Center for Energy and Environment

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U.S. DEPARTMENT OF ENERGY | Energy Efficiency & Renewable Energy

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U.S. Department of Energy

Spring 2012 Residential Energy Efficiency Stakeholder Meeting:
Combustion Safety in Tight Houses

Testing Protocols & Results: Airport Sound Program Experience and BPI/RESNET Development

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Building Performance Institute

All Tightening of Existing Homes Can Affect Combustion Appliance Safety

MSP secret: this Airport Sound Program does weatherization work to reduce sound

- Weatherization, custom windows & central air conditioning
- Attic insulation, wall insulation, and attic air sealing – borrowed specs from energy programs and used weatherization contractors
- Average house leakage: 7.8 ACH50 before 5.4 ACH50 after

Tightening work was done on 3000 homes with no testing, what could possibly go wrong?

Program Shutdown

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 Tuzon 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 2,300 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 board 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 houses 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 southeast 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

- Blue ribbon panel of international building science experts provide standards & ongoing review (1996)
- Go back to 3,200 completed homes
  - Do safety test & fix combustion safety issues
  - add people ventilation
- Design safety into 5,000 future homes
  - pre-test & homeowner fixes fails
  - Program work: tighten, add ventilation and select treatments to maintain safe operation – keep existing equipment when possible
  - test after work complete and add more/retest as necessary

Adopted by Milwaukee for 3000 homes, simplified
Applied in San Antonio for 5000 homes, ongoing, simplified further

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

Combustion safety tests

- Excluded specialty technician tests- done by energy auditors
- Natural gas appliance flue carbon monoxide
- Vented appliance worst-case combustion spillage
- Measure mechanical room (CAZ) worst-case pressure for design purposes
- Use house leakage, fan flows, and expected tightening to estimate depressurization after work

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%

“Clean and Tune” can reduce CO*

*** Even if only seen at backdraft “No over-firing”**

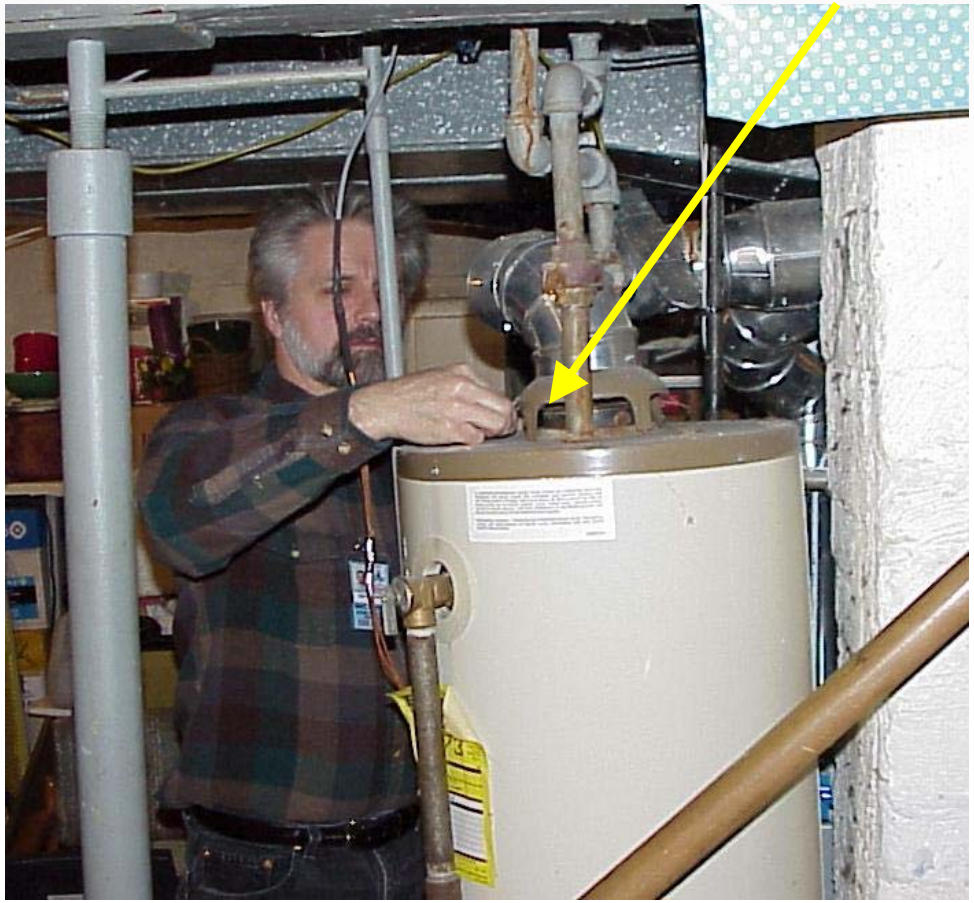
before : 4,500ppm CO, over fired 35%
3+ cups of rust,…

After: 0ppm CO, input to nameplate
15ppm natural

Usual CO test alone is not a clean & tune

Range (ppm)	*Water Heater*		*Nat. Drft. Furnace*	
	Norm.	*DD*	*Norm.*	*DD*
<= 25	90%	88%	85%	78%
25 - 50	5%	5%	5%	5%
50 - 100	1%	2%	2%	2%
100 - 150	0%	1%	2%	2%
150 - 250	1%	1%	1%	2%
250 - 500	1%	1%	1%	2%
> 500	2%	2%	4%	7%
Fail Std.	**3.5%**	**4.7%**	**7.7%**	**14.4%**
n =	1,356		548	

Appliance Combustion Spillage



Standards

"Worst-case" – turn on all exhaust fans/appliances, adjust doors

Program duration – furnace 1 minute & water heater 3 minutes

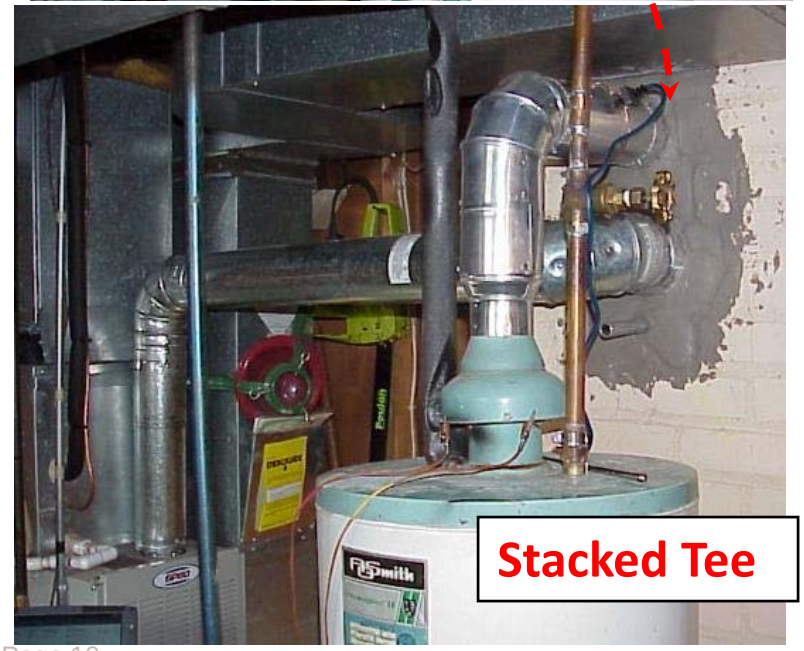
Code duration - 5 minutes

Failure Rate

Water Heaters: 19%

Furnaces: 10%

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



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 T (10%)
- system is more resistant to low depressurization

Cost:

$150 to $750

Connectors/liners

Pre-existing: repairs possible & costs not huge

Specifics vary with location

- Carbon monoxide
  - 84% - clean and tune
  - $80 median cost
- Spillage
  - 62% - connector modification, 17% - disconnect fan
  - $150 median cost
- **All combined**
  - **$80 median cost**
  - **$341 average cost** (some expensive repairs)

Re-vent to NFPA 54 table sizes

- Following National Fuel Gas Code (NFGC) tables yields systems that are very likely to vent properly
- Systems that are undersized are not guaranteed to fail
- For “normal” pressures or low depressurization

Worst-case “short term tests need to be interpreted with caution. Complementary approaches…such as checking venting systems for compliance with applicable codes, are strongly advised.”

ASTM E-1998-11: Standard Guide for Assessing Depressurization Induced Spillage from Vented Combustion Appliances

Vent sizing & depressurization

Water Heater Spillage Failure Rate

Vent Sizing		Measured Depressurization (Pa)		
Connectors	Chimney	0 to 3	3 to 5	5+
Under	Under	7%	12%	**100%**
OK	Under	6%	38%	**67%**
Under	OK	5%	13%	**75%**
OK	OK	2%	11%	**90%**
All	**All**	**5%**	**20%**	**82%**

Re-venting works within "normal" pressures

Almost guaranteed to spill

>5pa reverses most vents

Venting work in MSP construction

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

only 20% of the houses needed power venting

28% passed all tests with no changes

Equipment upgrades where needed

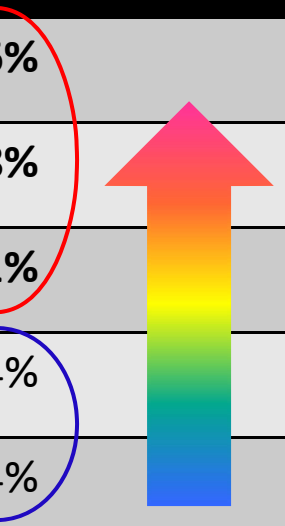
Depressurization resistant appliances , exterior fans

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)



no tile liners

Monthly tracking of results by staff suggested increased spillage failure in summer

Big picture - combustion evaluation

- Spillage test: does it work now? (pass/fail)
- Depressurization test: will it work in other weather (guidance)
- Not enough is known to set a “safe” pressure for warm weather water heater venting.
- Program data indicates a higher rate of warm weather spillage fails but still fewer than at 5pa

Water heater spill-monitoring option to re-venting.

394 water heaters, 60 days of normal operation

- Why? Failed draft standard with no spillage
- 87% had no spill events
- only1 failed: had spillage that was greater than 5% of the operating time

No action needed in 393 of 394

Program: draft pressure test stopped as pass fail
But done for information only

Depressurization limits

Appliance Type	Program 1996	New CGSB 2005*
Individual (orphan) water heater (WH)	2**	5
Natural draft WH and furnace or boiler	3	5
ID furnace/boiler & natural draft WH	5	5
Individual natural draft furnace or boiler	5	5
Individual ID furnace or boiler	15	5
Common vent with chimney-top inducer	15	5
Pellet stove with fan and sealed vent		15
Power vent and direct vent	>25	20

***- discloses not all conditions, excl. dhw in summer; fans only: HVAC w/mech. door shut, ventilation, kitchen , dryer, any >150cfm, cont.**
*** * spill alarm option in lieu of repairs, BPI 2-5pa**

Changes in source standard CGSB 51.71-2005

- Does not try to include all possible causes or weather
- Discloses test limits, no longer called “worst-case”
- Applies to heating season only
- Simpler: Only HVAC, kitchen fan, dryer, fans >150cfm, & ventilation fans

Canadian depressurization standard: summer water heater operation excluded

" **The limits are valid only during the heating season**

"These limits are not suitable for predicting non-heating season performance, such as water-heater operation during the summer months."

Note: *Fuel-fired water heaters connected to vertical chimneys pose a special problem when operated during the summer in an airtight dwelling. Even low levels of house depressurization may be unacceptable since flue gas buoyancy is reduced in warmer weather."*

"CAN/CGSB 51-71 -2005 Depressurization Test" Supercedes CGSB 51.71-95

Low or no safe limit clarifies choices, it is simpler.

Options when limits don't apply

Appliances in living space, marginal depressurization

- Provide spill alarm

  further action where indicated, or not

- Reduce depressurization by fan reduction, make up air, transfer air & duct balancing

If secure performance required:

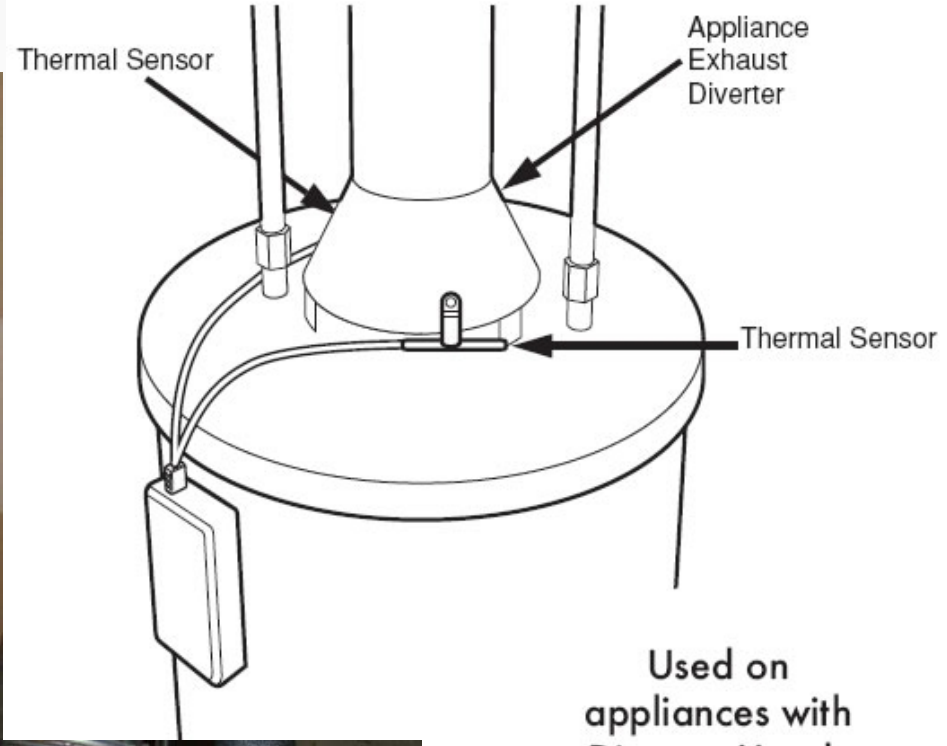
Upgrade: power/direct vent, Combo system, sidearm, Heat pump, move to isolate + combustion air, electric…

BPI interim guidance 5/25/07

Option: for DHW with depressurization from 2 to 5 pa

- Provide a spill switch to interrupt fuel supply if spillage occurs
- Provide a spill alarm on the water heater plus an additional CO alarm in the mechanical room
- Recommend power vent and direct vent upgrades or isolation from pressure sources and additional combustion air

Vent-Rite spill alarm



Used on appliances with Diverter Hoods

- Waters Heaters
- Furnaces
- Boilers

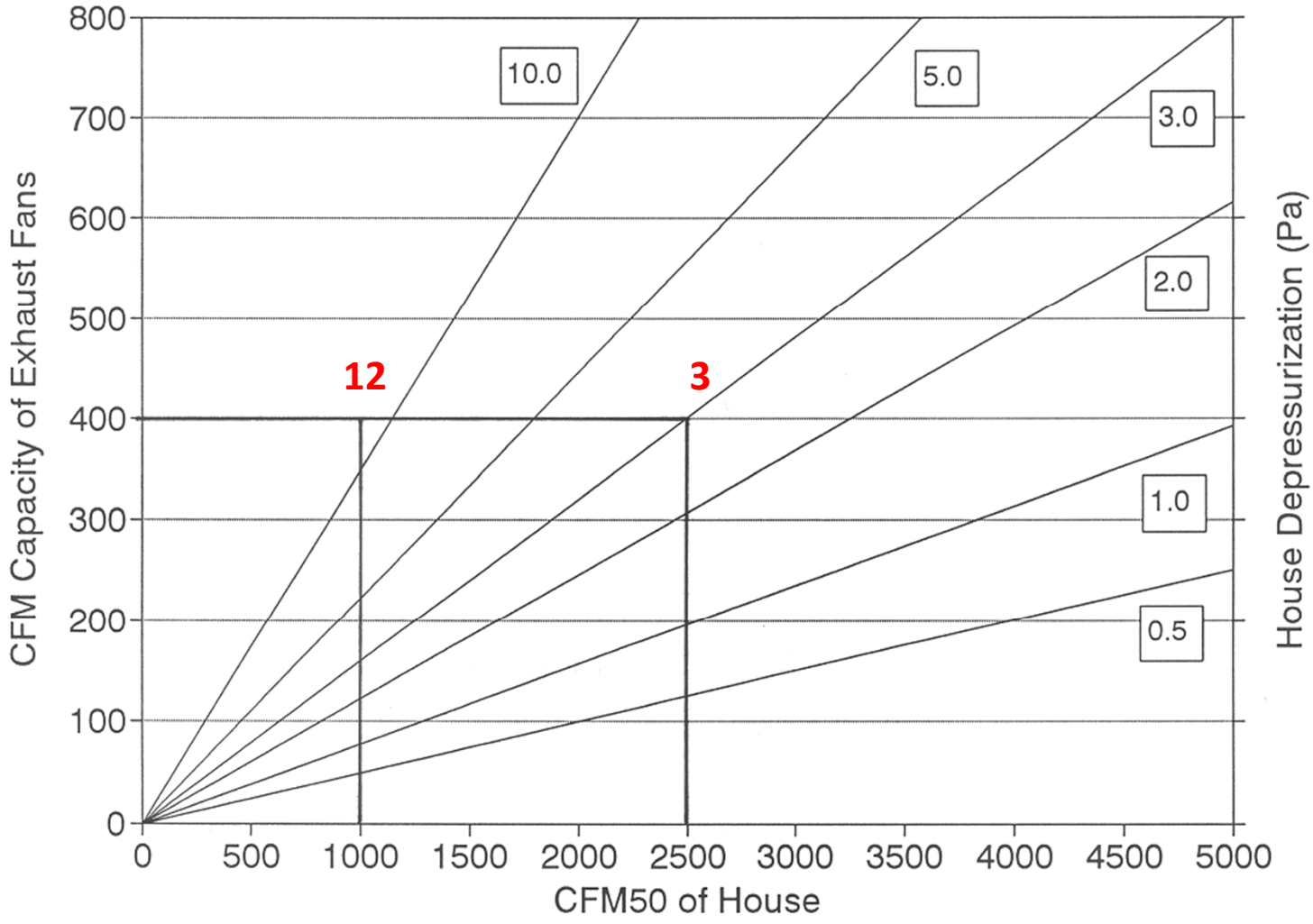
4 alarms in 3 years
Dryer + odd door closure

Example : Small, tight house 400 cfm exhaust => 100% spillage failure

fan interferes with combustion venting

Wind uncertainty:

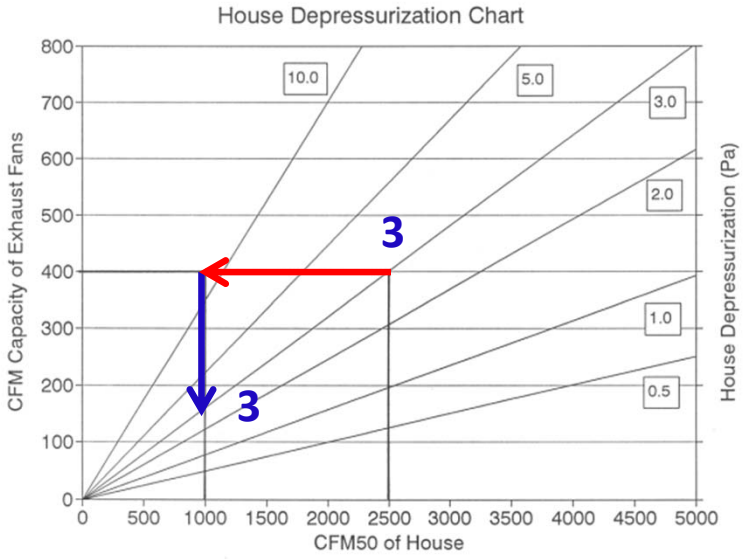
check exhaust fan flow at house cfm 50 to confirm pressure



Change fan flow & keep combustion safety

~~Continuous at 40cfm.~~ Installer sets high speed for allowable house pressure: 75, 160, or 390 cfm

IAQ Range Hood
Signature Series
By Venmar Ventilation



Combustion safety and priority of treatments

- Combustion safety has top priority,
- Maintaining all old fans is not required.
  - Replace legacy fan with quiet low flow continuous
  - Keep current combustion equipment operating safely
  - Disconnect old fan if a choice is required
- Short term: postpone tightening until combustion safety is resolved

Tight house with natural draft appliance:

1. Supply ventilation*: interlocked with dryer

2. HRV/ERV with exhaust diverter to inside, interlocked with dryer

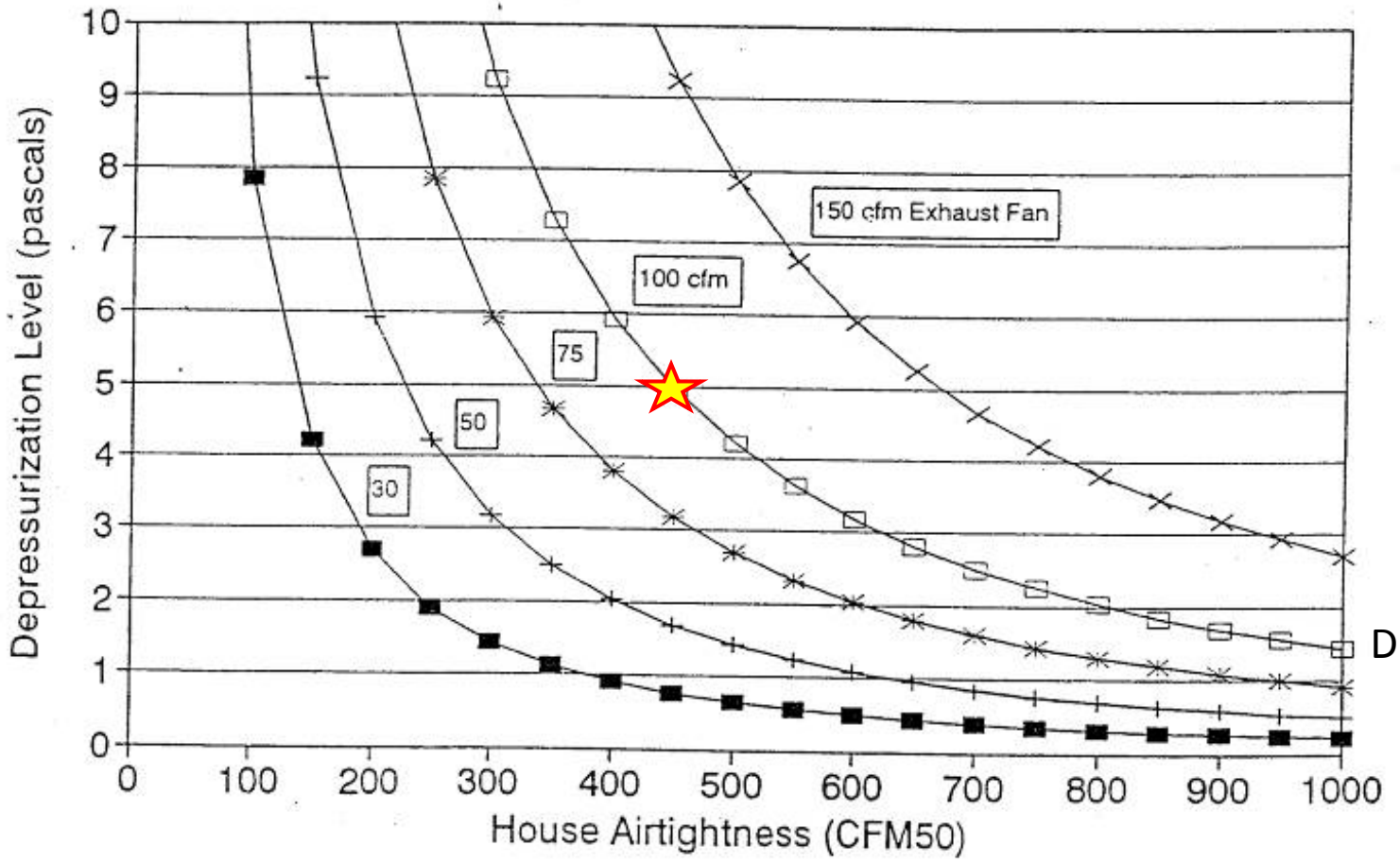
Pre-requisite: Reduce exhaust flows

High capacity kitchen fans require interlocked & conditioned make up air except in very mild climates.

Not for efficiency or tight homes.

* as developed by BSC/Armin Rudd for Building America: see BSC RR204

Depressurization From Exhaust Fans
(In Tight Houses)



Dryer 90-100

Dryer without supply air in 450 cfm50 house 5pa depressurization

Warm climate solutions: get simpler

5,000 home example by San Antonio airport

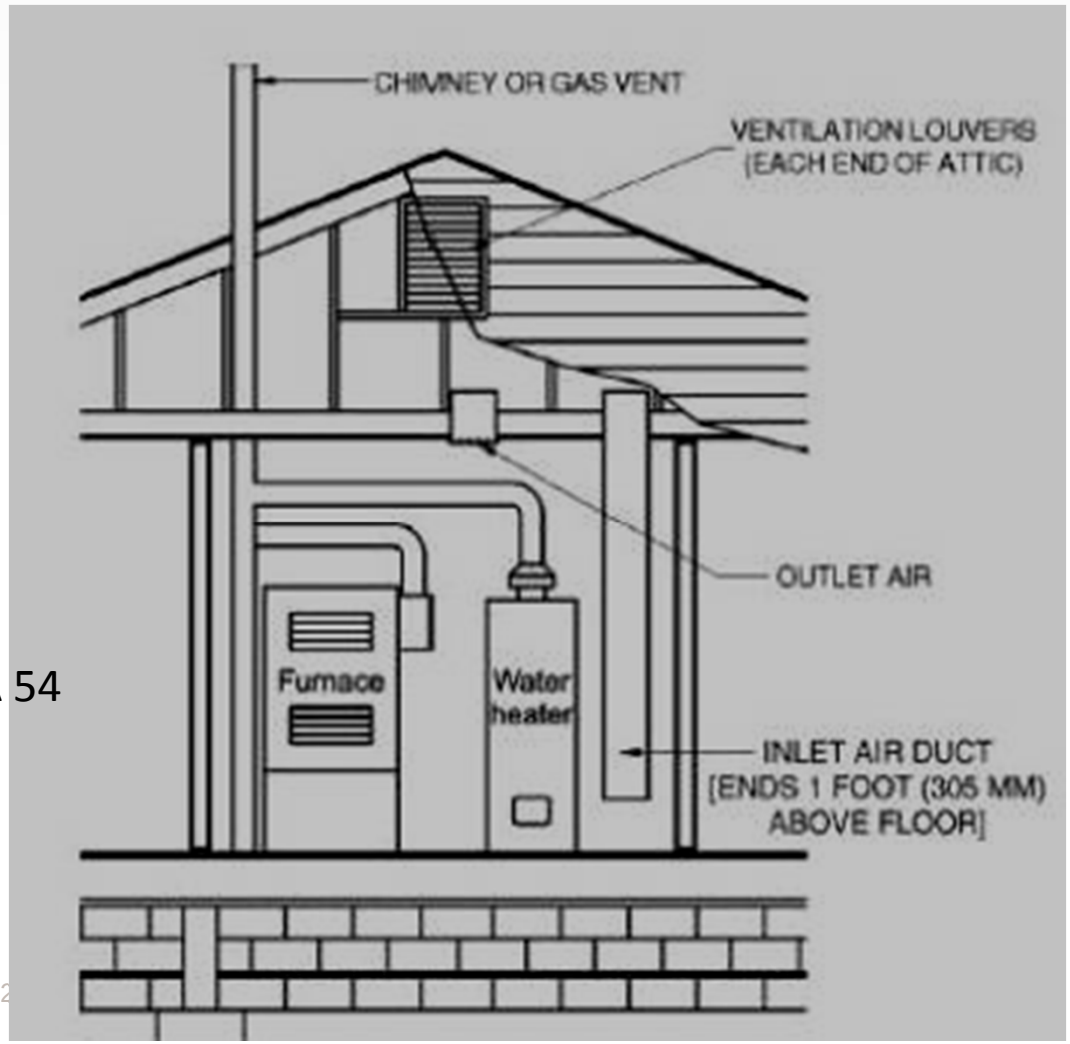
- Unvented heaters: replace all
- Appliances in mechanical closets, garages, attics
- Appliances in central part of house

" Water heaters in bedrooms/bathrooms either:

1. Installed in closets that have closer equipped doors with no openings and all combustion air from outside;
2. Direct vent type" Gas code at 10.28.1

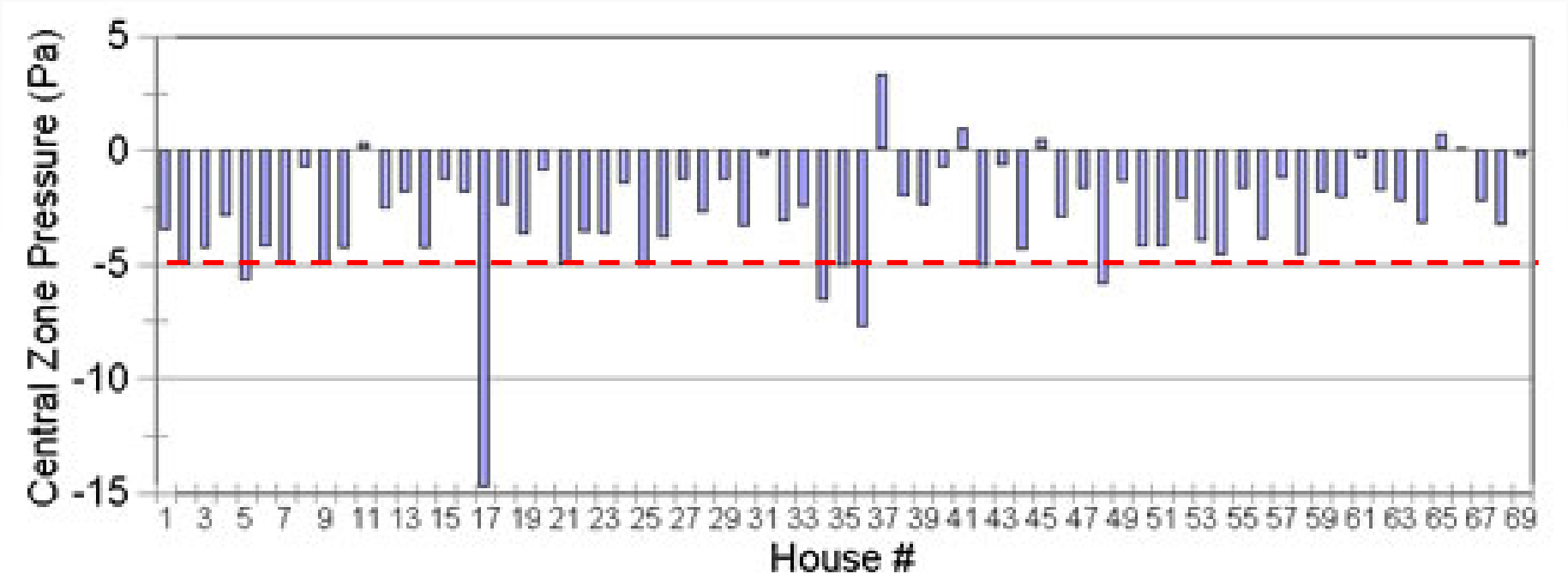
Mech. closet: all combustion air from outside & seal

Includes all equipment in garages and attics



NFPA 54
A 9.3

Unbalanced central returns – frequent large depressurization



Common – high fraction, frequent operation, too close to -5pa

From: Unbalanced Returns in Residences

FSEC J Cummings, C Withers ASHRAE Transactions Vol 112, Part 1, 2006

Transfer grilles ok for HVAC, not spillage

- Included in Florida work scopes, effective for cooling
- Not adequate fix for spillage from fans + central return effects (MSP w/ ducted AC to boiler houses, MKE)
- Power & direct vent upgrade works

When testing and repairs aren't going to make it – go to the answer.

Category 1 equipment in central return zone with kitchen fan and dryer

Upgrade to Power/Direct vent
(no test of what is gone)

No depressurization limit
is known safe from spillage
in warm weather.

Combustion safety test procedures under review

BPI

- Fuel leakage tests
- Vent system visual inspection
- WC depressurization test
  - Spillage
  - House pressure change – compare to limit
  - Vent draft pressure
  - Fail – repeat under natural
- Flue CO "as measured" level & test ovens
- Ambient CO < 35ppm

RESNET

- Fuel leakage tests
- Vent system visual inspection
- WC depressurization test
  - Spillage
  - House pressure change – compare to limit
  - Include 300cfm for fireplace
  - Fail – repeat under natural
- Flue CO "as measured" level & test ovens
- Ambient CO < 35ppm

Different depressurization limits

Depressurization limits share structure and limitations

Appliance Type	Program	BPI	RESNET**
Individual (orphan) water heater (WH)	2	5*	5
Natural draft WH and furnace or boiler	3	3	5
ID furnace/boiler & natural draft WH	5	5	5
Individual natural draft furnace or boiler	5	5	5
Individual ID furnace or boiler	15	15	5
Common vent with chimney-top inducer	15	50	5
Pellet stove with fan and sealed vent			15
Power vent and direct vent	>25	50	no test

* - 5Pa for properly sized chimney, 2Pa if oversized allow spill alarm

** - from CGSB 51-71 2005, plus 300 cfm fireplace simulator added to setup

Both under review

BPI & RESNET combustion safety

- Test equipment calibration requirement
- Required safety work included in weatherization work scope
- Some variations from industry/code procedures or standards – originate from weatherization legacy procedures
- BPI procedures are in use nation-wide, but often locally adapted and enhanced by program operators expertise .

Summary

- **Identify pre-existing problems & get fixed or add to scope**
- **Combustion safety tests can be used to determine when appliances are operating properly**
  - Check vent sizing & condition, flue carbon monoxide, spillage, house pressure, fans and return balance/paths. Confirm pressure when windy with fan flow and cfm50
- **Location and post-treatment success**
  1. Appliances inside:
     Code works for proper vent & chimney sizing
     Not always necessary to replace with PV/DV appliances
  2. Provide all combustion air from outside and seal appliances from house: attic, garage, closet- reduce testing
  3. Upgrade to power/direct vent if appliances in central return area or high pressures that can't be changed- reduce testing
- **Spill alarm is justifiable where questions remain**
- **Reduce test complexity, provide disclosure of test limits**

Additional material

- For more information see full report: http://www.state.mn.us/mn/externalDocs/Commerce/Ventilation_and_Depressurization_Research_022003031343_VentilationReport.pdf
- Scope and limits of depressurization test in CGSB 51.71-2005
- NFPA 54 Z223_1_2012 National Fuel Gas Code

- Combustion air from outside: single high opening, ducted to sides – see NFPA 54 after A 9.3

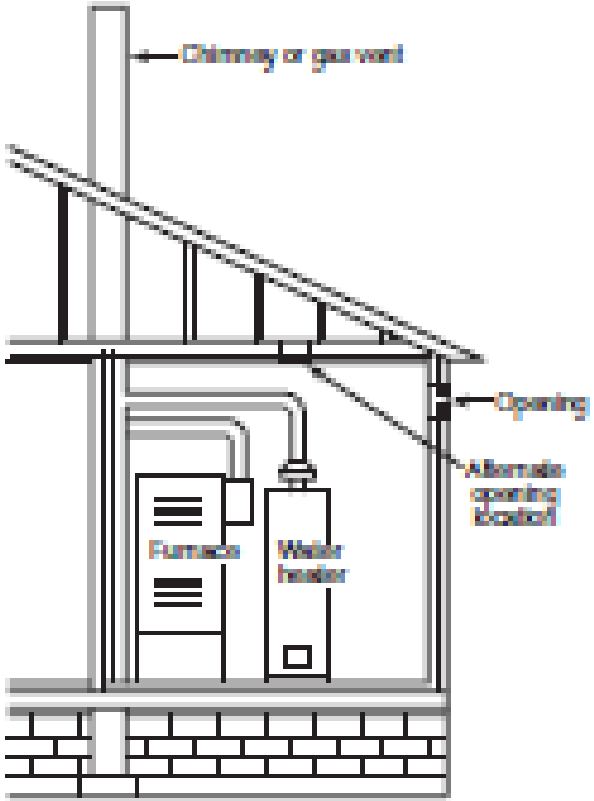


FIGURE A.8.3.3.2 All Combustion Air from Outdoors through Single Combustion Air Opening.

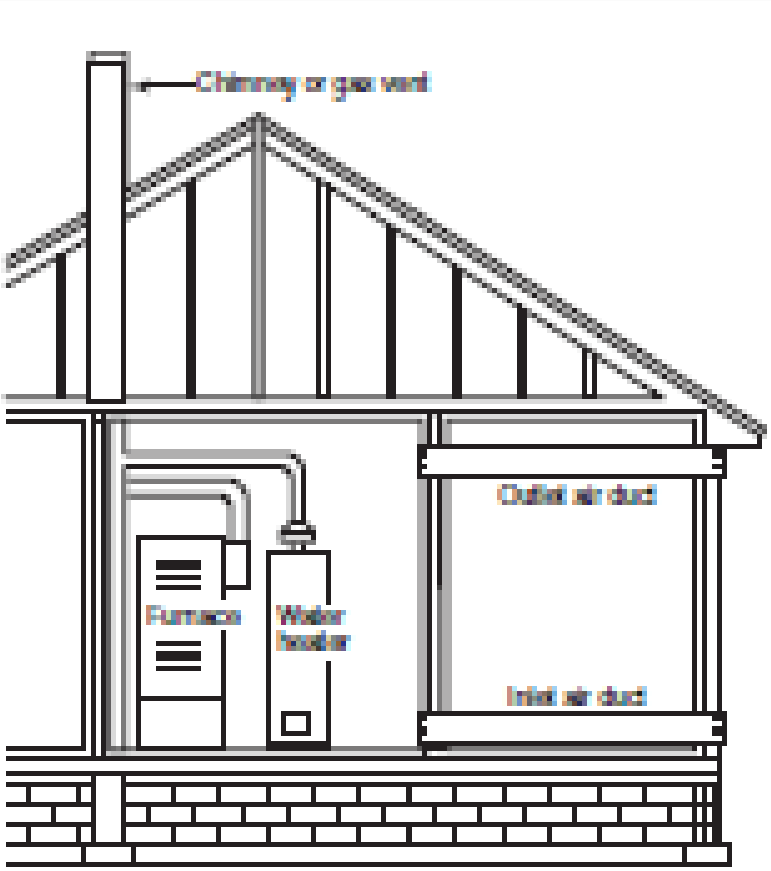


FIGURE A.8.3.3.1(2) All Combustion Air from Outdoors through Horizontal Ducts.