

Codes– High Efficiency Equipment Installation and Retrofit Issues

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Gas Technology Institute

- > Not-for-profit research, with 65+ year history
- > Facilities
 - 18 acre campus near Chicago
 - 200,000 ft², 28 specialized labs
- > \$60 million in revenue
- > Staff of 250
- > 1000 patents; 500 products
- > Commercial partners take our technologies to market



Offices
& Labs



Flex-Fuel
Test
Facility



Energy & Environmental Technology Center

Laboratory Capabilities

- > 3000 sq. ft.
- > 12 test bays
- > Exterior masonry chimney
- > Network-based data acquisition system
- > Full suite of gas analysis tools



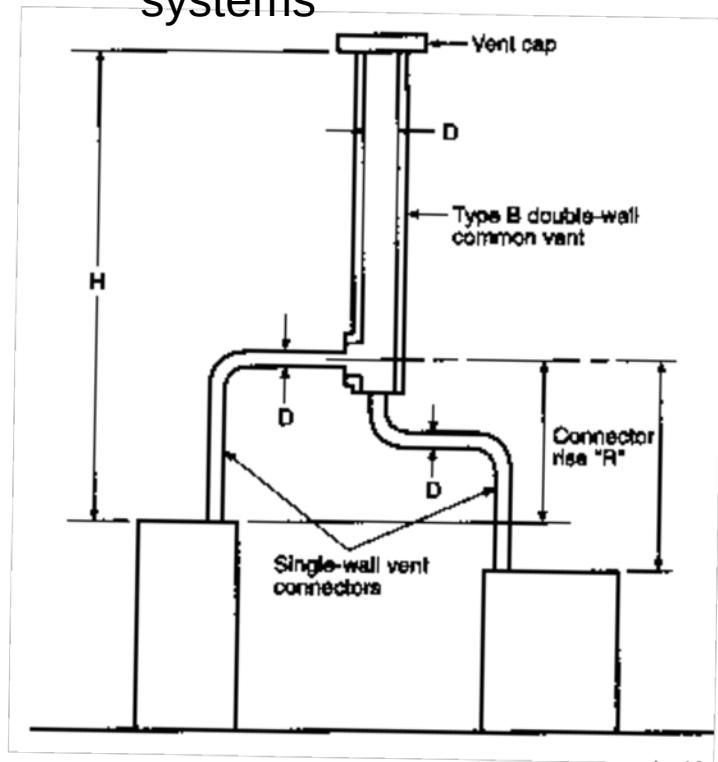
GTI – Venting Program

- > Objective – address and resolve issues associated with gas appliance installation and venting systems to reduce installation cost and improved vent system performance



The National Fuel Gas Code - NFPA54/ANSI z223.1

Category I single and common vented systems



Height H (ft)		3			4			5			6			7		
		Appliance Input Rating Limits in T														
		FAN		NAT	FAN		NAT	FAN		NAT	FAN		NAT	FAN		NAT
		Min	Max	Max	Min	Max	Max	Min	Max	Max	Min	Max	Max	Min	Max	Max
6	1	22	37	26	35	66	46	46	106	72	58	164	104	77	225	14
	2	23	41	31	37	75	55	48	121	86	60	183	124	79	253	16
	3	24	44	35	38	81	62	49	132	96	62	199	139	82	275	18
8	1	22	40	27	35	72	48	49	114	76	64	176	109	84	243	14
	2	23	44	32	36	80	57	51	128	90	66	195	129	86	269	17
	3	24	47	36	37	87	64	53	139	101	67	210	145	88	290	19
10	1	22	43	28	34	78	50	49	123	78	65	189	113	89	257	15
	2	23	47	33	36	86	59	51	136	93	67	206	134	91	282	18
	3	24	50	37	37	92	67	52	146	104	69	220	150	94	303	20
15	1	21	50	30	33	89	53	47	142	83	64	220	120	88	298	16

Common VENT Capacity

Vent Height <i>H</i> (ft)	Type B Double-Wall Commercial										
	4			5			6			7	
	Combined Appliance Input Rating										
	FAN +FAN	FAN +NAT	NAT +NAT	FAN +FAN	FAN +NAT	NAT +NAT	FAN +FAN	FAN +NAT	NAT +NAT	FAN +FAN	FAN +NAT
6	92	81	65	140	116	103	204	161	147	309	254
8	101	90	73	155	129	114	224	178	163	339	284



Installation Issues

Two cases where the building was designed with lower-efficiency equipment in mind:

- > Exterior masonry chimneys almost always require relining when changing or removing an appliance – is that really necessary?
- > Why protect condensing furnaces in attics with heat tape?

Masonry Chimney Relining

> Problem

- > Masonry chimney relining - is it really necessary?

> Approach

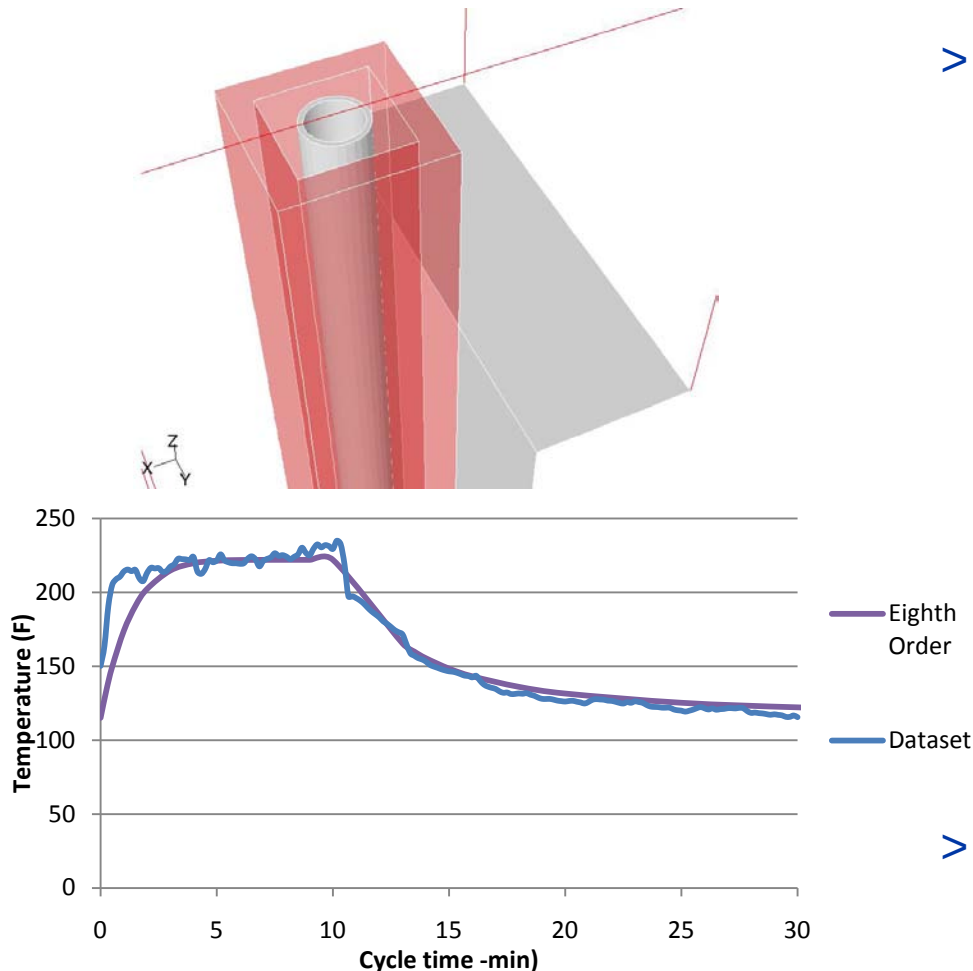
- > Model using VENT-II and CFD tools
- > Conduct lab experiment

> Parameters (same as NFGC)

- > 1 hour of full-fire from cold start
- > 12 hours of equipment cycling
- > The final furnace/boiler cycle is used to determine if chimney is “continuously-wet”
- > Outdoor temperatures are based upon “1,000th hour temperatures” - 1,000 hours of the heating season is at or below that temperature



Validation Case



> Validation Case:

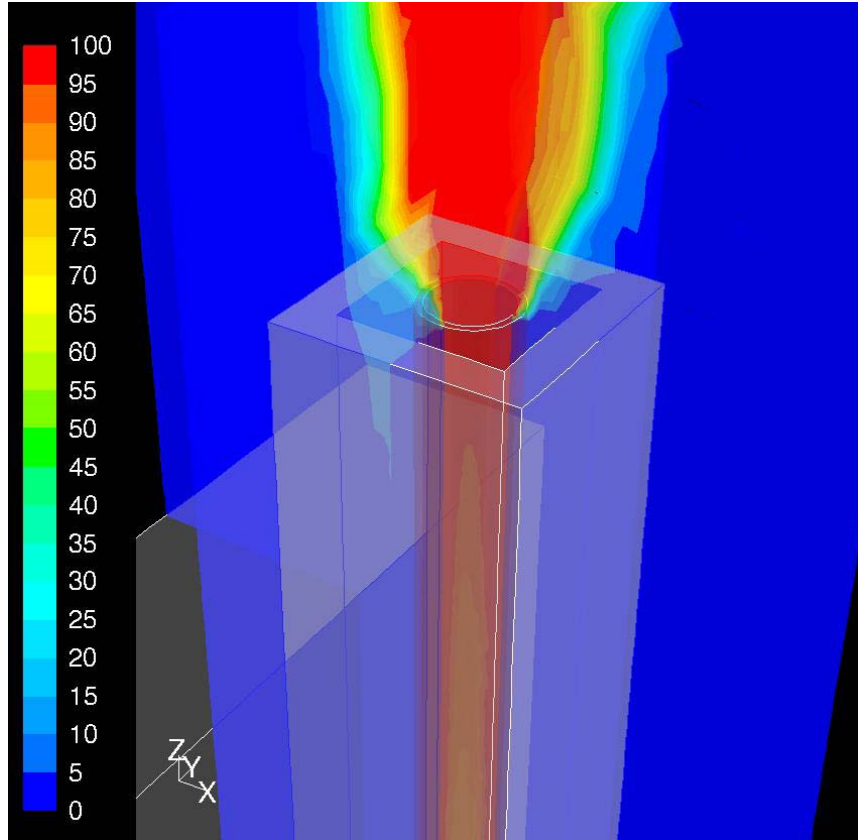
- **Boiler:** Input of 195,000 and 80.5% AFUE
- **WH:** 40 gallons/40 kBtu/hr and 0.59 EF
- **Cycle:** 1 hour preheat & 12 hours of cycling
- **1000 hr Outdoor T:** 25 °F
- **Chimney:** Exterior clay tile lined, 3 sides exposed

> Vent configuration requires relining per NFGC tables

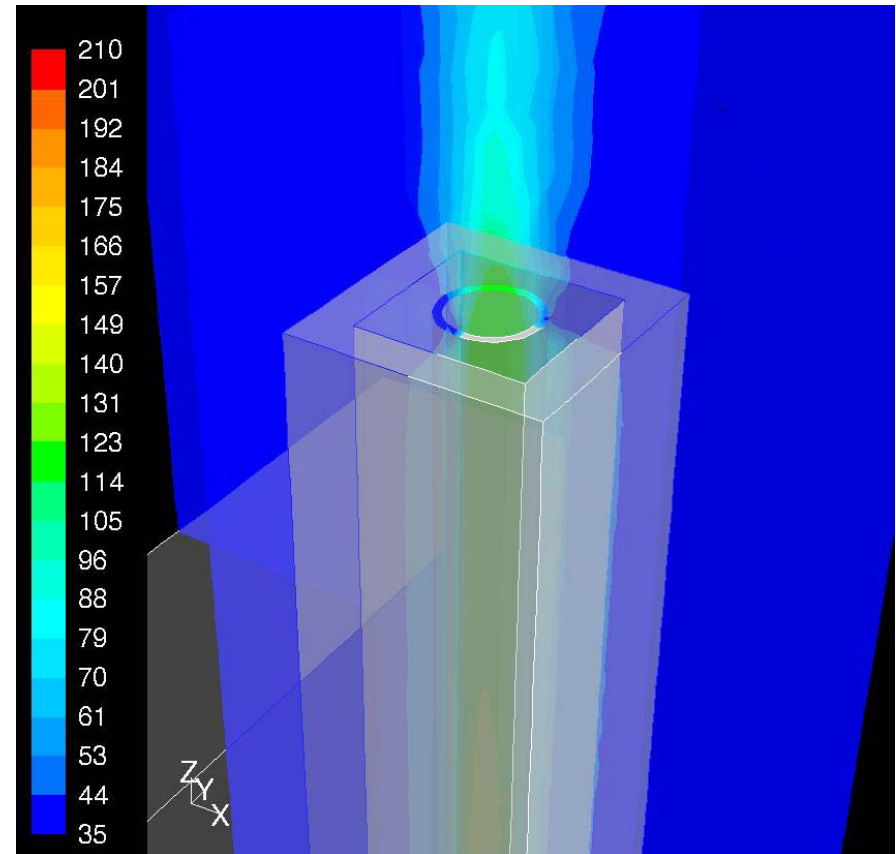
Lab Exterior Masonry Chimney



CFD Model



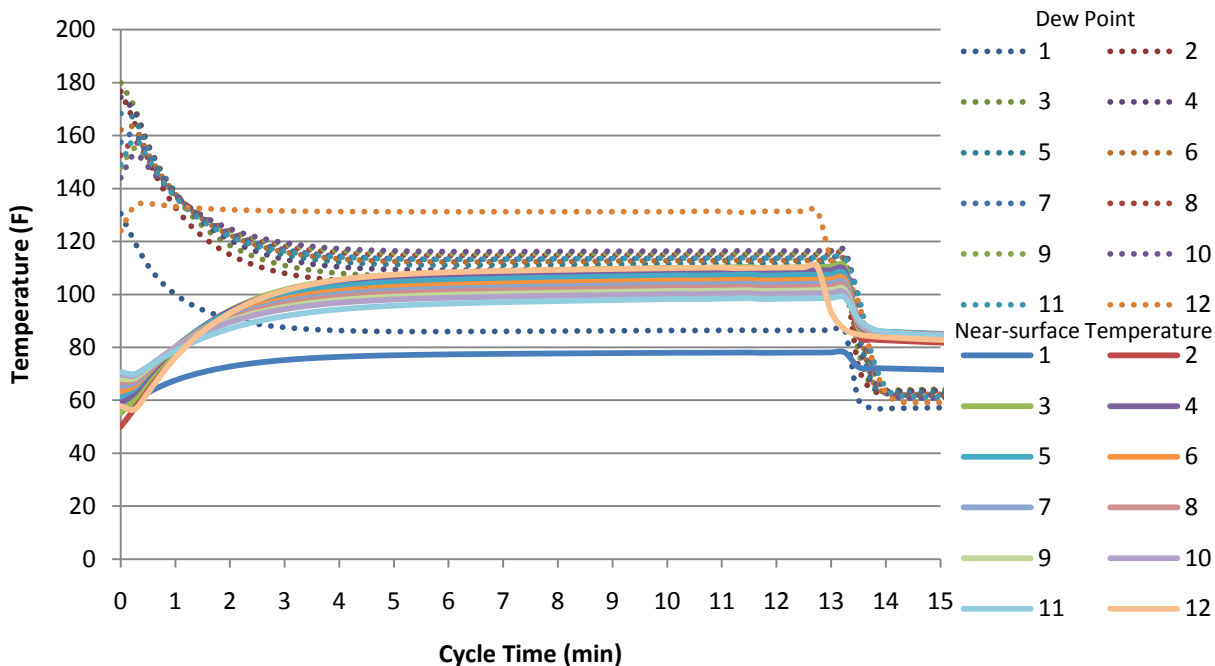
Contours of RH



Contours of T (F)

Direct Validation

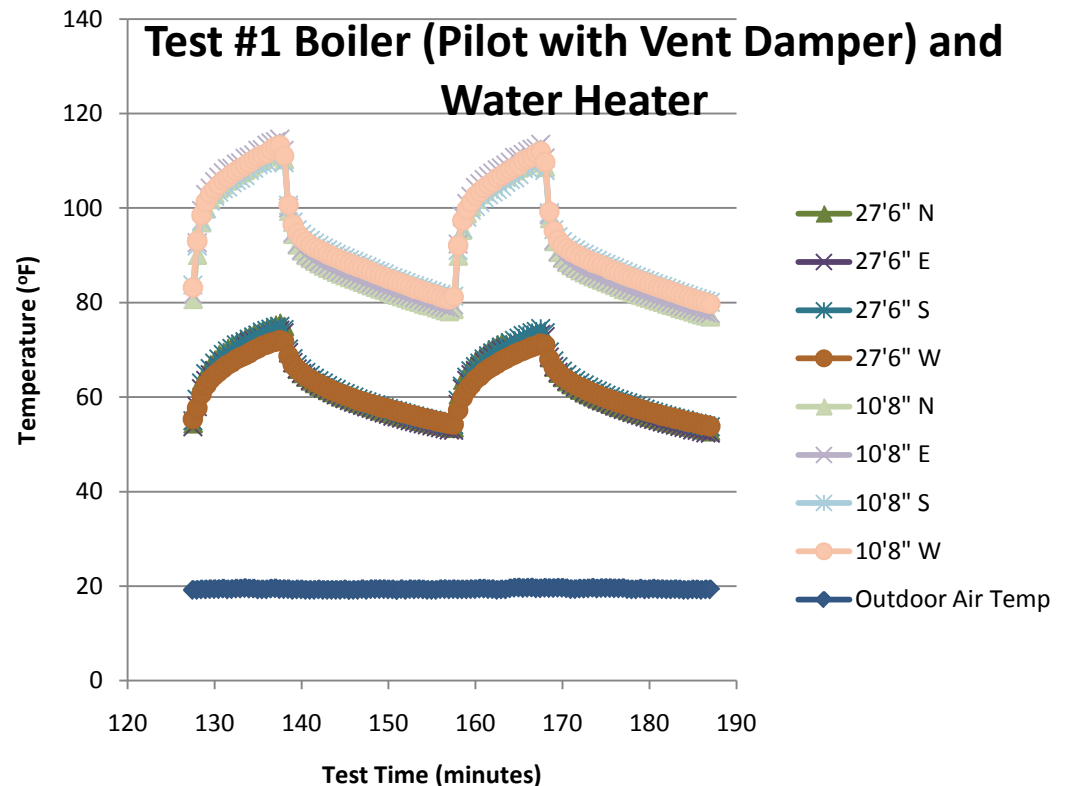
Condensation Within Exterior Chimney: Experimental Validation



- > With vent damper on boiler, off-cycle flow was measured as 9 cfm, 15% of on-cycle flow
- > Results for final cycle compare local dew point to local dry bulb temp.
- > Lab and model results agree, showing continuously wet conditions near chimney exit.

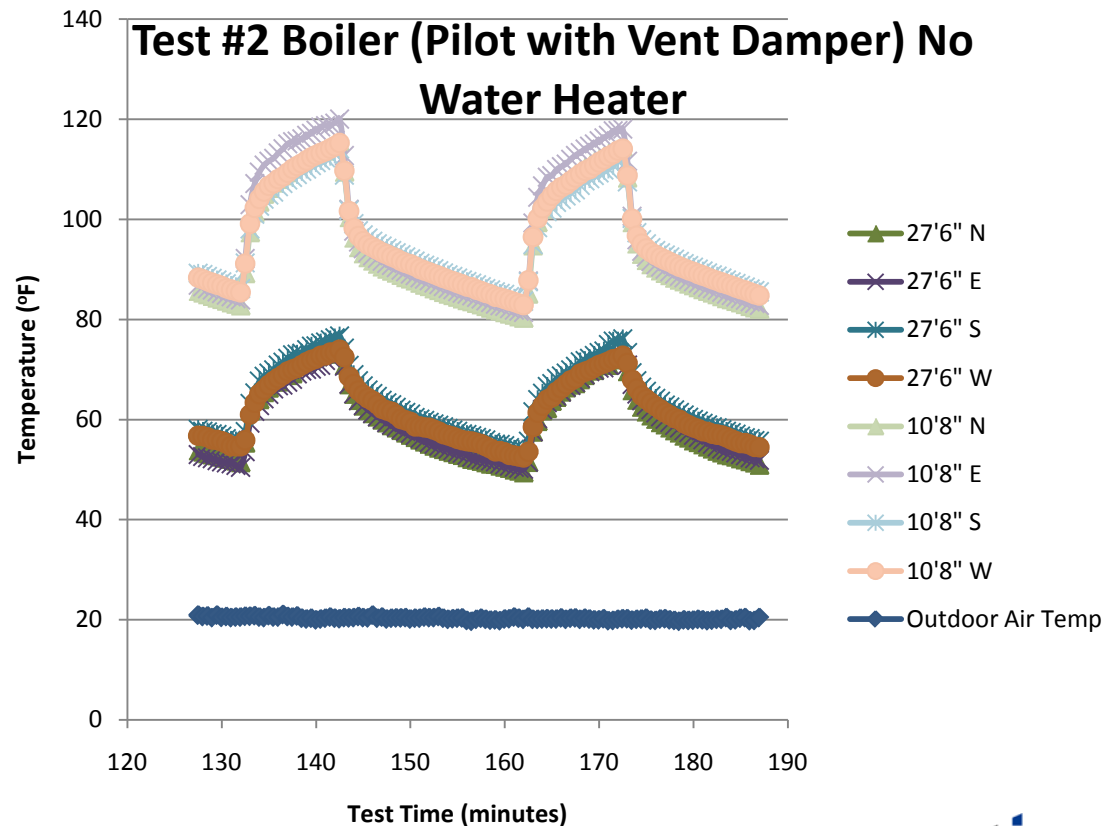
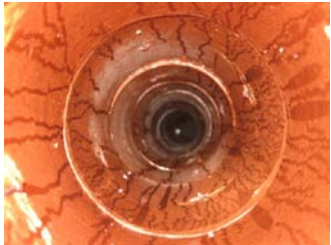
Test 1 – Boiler with Water Heater

- > Masonry Chimney wet at the end of 12 hour cycling, as expected



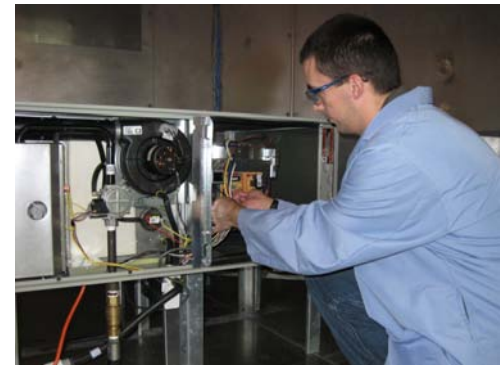
Test 2 – Boiler Without Water Heater

- > Masonry Chimney wet at the end of 12 hour cycling, as expected

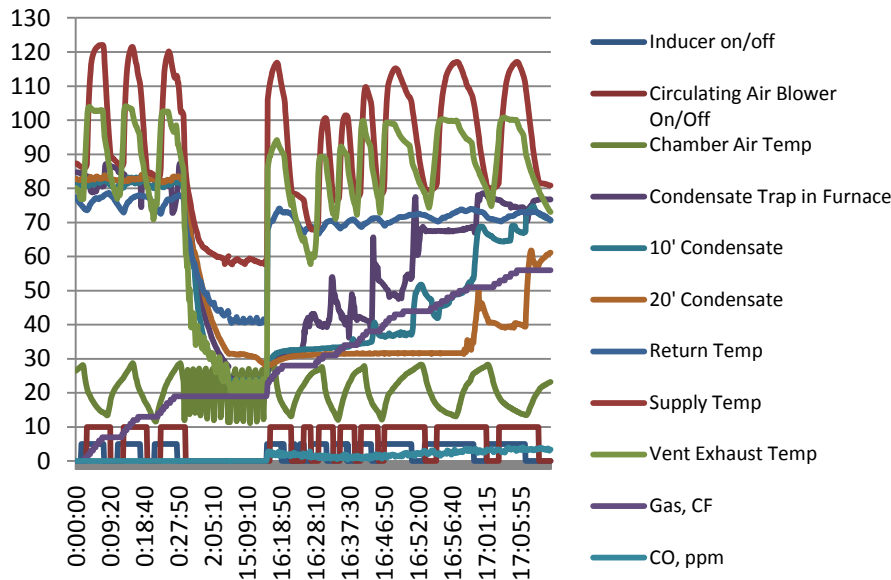


Condensate Drain System Freeze-up

- > Test plan developed based on recommended vs. poor installation practice.
- > Environmental chamber modified to simulate attic at 20 °F.
- > Two 90% furnaces tested.
- > No freeze-up failures under normal operation.

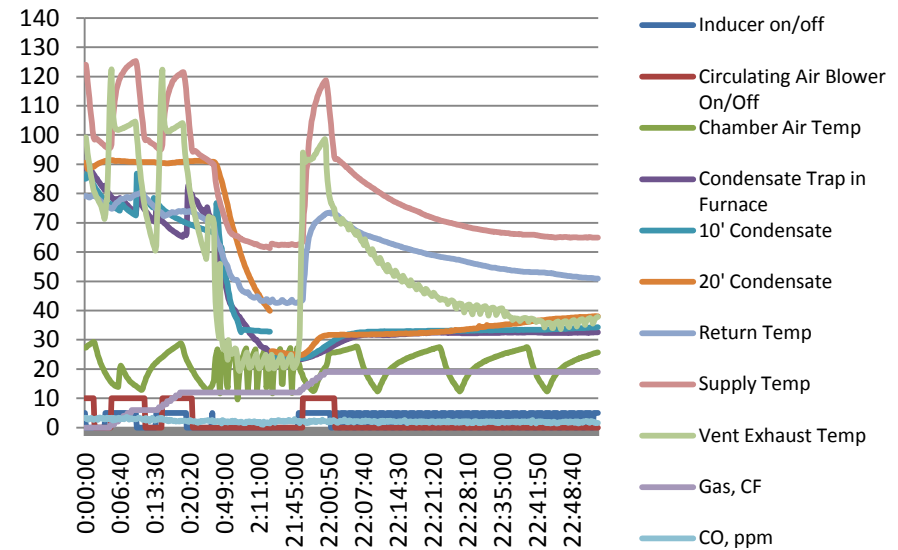


Results



Furnace B Test 6 – Power Outage Baseline

Baseline recovers after freeze-up as expected. Strong first cycle in recovery puts heat into the trap to help it thaw.



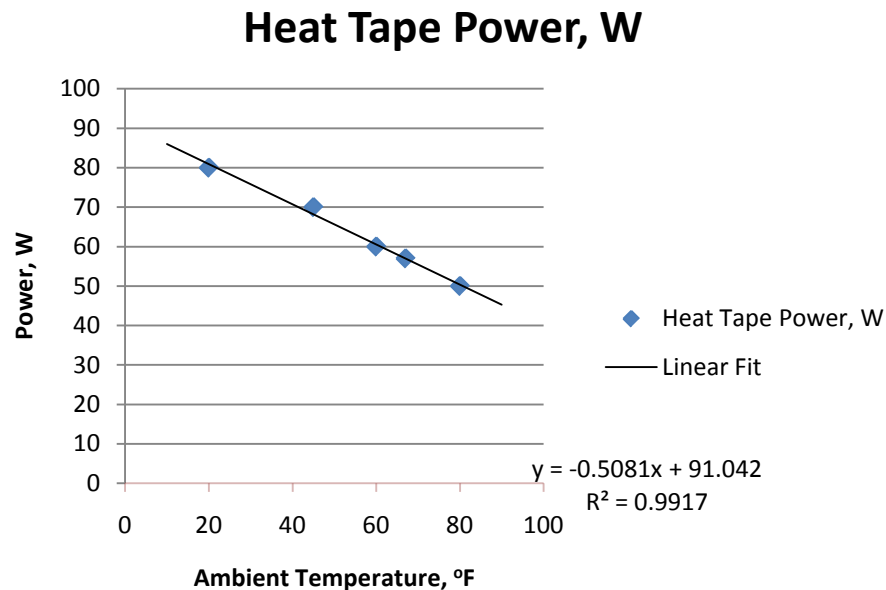
Furnace A Test 9 – Frozen at Drain

Poor installation practice case - frozen at drain to outside. Test fails as expected.

Results

Test	Furnace A	Results (Pass/Fa	Furnace B	Results (Pass/Fa	Results (Pass/Fail)	Observations
	Furnace	Condensate Line	Furnace	Condensate Line		
1 – Baseline PASS	P	P	P	P	Furnace operates normally. No freeze-up in condensate system.	Heat tape keeps the trap and drain system flowing.
2 – No condensate line insulation PASS	P	P	P	P	Furnace operates normally. No freeze-up in condensate system.	Insulation reduces the amount of energy from the heat tape. Also ran with insulation only with better results – heat tape not required for normal operation (no power outage).
3 – No condensate line insulation or heat tape PASS	P	P	P	P	Furnace operates normally. No freeze-up in condensate system.	Condensate temperature of 100 degrees enough to keep the line open if sloped properly and no power outage.
4 – Horizontal condensate line PASS	P	P	P	P	Furnace operates normally. No freeze-up in condensate system.	Heat tape and insulation keep condensate line clear when horizontal.
5 – Plugged drain line (frozen at end) FAIL	F	F	F	F	Furnace safety will not cycle gas valve open. Inducer will keep cycling and trying indefinitely.	Furnace will not operate if vent system or condensate system is blocked. After a few hours of no operation, the furnace will require restarting by a service technician because hoses inside the furnace will have ice in them with no heat source. Frozen condensate lines full of water will fail.
6 – Power outage (PO) baseline PASS	P	P	P	P	Furnace operates normally for one cycle and then safety will not cycle gas valve open. Condensate trap heats up and clears after about 30 minutes and furnace restarts.	The furnace can recover if several conditions are met: a condensate drain line that is heated, open, dry, and properly sloped, and a condensate trap that is heated and had been operating normally before the outage.
7 – PO no insulation or heat tape FAIL	F	P	F	P	Furnace operates normally for one cycle and then goes into plugged mode (test 5) because ice in the trap will not melt without heat tape.	After one cycle, the furnace will require restarting by a service technician who will melt the trap or replace it. Properly sloped condensate line will drain.
8 – PO and horizontal condensate line Marginal PASS	P	P	P	P	Furnace operates normally for one cycle until flooded and then continues trying to ignite. Over time, the heat tape on the trap and drain line melts the ice and normal operation resumes (Furnace A 3 hrs, Furnace B 18 min.).	Entire drain line has to warm up before the furnace will operate normally. Temperature in the condensate tubes within the furnace drops to 32 degrees so this case could result in a failure if conditions are slightly colder or condensate line has any dips in it.
9 – PO and plugged drain line (frozen at end) FAIL	F	F	F	F	Furnace operates normally for one cycle and then fails to re-ignite on a safety switch.	Once unplugged, frozen condensate hoses in the furnace (collector box and inducer fan drain lines) do not thaw with heat tape applied to the condensate trap. Service technician would be called to restart this furnace. Condensate line will fail.

Heat Tape Energy Consumption



Heat tape energy consumption, South Carolina climate and electricity prices

	Annual Electric Energy usage, kWh		Annual Energy Cost @9.4 cents/kWh	
	24 ft.	12 ft.	24 ft.	12 ft.
Heat Tape Length Without Temp Controller	555.3	277.7	\$ 52.20	\$ 26.10
Heat Tape Length With Temp Controller	159.1	79.6	\$ 14.96	\$ 7.48

Summary

- > Exterior masonry chimney relining requirements in NFPA54/ANSI z332.1 are valid and are supported by CFD modeling and experimental results.
- > Follow manufacturers instructions when installing furnaces in attics where weather can go below freezing: slope, insulation, and heat tape.

Future work –

What guidelines are available to avoid ice formation from sidewall vents in cold climates?

How long will Type B vents be compatible with Energy Star™ residential water heaters?