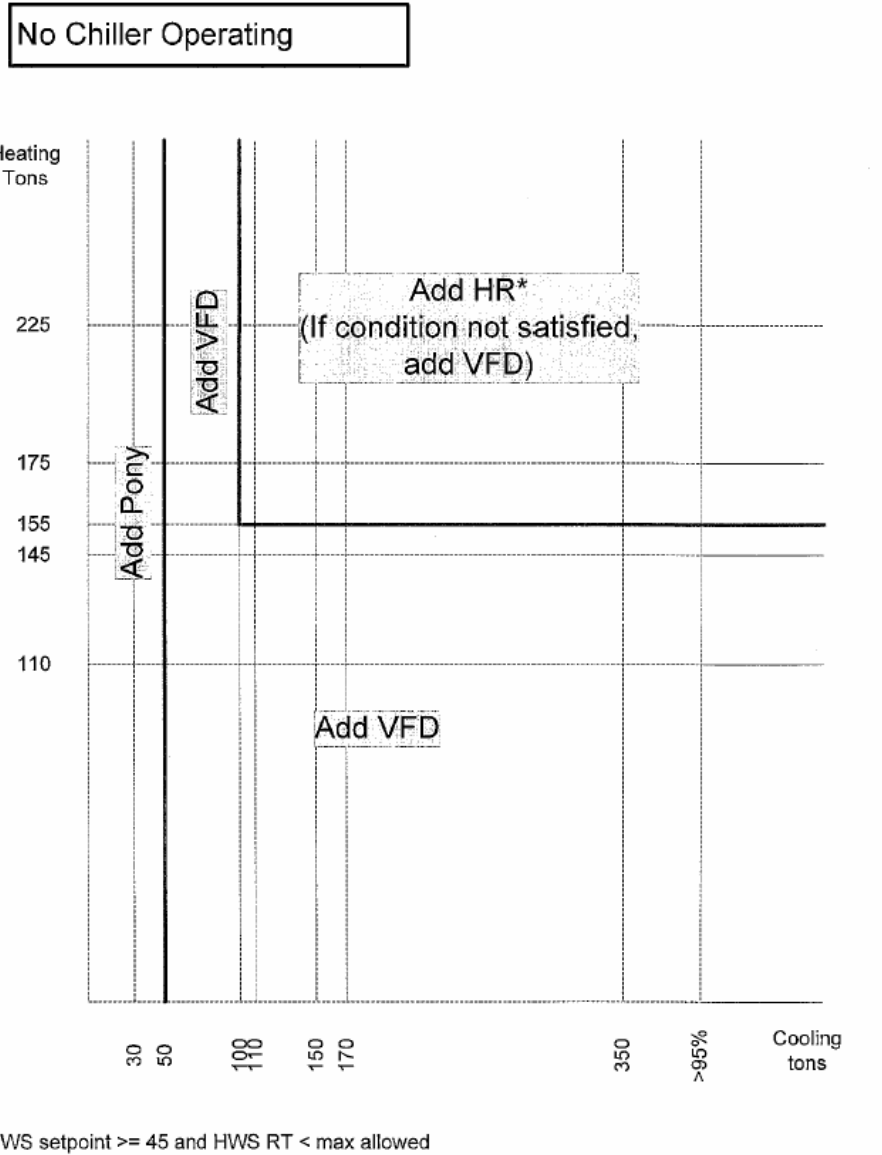


Plant Load Maps

Go team

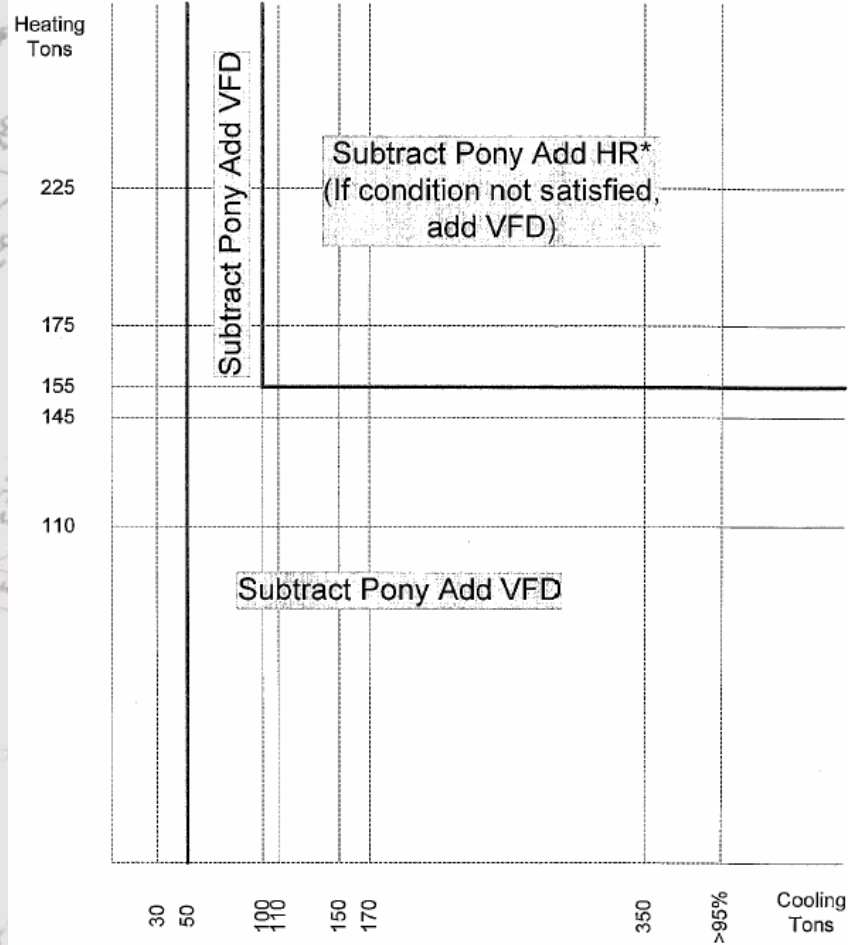


Plant Load Maps



Plant Load Maps

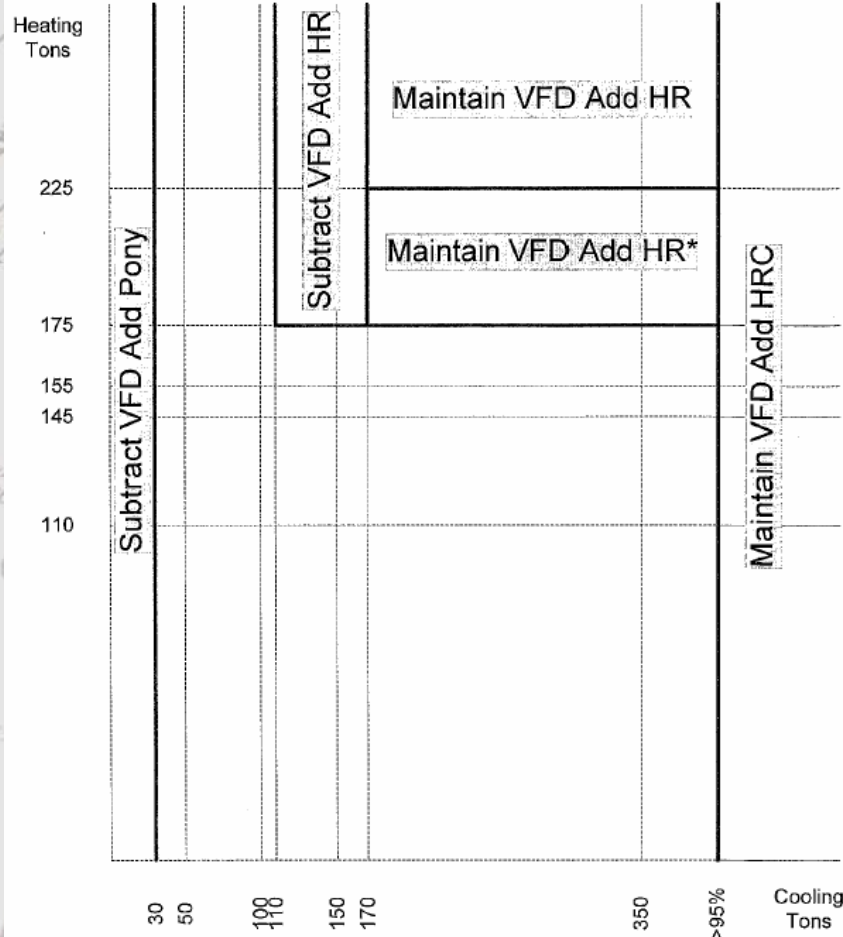
Pony Operating



HWS setpoint ≥ 45 and HWS RT $<$ max allowed

Plant Load Maps

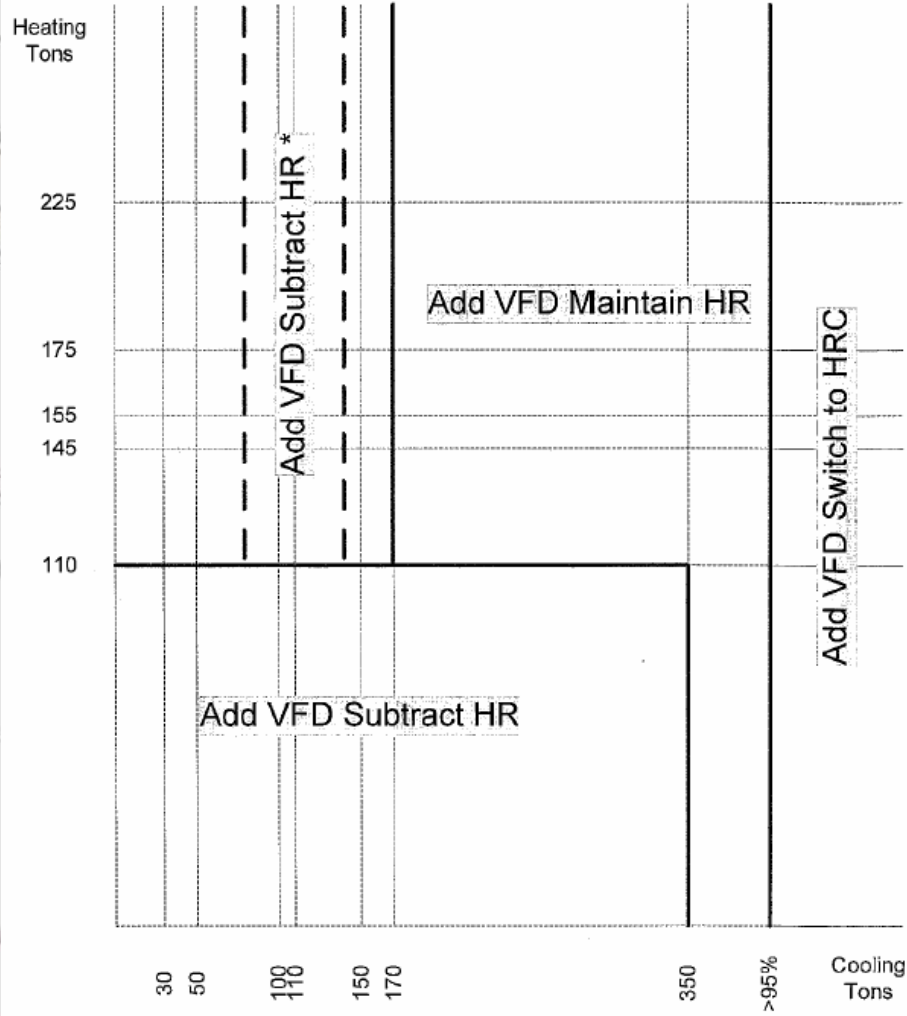
VFD Operating



DELTA P VALVE
SIZED FOR
490 GPM
(MAX 680 GPM)

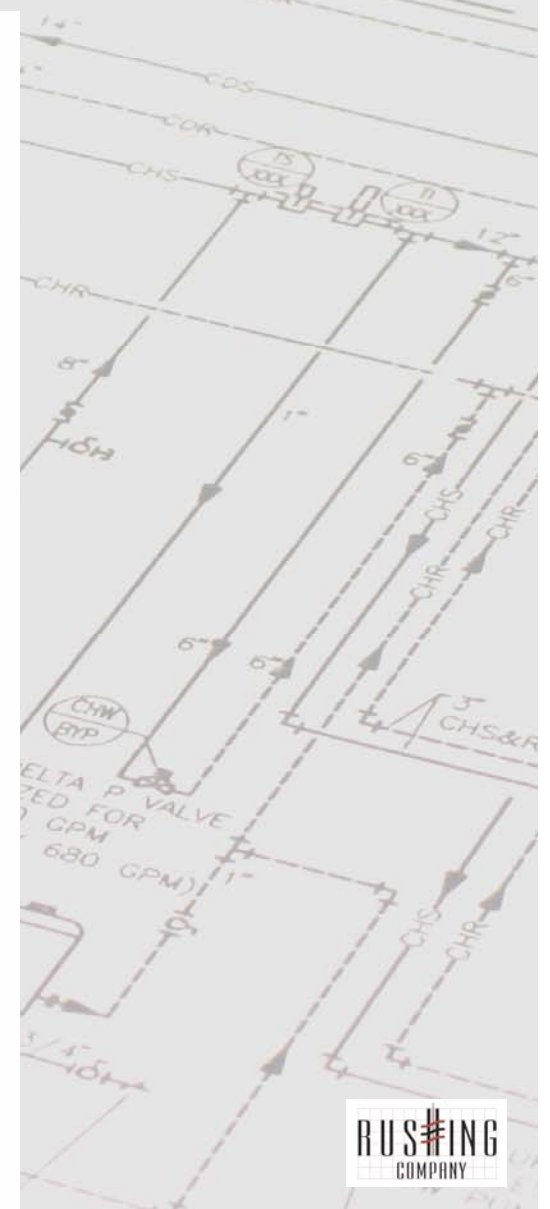
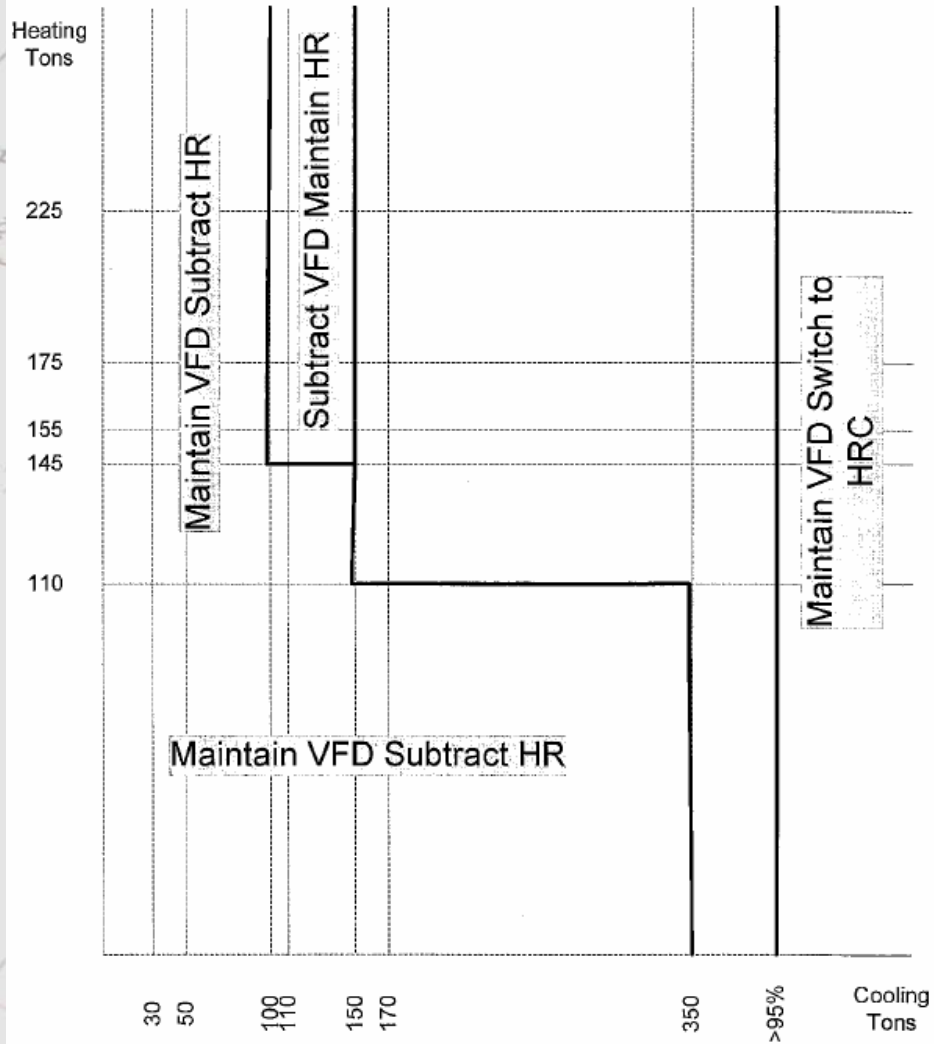
Plant Load Maps

HR Operating

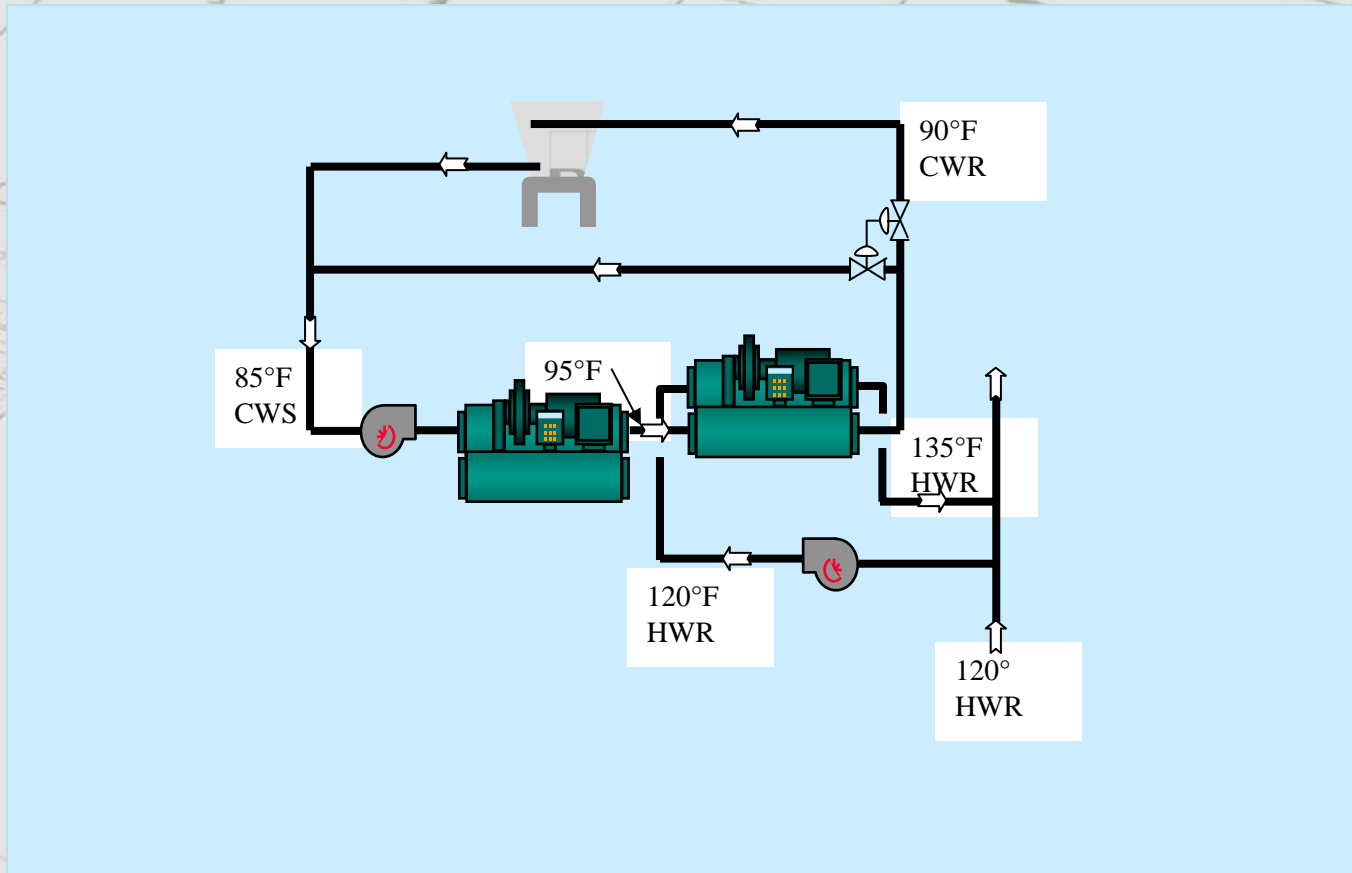


Plant Load Maps

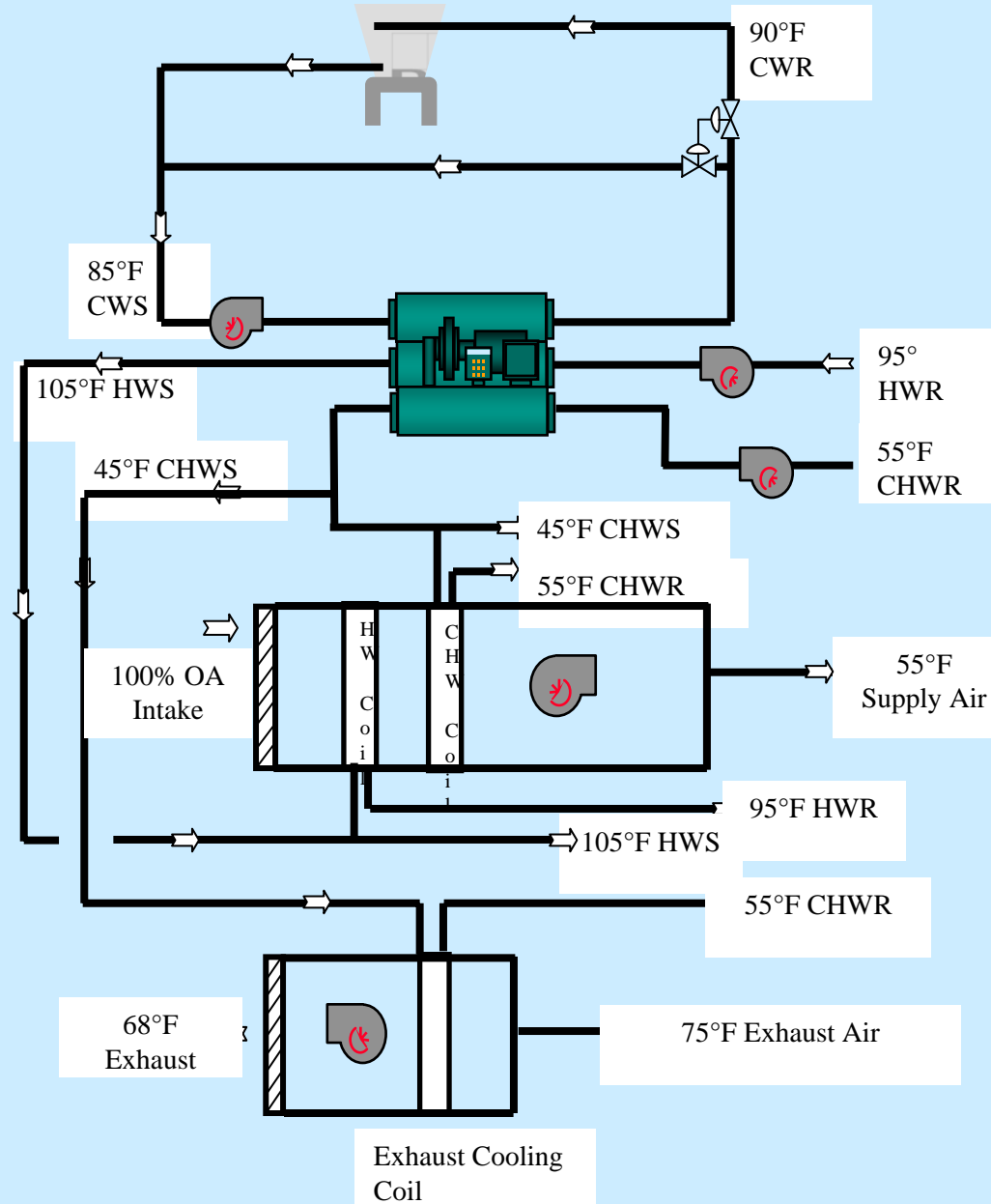
VFD and HR Operating



McQuay Templifier Condenser Water Cooler



Laboratory with "Waste" Coil



Thank You

