THE IMPACT OF COMMERCIAL AIR SEALING OF HOUSES ON AIR TIGHTNESS AND FUEL CONSUMPTION

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ABSTRACT

Commercial air sealing was carried out on 119 houses in five locations in Canada. The work was carried out by experienced contractors by generally following procedures from a manual of good practice. Air tightness was determined before and after sealing in accordance with a Canadian standard method. Annual heating fuel consumption was determined at three locations for pre- and post-retrofit. This paper presents an analysis of the results, including the relative effects of sealing different house components and the impact on energy consumption.

INTRODUCTION

Several air sealing projects have been carried out with funding from Energy, Mines and Resources Canada and provincial governments. The objectives of the projects were to obtain air tightness data on houses in various regions of Canada and to determine the effect of air sealing on energy consumption. A standard manual of air sealing procedures (1) was followed where feasible and a standard method of measuring airtightness (2) was followed.

CALGARY, ALBERTA

An air sealing project, funded jointly by the provincial and federal governments, was carried out during 1984 (3,4) in the city of Calgary, Alberta (5345 DD C or 9703 DD F). The airtightness of 117 houses was measured using a door-fan depressurization test. Twenty of these houses were sealed by a commercial air sealing contractor and were tested for airtightness after each of six leakage areas were sealed. Another ten houses were sealed by the homeowners and tested once after sealing. To avoid having to install retrofit make-up ventilation systems, houses to be air sealed were selected from the 117 so that a 30 % increase in airtightness would still leave them with an air flow rate greater than 350 litres/second at 50 pascals depressurization.

Initial Results. The houses in the total sample were built from 1907 to 1982 with the average being 1964. The sample included one-storey, two- storey, and split-level houses as well as detached, semi-detached, and row houses. Table 1 shows some characteristics of the total, contractor-sealed, and homeowner-sealed samples prior to air sealing.

TABLE 1
Average Characteristics of Samples Before Sealing

Sample	No. of Houses	Year Built	AC/H @ 50 Pa	ELA @ 10 Pa
Total	117	1964	4.31	0.092
Contractor-Sealed	20	1959	5.89	0.117
Homeowner-Sealed	10	1965	5.18	0.087

Overall Air Sealing Results. The results of the overall air sealing work are given in Table 2. The energy consumptions were for one year after sealing and five years before sealing; they were normalized to the long term average annual degree-days for Calgary. This simple method of normalizing heat consumption data for the before and after sealing periods does not account for any differences in the weather-related parameters determining heat losses due to air leakage.

TABLE 2
Average Overall Air Sealing Results

	Contractor-Sealed	Homeowner-Sealed
No. of Houses	20	10
Year Built	1959	1965
Pre-Seal AC/H @ 50 Pa	5.89	5.18
Post-Seal AC/H @ 50 Pa	4.54	4.25
% Decrease AC/H @ 50 Pa	23(33*)	18
Pre-Seal Consumption (GJ/yr)	213	170
Post-Seal Consumption (GJ/yr)	188	141
% Decrease Consumption	12	17
Saving @ 3.173 $/GJ ($/yr)	79	92
Sealing Cost ($)	689	181
Simple Payback (years)	8.7	2.0

* See Table 4 for the derivation of this 33% value.

The sealing cost for homeowner-sealed houses was for premium quality materials supplied by the contractor; the sealing cost for the contractor-sealed houses was the estimated commercial cost after the costs for extra time and fan tests for component testing were subtracted.

Even though the homeowner-sealed houses had a lower percentage decrease in AC/H (18% vs. 23%), there was a higher percentage decrease in consumption (17% vs. 12%); this could be because the homeowners willing to do the sealing work themselves may have been more interested in energy conservation and, therefore, may have taken more care to control their post-sealing consumption. Other lifestyle factors and changes, such as thermostat settings, could have influenced post-sealing consumption either up or down.

Component Sealing Results. The results from door-fan depressurization testing between component sealing for the commercial contractor work are shown in Table 3. Most houses were sealed during a one-day time period. The sequence of component sealing was variable. Some houses had two components sealed between fan tests; elimination of these double-component sealings results in a sample size less than 20 for each component. The total per cent reduction represents the difference between the average initial and average final leakage values for the houses in the sample.

Table 4 results are from eliminating the component sealing results that gave negative reductions in air leakage rates since most studies do not show this effect; the air sealing technique could have been the cause of this anomaly but more likely it resulted from an error in measurement due to various factors such as intermittent wind or an open door or window. The total per cent reduction obtained by eliminating negative values is close to results of other studies.

TABLE 3
Average % Reductions for Component Air Sealing

Component (# Houses)	A (13)	B (15)	C (16)	D (15)	E (12)	F (15)	G (17)	Total
% Reduction	5.4	5.4	1.9	3.9	3.5	2.9	0.4	23.4

TABLE 4
Average % Reductions for Component Air Sealing
(negative reductions omitted from Table 3)

Component (# Houses)	A (13)	B (14)	C (15)	D (12)	E (9)	F (11)	G (12)	Total
% Reduction	5.4	6.1	2.7	5.2	5.8	4.8	2.6	32.6

Note: A - band joist
B - window/door frames, light fixtures, attic hatch
C - exterior wall baseboards
D - window weatherstripping
E - door weatherstripping
F - plumbing stack, chimney chase, other ceiling penetrations
G - wall penetrations (electrical, plumbing)

CHESTERVILLE, ONTARIO

An air sealing project funded by the federal government was carried out in the summer of 1983 (5,6) in the town of Chesterville, Ontario (4673 DD C or 8693 DD F) and provided useful data on 9 houses. The air sealing work was restricted to the attics and basements since this was a commercial job with the monitoring work as an add-on. Door-fan depressurization testing was utilized to measure the change in airtightness.

Initial Results. The sample was comprised of two pre-1945 and seven post-1945 houses; these were five two-storey houses and four bungalows. Table 5 shows initial values for the airtightness of the houses.

TABLE 5
Initial Average Airtightness Results

No. of Houses	ELA @ 10 Pa (m2)	Q @ 50 Pa (L/s)	AC/H @ 50 Pa
9	0.165	1116	8.87

Overall Air Sealing Results. The results of the overall air sealing work are given in Table 6. The energy consumptions were for the year preceding and the year following the air sealing; they were normalized according to the long term average annual degree-days.

TABLE 6
Average Overall Air Sealing Results

No. of Houses	9
Pre-Seal ELA @ 10 Pa	0.165
Post-Seal ELA @ 10 Pa	0.129
% Decrease ELA @ 10 Pa	24.0
Pre-Seal Q @ 50 Pa	1116
Post-Seal Q @ 50 Pa	884
% Decrease Q @ 50 Pa	22.2
% Decrease Consumption	7.5
Energy Saving (GJ/yr)	10
Saving @ 6.70 $/GJ ($/yr)	67
Sealing Cost ($)	800
Simple Payback (years)	11.9

Component Sealing Results. The component results are shown in Table 7. The sequence of the air sealing work is shown along with the relative contributions of attic (A) and basement (B) sealing work. Basement work included sealing of plumbing and chimney chases. Attic work involved moving insulation to access leakage sources where possible.

TABLE 7
Average % Reductions for Component Air Sealing

Sequence (# of Houses)	% Reduction of Initial Q @ 50 Pa			% Contribution of Total	
	A	B	Total	A	B
A + B (3)	16.4	5.9	22.3	72	28
B + A (6)	12.2	9.9	22.1	58	42
Total	13.6	8.6	22.2	63	38

It should be noted that this air sealing work was more intense, for the components done, since the contractor did a two-stage sealing; the first stage sealed gross leaks and the second sealed fine leaks. The attic and basement sealing work appears to include series leakage paths that amount to about 4 % of the initial overall house leakage area.

NEW BRUNSWICK

An air sealing project, funded jointly by the federal and provincial governments, was carried out during 1984 (7) throughout the province of New Brunswick (4490-5340 DD C or 8235-9796 DD F). The airtightness of 156 houses was measured; 70 of these houses were then air sealed by a commercial air sealing contractor. In nineteen houses leakage tests were carried out after each of several components was sealed.

Initial Results. The sample was comprised of detached houses built from the early 1900's to 1983 and included 1 storey, 1 1/2 storey, 2 storey, and split-level/entry designs. The sample included both private and public ownership houses. The public houses were built in the 1970's and 1980's. Table 8 shows the airtightness of the total and sub-samples.

TABLE 8
Average Air Tightness of the House Samples

Sample	No. of Houses	Initial ELA	AC/H @ 50 Pa
Total	156	0.114	4.91
Private	116	0.131	5.29
Public	40	0.063	3.80

Overall Air Sealing Results. The results of the overall air sealing work are given in Table 9. No energy consumptions or cost data are available for the work. The low initial ELA values for the public houses are probably due to tighter specifications, closer inspections, and more recent construction techniques. It is interesting to note that about the same percentage reduction in ELA was achieved for the public houses as for the private houses having much higher initial ELA values.

TABLE 9
Average Overall Air Sealing Results

Sample	No. of Houses	Initial ELA	Final ELA	% Reduction in ELA
Private	30	0.122	0.074	39
Public	40	0.063	0.039	38
Total	70	0.0883	0.0540	39

Component Sealing Results. The results from sequential component sealing on 19 houses is given in Table 10 (8). There was no specific sequence of component sealing.

TABLE 10
Average % Reductions for Component Air Sealing

Component	Attic	Basement	Main Living	Total Area
(# Houses)	(18)	(17)	(19)	
	12.0	13.3	13.6	38.9

OTTAWA, ONTARIO

In 1985 5 federal government houses in Ottawa, Ontario (4673 DD C or 8693 DD F) were sealed and tested for airtightness, component by component (9).

Overall Results. The houses were all built in the 1950's and were all 2-storey. The overall results are shown in Table 11.

TABLE 11
Average Overall Air Sealing Results

No. of Houses	5
Pre-Seal ELA @ 10 Pa	0.148
Post-Seal ELA @ 10 Pa	0.096
% Decrease ELA	35.1

Component Sealing Results. The component sealing results are given in Table 12. No specific sequence of air sealing was followed.

TABLE 12
Average % Reductions for Component Air Sealing

Ceiling	Windows/Doors	Walls	Basement	Total
6	16	4	8	34

RICHMOND HILL, ONTARIO

An air sealing project, funded jointly by the federal and provincial governments, was carried out the spring of 1984 (10,11,12) in the town of Richmond Hill, Ontario (4082 DD C or 6827 DD F). T airtightness of 21 houses was measured and then 15 of these were sequentially sealed. Energy consumpti was monitored both before and after retrofit.

Initial Results. The houses in the sample were built from 1942 to 1969 with the average being 195 The houses were all detached 1 1/2 storey, 2 storey, and split level. Table 13 gives the initi airtightness results for all the houses.

TABLE 13
Average Initial Airtightness Results

Sample	No. of Houses	ELA @ 10 Pa	Q @ 50 Pa
Pre-Retrofit Houses	15	0.146	1101
Control Houses	6	0.108	836
All Houses	21	0.135	1025

Overall Air Sealing Results. The results of the overall air sealing work are given in Table 14. The energy consumptions were for one year after sealing and two years before sealing and were normalized to the long term average annual degree-days. The value of percent decrease in consumption for the 12 houses is the sum of the actual average percentage reduction plus the percentage change (increase) for the 6 control houses, all based on the normalized energy consumption values.

TABLE 14
Average Overall Air Sealing Results

No. of Houses	15
Year Built	1955
Pre-Seal ELA	0.146
Post-Seal ELA	0.100
% Decrease ELA	32
Pre-Seal Q @ 50 Pa	1101
Post-Seal Q @ 50 Pa	777
% Decrease Q	29
% Decrease Consumption (12 Houses)	9.8
Savings (GJ/yr)	11.0
Savings @ 6.70 $/GJ ($/yr)	73.7
Sealing Cost ($)	1404
Simple Payback (years)	19.1

Component Sealing Results. The results of component sealing are given in Table 15. The values of savings per year for the component sealing are taken to be proportional to their contribution to the percent reduction in Q50. In fact, for a given percent reduction in Q50, sealing of some components will be more effective in producing savings than sealing others.

TABLE 15
Average Results for Component Air Sealing

	Attic/ Ceiling	Windows/ Doors	Walls	Basement	Total
(# Houses)	(13)	(12)	(12)	(10)	
% Reduction Q50	10	11	3	7	31
Savings ($/yr)	23.8	26.2	7.1	16.6	73.7
Cost ($)	445	355	190	414	1404
Payback (yrs)	18.7	13.5	26.8	24.9	19.1

It should be noted that this air sealing work was more labour intensive than that for other projects. The contractor actually worked in most attics and the basements were almost all finished for living space (necessitating some removal and replacement of finish).

ANALYSIS AND CONCLUSIONS

The initial results on the airtightness of all the houses tested are summarized in Table 16.

TABLE 16
Average Initial Airtightness of Houses

Location	No. of Houses	ELA @ 10 Pa	Q @ 50 Pa	AC/H @ 50 Pa
Calgary	117	0.092	-	4.31
Chesterville	9	0.165	1116	8.87
New Brunswick	156	0.114	-	4.91
Ottawa	5	0.148	-	-
Richmond Hill	21	0.135	1025	-

From the average ELA values in Table 16 the Calgary houses are the tightest; houses in the prairie provinces of Canada generally have been built tighter than elsewhere, perhaps, because of the colder climate. The Ontario houses are similar in tightness while the New Brunswick houses are somewhat tighter due to the large number of public houses in the sample built in the 1970's.

The overall air sealing results are summarized in Table 17.

TABLE 17
Overall Commercial Air Sealing Results

	Calgary	Chester- ville	New Bruns- wick	Ottawa	Richmond Hill
No. of Houses	20	9	70	5	15
% Reduction in Leakiness	23(33)	24	39	35	32
% Reduction in Consumption	12	8	-	-	10
Savings ($/yr)	79	67	-	-	74
Sealing Cost ($)	689	800	-	-	1404
Payback	9	12	-	-	19

The reductions in leakiness, using the 33% value for Calgary, are all 30% or greater except for Chesterville at 24%; if more than just the attic and basement had been sealed at Chesterville the reduction would likely have been around 30%. Hence, it would appear that commercial sealing of the entire house produces an average reduction of 30-35% for a wide range of ELA's.

The percent reduction in space heating energy consumption appears to be about one-third of the percent reduction in leakiness (using the Calgary 33% reduction value) for the three groups of houses for which energy consumption data were available. This comparison of differences in energy consumption due to air sealing does not take account of differences in air leakage driving forces for the pre- and post-sealing periods used for analysis. A preliminary attempt to use the infiltration degree-day parameter for this purpose with some of the Richmond Hill houses was not successful. It was concluded that a more comprehensive investigation would be required to account adequately for the primary variables.

Minimizing the labour intensiveness of the commercial air sealing work appears to be the key that produces a shorter payback period since both the Chesterville and Richmond Hill contractors were taking extra care. It should be noted that the simple payback does not consider extra benefits of air sealing such as increased comfort and protection against structural moisture damage.

The component sealing results are summarized in Table 18 with the Calgary results based on Table 4.

TABLE 18
Component Air Sealing Results: % Reductions

Location (# Houses)	Attic/ Ceiling	Windows/ Doors	Walls	Basement	Total
Calgary (12)	7.9 (F+1/2B)	11.0 (D+E)	8.3 (C+G+1/2B)	5.4 (A)	32.6
Chesterville (9)	13.6	-	-	8.6	22.2
New Brunswick (18)	12.0	-	13.6	13.3	38.9
Ottawa (5)	6	16	4	8	34
Richmond Hill (12)	10	11	3	7	31
Weighted Avg.	10	12	9	9	33

The percent reductions average about the same for the different components (with large individual variations for three of the four components). This suggests that for an individual house it is most cost effective to seal those components that are the easiest (least costly) to seal.

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