Ventilation Standards for Homes in the Airport Noise Sound Insulation Program

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Part 150 Sound Insulation Program

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Program Scope

- **Sound Insulation Program Improvements**

  Acoustic storm/prime windows — Acoustic storm/prime doors
  Side wall and attic insulation — Attic air sealing
  Baffle attic vents — *Fireplace top dampers*
  Air conditioning (ID furnace, when necessary)
  Continuous ventilation (quiet exhaust fan)

Current average cost = $25,000 to $30,000

- **Type of Houses**

  1930s to 1950s construction
  Floor area: 2,200 sf average (includes basement)
  70% furnace, 10% gravity air, 20% hydronic
  Mix of rambler, 1 ½ story, 2 story
  Exhaust fans: kitchen – 40%, bath – 40%, dryer – 95%,
    Average, total exhaust flow = 190 cfm
  House air leakage:
    Before construction: 2,300 cfm50
    After construction: 1,600 cfm50, 6 ach50

- **Number of Houses**

  4,900 completed
  2,000 scheduled (700 to 800 per year through 2,002 and beyond)
  Approx. **4,500** tests from Oct. ’98 through Sept. ‘99
    Before: 640 initial and 660 retests
    After: 860 initial and 830 retests
    Past participants: 650 initial and 820 retests

Test Personnel

Center For Energy & Environment (12)

Pat Beagan	Jonathan Beale	Dave Bohac
Brian Foust	Jim Fitzgerald	Paul Gerold
John Hott	Terry Kemp	Kirk Kolehma
Pat Lawton	Paul Morin	Steve Youlan

Energy & Environmental Services (4)

Kevin Brauer	Worth Frank	Stewart Selman
Frank vonPoppen		

Sustainable Resource Center (2)

Peter Burns	Steve Johnson

Test Requirements

- **Type of Tests**
  - Appliance flue Carbon Monoxide
  - House depressurization
  - Combustion appliance venting (spillage/draft)
  - House tightness/ventilation

- **Performed Before and After Program Improvements**
  - Homeowners responsible for pre-treatment failures
  - Program responsible for post-treatment failures

Appliance Carbon Monoxide
Program Standards

Space Heating and Water Heating Combustion Appliances

- "As measured" flue CO <= 100ppm under steady operating conditions and proper combustion venting
- "As measured" flue CO <= 100ppm under steady operating conditions and down-draft venting (does not apply to induced-draft, power-vented, or direct vented appliances)

Ovens

- "As measured" flue CO <= 150ppm after five minutes of burner operation

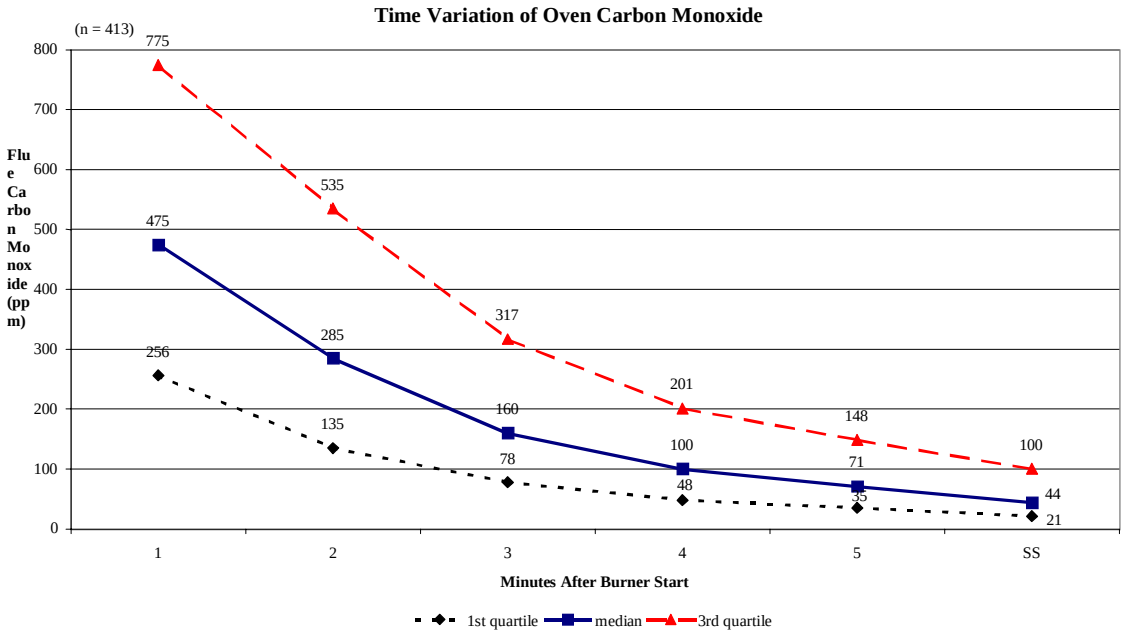
Test Results
Pre-treatment Tests

Appliance Type	Normal Venting		Down Draft	
	> 100 ppm	> 400 ppm	> 100 ppm	> 400 ppm
Water Heater (693)	4.9%	3.2%	6.5%	3.8%
Furnace (387)	12%	7%	19%	11%
Boiler (89)	12%	6%	17%	9%
Space Heater (42)	19%	12%	21%	12%
Furnace, Ind. Draft (96)	4.2%	1.0%		

About a 50% higher failure rate for down-draft conditions

Ovens

Time After Burner Start	> 100 ppm	> 150 ppm	> 400 ppm
2 minutes	84%	75%	40%
5 minutes	39%	29%	7%
Steady-state	26%		



Appliance Combustion Venting

Program Standards

Spillage

- No significant spillage under worst-case conditions after specified period of time:
    - Furnace: 1 minute Space heater: 2 minutes
    - Water heaters and boilers: 3 minutes

- When appliances are vented in common, spillage is also evaluated when all common vented appliances are operating.

- Use chemical smoke and three temperature sensors mounted about ½" below the draft divertor to determine spillage.

Combustion Vent Pressure (Draft)

- The static pressure in the appliance vent is measured about 2' downstream of the draft divertor. The draft pressure is averaged from four to five minutes after the burner is activated under worst-case pressure conditions. The draft standard varies with outside temperature: -0.5 Pa @90F and –2.5 @ 10F. The test helps predict performance under other outside temperature conditions?

Combustion Vent Test Failure Rate
Pre-test Houses

Appliance Type	Worst-Case		"Natural"	
	Spillage	Draft	Spillage	Draft
Water Heater (693)	26%	51%	14%	35%
Furnace (401)	19%	29%	9%	18%
Boiler (95)	13%	43%	2%	31%
Space Heater (44)	32%	59%	20%	36%
Furnace, Ind. Draft (104)	4%		1%	

Additional **3%** of water heaters pass worst-case spillage and fail during "all-appliance" spill test.

Water Heater Vent Test Failure Rate By Liner Type

Liner Type	#	**WC Fail**		**Natural Fail**		**Avg Depres**
		Spillage	**Draft**	**Spillage**	**Draft**	
Tile	41	**24%**	**54%**	**15%**	**41%**	**-1.8**
B-vent	46	**22%**	**54%**	**4%**	**35%**	**-2.4**
SW/Mas Int	63	**17%**	**44%**	**8%**	**30%**	**-1.9**
SW/Mas Ext	176	**26%**	**58%**	**16%**	**45%**	**-1.7**

House Depressurization
Program Standards

- Computerized data logger used to measure change in mechanical room pressure due to:
  - Air handler operation
  - Exhaust fans/other exhaust and air handler

- Whenever an exhaust fan is installed the mechanical room worst-case depressurization shall be less than the minimum pressure limit for all the vented combustion equipment in the house:

Equipment	Pressure Limit (Pa)
Direct vent	NA
Power vented	15
Individual induced draft	15
Mechanical draft inducer	10
Induced draft common vented with natural draft	5
Individual vented natural draft	5
Common vented natural draft	**3**
Orphan water heater	2

- The worst-case depressurization limit is **not** used as a criterion to pass/fail combustion equipment venting performance.

Depressurization Results

Worst-Case Conditions			
	< -5 Pa	< -3 Pa	< -2 Pa
Before construction (671)	6%	15%	29%
After construction (367)	8%	34%	59%

Air Handler Operation			
	< -3 Pa	< -1 Pa	> +1 Pa
Before construction (352)	1%	7%	4%
After construction (361)	1%	18%	4%

Pressure Limit Standard

Depressurization Limit Category			
	-10/-15 Pa	-5 Pa	< -3 Pa
Before construction (325)	1%	33%	66%
After construction (477)	5%	64%	31%

Type of Repair Work To Fix Spillage

(past houses)

	Replace Fan	Modify Connectors	Stacked Tee	Flue Liner	Power Water Htr.	Other
Number	56	24	24	22	11	17
Fraction	36%	16%	16%	14%	7%	11%

House Air Leakage/Ventilation

Program Standards

- A continuous ventilation system must be installed when the house air leakage is less than the adjusted floor area. The air leakage is recorded in units of CFM50 (cfm @50 Pa depressurization). The interior floor area is determined by multiplying the exterior floor area by 0.85. Finished and unfinished basements are included in the floor area.

- Before treatment 23% of the houses have an air leakage rate less than the adjusted floor area.

- After treatment 74% of the houses have an air leakage rate less than the adjusted floor area and require mechanical ventilation.

- The full capacity of the ventilation system is required to be at least 5 cfm per 100sf of floor area (ASHRAE 62-1989R). Whenever the house air leakage is less than 100% and greater than **60%** of the floor area (FA), the people and house ventilation requirements can be reduced by a fraction that is assumed to be supplied by natural infiltration. The full capacity outdoor air flow rates are multiplied by the mechanical ventilation fraction (F_{mv}) to determine the natural infiltration adjusted flow requirements:

$$F_{mv} = D \cdot (1 - Q_{50}/FA)$$

where:

F_{mv} = mechanical ventilation fraction
Q_{50} = house air leakage: exhaust flow measured at a house depressurization of 50 Pa, cfm
FA = house floor area: includes basement, square feet
D = 1 for balanced ventilation, 2 for exhaust only ventilation

SPILL MONITORING OPTION

- Homeowners have the option of spill monitoring an appliance when all the commonly vented appliances have passed the spillage criteria, but one or more of the appliances have failed the draft criteria. (see attached sheet for further information)

- The monitor consists of a spillage switch that is installed under the lower edge of the draft divertor, a burner run-time indicator, and run time/event meters. The spill switch is manufactured to trip at a temperature of 175°F +/- 15°F (after about 30 seconds – faster at higher temperatures). The resolution of the burner and spillage run-time meters is 0.1 hour and the event recorder counts the number of spillage events.

- Spill monitoring is required for a two month period. The appliance fails if the spillage time is greater than 5% of the burner run-time.

- 394 appliances have completed spillage monitoring. The operating time typically varies from 50 to 150 hours, with a median value of 90 hours. 87% of the appliances had no spill events and only 14 (3.5%) had more than 5 events. Nine houses had more than 1 hour of spillage and only one had spillage that was greater than 5% of the operating time (i.e. a fail).

- Based on the results of the first 185 appliances monitored, the draft pressure standard was reduced by one half (see attached memo dated March 20, 1998). In addition, the requirement for meeting the draft standard is waived if the vent system meets the requirements of the National Fuel Gas Code and the house depressurization does not exceed SIP limits. No spillage monitoring policies have changed.

House Total Exhaust Flow

- Pre construction (n=717):
  61% > 125cfm 35% > 200cfm 12% > 300cfm

HOUSE AIR LEAKAGE/VENTILATION
SIP STANDARDS

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  where:
  F_{mv} = mechanical ventilation fraction
  Q_{50} = house air leakage: exhaust flow measured at a house depressurization of 50 Pa, cfm
  FA = house floor area: includes basement, square feet
  D = 1 for balanced ventilation, 2 for exhaust only ventilation

  The minimum mechanical ventilation system air flow rate (Q_{hse}) is then computed from:

  Qhse = (FA - Q50)/10, not less than 50 cfm (exhaust only)
  Qhse = (FA - Q50)/20, not less than 25 cfm (balanced)

  The *Mechanical Ventilation System Standards* (see attached) includes more complete system requirements.

HOUSE AIR LEAKAGE RESULTS

- 23% of the homeowners are required to install ventilation systems before they enter the program.

- Ventilation systems are required in 74% of the houses after construction.

- Ventilation systems are required in 61% of the past participant houses.

- The pre to post construction air leakage reduction has averaged 24%. The average air leakage reduction varies from 7% to 40% depending on the pre-construction air leakage. There is a consistent trend that tighter houses achieve less leakage reduction. The average post-construction air leakage ratio is 0.9 or about 7 ach50. The air leakage ratio for the tightest house is about 0.5 or 4 ach50.

- At the present time, there is no significant trend in the air leakage reduction by construction date.

- Of the 205 exhaust fans designed for installation before or during construction, 92% only required the minimum flow rate of 50cfm.

- Of the 239 exhaust fans designed for installation after recent construction, 60% only required the minimum flow rate, 15% required more than 80cfm, and 4% required over 100cfm.

- **MAC Part 150 Sound Insulation Program Overview**
  - Program scope and housing stock
  - Test requirements
  - Assuring safety of natural draft appliances in moderately tight houses

- **Carbon Monoxide Standards and Results**
  - Test method and standards
  - Summary results
  - Remediation case study

- **Mechanical Room Depressurization Test**
  - Method: Worst-case and air handler
  - Summary results
  - Worst-case case study (M4132)
  - Air handler case study (R0083/M3117)

- **Combustion Vent Test**
  - Description of test method
  - Summary results
  - Brief examples
  - Case studies:
    - Acceptable (M4069)
    - Vent system deficiency (M4064 – M4087)
    - Depressurization (M4132 – M4088 – M4074)