seventhwave

Combustion Products Spillage from Gas Water Heaters *Monitoring Results*

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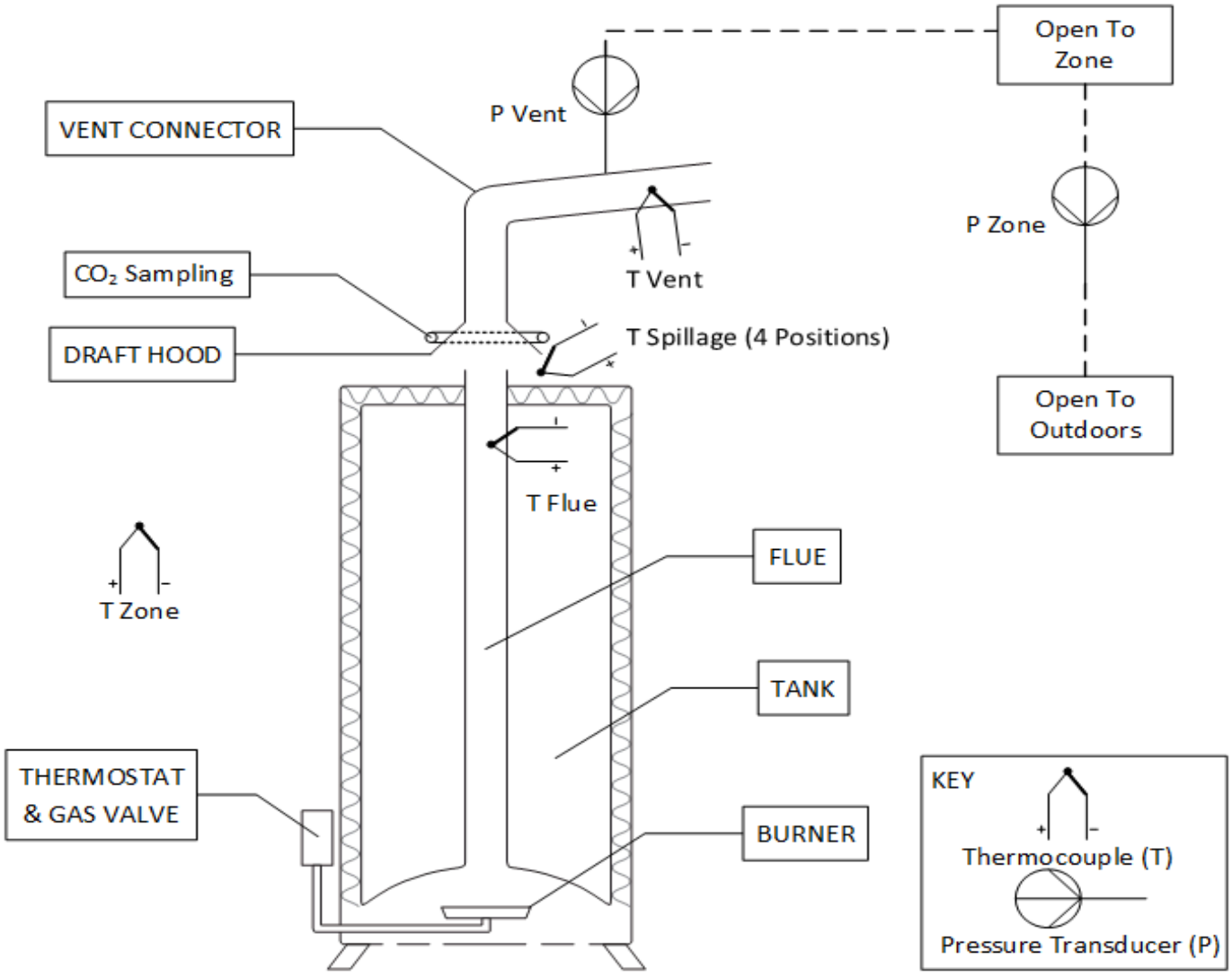
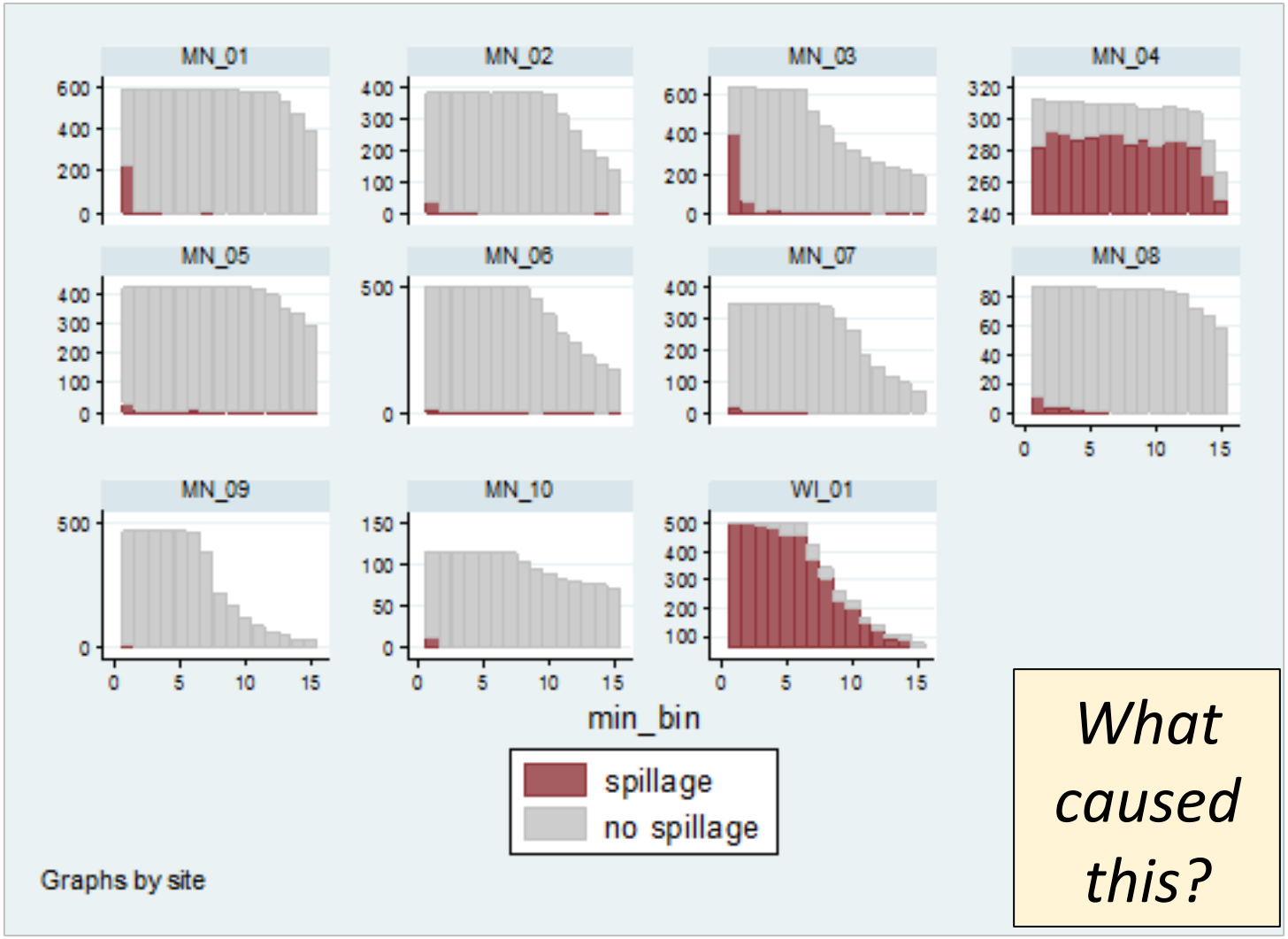
Our Field Study

- 11 homes, MN and WI
- Atmospheric draft natural gas water heaters in basements
- Measured or observed
  - Burner operation (via temperature)
  - CO2 near draft hood (as indicator of spillage)
  - Pressures and fan status
  - Etc
- Data collection for 3 to 6+ months, 1500 days of data
- Part of overall project including testing each home, and a survey

Monitoring setup
CO2 near vent used to identify spillage



Spillage by minute of operation, by site



What caused this?

Two sites showed excessive spilling; ***both had venting defects***

- MN_04 had an undersized water heater vent (vent capacity = 75% of burner input)

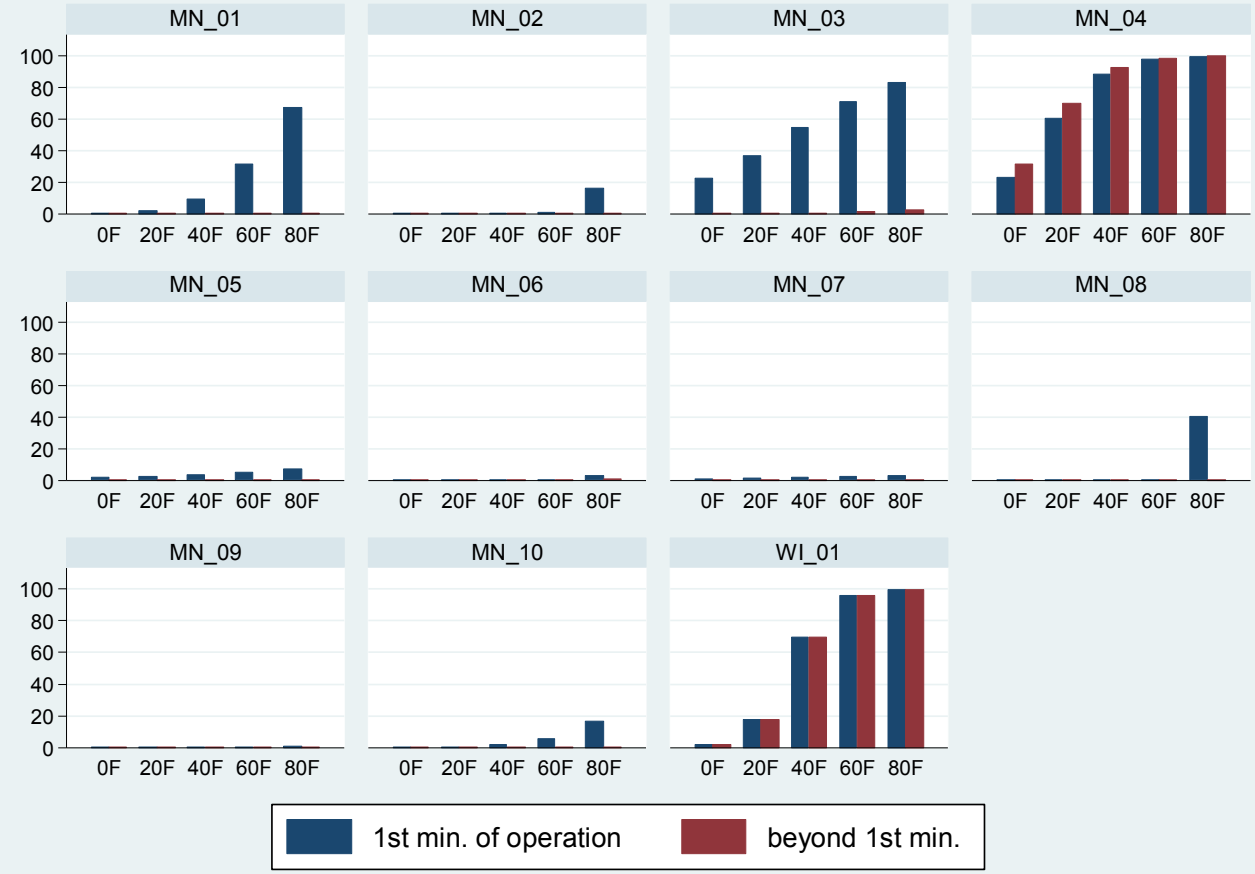
3” vent, 6’ run, 4 elbows

- WI_01 had a large opening downstream of the water heater (unused, partially repaired connection for a furnace)

Water heater and unused furnace vent

Images courtesy CEE

Effect of first minute of operation and outdoor temperature



Estimated probabilities from logistic regression model

Logistic regression: Effect of first minute, outdoor temp, & zone pressure

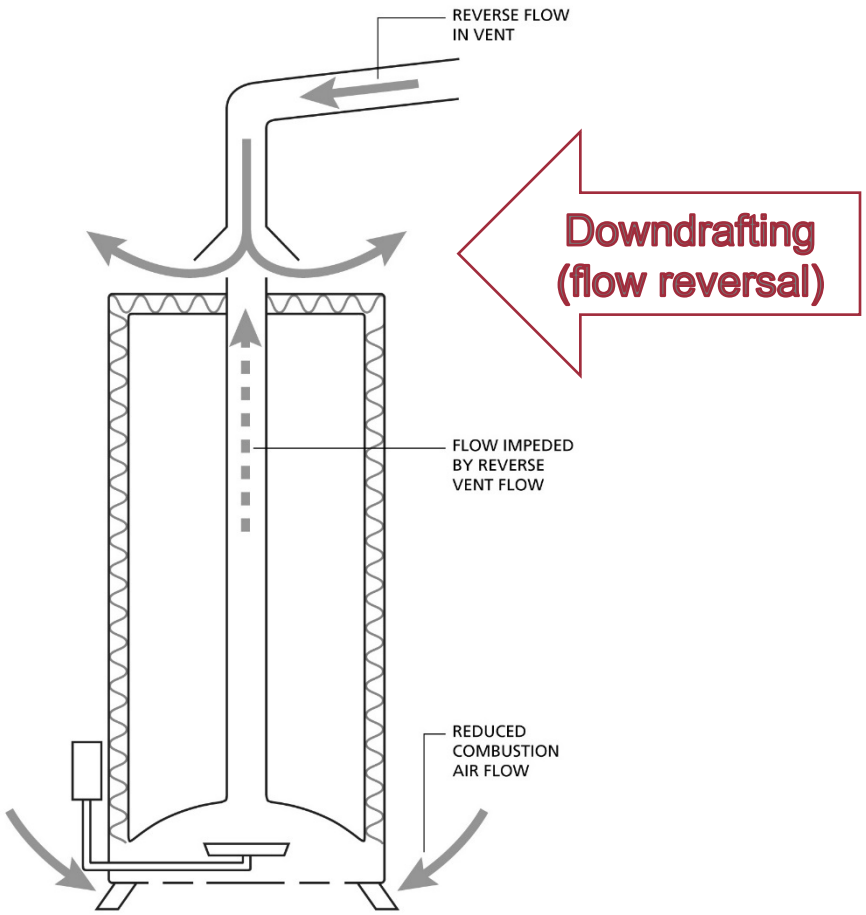
Site	1st minute of operation (binary)	Outdoor temperature (F)	Combustion zone depressurization relative to outside (Pa)§
MN 01	1,005.01 ***	1.10 ***	1.46 ***
MN 02	213.78 ***	1.23 ***	4.29 ***
MN 03	171.39 ***	1.07 ***	1.65 ***
MN 04	0.65 *	1.10 ***	1.21 *
MN 05	15.61 ***	1.06 ***	2.36 ***
MN 06	3.69 ***	1.10 ***	1.39 ***
MN 07	31.48 ***	1.03	2.32 ***
MN 08	244.16 ***	1.27 ***	NA†
MN 09	13.81 ***	1.09 *	2.79 ***
MN 10	396.99 ***	1.13 **	2.74 ***
WI 01	NA‡	1.13 ***	1.07 *

Remember, most absolute values quite small!

Logistic regression: Odds ratios for individual fans, air handlers, & doors

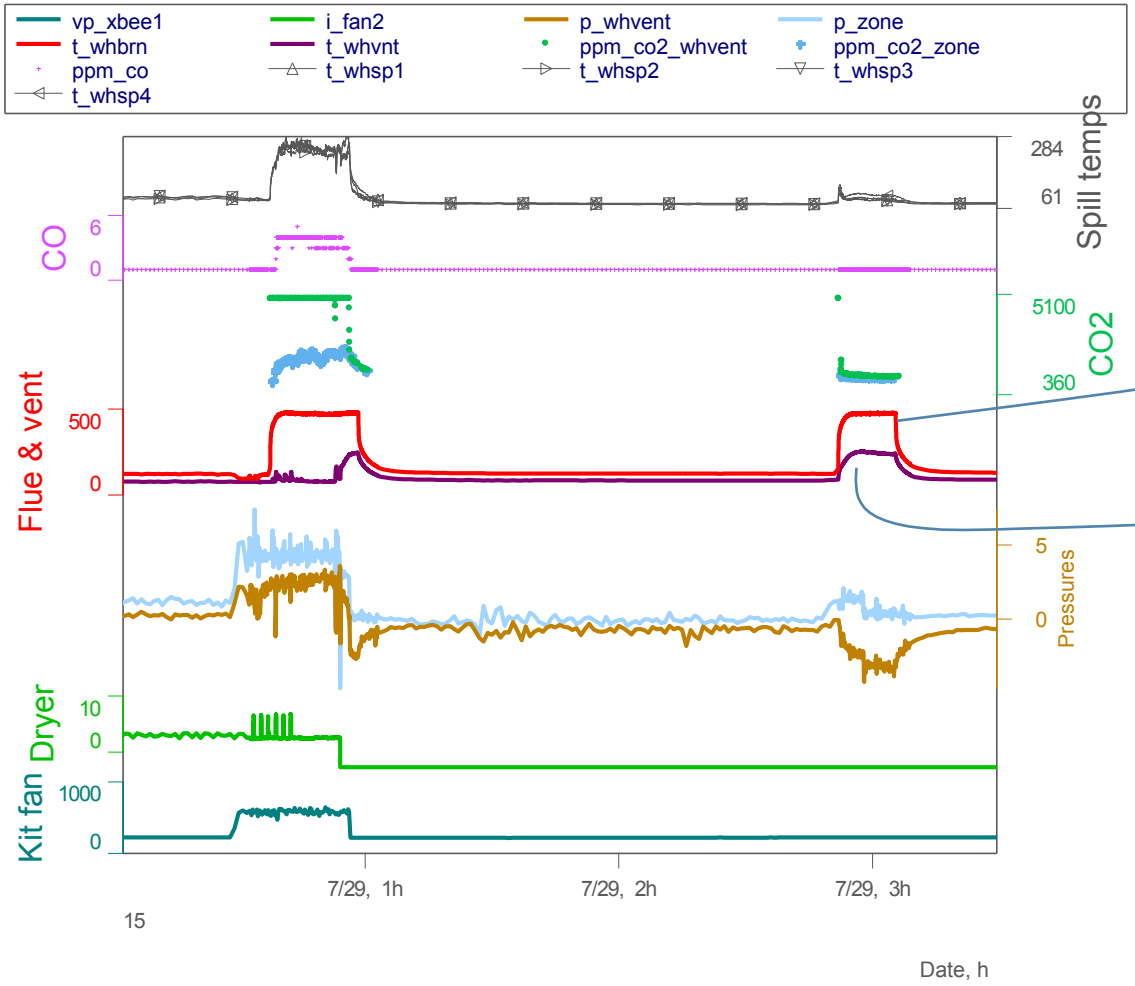
Site	Dryer		Kitchen fan		Bath fan 1		Bath fan 2		Air handler		Door	
MN 01	3.17	***	2.91	***	ND		ND		ND		NV	
MN 02	15.03	***	ND		1.78		19.17	***	1.93		NV	
MN 03	3.28	**	27.07	***	2.40	***	0.76		2.37	**	NV	
MN 04	1.90		AS		ND		ND		ND		NV	
MN 05	2.18	**	NS		NV		ND		1.04		1.95	
MN 06	NS		NV		2.75	**	ND		1.79		ND	
MN 07	NS		13.10	***	NS		ND		16.09	**	NV	
MN 08	NV		NV		ND		ND		NV		NV	
MN 09	4.21		NS		NS		ND		9.E+04	***	0.06	**
MN 10	ND		ND		0.55		ND		NS		NV	
WI 01	1.73		ND		NV		ND		0.91		1.05	

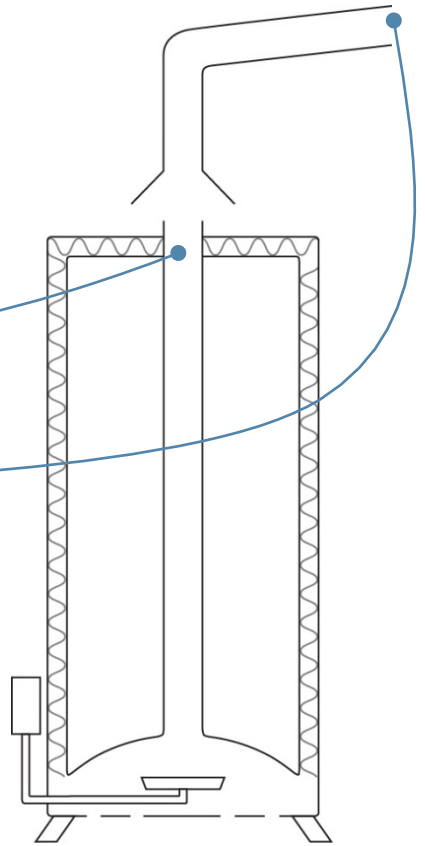
Downdrafting – vents goin' crazy



Site	Number of episodes	Number of minutes in down-drafting	Maximum duration
MN 01	34	283	44
MN 02	27	140	63
MN 03	71	791	92
MN 04	48	1,038	383
MN 05	1	1	1
MN 06	0		
MN 07	142	1,670	102
MN 08	0		
MN 09	1	6	6
MN 10	18	406	137
WI 01	105	1,042	211
Total	447	5,377	383

Downdrafting behavior





Contributors to downdraft formation

- Similar to spillage in general (zone depressurization, individual fan operation, higher outdoor temperature all appear to contribute)
- NOT clear when and why it becomes stable at some times, not others

Conclusions

- **Typical, normal systems don't spill excessively**, and don't produce much carbon monoxide
- **Vent defects are an important cause**, perhaps the largest cause, of excessive spillage. Vent inspection is *critically important* in evaluating safe operation.
- **Testing** in current form **may not tell us much** about the propensity of water heaters to spill beyond the first minute
- **Downdraft** formation remains somewhat mysterious, is not predicted by testing, and needs more work