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Model Based Building Chilled Water Loop Delta-T Fault Diagnosis

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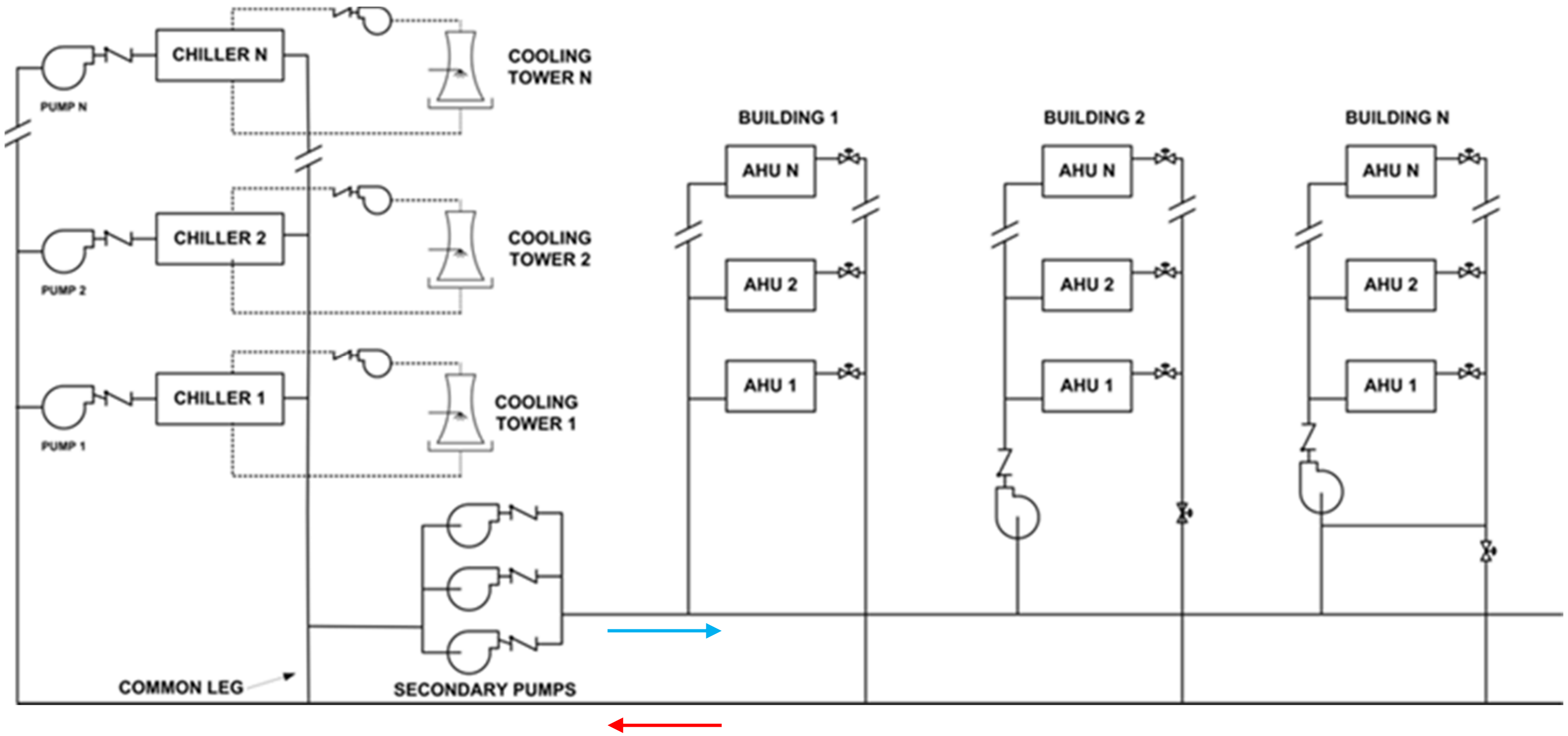
Introduction

- Low chilled Water (CHW) delta-T is not only a waste of distribution pump power but the impact on the central plant even greater
- Many factors contribute to low CHW delta-T
- Avoidable causes and Non-avoidable causes
- CC engineers need to evaluate the chilled water loop delta-T performance and identify avoidable causes

Energy impact of degrading Delta-T



$$Q\left(\frac{Btu}{h}\right) = 500\ GPM\ \Delta T$$

Cooling coil Model

- Effectiveness-NTU model (Braun,1989)

$$\dot{Q}_{dry} = \varepsilon_{dry,a}\dot{m}_a C_{pm} \left(T_{a,i} - T_{w,i}\right)$$

$$\varepsilon_{dry,a} = \frac{1 - \exp(-Ntu_{dry}\,(1 - C^*))}{1 - C^* \exp(-Ntu_{dry}\,(1 - C^*))}$$

$$C^* = \frac{\dot{m}_a C_{pm}}{\dot{m}_w C_{pw}}$$

$$Ntu_{dry} = \frac{UA_{dry}}{\dot{m}_a C_{pm}}$$

Cooling coil Model (Cont.)

$$\dot{Q}_{wet} = \varepsilon_{wet,a}\dot{m}_a(h_{a,i} - h_{s,w,i})$$

$$\varepsilon_{wet,a} = \frac{1 - \exp(-Ntu_{wet}(1 - m^*))}{1 - m^* \exp(-Ntu_{wet}(1 - m^*))}$$

$$m^* = \frac{\dot{m}_a C_s}{\dot{m}_{w,i} C_{pw}}$$

$$Ntu_{wet} = \frac{UA_{wet}}{\dot{m}_a}$$

Cooling coil Model (Cont.)

$$f_{dry} = \frac{-1}{K} \ln\left[\frac{(T_{dp} - T_{w,o}) + C^* (T_{a,i} - T_{dp})}{\left(1 - \frac{K}{Ntu_0}\right)(T_{a,i} - T_{w,o})}\right] \qquad K = Ntu_{dry}(1 - C^*)$$

(Braun,1989)

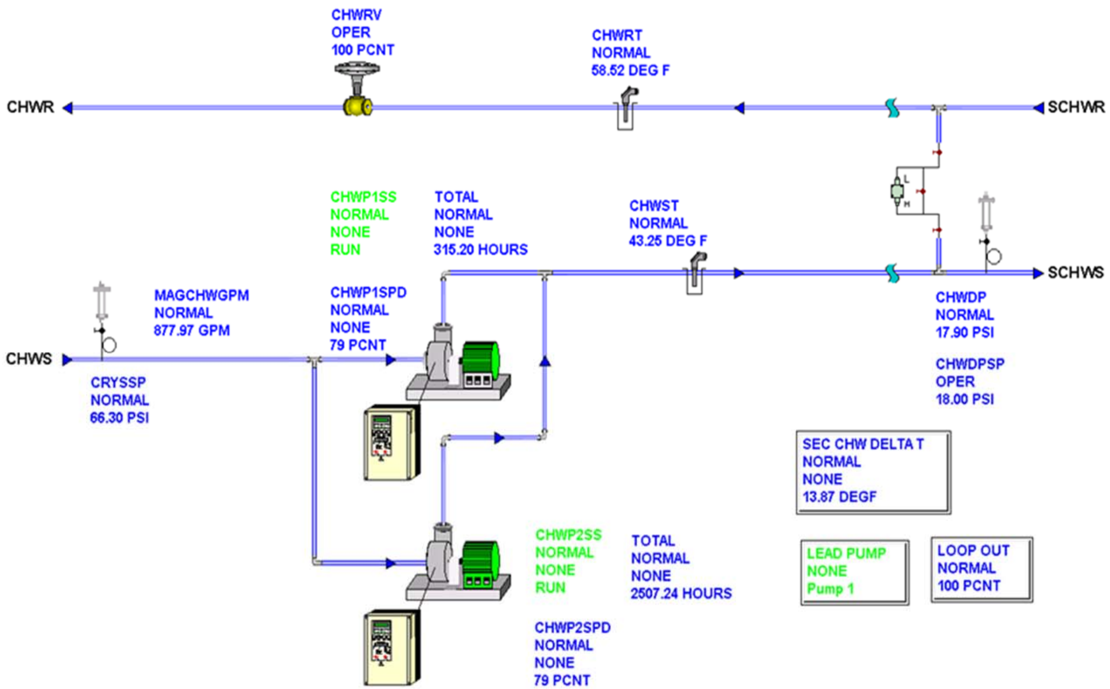
$$\varepsilon_{wet,a} = \frac{1 - \exp(-(1 - f_{dry})Ntu_{wet}(1 - m^*))}{1 - m^* \exp(-(1 - f_{dry})Ntu_{wet}(1 - m^*))} \qquad \varepsilon_{dry,a} = \frac{1 - \exp(-f_{dry}Ntu_{dry}(1 - C^*))}{1 - C^* \exp(-f_{dry}Ntu_{dry}(1 - C^*))}$$

$$T_{w,x} = \frac{T_{w,i} + \frac{C^* \varepsilon_{wet,a}(h_{a,i} - h_{s,w,i})}{C_{pm}} - C^* \varepsilon_{wet,a}\varepsilon_{dry,a} T_{a,i}}{(1 - C^* \varepsilon_{wet,a}\varepsilon_{dry,a})}$$

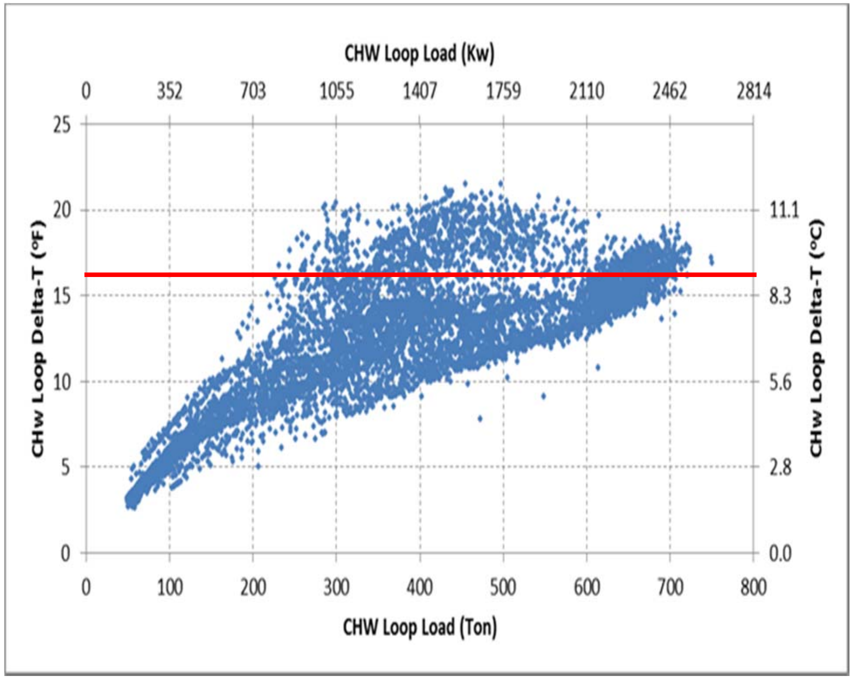
$$T_{w,o} = C^* \varepsilon_{dry,a} T_{a,i} + (1 - C^* \varepsilon_{dry,a}) T_{w,x}$$

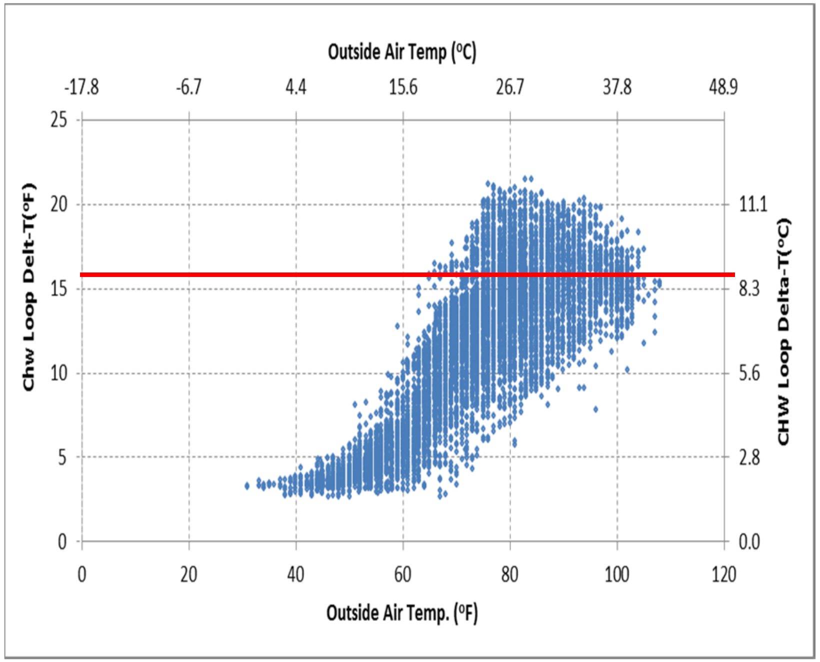
Case study building

- 166,079 ft^2
- Two 20 HP, 840GPM
- 201,670CFM
- OA 161,400CFM



Case study building chilled water loop delta-T





CHW Delta-T Vs. Load

CHW Delta-T Vs. OAT

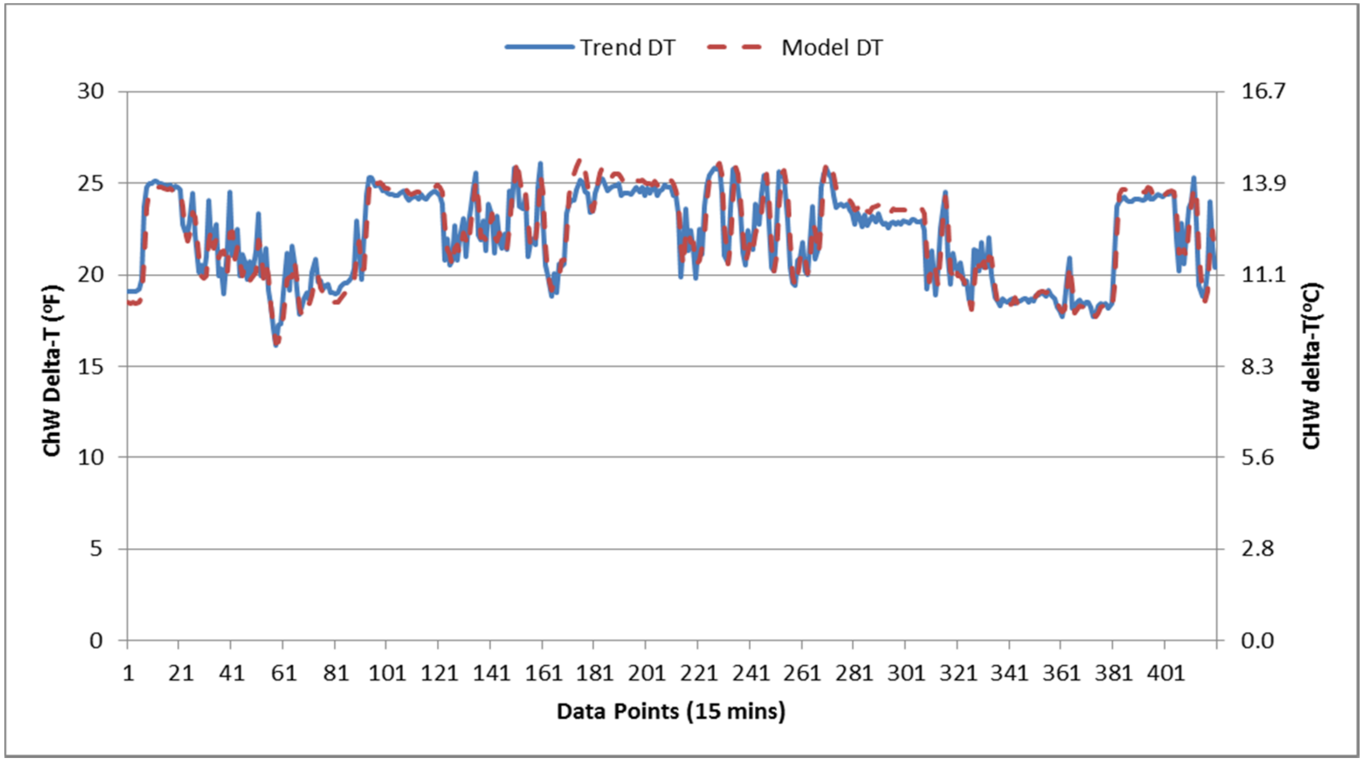
Case study building——AHUs

Unit	Service	Supply cfm	Min Outside Air cfm	Max Outside Air cfm	Design Area SQFT	ENT. Air		LVG. Air		FIN /IN
						D.B °F	W.B °F	D.B °F	W.B° F	
AHU L1	LABS	44,500	44,500	44,500	90	96	76	50.7	50.7	14
AHU L2	LABS	45,000	45,000	45,000	90	96	76	50.9	50.9	14
AHU L3	LABS	45,000	45,000	45,000	90	96	76	50.7	50.7	14
AHU L4	ANIMAL ROOM	11,760	11,760	11,760	29.4	96	76	50.4	50.4	14
AHU LS	SEMINAR	4,500	1,310	4,500	11.5	83.8	69	50.7	50.7	8
AHU LB	BOOKSTORE	4,650	460	4,650	11.5	79.8	63.8	50.8	50.5	8
AHU LC	COPYSTORE	4,300	430	4,300	11.5	79.8	63.8	50.7	50.5	8
AHU LD	DINING	14,160	7,840	14,160	29.4	89.4	71.5	50.5	50.5	14
AHU LO	OFFICES	19,000	5,600	19,000	42.8	83.3	66.8	51.8	51.5	10
AHU SG	SWITCHGEAR	8,800	0	8,800	20.4	90	72	52.5	52.5	14

Case study building——AHUs(Cont.)

No	Parameters	AHU L2	AHU O
1	Width (inch)	130	102
2	Height (inch)	90	55
3	Number of rows	8	6
4	Tube outside diameter (inch)	0.5	0.5
5	Tube inside diameter (inch)	0.45	0.45
6	Tube material	copper	copper
7	Fin/Inch	14	10
8	Fin thickness (inch)	0.008	0.008
9	Fin material	Aluminum	Aluminum
10	Tubes center to center distance (perpendicular to air flow) (inch)	1.25	1.25
11	Tube Spacing (Parallel to air flow) (inch)	1	1.25

Model Calibration

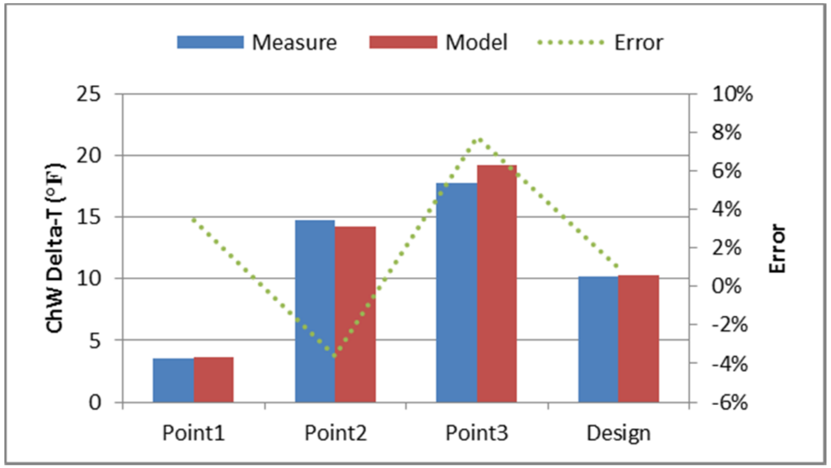


AHU L2 chilled water delta-T(Model Vs. Trending)

CV(RMSE) error is 2.9%

Model Calibration (Cont.)

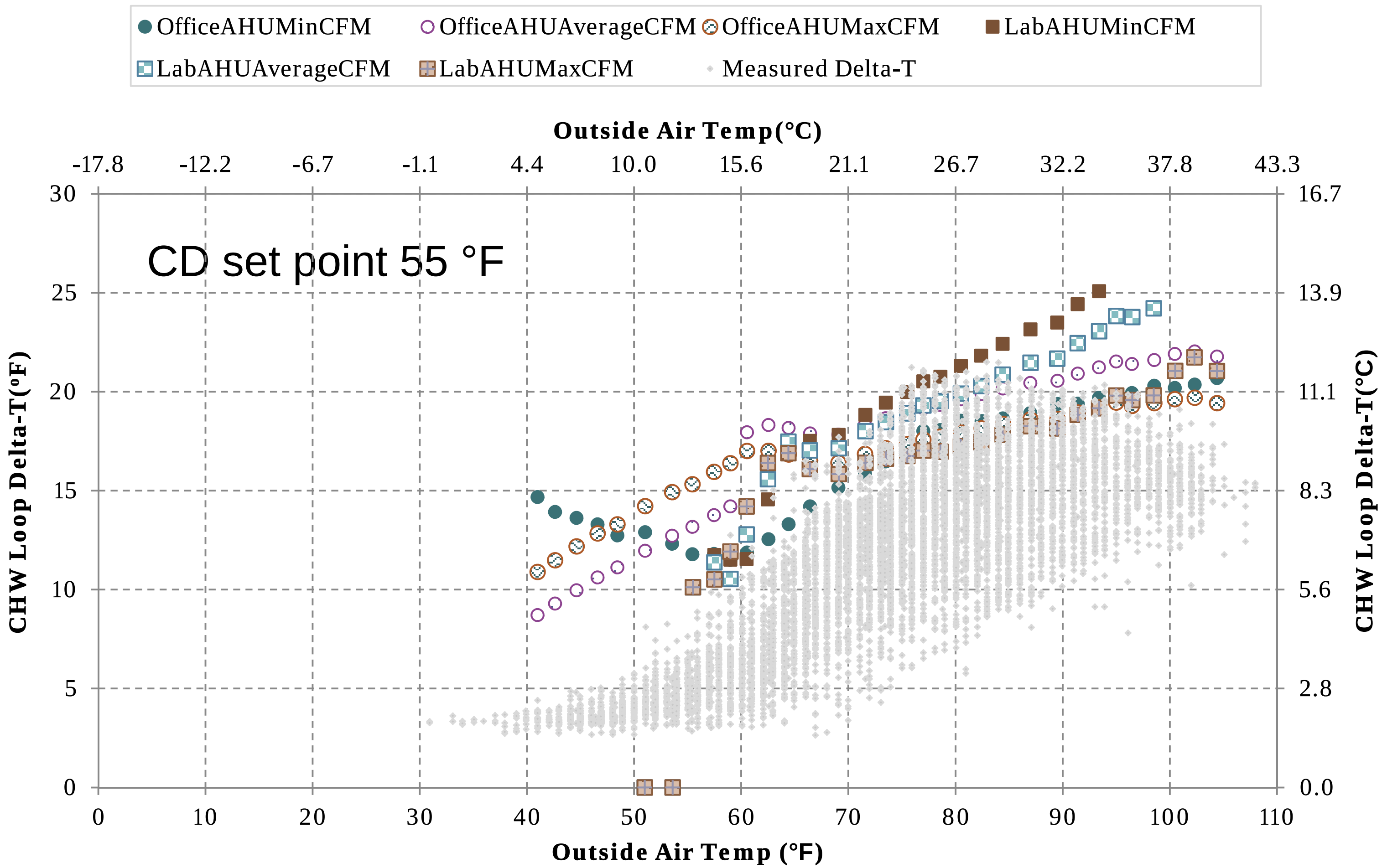
AHU O	Air Side					Waterside		
	flow	Before		After coil		Supply	Return	flow
No	CFM	T (°F)	RH (%)	T (°F)	RH (%)	T (°F)	T (°F)	GPM
1	6,450	74.9	61.6%	45.6	89%	42.8	46.3	224
2	6,450	97.1	26%	50.8	95%	42.8	57.6	55
3	6,450	97.9	25%	55.5	97%	42.8	60.6	35
Design	19,000	83.3	42%	51.7	94%	44	54.2	177



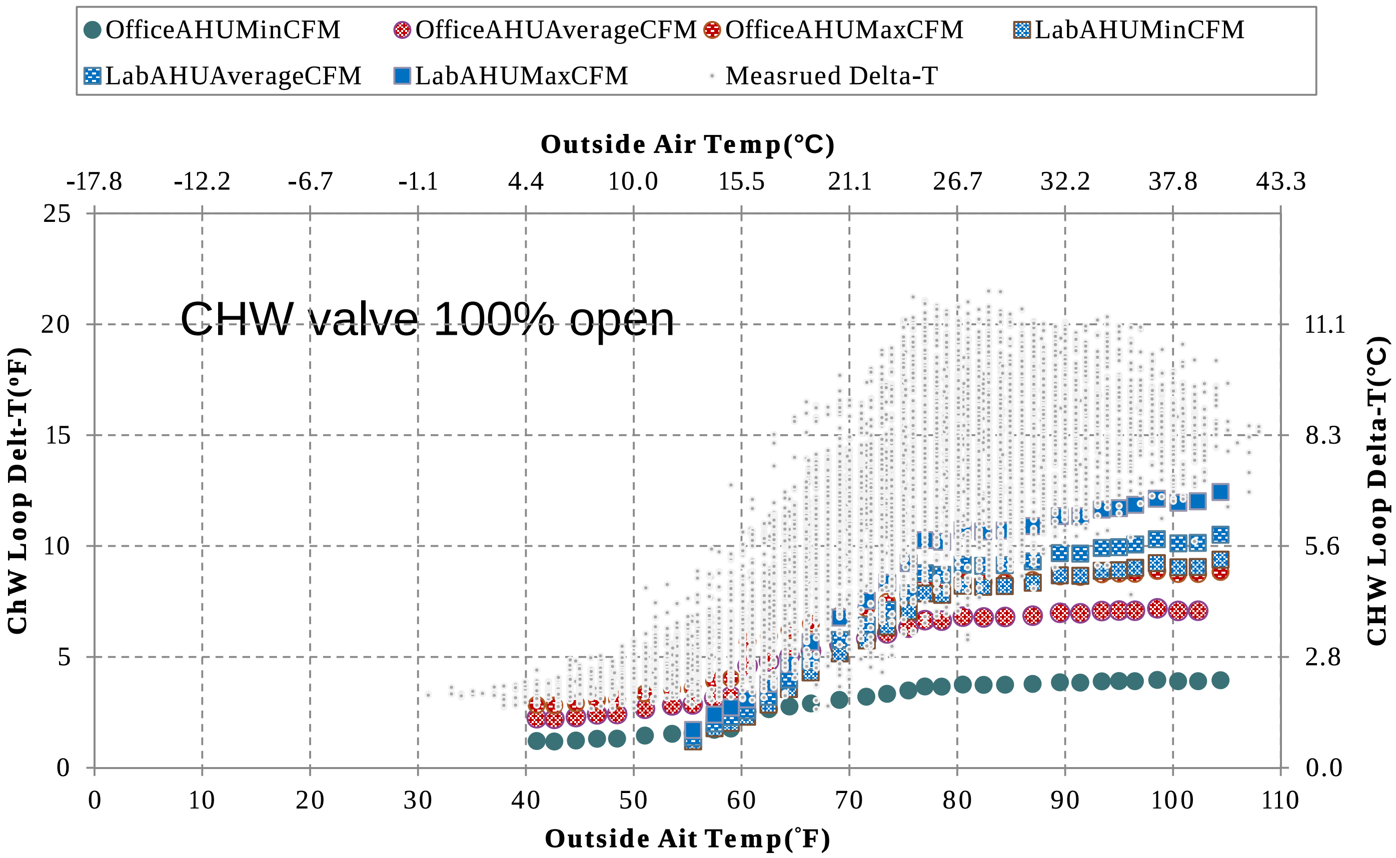
AHU O Model:

CV(RMSE) is 6%

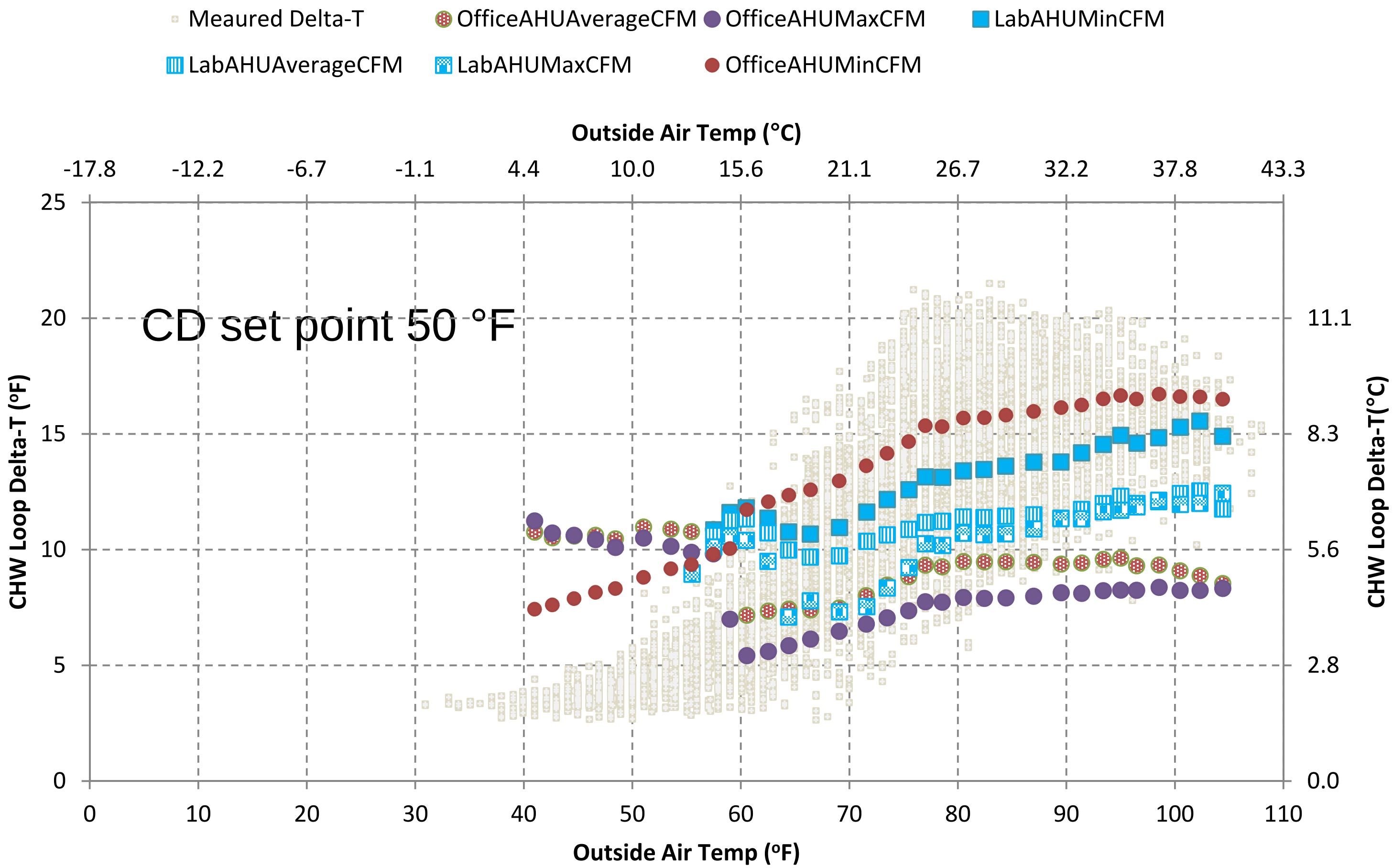
Fault Diagnosis



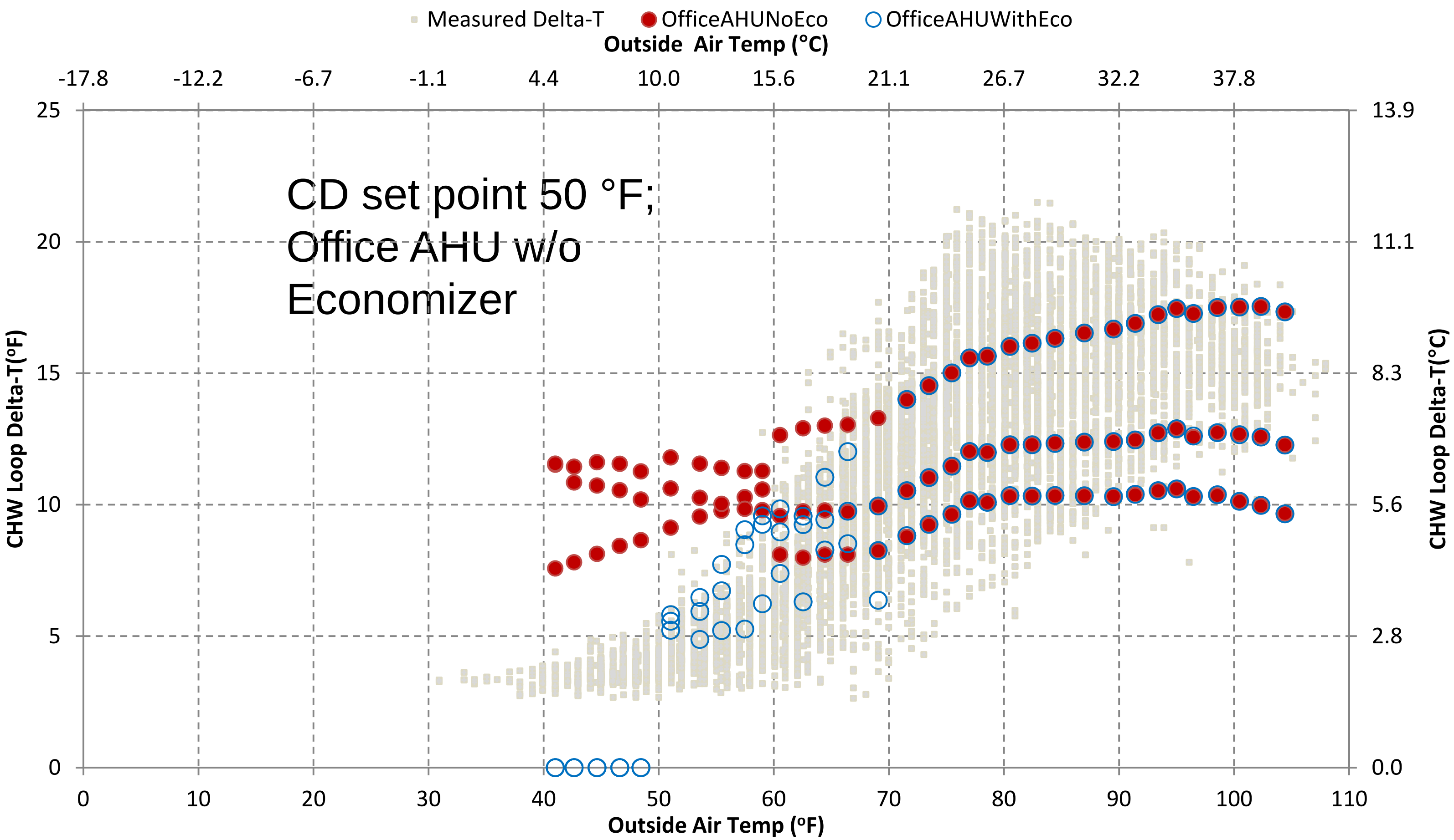
Fault Diagnosis (Cont.)



Fault Diagnosis (Cont.)



Fault Diagnosis (Cont.)



Summary

- Based on simulation results, there is a good potential to improve the case study building's chilled water delta-T.
- The lower discharge air temperature set point is the main avoidable cause of low chilled water delta-T for the case study building
- Economizer contributes to low chilled water delta-T during cool season.
- The chilled water laminar flow in the cooling coil is not a major cause for cooling coil lower delta-T

Summary (Cont.)

- A few of the chilled water valves may be leaking by or the coil control valves may not precisely modulate the chilled water flow, although the chilled water valves are overall under fairly good controlling.

Thanks