Verification of HRAI Depressurization Calculation

Field Study

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NOTE

Funding for this project was provided by the Government of Canada under the Green Plan.

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SUMMARY:

30 houses were tested for air-tightness and depressurization at 75 and 150 L/s.

The HRAI allowable airflow at 5 pa calculation was validated against the data obtained from the field and found to be somewhat lenient. That is to say that the HRAI calculation very often allowed more exhaust airflow than a field test. The average over-estimation appears to be 20%. Accuracy of the calculations appeared to be in the range of +/- 15%.

A revised, simplified and corrected calculation method is recommended. The recommended calculation method is slightly less accurate, but is simpler to use.

The sealed and open flue depressurization test conditions described in the HRAI Ventilation Manual were compared. No difference between the tests could be found for the group of houses, although individual houses could experience differences of up to +/- 2 pa depending on the test condition. The open flue depressurization method is recommended over the sealed flue method, simply because it is easier to carry out.

Re-examination of the air-tightness assumptions contained in the HRAI Ventilation Manual is recommended. This re-examination should take account of the findings of this study.

SOMMAIRE:

30 maisons étaient essayés pour l'étanchéité à air et dépressurisation à 75 et 150 L/s.

Le débit d'air admissible par le calcul de l'ICCR à 5 pa a été validé contre les données obtenu du champ et ils ont été trouvés a être relativement indulgent. C'est-à-dire que le calcul ICCR permettait très souvent plus d'évacuation d'air qu'un essai du champ. Le moyen sur-estimation paraît être 20%. L'exactitude des calculs parait être dans la gamme de +/- 15%.

Une méthode de calcul corrigé, simplifié et révisé est recommandée. La méthode de calcul recommandée est légèrement moins exacte, mais il est plus simple à employer.

Les essais de dépressurisation avec conduit de cheminé ouvert et fermé décrites dans le Manuel De Ventilation de l'ICCR étaient comparés. Aucune différence entre les essais ne pourrait être trouvée pour le groupe de maisons, mais maisons individuelles pourraient éprouver des différences de jusqu'à +/- 2 pa dépendant de la condition d'essai. La méthode de dépressurisation "conduit de cheminée ouverte" est recommandée sur la méthode "conduit de cheminée fermé" simplement parce qu'il est plus facile à exécuter.

Le réexamen des suppositions d'étanchéité d'air contenues dans le Manuel De Ventilation de l'ICCR est recommandé. Ce réexamen devrait tenir compte des résultats de cette étude.

CONTENTS

ACKNOWLEDGEMENTS

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Broan Canada Ltd.	
Gary Nelson	The Energy Conservatory

1. GENERAL

1.1 Ontario Building Code (ref 1) allows Depressurization Compliance by Test or Calculation:

Under the current provisions of the Ontario Building Code, houses equipped with a natural-draft non-solid fuel combustion appliances are required to have the design and installation for the ventilation system completed using the methods provided by standards of "Good Engineering Practice". For single-family residences, the standard of choice for ventilation system design is the CSA standard F326-M91 Residential Mechanical Ventilation Requirements (ref 2).

The F326 Standard requires that for houses which are equipped with natural draft combustion equipment, the negative pressure induced by the ventilation system together with certain exhaust appliances not cause depressurization in excess of 5 Pa. With respect to compliance, the F326 standard provides that the 5 Pa depressurization limit be demonstrated by a test or a calculation. The calculation is set out in the HRAI Residential Mechanical Ventilation Manual (ref 3).

1.2 Calculation uses "Assumed" house ELA_{10}

The calculation procedure set out in the HRAI Ventilation Manual requires that an ELA_{10} (See note) be measured or assumed for the house. The ELA_{10} is usually always assumed because the test to actually determine the ELA_{10} value is more costly than the test set out in CSA F326.

ELA_{10} = *Equivalent Leakage Area @ 10 Pa.*, as defined in CAN/CGSB 149.10-M86, "Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method" (ref 4).

1.3 HRAI sets "Assumed" ELA_{10} for use in Calculation.

The HRAI Manual provides suggested values of NLA_{10}* for this calculation of 0.7 cm^2/m^2 for a new home. This value is based on the 10th percentile of tightness from the 1989 Study of Air-Tightness of 200 Merchant-Built New Homes (ref 5).

* $ELA_{10}/(\text{house envelope area}) = NLA_{10}$

2. PROBLEM STATEMENT

2.1 Predicted Exhaust @ 5 Pa is often less than Tested Exhaust @ 5 Pa

Calculations carried out according to the HRAI procedure (using the assumed NLA_{10} values provided) generally result in predicted exhaust rates @ 5 pa of less than 75 L/s (160 cfm) for houses of less than 4,000 ft^2. *When field tests are carried out, many practitioners report that the permitted (tested) exhaust rate often exceeds the predicted rate by a wide margin.*

This discrepancy may occur due to one or more of the following causes:

a. **Lack of test instrument accuracy:** Until recently, the instruments most often used for carrying out the 5 Pa test were:

-dwyer 115 inclined manometer
-dwyer 25000-00 magnehelic Gauge.

Both of these instruments are problematic in that their resolution is only barely acceptable to the required measurement (+/- 1 Pa). When combined with any uncertainty due to wind pressures, the overall accuracy of these devices cannot be relied upon to give a result of more than +/- 2 Pa with any certainty. New instruments are now available which can provide much better accuracy (+/- 0.1 pa).

b. **Calculation procedure:** The calculation procedure set out in the HRAI Ventilation Manual is based on the theory of air-tightness set out in CGSB 149.10-M86. The calculation requires either an NLA_{10} or ELA_{10} value generated according to CGSB using the appropriate "blower-door" air-tightness testing equipment, or an assumed NLA_{10} as described above. The allowable exhaust is then derived for a differential pressure of 5 Pa using the formula:

$Q = 0.15*ELA_{10}$, where
Q = flowrate in L/s, and
$ELA_{10} = ELA_{10}$ @ 10 Pa (CGSB 149.10)

An alternative method of calculation uses the relationship of $Q = Cp^n$ set out in CGSB 149.10, where

Q = flow, L/s
C = flow, L/s at 10 Pa
n = flow exponent, dimensionless
(varies from 0.5 to 0.9)

When the two calculation methods are compared using CGSB 149.10 test data for actual houses, the difference between the two calculation methods is generally less than +/- 10%, however for 10% of the houses, variations of +/- 50% may occur.

c. **Difference between test conditions:**

i *The CGSB 149.10 test procedure* allows that intentional openings and the ventilation system be sealed. It also requires that flue openings be sealed during the test.

ii *The CSA F326 test* permits intentional openings to remain, and requires that the ventilation system continue to operate at the "Minimum Ventilation Capacity" rate. The F326 procedure also requires flue openings to be sealed.

The CSA F326 test procedure is described in more detail in section 3.1f of this report where it is referred to as the "Sealed" test condition.

iii *The HRAI alternate procedure* is the same as the CSA-F326 except that it allows certain flue openings to remain open during the test providing that the combustion devices remain in operation and that no combustion spillage occurs during the test. Combustion air openings which serve the operating combustion appliances are also allowed to remain open. This test procedure;

- is easier to carry out on site as it does not require the dismantling of chimney connectors
- reduces the possibility that the tester will leave flues or vent pipes blocked by accident.
- allows the evaluation of combined combustion/make-up air openings.

The HRAI alternate procedure is described in more detail in section 3.1f of this report where it is referred to as the "Open" test condition.

d. **No Direct Comparison of Test and Calculation Available:**
The accumulated uncertainties which exist in comparing the two compliance methods are magnified by the fact that there have been virtually no houses in which both the blower door and the 5 Pa test have been carried out. There is no data which actually

compares the two test methods. The reason for this lack of data is that in most commercial situations, the client is willing to pay for a blower-door test, or a 5 Pa test, but not both.

3. METHODOLOGY

3.1 Field Testing

a. 31 houses were tested using the CGSB 149.10 blower-door test method and the CSA F326 depressurization test method.

b. Due to the difficulty of measuring flows of installed appliances, the exhaust flow for the CSA F326 depressurization test method was set at 75 L/s and 150 l/s, generated using the blower door at a fixed flow-rate.

c. The houses tested represented a wide range of sizes and features.

- Date of construction 1955 to 1995
- With and without natural draft combustion appliances
- attached and detached
- volume range 14,246 ft^2 to 45,547 ft^2

d. None of the houses were registered R-2000 homes.

e. All houses were located in south-central Ontario and were tested using the same equipment set-up. All testing was carried out by one of two technicians.

f. The blower-door was cross-calibrated to an "duct-test-rig" type of flow-measurement after testing was complete and it was found that actual flows were 79 L/s and 154 L/s respectively. Where appropriate, data has been corrected to account for this slight discrepancy.

g. Houses were tested at the 79 L/s and 154 L/s flows in two conditions:

"Sealed"
- all intentional openings such as dryer vents and combustion air intakes sealed,
- active flues sealed or flue dampers shut if tight-fitting,
- HRV operating on high speed.

(This duplicates the standard depressurization test condition as set out in CSA F326)(see also 2.1c ii)

"Open"
- * all intentional openings such as dryer vents and combustion air intakes open,
- * active non-solid fuel chimney-connected appliances operating with no back-spillage,
- * fireplaces flues sealed or damper closed if tight-fitting.
- * HRV operating on High Speed.

(This duplicates the "alternate" test condition allowed by the HRAI Ventilation Manual.)(see also 2.1c iii)

3.2 Data Analysis

a. The HRAI calculation method predicts an exhaust airflow at 5 or 10 Pa. The field data is in the form of depressurization levels at fixed flows of 79 and 154 L/s. The range of depressurization measured at a fixed flow of 79 L/s exhaust is 2 to 14 Pa.

In order to compare the data, the field flow-rates were adjusted to a pressure difference of 5 Pa using the equation:

$$Q = Cp^n$$

where:
Q = airflow
p = pressure difference
C = flow coefficient constant for characteristic pressure - flow relationship
n = flow exponent from blower door test results of house in question

The decision to use the "n" value from the blower-door test for the house in question was based on comparison of data generated using four alternate values of "n" as follows:

Average Differences and Standard Deviations of Adjusted 5Pa Actual Flows vs Predicted ELA_{10}*0.15 Flows : for Various values of "n" used in Adjustment Calculation

	Average Difference	Standard Deviation
n = 0.5	17%	15%
n = 0.65	19%	13%
n = 0.688	19%	14%
n = test	19%	13%

Analysis of the different "n" values showed that the 0.65 and 0.688 values gave results which were consistent with the "n" values obtained from the blower-door test results. The 0.5 "n" value was not consistent.

Note: 0.688 is the average of "n" values for the houses in this study. See section 4.1.

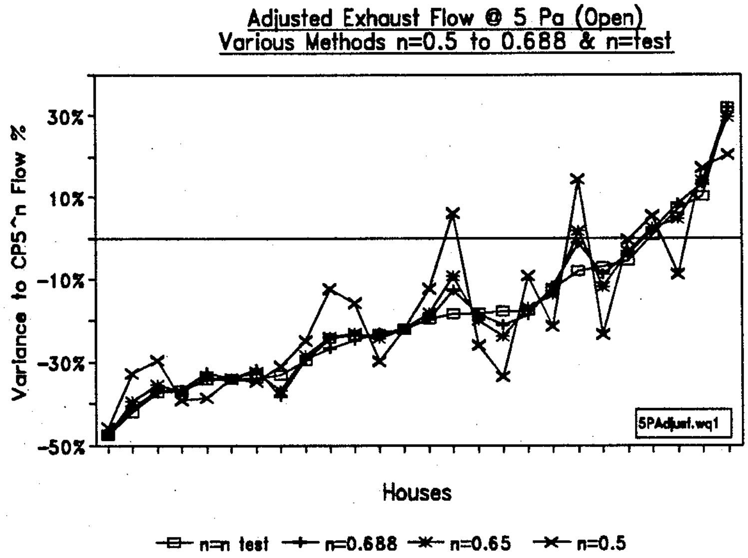

Figure 1

b. Air-tightness data with a correlation coefficient of .975 and higher was accepted (House # 6 was eliminated on this basis). Houses with air-tightness data of less than 0.975 were not used in the analysis. Of the remaining houses only two had correlation coefficients of less than .991.

c. Analysis of predicted vs actual flows were carried out using the data from the "open" 79 L/s test condition. As discussed in section 4.2 the "Sealed" and "Open" test results are similar statistically, but often differ for individual houses. The decision to use the "Open" test results was based partly on the likelihood of this test procedure being used most often in the future.

4. RESULTS

4.1 General

The houses were found to have a range of airtightness between 1.19 and 5.71 Air Changes per Hour @ 50 Pascals (ACH50). Their was only a slight correlation with the year of construction. (Figure 1)

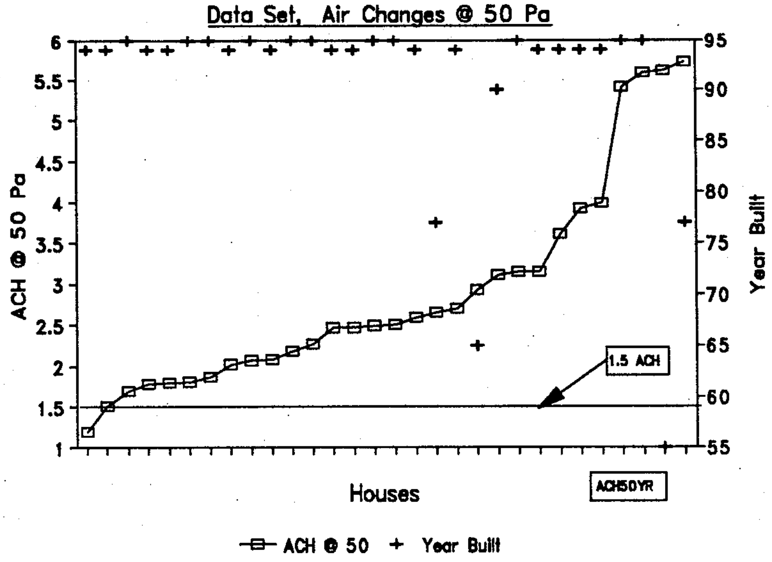

Figure 2

Depressurization levels ranging from 2 to 12 Pa were recorded at the 79 L/s exhaust flow. There was a general relation ship between the recorded depressurization and the level of air-tightness when expressed as ACH50.

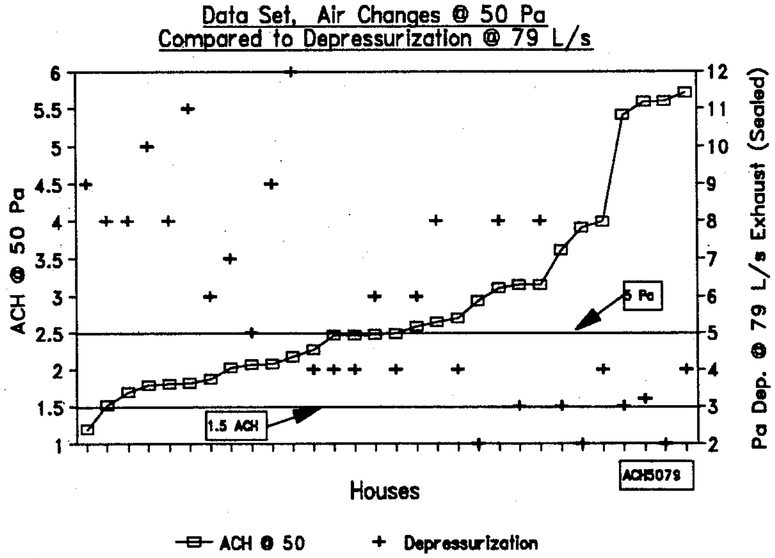

Figure 3

Normalized leakage areas ranging from 0.69 to 2.49 cm²/m² were recorded. There was only a general relationship between the NLA_{10}'s and the levels of depressurization recorded.

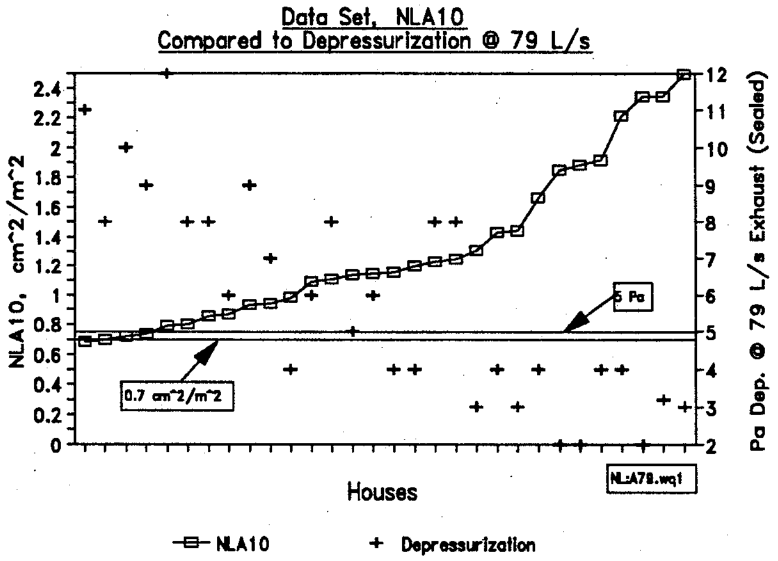

Figure 4

The average value of the flow exponent "n" for the houses in this study was 0.688. The lowest "n" value was 0.551, the highest 0.841.

4.2 SEALED (CSA F326) vs OPEN (HRAI Alternate) Test Conditions

No clear trend could be identified as a difference between the "Sealed and "Open" test conditions. The "Open" test condition resulted in depressurization levels both above and below the "Sealed" test condition.

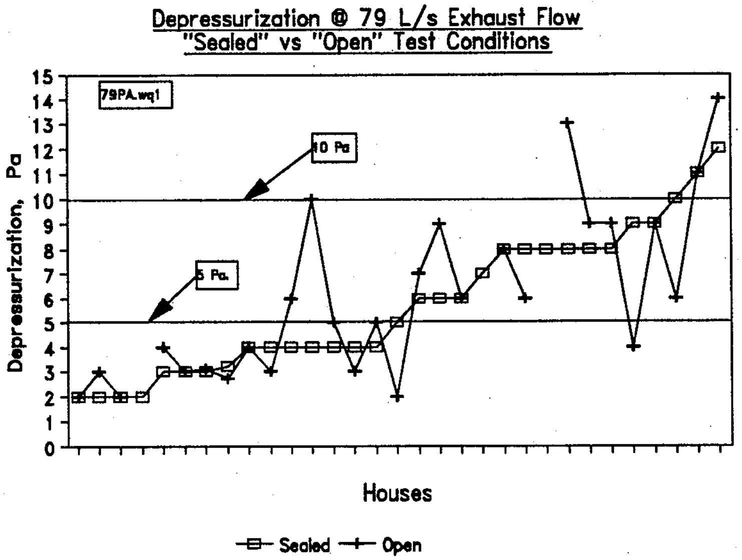

Figure 5

For the 79 L/s test flow, there was no average difference between the depressurization levels. The standard deviation was 2 Pa and the statistical variance 5 Pa. Absolute differences ranged from -6 to +5 Pa.

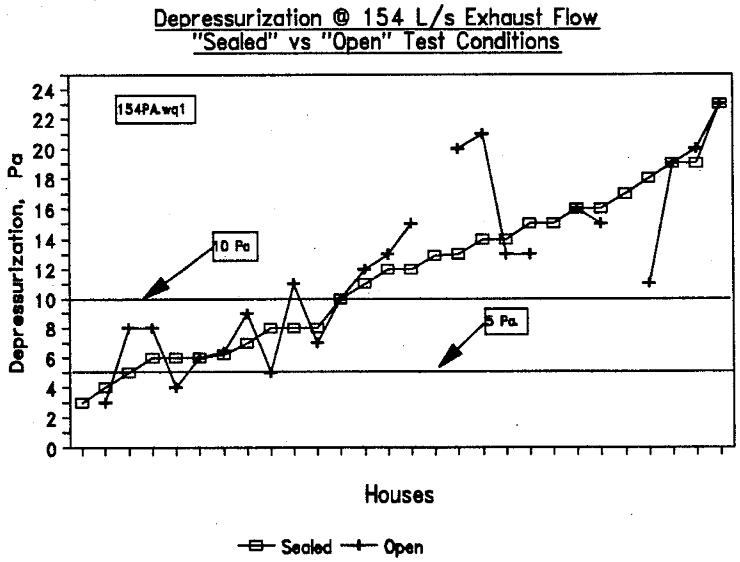

Figure 6

For the 154 L/s test flow, the "Open" test condition results were an average 1 Pa lower than the "Unsealed" values. The standard deviation was 3 Pa and the statistical variance 8 Pa. Absolute differences ranged from -7 to +7 Pa.

No trends or features were identified which could be used to flag houses with large variances between Sealed and Open conditions. trends or features analyzed were:

- type of combustion venting
- presence or absence of HRV
- windspeed at time of test
- rest pressure during test
- building height

It was surmised prior to data analysis that the presence of an active, operating flue would influence the recorded pressure of "Open" tests. This hypothesis was not supported by the data as shown in the following table.

Variance in Depressurization Between "Sealed" & "Open" Test Conditions for 79 L/s Exhaust Flow, Houses with Active, Natural Draft Flues

House #	Variance, Pa.
32	-2
34	-2
21	-1
20	0
26	0
30	+1
15	+1
31	+2

4.3 Comparison with ELA_{10}*0.15 Calculation Method

The HRAI calculation method yielded only approximate correlation to the actual depressurization results.

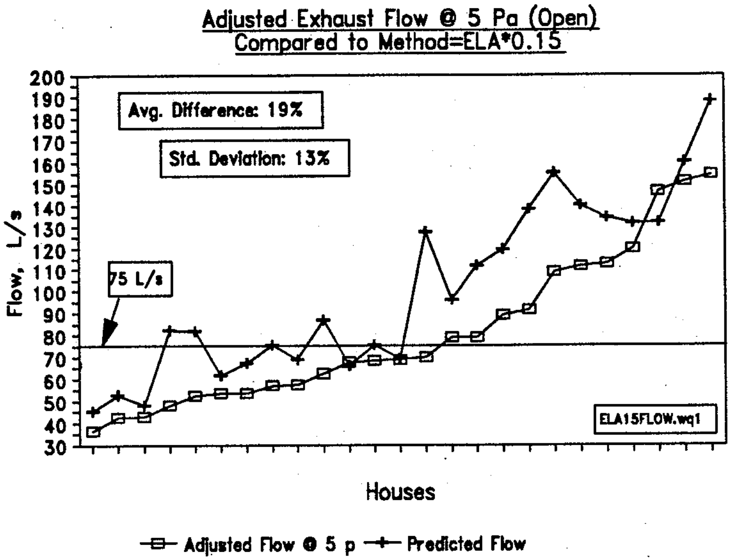
Adjusted Exhaust Flow @ 5 Pa (Open)
Compared to Method=ELA*0.15

Figure 7

Statistically, the predicted flows at 5 Pa averaged 19% above the test results derived from the 75 L/s exhaust test. This is to say that the current calculation is more generous than the actual test results.

The standard deviation of 13% is within the range of accuracy expected for blower-door type tests (+/-15%).

4.4 Comparison to CP^n Calculation Method

This calculation method is somewhat less precise than the $ELA_{10}*0.15$ method. The standard deviation of 15% is slightly higher than obtained using the $ELA_{10}*0.15$ method, but remains within the range of accuracy expected for these tests.

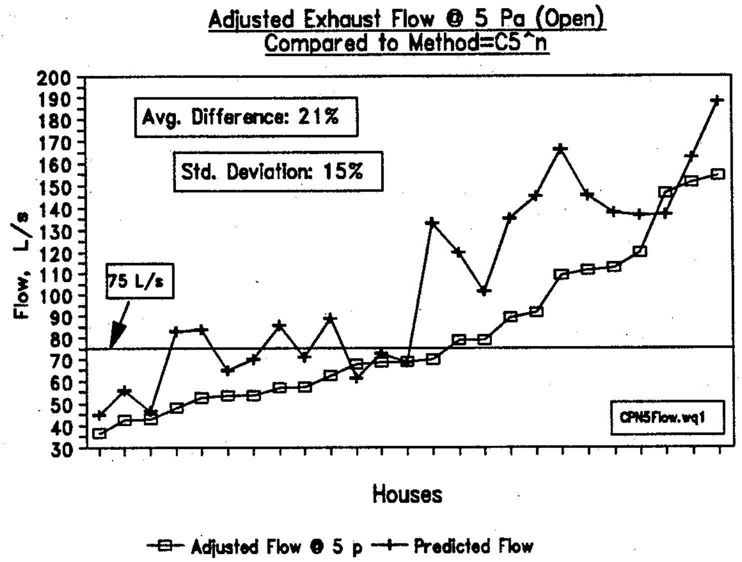

Figure 8

Statistically, the predicted flows at 5 Pa averaged 21% above the test results derived from the 75 L/s exhaust test.

4.5 Comparison of CP^n Calculation Method to $ELA_{10}*0.15$ Method

The predictions of both the $ELA_{10}*0.15$ and the CP^n method are very similar as shown in Figure 8.

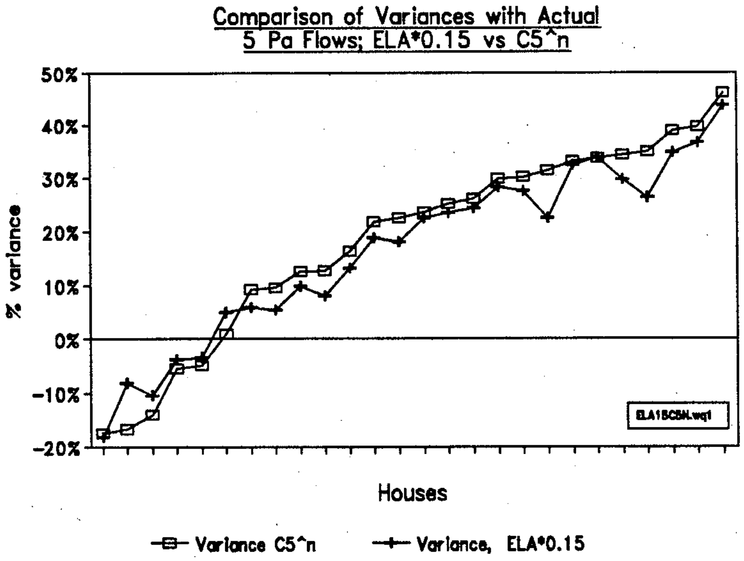

Figure 9

4.6 Alternate Calculation Methods:

a. Q50 @ n=0.7

The results of the CGSB blower door test are less accurate at lower test pressures, particularly under windy test conditions. Errors in the lower pressure tests can result in errors in the ELA_{10} and "C" value.

Gary Nelson of the Energy Conservatory has suggested that the airflow @ 50 Pa (Q50) is the most reliable value to be derived from the CGSB blower door test. Mr Nelson has further suggested that if a flow value at pressures other than 50 Pa were required it would be sufficient to assume that the value of n = 0.65. Other authorities (Tom Hamlin) cite a value of 0.7 as being a more appropriate value to be used where new housing is under consideration. The decision to use 0.7 was based on the average "n" value of the houses in this study (0.688).

Analyzed in this way, that predicted flows at 5 Pa were found to have a fairly reliable relationship to the actual values (standard deviation of 11%), however on average they were 20% higher.

The following figure 10 shows predicted airflows at 5 Pa using a method which uses the Q50 value, adjusted to 5 Pa assuming that the n value is 0.7, and adjusted downward by 20%.

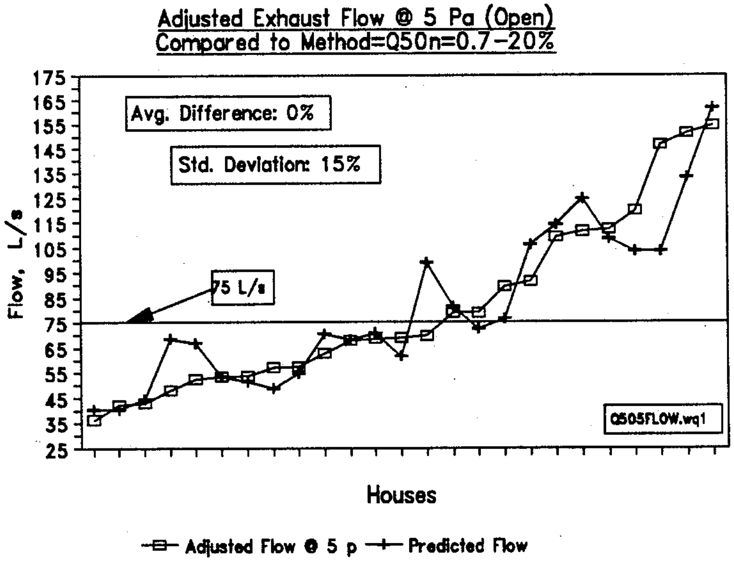

Figure 10

Although improved over the current prediction methods, the standard deviation remains quite high, at 15%.

b. Q50/6.3

If one assumes that the Q50 value is the most reliable value, the simplest calculation method would involve a simple divisor or multiplier. To find the allowable net exhaust @ 5 pa, one would divide the Q50 value by a dimensionless factor. The Q50 can be easily calculated for any house if the ACH50 and volume are known.

For the houses in this study Q50/6.3 produced predicted exhaust flows at 5 pa comparable to those obtained using the Q50 @ n=0.7-20% method. The straight divisor method is slightly easier to calculate however, not requiring a calculator with an fractional exponent function.

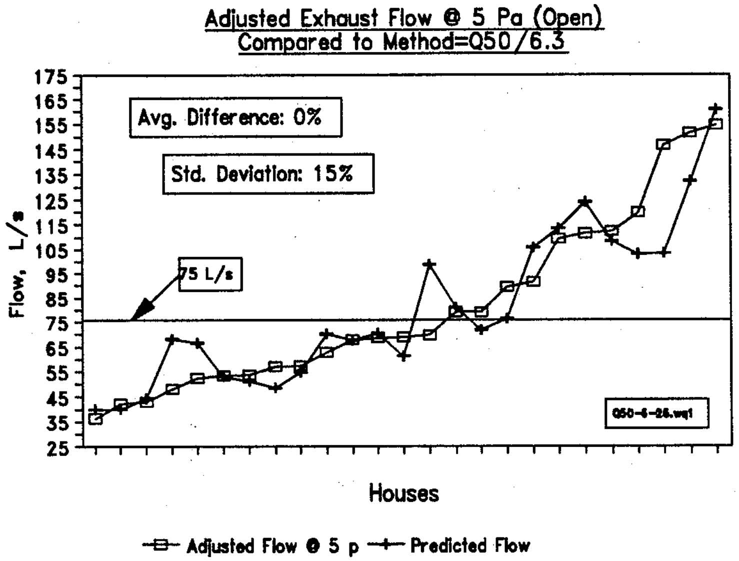

Figure 11

c. ELA_{10}*0.15 - 19%

The ELA_{10}*0.15 method is slightly more accurate than other predictive methods, however there is a tendency to over predict the actual airflow required to induce 5 pa of depressurization. When adjusted by 19% to compensate for the over-prediction this method produces results similar to the other methods.

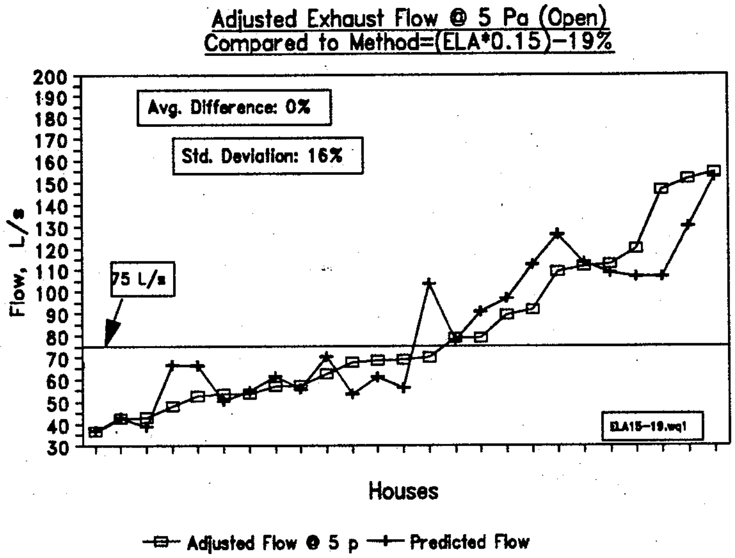

Figure 12

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 SEALED (CSA F326) vs OPEN (HRAI Alternate) Test Conditions

For the group of houses studied, there appears to be no difference between the open and closed test conditions on a general basis. The two test conditions may result in different values for specific houses however, and these differences do not appear to be predictable.

The open test condition is easier to carry out and is applicable to the widest range of house configurations. It is recommended therefore that the open test condition be the recommended protocol for general use. This protocol should be added to the CSA F326 Standard and it's use should be emphasized in the HRAI Manual. There is no reason however to remove the option of the closed test condition from the CSA F326 standard.

5.2 Calculation Method

Neither the ELA_{10} * 0.15, nor the CP^n calculation methods provide exceptionally reliable approximations of the results of the field test. While both methods under-estimate the actual depressurization, the CP^n method appears to be less reliable for individual homes.

The ELA_{10} * 0.15 method is as accurate as other methods however it requires the calculation of the house envelope area and uses a statistical factor (NLA) which is somewhat more abstract than the "Air Change per Hour at 50 Pa" (ACH_{50}) which is commonly used to describe the air-tightness of a individual houses.

It appears that most predictive calculations are able to predict actual depressurization of a home with an accuracy of about +/- 15%.

Comparison of Predictive Calculation Methods

Calculation Method	Average Difference	Standard Deviation
ELA_{10} * 0.15	19%	13%
CP^n	21%	15%
Q50 @ n=0.7	20%	12%
Q50 @ n=0.7-20%	0%	15%
Q50/6.3	0%	15%
ELA_{10} * 0.15-19%	0%	16%

Based on the sample houses used for this study, it would appear that a calculation which uses a simple divisor of the ACH_{50} airflow volume will be similar in accuracy to the other available methods. This approach would not tend to under-estimate the actual depressurization and would be simpler to carry out.

It is recommended therefore that the simple divisor method be adopted by HRAI as the preferred calculation method by which system designers may approximate the probable depressurization of houses prior to construction. If the CSA F326 Standard requires modification to reflect the use of such a calculation method, such modification should be carried out.

5.3 Further Study

While this study examines the relationship between the field test and the calculation method as well as the calculation method itself, it does not examine the appropriateness of the "airtightness descriptor" to be assumed by the system designer prior to construction.

The current "air=tightness descriptor" used by HRAI for newly constructed houses is $NLA_{10} = 0.7cm^2/m^2$. This value was chosen based on a review of the 1989 200-Home air-tightness data set (ref 5). A recent validation the HRAI value (ref 6) established that it was appropriate for 90% of new homes. Both of these studies assumed that the CP^n calculation method was reasonably accurate. This study has shown that the CP^n calculation may produce an error of 20%.

The choice of a particular value as an "air-tightness descriptor" should therefore be re-examined using the most recent airtightness data available. New airtightness descriptors should then be selected based on the known inaccuracies of the calculation method to be used.

Prepared 16 September 1995
by: Dara Bowser maato

REFERENCES

1. Ontario Building Code, Ontario Regulation 413/90, 158/93 & 160/93, July 1st 1993, Ontario Ministry of Housing.

2. Residential Mechanical Ventilation Systems CAN/CSA-F326-M91, revised October 1993, Canadian Standards Assn.

3. Residential Mechanical Ventilation Systems Manual, Heating Refrigerating and Air Conditioning Institute, 1993 Edition, September 1993.

4. Determination of the Airtightness of Building Envelopes by the Fan Depressurization Method CAN/CGSB 149.10-M86, Canadian General Standards Board, 1986

5. 1989 Survey of Airtightness of New, Merchant Builder Houses, Haysom, J.C. & Monsour, R., Indoor Air '90, paper # NT-87-27-2; Toronto, 1990

6. Ventilation and Airtightness in New Ontario Housing, Bowser Technical Inc., July, 1994

APPENDIX - HOUSE DATA - page 1

#	Year Built	Height ft	HRV? Y/N	Comb. Appl. *See Note 1*	Wood Burn *See Note 2*	Env. Area ft^2	Vol. ft^3	"C" CFM/Pa	"N"	ELA @ 10 Pa in^2	ACH @ 50 Pa
01	94	21	N	2,3	N	4444	14246	58.35	0.687	83.43	3.61
02	94	26	N	2,3	N	3800	14560	41.81	0.743	68	3.15
03	94	21	N	2,3	N	5950	23358	75.54	0.65	99.24	2.47
04	94	23	N	2,3	N	4747	17800	41.33	0.654	54.77	1.80
05	94	17	N	2,3	N	4916	20592	45.71	0.695	66.63	2.02
06	94	26	Y	2,2	N	5713	24075	49.75	0.721	76.87	2.08
07	94	17	Y	2,3	N	7359	32670	74.26	0.554	78.25	1.19
08	65	18	N	1,1	3,3	8640	45547	175.88	0.649	230.69	2.93
09	95	26	N	2,3	N	5945	19421	118.06	0.551	123.51	3.15
10	95	26	N	2,3	N	5135	21429	57.46	0.7	84.59	2.49
11	95	26	Y	2,2	N	6009	23987	55.94	0.713	84.89	2.28
12	94	17	N	2,3	N	6946	27489	43.33	0.751	71.74	1.79
13	95	17	N	2,3	N	5016	19516	28.24	0.777	49.64	1.81
14	95	26	Y	4	3	8321	39924	97.84	0.676	136.39	2.07
15	77	17	N	1,1	3	4354	15156	95.55	0.694	138.85	5.71
16	95	17	N	2,3	N	4986	21120	271.03	0.469	234.68	4.82
17	95	17	N	2,2,3	N	5782	25738	50.17	0.684	71.24	1.70
18	94	26	N	3,4	2	6692	26244	92.13	0.63	115.63	2.48
19	94	26	Y*	1,2	N	6045	36825	104.09	0.675	144.9	2.70
20	55	17	N	1,1	N	5762	22988	122.56	0.732	194.35	5.61
21	94	26	Y	2,3	N	6385	28239	47.12	0.665	63.99	1.51
22	95	26	Y	2,1,1	4	6949	33904	106.32	0.661	143.19	2.50
26	95	26	Y	2,2,3	N	6230	30199	43.28	0.787	78.01	1.87
27	94	22	N	2,2	N	5723	21709	61.21	0.698	89.72	2.59
28	95	17	N	2,3	N	4486	16797	127.55	0.632	160.79	5.41
29	77	16	N	1,1	4	3947	15437	51.22	0.661	69.79	2.65
30	95	25	N	1,1	N	4038	14767	97.65	0.676	136.21	5.59
31	90	17	N	1,1	1	4294	17425	33.68	0.841	68.61	3.11
32	95	17	N	2,3	N	4103	14727	28.05	0.754	46.82	2.18
33	94	25	Y	1,1	N	6105	27043	110.02	0.71	165.79	3.92
34	94	17	N	2,3,3	N	4769	19808	96.11	0.669	131.85	3.99

Note 1: Combustion Appliance Code: 1 - natural; 2 - side-wall; 3 - Direct-vent; 4 - side-wall oil

Note 2: Wood Burning Code: 1 - stove; 2 - airtight stove; 3 - fireplace with door; 4 - Fireplace Open

........cont'd on following page

APPENDIX - HOUSE DATA - page 2

#	Cor-relation Coef-ficient	Error @ 50pa %	Wind MPH	Rest Pres-sure Pa	CombType Nat? y/n	"Sealed"			"Open"			Flow @ 5 Pa @ CP^n L/s	Flow @ 5 Pa @ ELA* $0.15cm^2$ L/s
						@ 79 L/s Pa	@ 154 L/s Pa	Flow @ 5 Pa @ Qp^n L/s	@ 79 L/s Pa	@ 154 L/s Pa	Flow @ 5 Pa @ Qp^n L/s		
01	0.993	1.1%	9	0.0	n	3	12.9	112	3.1	ERR	110	83	81
02	0.996	1.1%	7	-1.0	n	8	17	56	ERR	ERR	ERR	65	66
03	0.989	1.7%	6	-1.0	n	4	11	91	5	12	79	101	96
04	0.996	0.9%	3.5	-3.5	n	8	ERR	58	13	ERR	42	56	53
05	0.99	1.6%	8	-1.0	n	7	15	63	ERR	ERR	ERR	66	64
06	0.85	6.9%	9	-10.0	n	9	19	*note 1*	4	19	*note 1*		
07	0.998	0.4%	5	11.0	n	9	14	57	9	13	57	85	76
08	0.995	0.9%	0	-1.5	y	2	3	143	ERR	ERR	ERR	236	223
09	0.993	1.0%	6	-5.0	n	3	10	105	4	10	89	135	120
10	0.993	1.0%	8	-4.0	n	6	13	70	9	20	52	84	82
11	0.991	1.3%	4.5	-6.0	n	4	14	93	10	21	48	83	82
12	0.978	2.1%	2	-0.5		10	16	47	6	15	69	68	69
13	0.996	1.0%	1.5	-3.0		11	23	43	11	23	43	47	48
14	0.999	0.3%	5	-2.0	y	5	8	79	2	5	147	137	132
15	0.997	1.0%	?	?	y	4	6	92	3	6	113	138	134
16	0.997	0.7%	9	-5.0	n	2	6	*note 1*	3	4	*note 1*		
17	0.995	1.2%	5	-3.5	n	8	16	57	8	16	57	71	69
18	0.992	1.2%	0	-0.5	n	4	ERR	91	5	ERR	79	120	112
19	0.999	0.3%	5	0.1	y	4	8	92	3	7	112	146	140
20	0.995	1.0%	1	0.5	y	2	4	154	2	3	154	188	188
21	0.999	0.2%	2	-1.0	n	8	19	58	9	20	53	65	62
22	0.996	1.1%	8	-3.0	y	4	8	92	4	11	92	145	139
26	0.996	0.8%	4	-1.0	n	6	12	68	6	13	68	72	75
27	0.999	0.1%	0	-1.5	n	6	12	70	7	15	62	89	87
28	0.998	0.5%	7	-1.0	n	3	6	109	3	8	109	166	156
29	0.999	0.2%	1	-1.0	y	8	18	58	9	11	54	70	68
30	0.999	0.3%	7	-0.8	y	3.2	6.2	107	2.7	6.4	120	137	132
31	0.999	0.4%	5	-1.0	y	8	15	53	6	13	68	61	66
32	0.996	1.0%	6	-1.0	n	12	ERR	41	14	ERR	36	45	45
33	0.996	1.4%	3	-3.0	y	2	5	151	2	8	151	163	160
34	0.999	0.3%	5	-0.5	n	4	7	92	6	9	70	133	128

Note 1: data not used, too windy