MEASURED ENERGY SAVINGS FROM VENT DAMPERS IN LOW RISE APARTMENT BUILDINGS

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Numerous field, laboratory and modelling studies have explored the effectiveness of vent dampers in single family homes but no research that we are aware of has investigated savings from vent dampers alone in multifamily buildings. Vent dampers can reduce fuel use in two ways: (1) they can reduce heat loss due to air flow over the heat exchanger, either by actually reducing this air flow or more typically by causing the heated air to spill through the draft diverter into the boiler room, where it may become useful heat gain, (2) they can reduce building infiltration by reducing escape of warm house air through the chimney during the off cycle.

Several differences between single family and multifamily buildings could lead to differences in savings from vent dampers. (1) The degree of communication between the boiler room and the heated space is often much less in a multifamily building, which could be expected to reduce savings. (2) An apartment building's boiler (and distribution system, if circulation is continuous) has a much larger thermal mass than a furnace in a single family home and provides a much larger source of heat for off-cycle vent loss. (3) In Minneapolis, at least, buildings with boiler inputs over 400,000 Btu/hr are not required to have a metal chimney liner, and a massive brick chimney is the norm, probably causing the off-cycle draft to be sustained longer. (4) In older, steam heated buildings the old boilers converted from coal to gas have barometric dampers rather than draft diverters. When the vent damper installed on such a boiler closes, the barometric damper also swings closed, greatly limiting spillage and holding more heat in the boiler itself. The last three factors could be expected to increase savings in multifamily buildings relative to single family buildings.

The buildings used in the tests are typical of the multifamily housing stock in Minneapolis and include four hot water heated and two steam heated low rise buildings (table I). To maximize any possible savings, tight, quick closing dampers were selected, which legally necessitated use of dual automatic gas valves and electronic ignitions on the boilers. The boilers in the four newer buildings had draft diverters, so dampers were installed on the water heaters as well to prevent escape of heated air spilled into the boiler room. Dual automatic valves and 24V controls were added to these water heaters to allow use of quick closing dampers. Water heater dampers were added to the two steam heated buildings in the second year. The various precautions to maximize savings greatly increased costs (table II).

The buildings were run alternately with no dampers, boiler damper only and boiler plus water heater dampers over the test period, allowing each building to serve as its own "control". The first year, readings were taken weekly and modes changed every two weeks. No significant differences were found in the week-one vs. week-two residuals within modes, which indicated that the period of restabilization after the change is short when compared to the weekly reading interval. In the second year modes were therefore changed weekly and all three modes were rotated in each building. The purpose of this was to test the importance of the water heater damper in space heating savings, since it constituted a significant fraction of the costs. Submetered space heating gas use was regressed against degree days and normalized for weather using the method described in Hewett and Peterson (ACEEE, Vol.C,1984).

The 1984-85 data show space heating savings of 11 and 14% for dampers on the boilers only in the two steam heated buildings and 13 and 16% for dampers on the boilers and water heaters in the two hot water heated buildings, all statistically significant at the 1% level (Table III). Results at building 2317 agree closely with savings estimated from measurements of stack flow and temperature by Lawrence Berkeley Laboratory staff in February, 1985 (Modera, pers. comm.).

The results for 1985-86 do not corroborate this simple picture (Table III). Many of the normalized consumption estimates changed considerably, and many of the savings were not statistically significant. For the four hot water heated buildings, the savings with both dampers ranged from -4 to 33%, and the savings for the boiler damper only in two buildings were 4 and 23%. Savings did not follow the patterns we expected: building 1910 did poorly in spite of the fact that the boiler room door is always open to the hallway, 2002 did well even though the boiler room is under the parking lot and only abuts the building on one wall, and the boiler has a metal chimney, building 2600 did well even when only the boiler damper was active. The two steam buildings showed savings of 6 and 15% with one damper and 11 and 3% with both dampers, again contrary to our expectations. Observation and owner interviews have identified only a few changes from the first year to the second. Building 1518 hired a different and probably less skilled caretaker. The exterior window trim at 2600 was caulked. Building 3033 and 2600 experienced 88 and 43% turnover respectively between the two test years. Building 2317 had no turnover and data are not yet available for 1518. Vacancies are known to have been very low except at 1518 where data are not yet available.

Simple paybacks for the two steam heated buildings are less than three years for the vent damper on the boiler only. Paybacks for the whole package in the hot water heated buildings appeared to be five years or less based on 1984-85 data but more variable and often longer based on 1985-86 data. (Gas costs are $0.57/therm except $0.45/therm at 1518.) The results thus far do not support widespread installation of vent dampers in multifamily buildings. These tests will be continued in 1986-87, but detailed monitoring and modelling of boiler and building energy flows are also needed.

Table 1. Test building characteristics.

BUILDING I.D.	DATE BUILT	GROSS AREA, FT.^{2}	NO. OF UNITS	DISTRIB. MEDIUM	BOILER TYPE	MEAS. BOILER INPUT,BTU/HR	BOILER VENT DIAM, IN	BOILER DRAFT RELIEF	RATED WATER HEATER INPUT,BTU/HR	WATER HEATER VENT DIAM, IN	COMMON CHIMNEY DIM, IN, AND TYPE
1518	1920	20,592	32	steam	site built, brick set, steel fire tube, atm, coal to gas/coal conv.	1,380,000	20	none	250,000	8	32 x 36 brick
2317	1910	13,360	7	steam	site built, brick set, steel fire tube, atm, coal to gas conv.	1,280,000	20	barometric	55,000 40,000	ea 4	43 x 47 brick
3033	1963	11,550	17	hot water	packaged, cast iron, atm, gas-designed	177,000 183,000	ea 8	diverter	199,000	6	21 x 38 brick with 11 x 11 tile liner
2600	1968	18,194	30	hot water	same	612,700	12	diverter	199,900 199,900	ea 7	28 x 28 brick with 9 x 9 tile liner
1910	1962	16,331	18	hot water	same	487,300	12	diverter	199,000	7	25 x 46 brick with 11 x 11 tile liner
2002	1974	15,300	18	hot water	same	219,500 201,700	ea 8	diverter	250,000	7	14 diameter double wall metal

Table II. Estimated fair market cost of installations.

BUILDING	BOILER MATERIALS: vent damper	dual auto. gas valve[1]	additional main gas valve[1]	pilot valve	pilot pressure regulator	electronic ignition[2]	100 VA transformer[3]	operating high limit astat[4]	isolation relay[5]	COST, $[6]	BOILER LABOR: HOURS	COST, $[7]	BOILER TOTAL: COST, $
1518			not itemized										1700.00
2317			not itemized										850.00
3033	2	2				2	1	1		1118.47	12.0	516.00	1634.47
2600	1		1	1	1	1	1	1	1	828.05	10.0	430.00	1258.05
1910	1		1				1	1		538.73	9.5	408.50	947.23
2002	2	2				2	1	1		1118.47	14.9	640.70	1759.17

BUILDING	WATER HEATER MATERIALS: vent damper	dual auto. gas valve[1]	additional main gas valve[1]	40 VA transformer	24V operating astat[8]	24 V high limit astat[8]	COST, $[6]	WATER HEATER LABOR: HOURS	COST, $[7]	WATER HEATER TOTAL: COST, $	GRAND TOTAL: COST, $
1518	1		1	1	1	1	484.03	5.0	215.00	699.03	2399.03
2317	2	2		2	2		930.36	15.0	645.00	1575.36	2425.36
3033	1	1		1			396.94	4.0	172.00	568.94	2203.41
2600	2	2		2	2	2	1161.82	7.0	301.00	1462.82	2720.87
1910	1	1					386.08	4.5	193.50	579.58	1526.81
2002	1	1		1	1	1	569.04	6.1	262.30	831.34	2590.51

[1]The tightest, most quickly closing vent dampers are required by ANSI standard Z21.666-1982 to be equipped with two automatic gas valves to control all main gas flow. We were able to find dual valves to replace the original valve for inputs as high as 210 ft^3/hr; for higher inputs a second gas valve was simple added.

[2]Electronic ignitions were added at 3033, 2600 and 2002 so that the pilot knockout in the vent damper could be sealed, but this was omitted at 1910 to reduce expense. 2317 and 1518 already had electronic ignition.

[3]Addition of controls necessitated a heavier duty transformer.

[4]The manufacturers' wiring diagrams call for the vent damper to remain open when the burner is shut off by the high limit, a logical safety precaution in single family homes. In hot water multizone buildings, the boiler will shut off on the high limit whenever the outdoor reset control setpoint exceeds this limit. We installed an "operating" high limit which allows the damper to remain closed, and set the preexisting high limits higher to serve as safeties.

[5]Interference between electronic controls caused chattering of the gas valve, necessitating an isolation relay.

[6]Based on manufacturers' suggested retail prices.

[7]At $43/hour.

[8]The original controls were either gas actuated or run on a millivolt circuit. The former had to be replaced, while the latter were aaptable to a 24V control circuit.

Table III. Estimates of normalized annual space heating (NSHU) with and without vent dampers.

Building	NSHU (therms) ± std err: Mode 0	Mode 1	Mode 2	DIFFERENCE (MODE Ø − MODE 2): Δ NSHU ±std err	t(df) p	% Δ NSHU	DIFFERENCE (MODE Ø − MODE 1): Δ NSHU ±std err	t(df) p	% Δ NSHU	DIFFERENCE (MODE 1 − MODE 2): Δ NSHU ±std err	t(df) p	% Δ NSHU
1984–85												
1518	15049 ± 260	13419 ± 349					1630	3.5986 (11) $0.001 < p < 0.01$	10.8			
2317	9548 ± 224	8243 ± 183					1306	4.5211(8) $0.001 < p < 0.01$	13.7			
3033	6334 ± 138		5516 ± 165	818	3.2832(16) $0.001 < p < 0.01$	12.9						
2600	10022 ± 349		8441 ± 274	1581	3.4567(17) $0.001 < p < 0.01$	15.8						
1985–86												
1518	16444 ± 537	14007 ± 606	15954 ±604	490	0.635(14) $0.5 < p < 0.9$	3.0	2437	3.018(12) $0.01 < p < 0.02$	14.8	−1947	2.273(14) $0.02 < p < 0.05$	−13.9
2317	9252 ±249	8668 ±275	8234 ±152	1018	3.409(15) $0.001 < p < 0.01$	11.0	584	1.557(17) $0.1 < p < 0.2$	6.3	434	1.296(16) $0.5 < p < 0.9$	5.0
3033	5344 ± 66	5105 ± 70	5237 ± 49	107	1.320(16) $0.2 < p < 0.4$	2.0	239	2.480(13) $0.02 < p < 0.05$	4.5	−132	1.60(15) $0.1 < p < 0.2$	−2.6
2600	11634 ±272	8967 ±202	7838 ±190	3796	10.976(13) $p < 0.001$	32.6	2667	7.830(14) $p < 0.001$	22.9	1129	4.03(13) $0.001 < p < 0.01$	12.6
1910	5417 ±186		5613 ±138	−196	0.779(12) $0.4 < p < 0.5$	−3.6						
2002	5517 ±281		4336 ±223	1181	3.241(10) $0.001 < p < 0.01$	21.4						

Mode Ø no dampers, mode 1 boiler damper only, mode 2 boiler and water heater dampers.
NSHU was calculated for a heating season from October 15 to April 30 (see text).
Savings are significant if $p < 0.05$. P is the probability of achieving the observed difference in NSHU by chance.
One therm = 100,000 Btu.