Energy Design Conference 2016

Test Protocols & Results: Airport Sound Program and Building America Field Tests

Dave Bohac, PE
Center for Energy and Environment

MSP Airport Sound Program Weatherization To Reduce Sound

- Replace or upgrade windows & install central AC
- Attic air sealing & attic and wall insulation
- Borrowed specs from energy programs, used weatherization contractors, strong QC requirements
- Average house leakage (average 30% reduction)
  - Before: 7.8 ACH50
  - After: 5.4 ACH50

Tightening work on 3,200 homes with limited testing, what could possibly go wrong?

Program Shutdown (1996)

Saturday
OCTOBER 5, 1996

Star Tribune

Minneapolis Edition

NEWSPAPER OF THE TWIN CITIES

Some noise-insulated homes unsafe

A Star Tribune investigation revealed flaws in the Metropolitan Airports Commission (MAC) sound insulation program and safety issues in some insulated houses. MAC was told about air quality and moisture problems four years ago. Now the MAC is proposing to fix the program and repair homes.

By Karen Tosen and Donna Halvorsen
Star Tribune Staff Writers

A program to insulate thousands of homes near Minneapolis-St. Paul International Airport against airplane noise is making some of those homes unsafe for their inhabitants, the Star Tribune has found.

An expert who tested five sound-insulated homes for the Star Tribune found that three are unsafe. He found the other two have serious ventilation problems that are damaging the homes' structural integrity or making them dangerous under certain circumstances. In all cases, the homeowners whose houses were tested were unaware of the extent of the problems.

In response to the Star Tribune investigation, program administrators will recommend to a Metropolitan Airports Commission (MAC) committee Tuesday that MAC conduct safety tests in the more than 7,300 houses it has insulated and make repairs where necessary. A plan to conduct safety tests in every house insulated in the future already has been approved, MAC officials said.

"I want to leave the home knowing that everything is operating properly," said Tom Brown, MAC's construction manager for the program.

Program administrators also said they will recommend to MAC that carbon monoxide detectors be delivered to every sound-insulated home.

The remedial work, including testing, repairs and the addition of carbon monoxide detectors, is projected to cost about $2.25 million.

In October 1995, MAC began testing the air quality in 20 percent of the homes it was insulating. The MAC gave test results to the Star Tribune this week showing that 4.7 percent were too tight. That is, they failed to meet national standards for safe indoor air quality, which means the houses don't get enough fresh air to replace stale air tainted by indoor pollutants.

Turn to MAC on A14

Residents on the southwest side of Lake Nokomis in Minneapolis and others who live near Minneapolis-St. Paul International Airport are part of a Metropolitan Airports Commission-administered program to insulate about 9,000 homes against jet noise.

Inside:

- Some homeowners are satisfied with the sound insulation job; others are concerned about the quality of air in their homes. "It's real scary to think that we did this to change noise pollution, and now we've changed air quality," said one owner. Turn to A14.
- Contracts homeowners sign tell them that the insulation will reduce the flow of fresh air into the home and that it is up to them to correct ventilation problems. Turn to A15.
- When there is carbon monoxide present in your home and when fuel-burning appliances are not operating as intended, your home is unsafe. Turn to A15.

Spurred safety testing

Program Response

Do No Harm

- Panel of international building science experts establish standards & on-going review

- Design safety into 5,000 future homes
  - Test before work & homeowner fix failures
  - Program work: tighten, add ventilation and select treatments to maintain safe operation – keep existing equipment when possible
  - Test after work complete and fix/retest as necessary

- Go back to 3,200 completed homes

Similar approach for Milwaukee (3,000 homes) & San Antonio (5,000 homes)

Full report: http://www.state.mn.us/mn/externalDocs/Commerce/Ventilation_and_Depressurization_Research_022003031343_VentilationReport.pdf

Combustion Safety Tests

- Natural gas appliance flue carbon monoxide
- Vented appliance worst-case combustion spillage
- Measure mechanical room (CAZ) worst-case pressure for design purposes
- Estimate depressurization after tightening & added (or reduced) exhaust flow => power-vent water heater or ?

Appliance Carbon Monoxide: a maintenance issue

Standards

Ovens: 150ppm

Others: 100ppm

- Local gas utility service standard
- National WX practice
- National appliance = 400ppm “air free”

Failure Rate

Ovens: 25%

Water Heaters: 4%

Furnaces: 14%

Draft pressure: a good predictor of spillage?

Initially used draft pressure for pass/fail
Many water heaters failed draft and passed spillage
Used spillage monitoring study to evaluate draft standard

- Monitored water heaters that failed draft pressure standard & passed spillage
- 394 water heaters monitored 60 days for spillage
- 87% had no spillage events
- Only1 failed: had spillage that was greater than 5% of the operating time

Result: draft pressure no longer used for pass/fail

Appliance Combustion Spillage

Standards

"Worst-case" – turn on all exhaust fans/appliances, open/close doors, air handler on/off

Duration – furnace 1 minute & water heater 3 minutes

Failure Rate

Water Heaters:	19%
Furnaces:	10%

Depressurization & vent sizing

What Causes Water Heater Spillage?

Spillage Result	Frequency	WC Pres. (Pa)	WC < Limit	Vent Cap / Input
Pass Both	81%	-1.0	8%	0.97
Pass Natural/**Fail WC**	**9%**	-3.5	**51%**	0.96
Fail Both	**11%**	-1.1	9%	**0.79**

"Natural" = No depressurization

>1 indicates sizing is OK

- Pass Both Conditions: low depressurization and properly sized common vent (e.g. chimney)
- Pass Natural/Fail WC: about half have WC pressure > limit
- Fail Both: undersized chimney or vent connectors

Depressurization & vent sizing

Water Spillage Failure Rate

WC Depressurization (Pa)		
0 to 3	3 to 5	5+
5%	24%	82%

- Very LOW spillage failure when WC pressure < 3 Pa (5%)
- Very HIGH failure when WC pressure > 5 Pa: (82%)
- WC pressure 3 to 5 Pa: sometimes fails

Good indicator of when start having problems. Not highly reliable for predicting pass/fail for moderate conditions.

Depressurization & vent sizing

Water Heater Spillage Failure Rate

For Natural Conditions

Connector Ratio	Chimney Cap/Input Rate		
	< 0.85	>= 0.85	All
< 0.6	**39%**	**18%**	31%
0.6 - 0.8	**15%**	7%	11%
0.8 – 1.0	8%	11%	10%
1.0 – 1.2	5%	1%	3%
1.2 – 1.4	6%	7%	6%
> 1.4	2%	2%	2%
All	**14%**	**7%**	**11%**

High failure when chimney more than 15% undersized and connectors more than 20 - 40% undersized

Vent Sizing

- Half or more of the spillage problems were due to undersized or improperly installed vents
- The venting tables in the code have been around since the 1950's with an update in the 1980's
  - Time-tested
  - Will solve most problems

Source: Larry Brand, GTI

Vent Capacity Tables

Example:

- 100,000 Btu/hr furnace
- 40,000 Btu/hr water heater
- Common vented
- Type B double wall vent
- Type B double wall connector
- 2 ft rise
- 20 ft common vent height

Result:

- 4 inch vent connector for water heater,
- 5 inch vent connector for furnace

Table 13.2(a) Type B Double-Wall Vent

Number of Appliances:	Two or More
Appliance Type:	Category I
Appliance Vent Connection:	Type B Double Wall Connector

Vent CONNECTOR Capacity

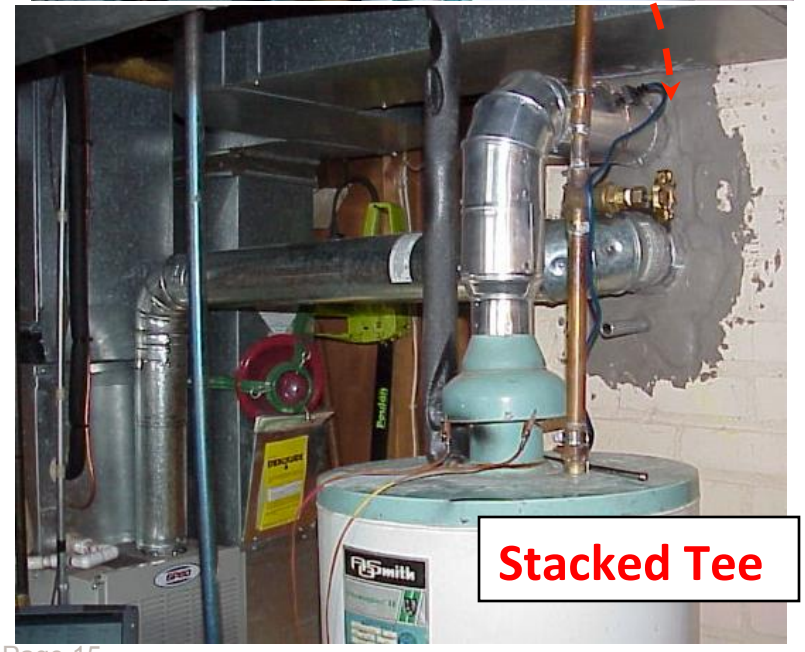
Height H (ft)	Connector Rise R (ft)	Type B Double-Wall Connector Diameter — D in.																					
		3			4			5			6			7			8			9			10		
		Appliance Input Rating Limits in Thousands of Btu per Hour																					
		FAN		NAT	FAN		NAT	FAN		NAT	FAN		NAT	FAN		NAT	FAN		NAT	FAN		NAT	FAN		NAT
		Min	Max	Max	Min	Max	Max	Min	Max	Max	Min	Max	Max	Min	Max	Max	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	142	92	296	185	109	376	237	128	466	289
	2	23	41	31	37	75	55	48	121	86	60	183	124	79	253	168	95	333	220	112	424	282	131	526	345
	3	24	44	35	38	81	62	49	132	96	62	199	139	82	275	189	97	363	248	114	463	317	134	575	386
8	1	22	40	27	35	72	48	49	114	76	64	176	109	84	243	148	100	320	194	118	408	248	138	507	303
	2	23	44	32	36	80	57	51	128	90	66	195	129	86	269	175	103	356	230	121	454	294	141	564	358
	3	24	47	36	37	87	64	53	139	101	67	210	145	88	290	198	105	384	258	123	492	330	143	612	402
10	1	22	43	28	34	78	50	49	123	78	65	189	113	89	257	154	106	341	200	125	436	257	146	542	314
	2	23	47	33	36	86	59	51	136	93	67	206	134	91	282	182	109	374	238	128	479	305	149	596	372
	3	24	50	37	37	92	67	52	146	104	69	220	150	94	303	205	111	402	268	131	515	342	152	642	417
15	1	21	50	30	33	89	53	47	142	83	64	220	120	88	298	163	110	389	214	134	493	273	162	609	333
	2	22	53	35	35	96	63	49	153	99	66	235	142	91	320	193	112	419	253	137	532	323	165	658	394
	3	24	55	40	36	102	71	51	163	111	68	248	160	93	339	218	115	445	286	140	565	365	167	700	444
20	1	21	54	31	33	99	66	46	157	87	62	246	125	86	334	171	107	436	224	131	552	285	158	681	347
	2	22	57	37	34	105	66	48	167	104	64	259	149	89	354	202	110	463	265	134	587	339	161	725	414
	3	23	60	42	35	110	74	50	176	116	66	271	168	91	371	228	113	486	300	137	618	383	164	764	466
30	1	20	62	33	31	113	59	45	181	93	60	288	134	83	391	182	103	512	238	125	649	305	151	802	372
	2	21	64	39	33	118	70	47	190	110	62	299	158	85	408	215	105	535	282	129	679	360	155	840	439
	3	22	66	44	34	123	79	48	198	124	64	309	178	88	423	242	108	555	317	132	706	405	158	874	494
50	1	19	71	36	30	133	64	43	216	101	57	349	145	78	477	197	97	627	257	120	797	330	144	984	403
	2	21	73	43	32	137	76	45	223	119	59	358	172	81	490	234	100	645	306	123	820	392	148	1014	478
	3	22	75	48	33	141	86	46	229	134	61	366	194	83	502	263	103	661	343	126	842	441	151	1043	538
100	1	18	82	37	28	158	66	40	262	104	53	442	150	73	611	204	91	810	266	112	1038	341	135	1285	417
	2	19	83	44	30	161	79	42	267	123	55	447	178	75	619	242	94	822	316	115	1054	405	139	1306	494
	3	20	84	50	31	163	89	44	272	138	57	452	200	78	627	272	97	834	355	118	1069	455	142	1327	555

Source: Larry Brand, GTI

NFPA 54 vent tables programmed into "vent test" checked on every home

Vent upgrades included in work scope

Work Type	Frequency
None	28%
Connectors	38%
Liners	22%
PV/DV water heater or chimney-top inducer	20%
Custom	6%



Fix: replace saddle with stacked tee to meet code

Reduce restriction & increase rise

- metal common vent / liner
- larger connector (4”)
- 2 fewer elbows (10% ea)
- 1’ more rise at diverter
- direct into vertical – stacked tee (10%)
- system is more resistant to low depressurization

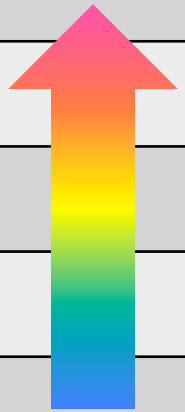
Equipment upgrades where needed

Power or direct vent water heater: 15%

Chimney-top draft inducer: 5%

Water heater spillage test failures **doubled** during warmer weather

Outside Temperature (F)	Spillage Failure Rate
> 80	**36%**
60 - 80	**28%**
40 - 60	**31%**
20 - 40	14%
< 20	14%
All (1071 tests)	23% (249 fails)



does not include tile liners

Big picture - combustion evaluation

- Spillage test: does it work now? (pass/fail)
- Measured depressurization vs guideline: will it work after weatherization & in other weather? (guidance)
- Higher rate of warm weather spillage fails: no method of compensating

Combustion Safety Test Procedure

- Is setting up worst-case depressurization really necessary to catch combustion safety failures?
- Can we develop a simplified test procedure that:
  - Easier to perform & more repeatable
  - Reduces "failures" for acceptable situations
  - Still finds hazardous situations

DOE Building America sponsored field research

Building AMERICA U.S. Department of Energy

Source: Larry Brand, GTI

Simplified Test Conditions

	Test Procedure		
	Comprehensive	BPI 2015	Simplified
Dryer & Kitchen	On	On	On
Next Largest Exhaust Fan	On	On	On
Other Exhaust Fans	On	On	Off
CAZ Door	Check	Check	Closed
Other Doors	Check	Open= exhaust fan or return register in room	Open= exhaust fan or return register in room
Air Handler	Check	Check	Check

Check= which ever produces lowest CAZ pressure

Simplified and BPI Test Methods

- Maximum spillage duration
  - Water heaters & warm vent furnace/boiler = 2 minutes
  - Cold vent furnace/boiler = 5 minutes
- Draft pressure not used for pass/fail
- CAZ depressurization not used for pass/fail

Field Study: monitor spillage under normal operation

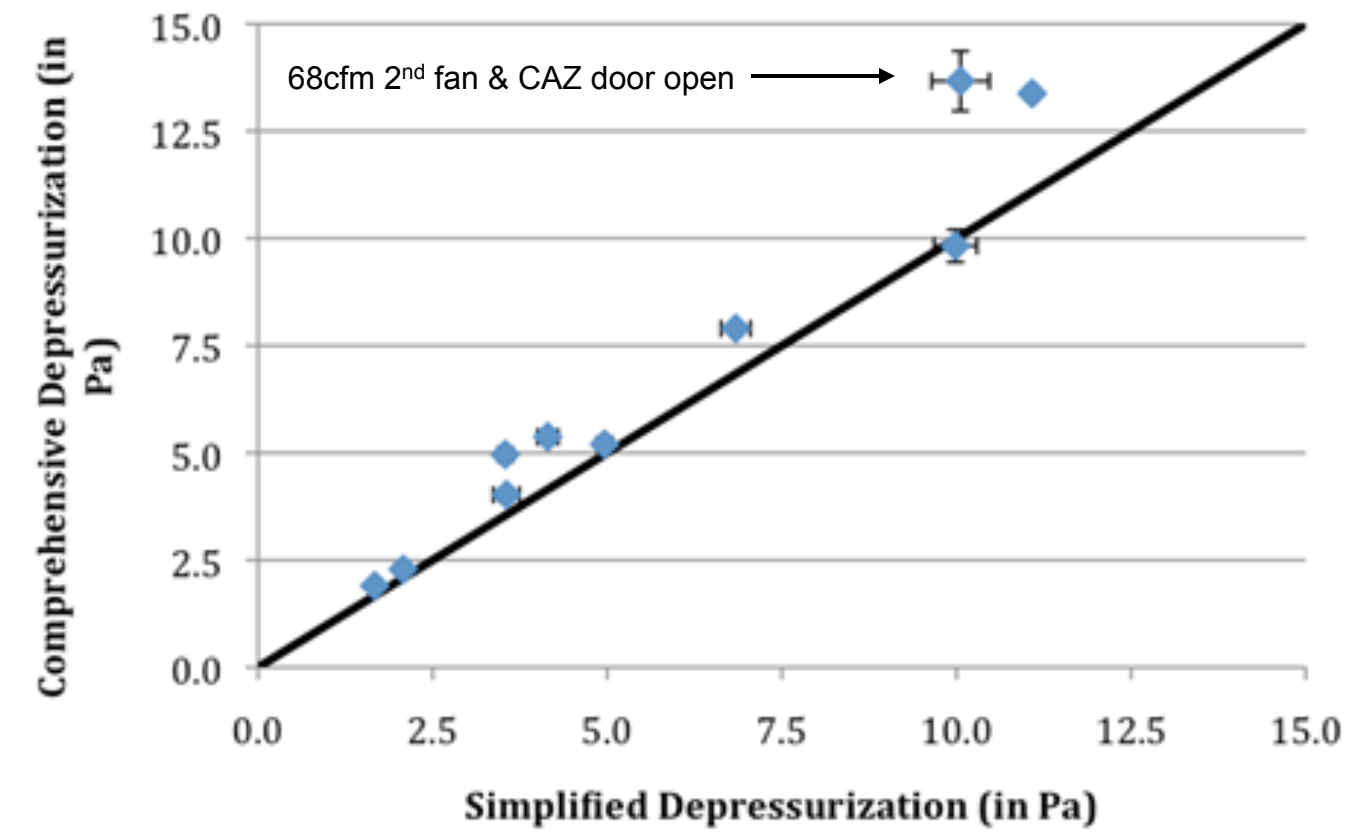
- Selection Criteria:
  - Spillage fail for simplified conditions
  - Spillage pass: kitchen fan= low & other fans off
- 11 homes in Minnesota and Wisconsin
- Atmospheric draft natural gas water heaters in basements
- Data collection for 3 to 6+ months, 1500 days of data

House Characteristics

	Minimum	Maximum	Average
Air Leakage (ACH50)	3.9	11.1	6.2
Kitchen Fan (cfm), [10/11]	121	276	219
Bathroom Fan (cfm), [11/11]	30	130	65
2nd Bath Fan (cfm), [7/11]	20	72	41
CAZ Depress (Pa)	-1.9	-13.7	-6.9

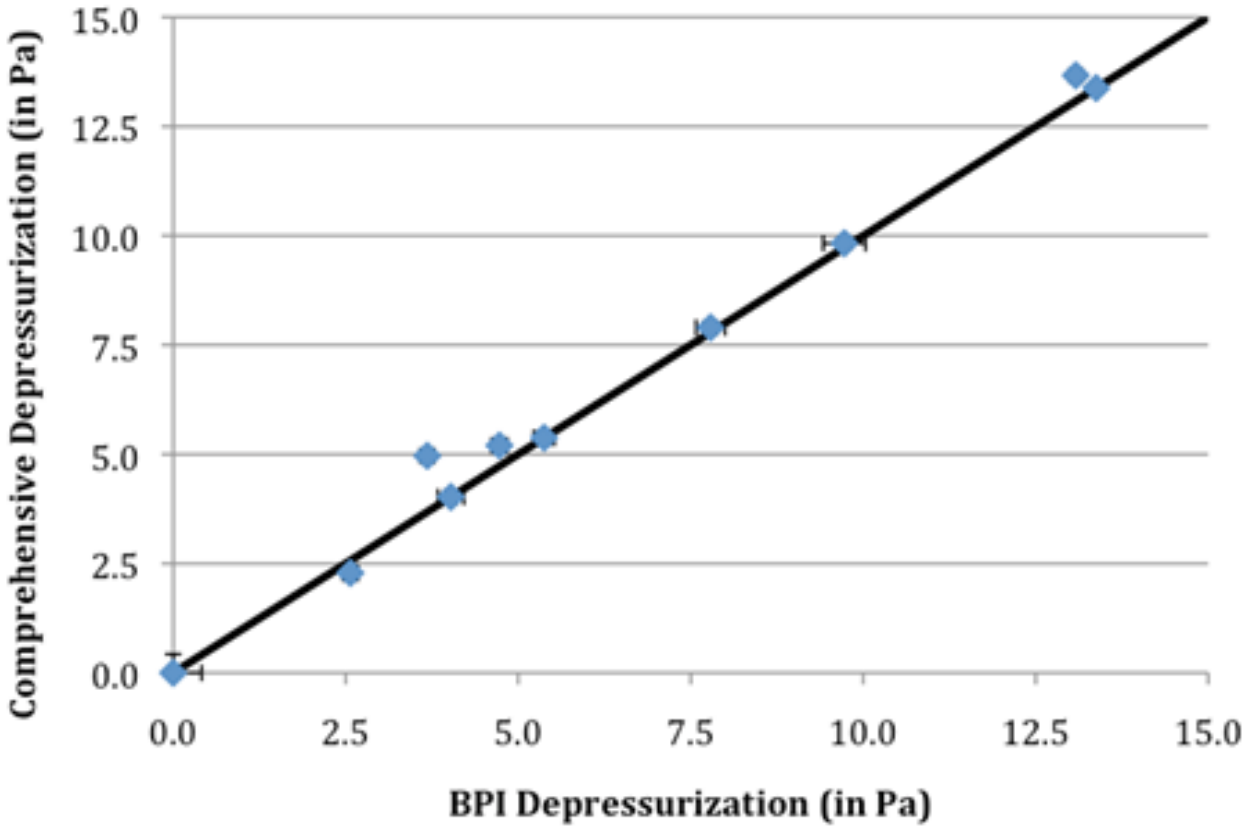
Depressurization Conditions

Comprehensive versus Simplified



Depressurization Conditions

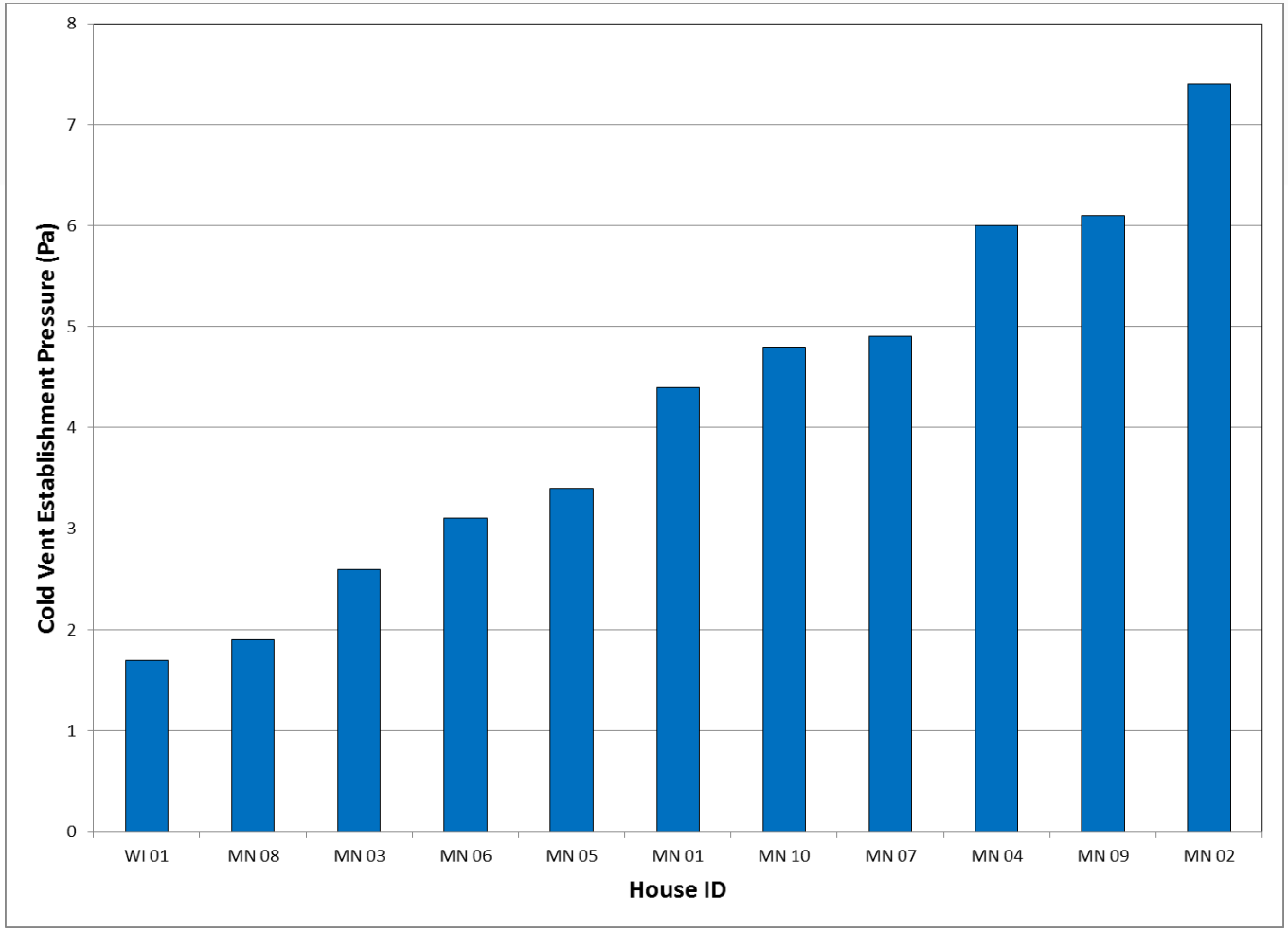
Comprehensive versus BPI



For these 11 houses: interior door position can be determined by whether there is an exhaust fan or return register in the room

Cold Vent Establishment Pressure

Greatest depressurization that the water heater can overcome



Conclusions

- Worst-case test conditions about equal for Simplified and Comprehensive methods.
- Large variation in level of depressurization required to cause spillage (-1.7 to -7.4 Pa).

Next speaker: Dan Cautley- monitoring results