the Energy to Lead

Advanced Gas Water Heaters for High Performance DHW and Combi-System Applications

2015 ACEEE Hot Water Forum

Measuring the Performance of Advanced Gas Water Heaters

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Tim Kingston

Gas Technology Institute (GTI)

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Research Discussions

> What have we done

> What methods did we use

> What have we learned

> Potential solutions

Laboratory Research

- As-installed combi performance
  - Forced-air with storage WH
  - Forced-air with tankless WH
  - Integrated heat pump and WH
- Combi configuration development
  - Integration solutions
- Advanced AHU development
  - Condensing operation
  - Supply air comfort
  - Heat pump integration

24-Hour Profile Testing in Laboratory

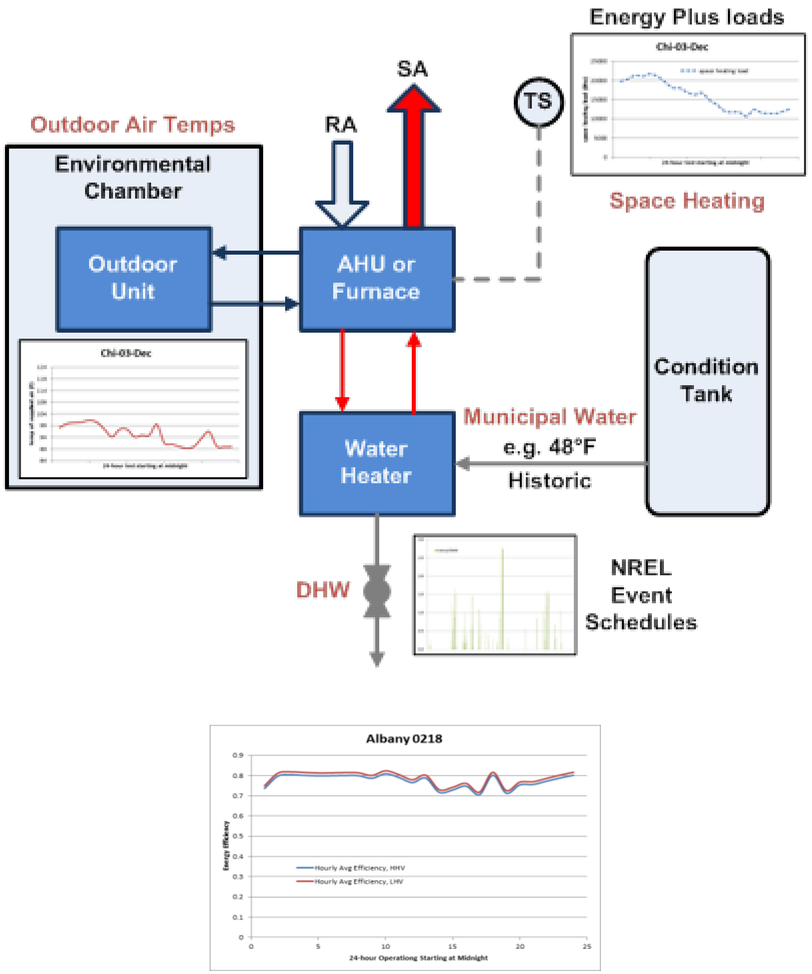
> As-installed Performance testing

> Lab test methodology
  – SH loads and thermostat calls
  – DHW draws and flows
  – Outdoor air temperatures
  – Municipal water inlet temperatures

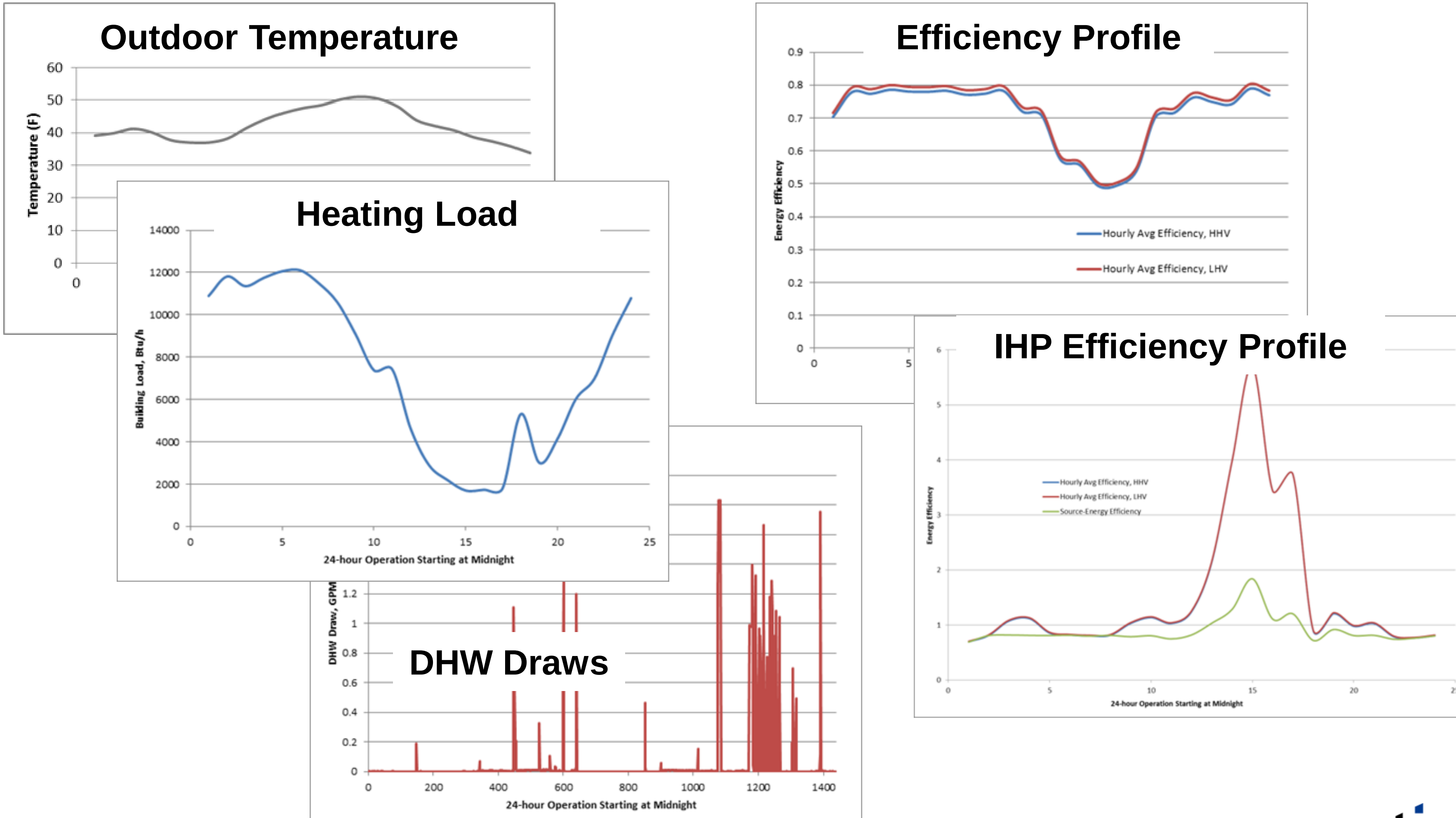
> Simulates as-installed field conditions in controlled lab setting

> Can compare performances of different systems on equal footing

> Strategically selected 24-hour profiles
  – Cold, moderate, mild
  – Wide range of DHW draws

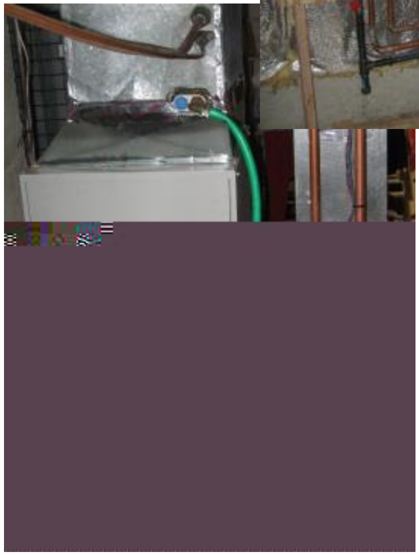


Efficiency Profiles



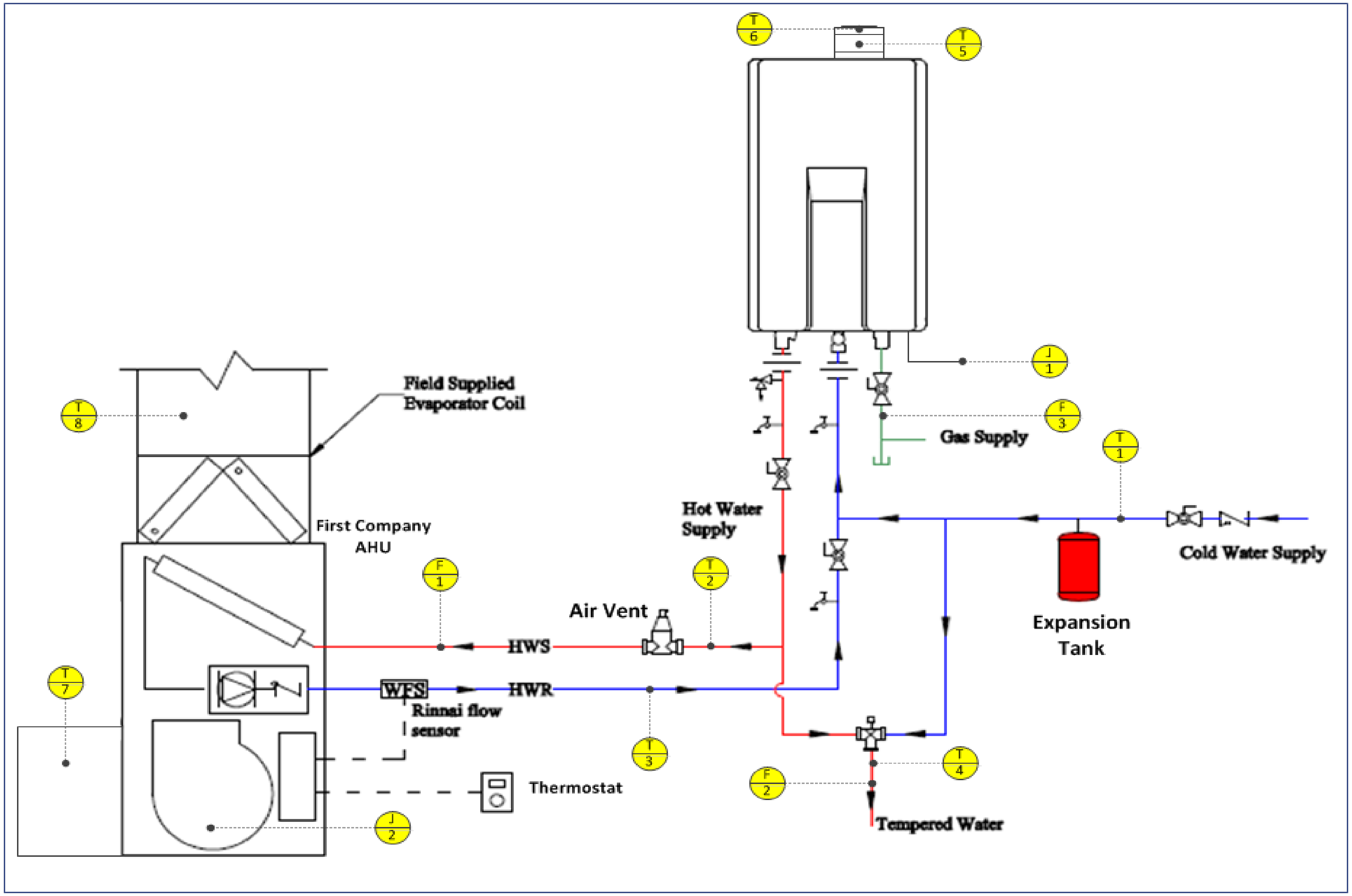
Field Research

- >50 combis installed in field
  - – NYSERDA
  - – Nicor Gas
  - – SoCal Gas
  - – United Illuminating
- >1-year monitoring programs
- >Contractor training
- >Performance evaluations
- >Homeowner surveys
- >Foster market transformation



Performance Measurement and Evaluation

- Q_{in} = WH gas + WH elec.
- Q_{in} does not include AHU elec.
- Q_{out} = energy delivered to DHW + SH
- Consistent with AFUE testing of separate equip



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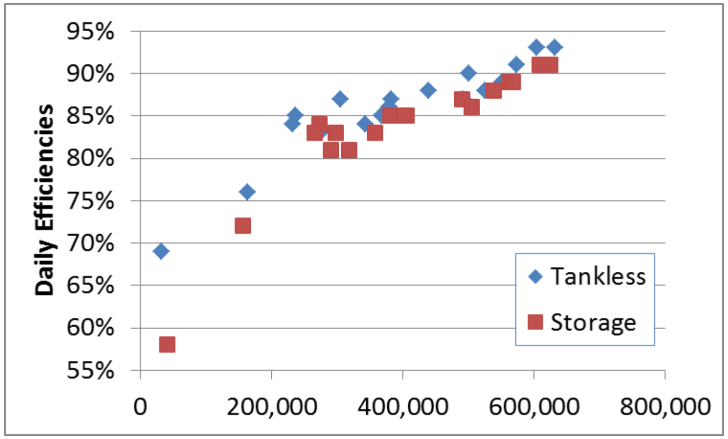
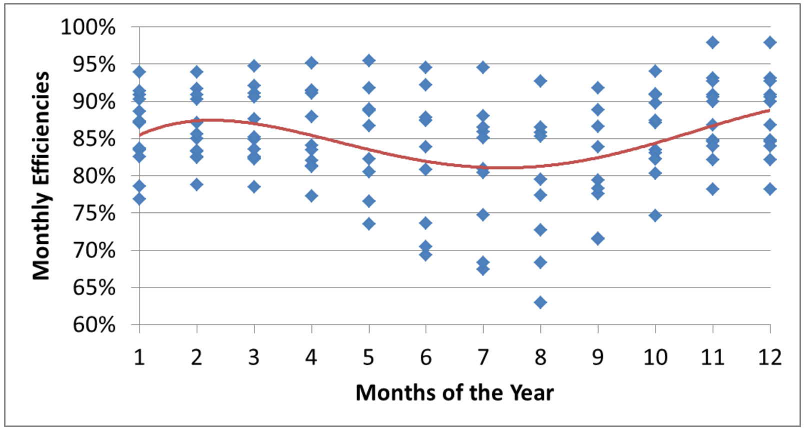
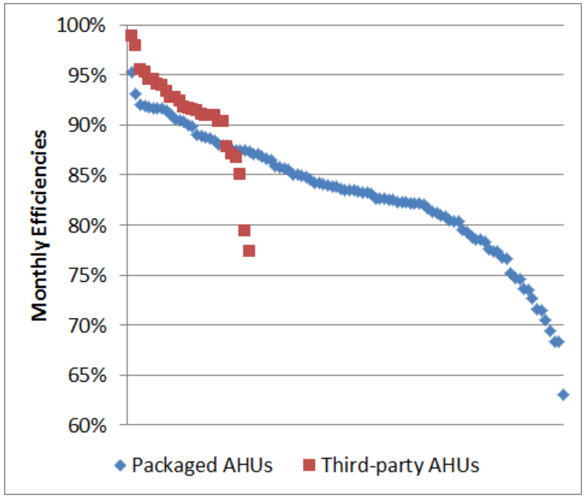
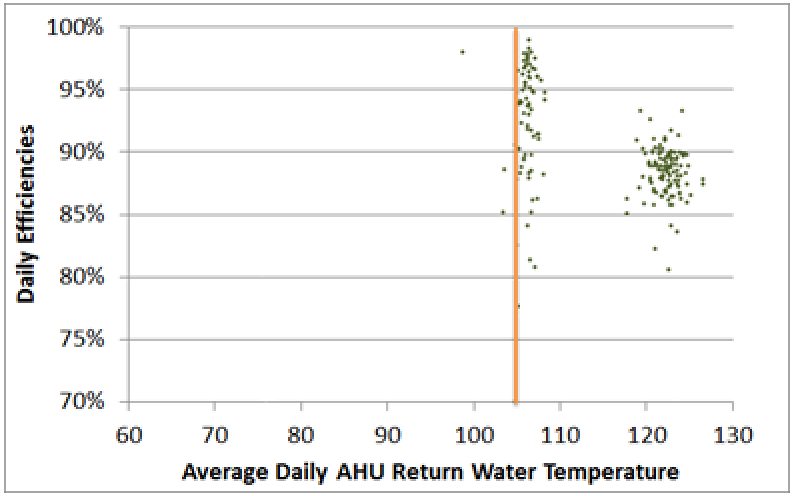
Efficiency Trends









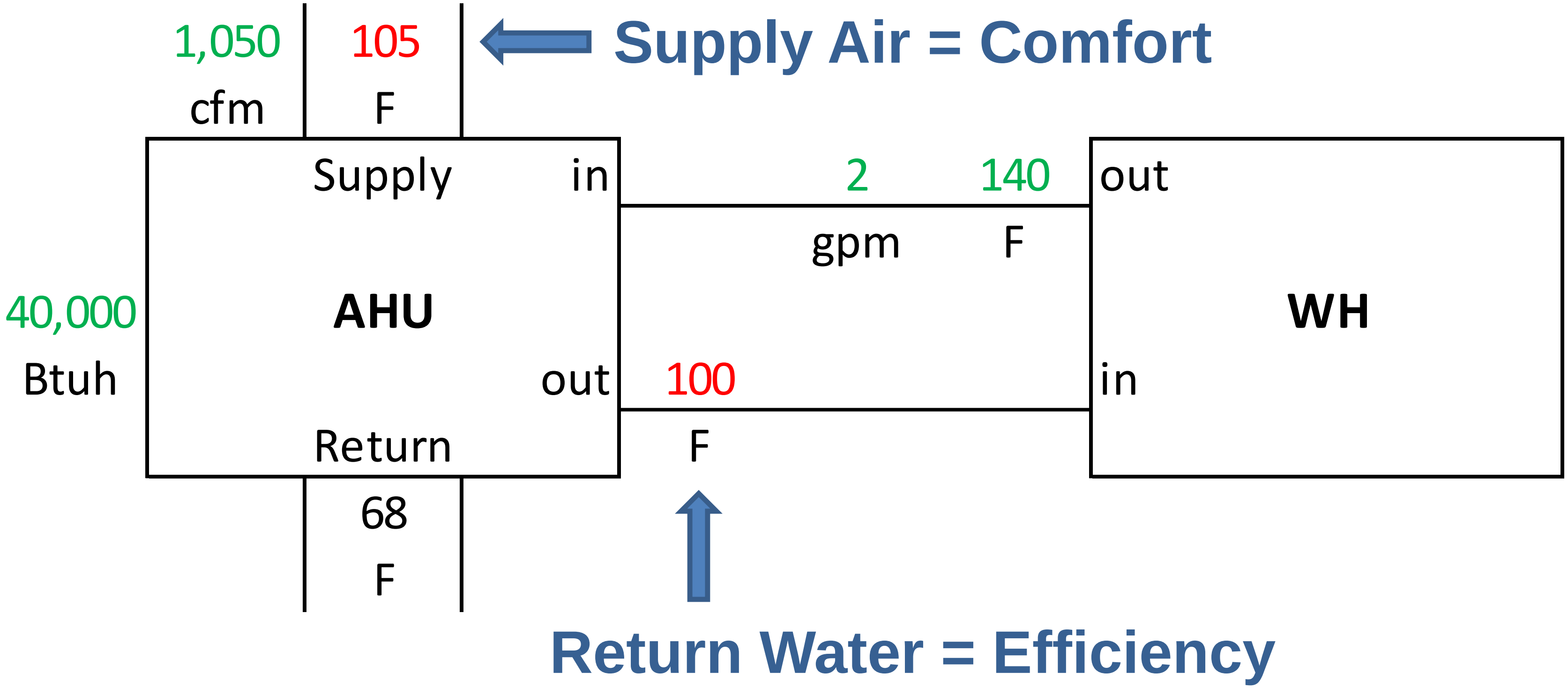
Summary of Key Findings

> Combi efficiencies are generally in the 80s percent
  - 90%+ efficiencies with air and water flow engineering
  - Efficiencies for storage and tankless combis are similar
  - Efficiencies are highly dependent upon loads
  - Return water temps critical (verified CEE findings)
  - 90%+ efficiencies with heat pump integration
  - Comfort vs. efficiency tradeoffs with existing AHUs
  - Supply air temps compromised with low RW temps
  - Inadequate AHU documentation for combi integration
  - There is a DHW and space heating disparity
  - AHU pump timer causes efficiency/comfort problems
  - Tankless water heaters have ancillary issues

Critical Needs

- Hydronic AHU product lines that are well-documented, cost-effective, and technically suitable for condensing combi configurations
  - Designed, documented for condensing operation
  - Well-defined integration practices and instructions
  - Potentially eliminate need for matching/packaging
- Improved water heater designs or innovative integration strategies to address:
  - Peak DHW vs. space heating and non-peak DHW
  - Ease of AHU integration (e.g. pressure losses)
  - Temperature control (sandwich, time to receive DHW)

Comfort vs. Efficiency Dilemma



Need all of these numbers to tell the whole story

Typical AHU Documentation

NOM. COOLING BTUH	MOTOR SPEED CONN.	CFM @ .3 ESP	GPM (HTG.)	P.D. (FT. WTR.)	BTUH (1000) AT ENTERING WATER TEMPERATURE 140°F	160°F	180°F
18,000	HIGH	650	3	1.13	24.6	31.6	38.7
			2	0.51	22.7	29.2	35.7
			1	0.13	17.0	21.9	26.8
	MED.	550	3	1.13	22.4	28.7	35.1
			2	0.51	20.7	26.6	32.5
			1	0.13	15.8	20.4	24.9
	MED. LOW	420	3	1.13	18.9	24.3	29.7
			2	0.51	[illegible]	[illegible]	[illegible]
			1	0.13	[illegible]	[illegible]	[illegible]

- > Supply air temp?
- > Return water temp?
- > Capacity impacts?

WATER INLET TEMP (°F) [°C]	WATER OUTLET TEMP (°F) [°C]	WATER FLOW LB/HR [kg/hr]	WATER FLOW GPM	AIR INLET TEMP (°F) [°C]	AIR OUTLET TEMP (°F) [°C]	AIR CFM [L/s]	CAPACITY (BTU/HR) [kW]	AIR TEMP RISE (°F) [°C]
120 [49]	110 [43]	2000/ [907]	4	68 [20]	106 [41]	646 [305]	20900 [6.13]	30 [17]
130 [54]	117 [47]				113 [45]		25800 [7.56]	37 [21]
140 [60]	125 [52]				122 [50]		29800 [8.73]	43 [24]
150 [66]	132 [56]				130 [54]		35000 [10.26]	50 [28]
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120 [49]	100 [38]	2000/ [907]	4	68 [20]	105 [41]	1000 [472]	38200 [11.20]	31 [17]
130 [54]	108 [42]				109 [43]		44900 [13.16]	37 [21]
140 [60]	115 [46]				116 [47]		50600 [14.83]	42 [23]
150 [66]	120 [49]				126 [52]		60000 [17.58]	49 [27]
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120 [49]	97 [36]	2000/ [907]	4	68 [20]	103 [39]	1450 [684]	45500 [13.33]	26 [14]
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160 [71]	120 [49]				123 [51]		80500 [23.59]	47 [26]
120 [49]	96 [36]	2000/ [907]	4	68 [20]	100 [38]	1800 [850]	47200 [13.83]	27 [15]
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150 [66]	111 [44]				119 [48]		77000 [22.57]	44 [24]
160 [71]	106 [46]				124 [51]		86800 [25.44]	50 [28]

- > Water flow impacts?
- > Capacity impacts?

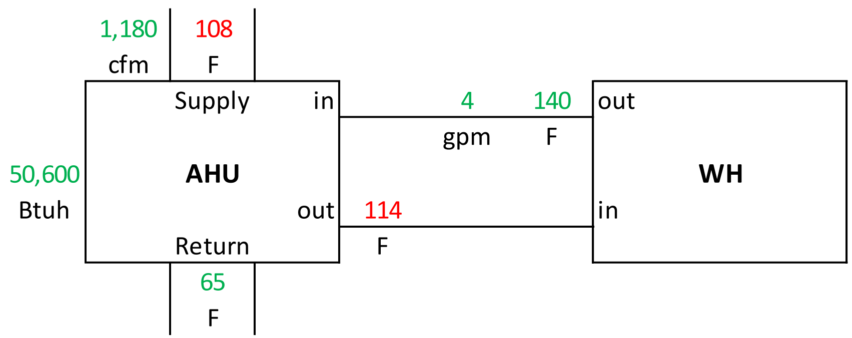
Better AHU Documentation

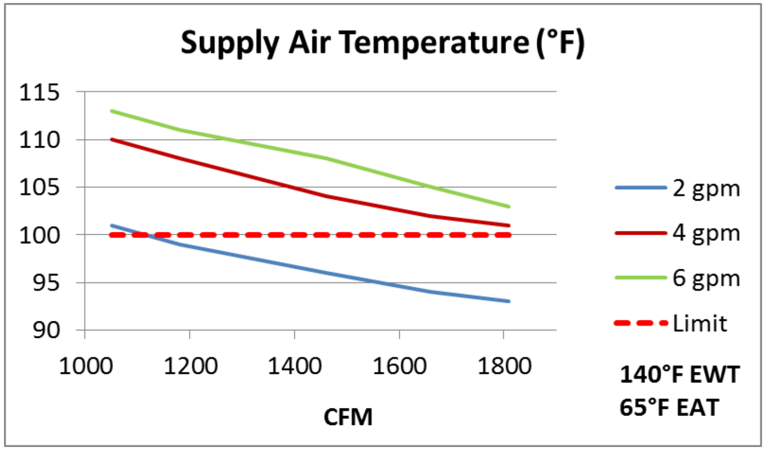
Entering db (°F)	Air flow S - (ft^3/min)	Fluid name	Entering fluid temp. (°F)	Tube flow (gal/min)	Tubeside dT (d°F)	Total capacity (Btu/hr)	Leaving Air DB	Leaving fluid temp. (°F)	Face velocity (ft/min)	Tubeside pd (ft H2O)
70	600	Water	100	3	10.5	15,629	93.8	89.5	212	0.99
70	600	Water	100	5	7	17,383	96.5	93	212	2.57
70	825	Water	100	3	13.4	18,434	90.4	87.6	292	0.99
70	825	Water	100	5	8.6	21,441	93.7	91.4	292	2.58
70	1,155	Water	100	3	14.2	21,159	86.7	85.8	408	0.99
70	1,155	Water	100	5	10.3	25,723	90.3	89.6	408	2.58
70	600	Water	140	3	25.3	37,343	126.8	114.7	212	0.94
70	600	Water	140	5	16.7	41,061	132.5	123.3	212	2.45
70	825	Water	140	3	30	44,295	119	110	292	0.94
70	825	Water	140	5	20.7	50,871	126.3	119.3	292	2.45
70	1,155	Water	140	3	34.6	51,082	110.4	105.4	408	0.94
70	1,155	Water	140	5	24.9	61,270	118.4	115.1	408	2.45
70	600	Water	180	3	40.7	59,338	160.3	139.3	212	0.9
70	600	Water	180	5	26.7	65,026	169	153.3	212	2.34
70	825	Water	180	3	48.4	70,545	148.1	131.6	292	0.9
70	825	Water	180	5	33.2	80,795	159.4	146.8	292	2.34
70	1,155	Water	180	3	55.9	81,477	134.4	124.1	408	0.9
70	1,155	Water	180	5	40.1	97,566	147.1	139.9	408	2.35

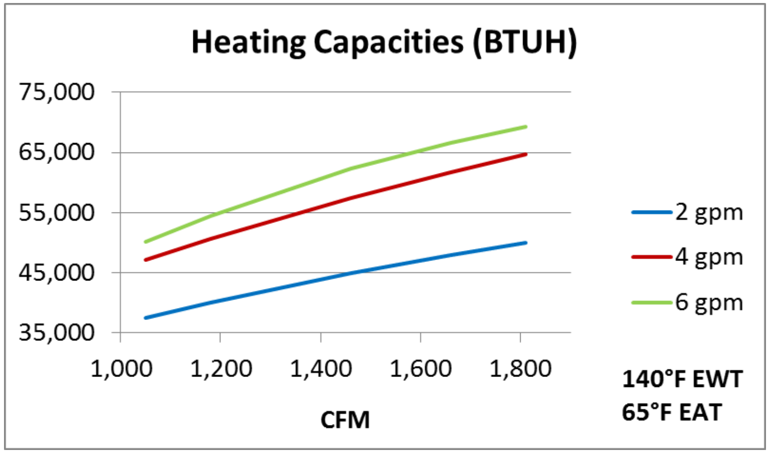
Water flow impacts?

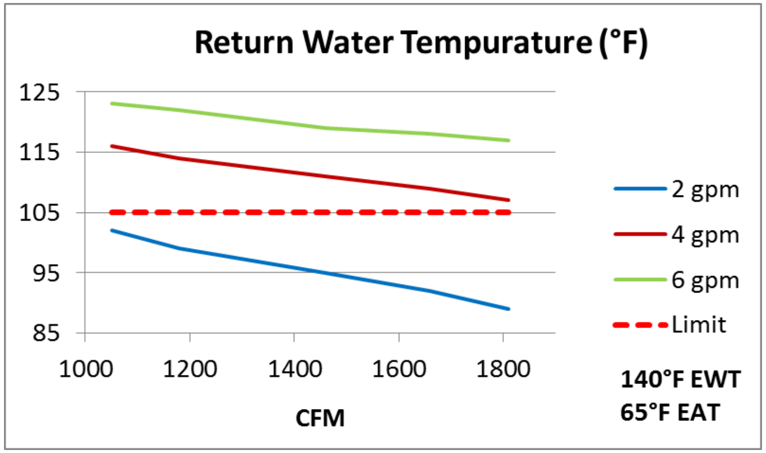
AHU Mismatch for Condensing Combi

The whole story









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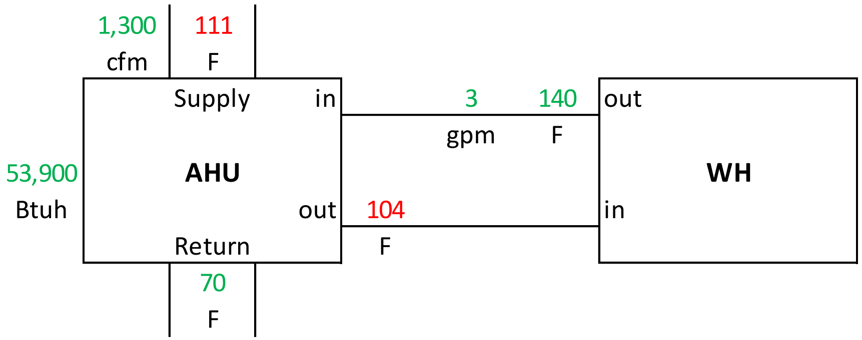
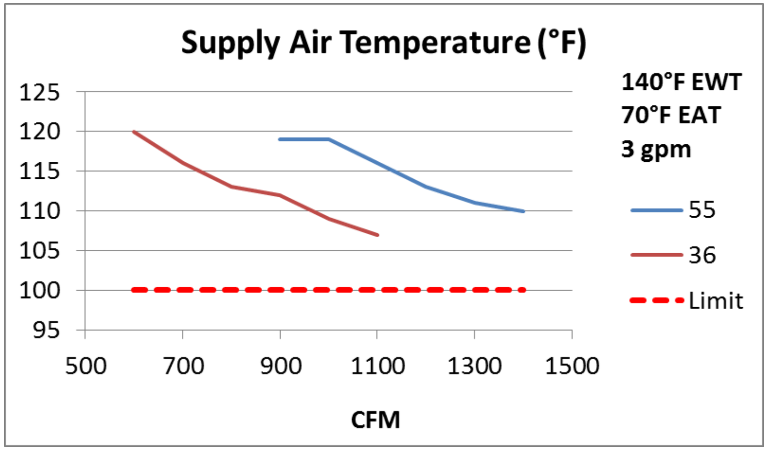
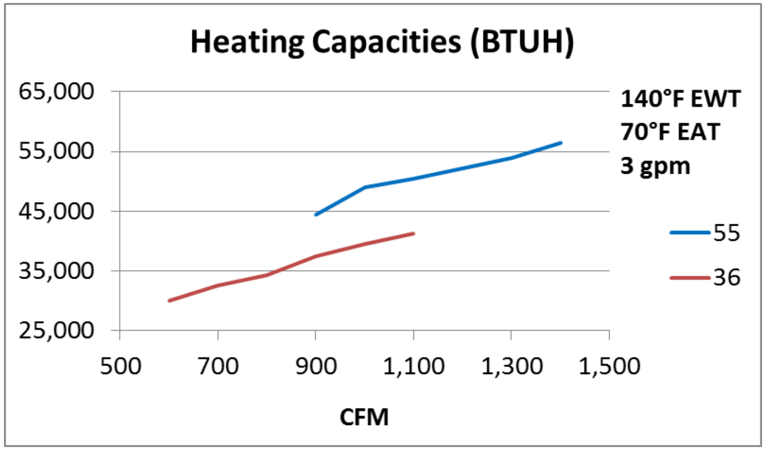
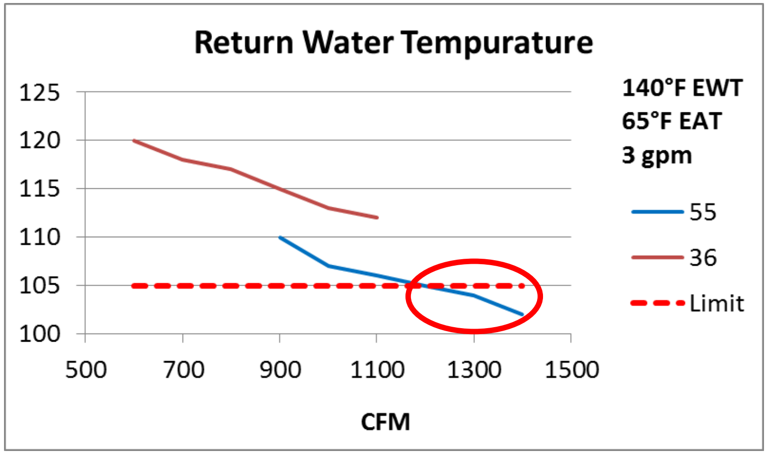
AHU Potential for Condensing Combi



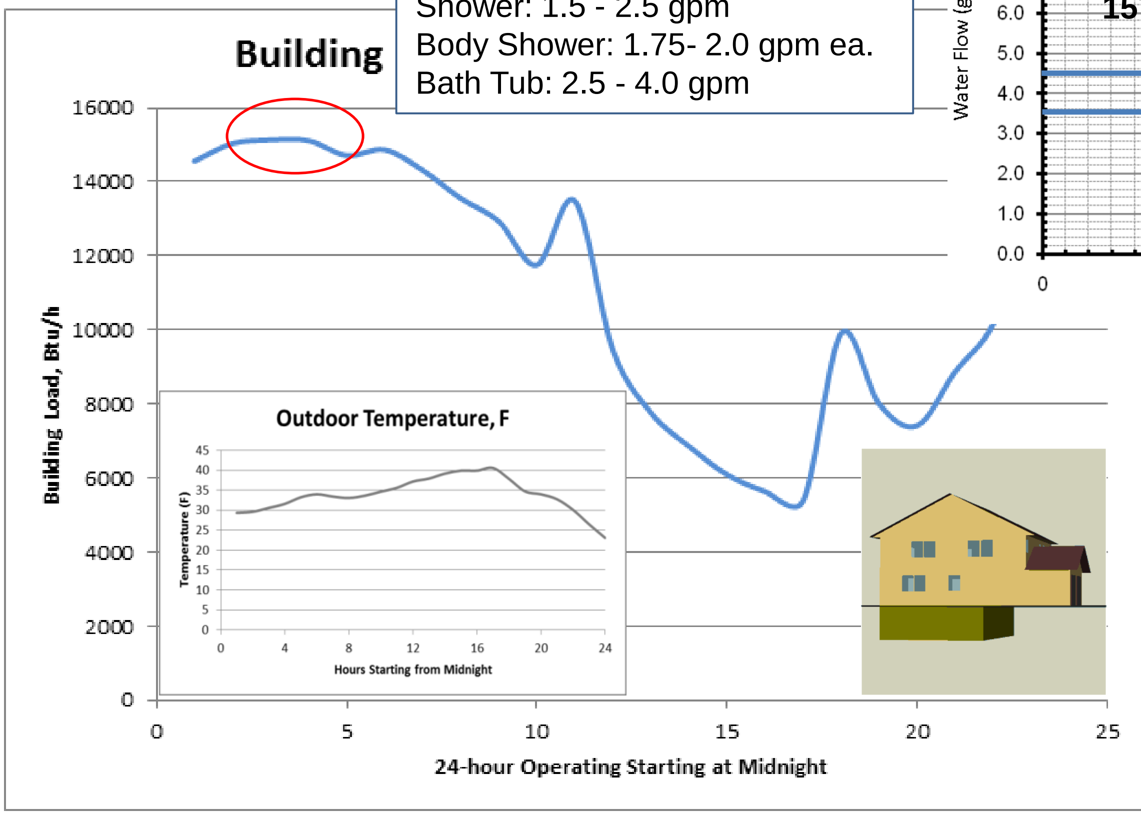


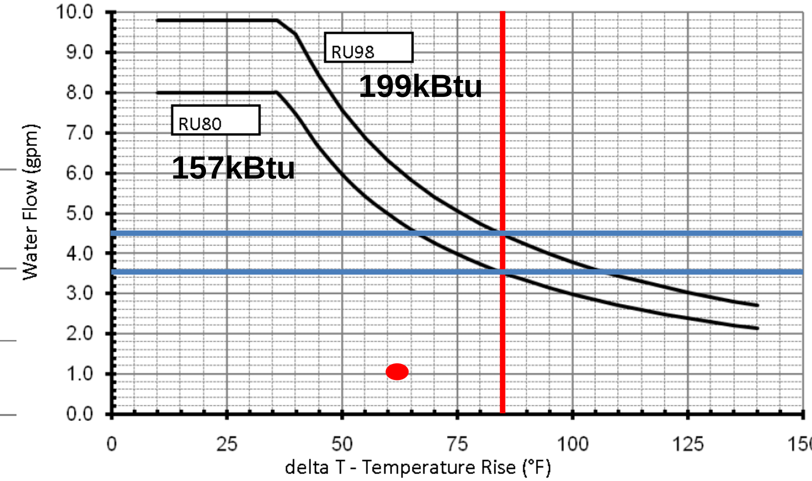




DHW and Space Heating Disparity

Typical Flow Rates
Dishwasher: 0.5 - 1.0 gpm
Sink: 0.5 - 2.0 gpm
Washing Machine: 2.0 - 2.5 gpm
Shower: 1.5 - 2.5 gpm
Body Shower: 1.75- 2.0 gpm ea.
Bath Tub: 2.5 - 4.0 gpm





More than 10:1 turndown for typical space heating

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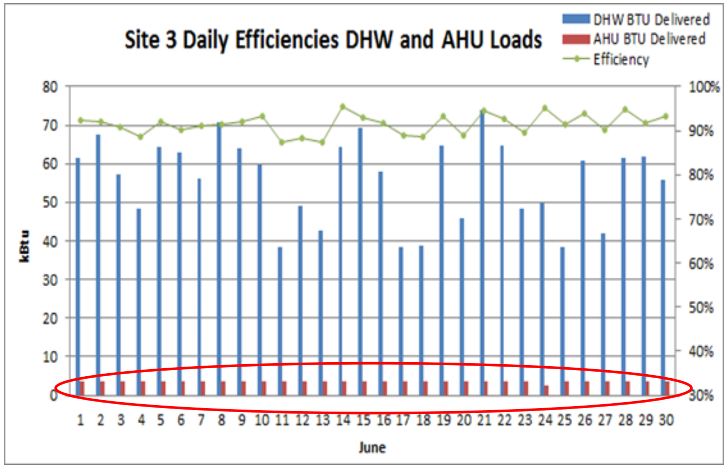
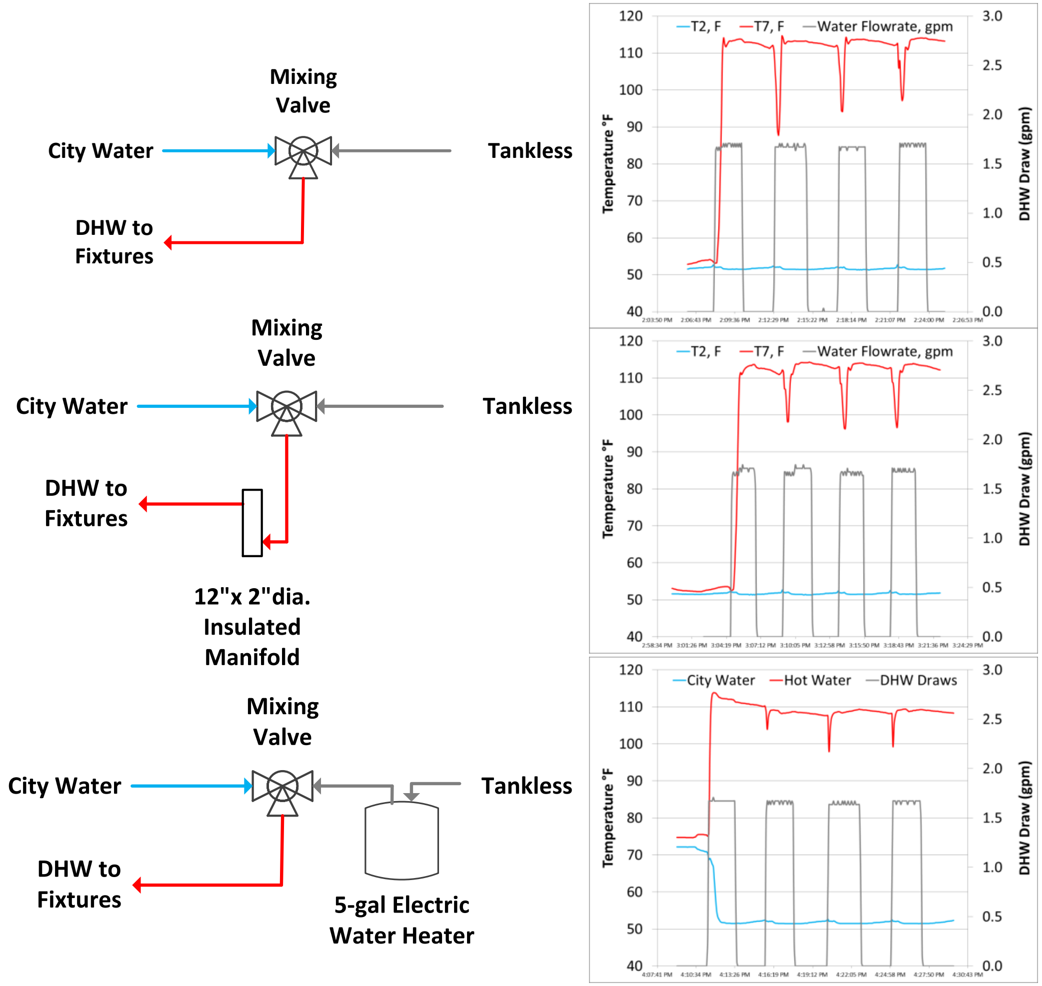
Pump Timer Problems

- ➢ Why heating loads in the summer?
- ➢ Pump timers circulate water every 6 hours to address Legionella concerns
- ➢ Circulates for ~30 seconds even in the summer… and the WH burner comes on
- ➢ Heats air conditioned supply air briefly ~85°F



- ➢ Pump timer for combi forces WH burner on for ~2 minutes per day
  - – ~6k BTU per day just to circulate AHU water
- ➢ For reference: storage WH standby losses might use 40k to 50k BTU per day
- ➢ Need a better solution

Cold Water Sandwich / HW Delay

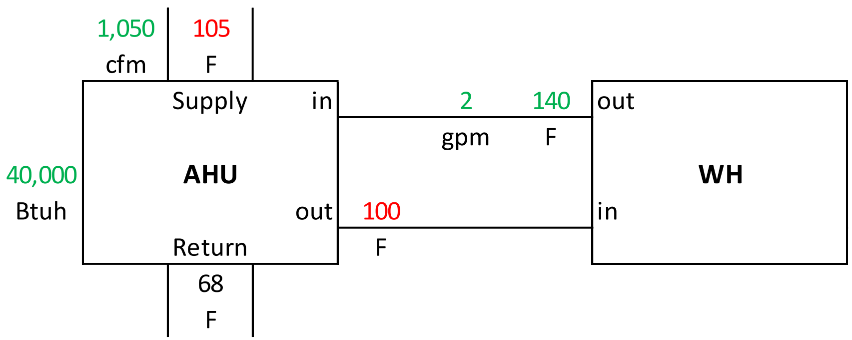


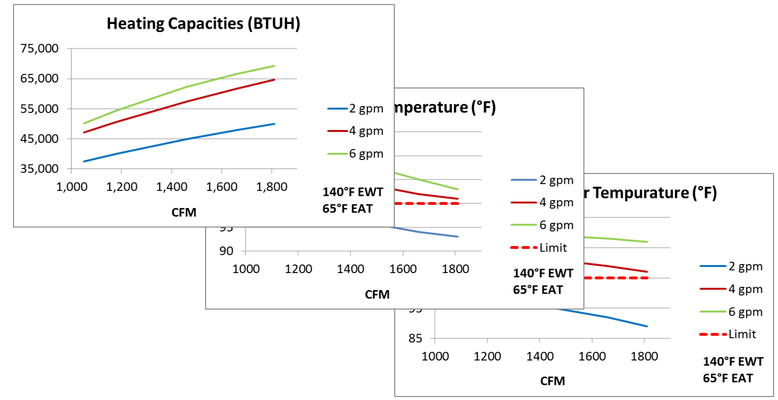
- No control measure
- 27°F sandwich
- Drops below 90°F (cool)

- ¼-gal manifold (low-cost)
- 15°F sandwich (still ~100°F)
- 44% improvement

- 5-gal electric water heater
- Higher cost ($300)
- 6°F sandwich
- 81% improvement

AHU Example for Condensing Combi





Hypothetical Well Documented AHU

BTUH	CFM	SA	GPM	EWT	RWT
60,000	1,550	105	3.00	140	100
50,000	1,300	105	2.50	140	100
40,000	1,050	105	2.00	140	100
30,000	780	105	1.75	135	100
20,000	520	105	1.60	130	100

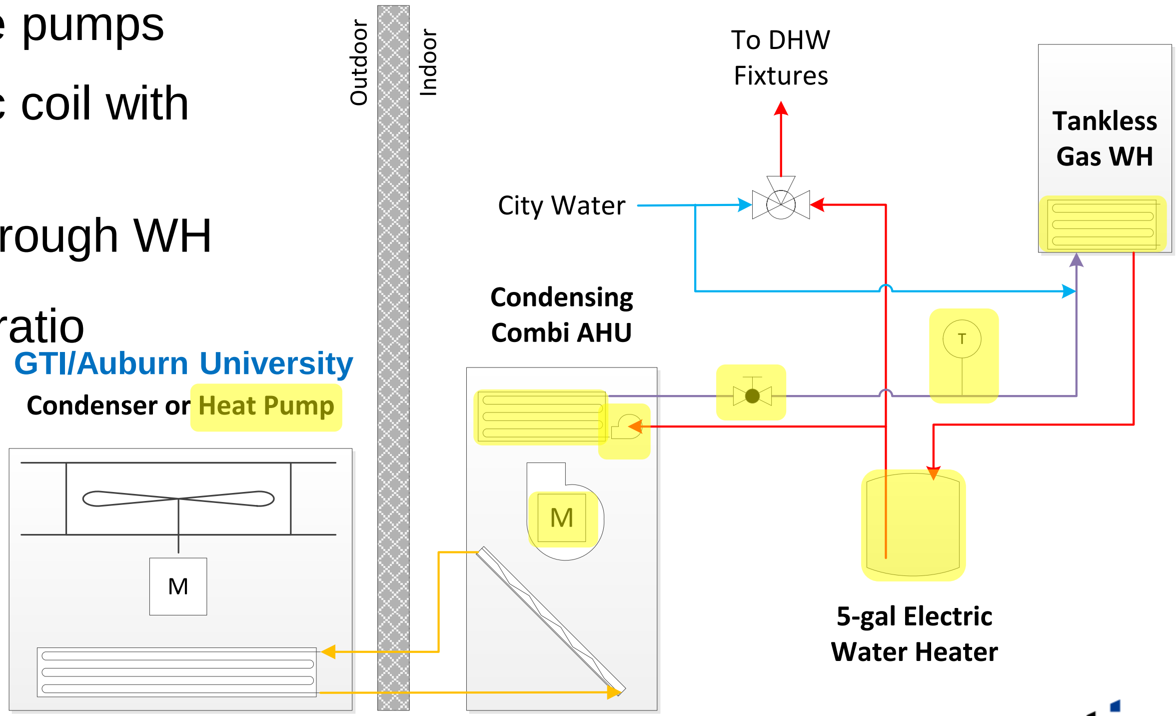
BTUH	CFM	SA	GPM	EWT	RWT
	900		2.0	140	
	1000		2.0	140	
	1100		2.0	140	
	1200		2.0	140	

BTUH	CFM	SA	GPM	EWT	RWT
	900		2.3	140	
	1000		2.3	140	
	1100		2.3	140	
	1200		2.3	140	

Condensing Combi Integration

- Add a small electric water heater to temper cold water sandwich, reduce hot water delay, and provide hot water for short heating cycles
- Add a throttle valve and temperature gauge to control return water temp
- Size pump to account for large pressure loss then throttle water flow down - or make easily swappable pumps
- Develop high-ΔT hydronic coil with low-static pressure loss
- Minimize pressure loss through WH
- Maximize WH turn-down ratio
- Swappable fan motor
- Integrate heat pump for cooling and high-COP heating during mild outdoor conditions

GTI/Auburn University



Questions?