THE IMPLEMENTATION AND EFFECTIVENESS OF AIR INFILTRATION STANDARDS IN BUILDINGS

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PAPER 4

AIRTIGHTNESS STANDARDS FOR BUILDINGS - THE CANADIAN EXPERIENCE AND FUTURE PLANS

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SYNOPSIS

The situation in Canada with regard to building regulations affecting the airtightness of buildings is reviewed with emphasis on a new standard test method for measuring airtightness which departs somewhat from methods used in other countries. The purpose of this test is held to be primarily to determine an important aspect of building envelope quality, namely the degree to which unintentional openings have been avoided, rather than to determine energy conservation potential. The procedures used in the method, the rationale behind those procedures and the experience to date in using the method are summarized. The reasons why there is very little regulation of building airtightness in Canada at present and the prospects for increased regulation are given. It is concluded that it is unlikely there will be widespread regulation in this area in the near future.

1. INTRODUCTION

The purpose of this paper is to present the current status of Canadian building standards relating to airtightness and to speculate on how the situation might change in the future.

I will first establish the context with a brief synopsis of the standards writing and implementation process in Canada and then concentrate principally on the Canadian General Standards Board Standard 149.10, "Determination of Airtightness of Buildings by the Fan Depressurization Method"[1]. I will review its main features, giving the rationale for each, and relate some of the results of its use to date. I will close by suggesting how this standard and others might be used to a greater extent in the future to improve the airtightness of Canadian buildings.

2. THE CANADIAN STANDARDS WRITING AND IMPLEMENTATION PROCESS

To understand the current situation regarding standards affecting airtightness and other building characteristics related to energy conservation, it is first necessary to have an appreciation of the the process by which standards are developed and implemented in Canada.

Virtually all our standards affecting buildings, and most other products, are developed by the consensus process. Even government agencies with the mandate to do so are reluctant to simply impose standards on the building industry without fairly thorough prior consultation. The consultation process is facilitated by the existence of five "Standards Writing Organizations" recognized by the Standards Council of Canada. The Canadian Standards Association (CSA) is one of these "Standard Writing Organizations" (SWO's) you might be familiar with. The Canadian General Standards Board is another.

When the need for a new standard is identified, the SWO in whose area of expertise or experience the standard is recognized to fall forms a committee and attempts to establish membership on that committee that will have a balanced matrix of "producers", "users" and neutral third parties. The terms "producers" and "users" are often not very appropriate; but the general concept of balancing those who might be expected to argue for a less stringent standard with those who might be expected to argue for a more stringent one is the guiding principle. Usually several drafts are required before a standard is developed which may represent a reasonable compromise between these two groups.

Once developed, the standard has no force until referenced, usually in a building code, by some government agency, normally a provincial government. The process provides such agencies with some degree of assurance that the standards they thus invoke are not likely to be unreasonably stringent or unreasonably lenient, because they know there has been some input by those likely to be affected by the standard's being implemented.

Even our National Building Code[2] is developed and updated by a similar consensus process and it too has no force until adopted or adapted by a provincial government, since our Constitution gives the provinces the mandate to regulate building. Although the National Building Code is only a model code, it nevertheless has a great deal of influence as most of the provincial codes are modelled quite closely on it.

3. THE CURRENT SITUATION

There are currently two standards in Canada relating to the airtightness of buildings - the above-mentioned CGSB Standard 149.10, "Determination of Airtightness of Buildings by the Fan Depressurization Method" and "Measures for Energy Conservation in New Buildings", a supplement to the National Building Code.

3.1 CGSB Standard 149.10

The CGSB Committee on Airtightness and Air Leakage Testing of Buildings was formed in April 1982. The committee believed it had completed work on this standard in September 1983 but the final draft was not approved by the necessary majority on the last ballot due to some last minute concerns regarding temperature corrections and curve fitting procedures. Even though it has not been published in final form, the standard is being fairly widely used as a testing protocol to ensure uniformity of approach in research projects on airtightness of houses and ways of improving that airtightness. An airtightness testing procedure more-or-less along the lines described in the CGSB draft is also being used by the small but growing number of air sealing contractors, who use the before and after results to demonstrate to homeowners what their work has accomplished. Finally, this test procedure is used in a federal government program of subsidies for the construction of low energy houses. Among other criteria in this program, a house must be demonstrated to experience no more than 1.5 air changes per hour at 50 Pa test pressure to be eligible for the subsidy.

I should emphasize that this standard is a standard test **procedure** only - it includes no pass/fail criterion for airtightness nor does it even provide any guidance as to what constitutes high or low, good or bad airtightness. It merely establishes a definition for airtightness (which I will look at more closely below) and a method of testing to determine the airtightness of a particular building. It is left to others to establish criteria.

3.2 Measures for Energy Conservation in New Buildings[3]

This supplement to the National Building Code is one place where one might reasonably expect to find such a criterion. However, the energy "Measures" (the verbal shorthand name adopted by most people who have occasion to talk about this document) was first published in 1978 and revised in early 1983. The committee responsible for developing and maintaining the "Measures" was reluctant to specify such a criterion until a standard test method was established - something of a "chicken-and-egg" situation. Thus this document's only requirements regarding airtightness, thus far, are some rather vague statements about the need to caulk or seal likely points of air leakage and infiltration test criteria for windows and doors.

Like the document it supplements, the "Measures" is another model document with no force unless adopted by some authority with a mandate to regulate buildings, such as a provincial government. Thus far only one province - Quebec - has seen fit to do so. However, the federal government's housing agency, Canada Mortgage and Housing Corporation, applies the 1978 edition of the "Measures" to houses built under its mortgage insurance and subsidized housing programs - about one third of new housing starts.

4. A CLOSER LOOK AT CGSB STANDARD 149.10, "DETERMINATION OF AIRTIGHTNESS OF BUILDINGS BY THE FAN DEPRESSURIZATION METHOD"

Let us now look in more detail at the testing and reporting procedure described in Standard 149.10.

4.1 What Does the Test Set Out to Measure?

In contrast to the practice used in several other countries, it was decided at the outset that the result of the test should be expressed as an "equivalent leakage area" rather than as air changes per hour at some test pressure. There were two principal reasons for this decision -

- o One reason was the committee's concern that an air change per hour figure would be inadvertantly or deliberately confused with the natural air change rate of the house under wind and buoyancy forces. I mention "deliberately" because there had already been reports of sealing contractors using the air change at 50 Pa figures, divided by some unsubstantiated factor (often fanciful and sometimes equal to 1) to exaggerate claims about the benefits of their service. Even the honest contractors were looking for such a factor that could be used with confidence. Many members of the committee were skeptical that such a factor or even a more complicated correlation could be found and wished to choose a method of expressing the results of an airtightness test that would discourage this direction of thinking.

- o The other principal reason for avoiding the air change per hour approach was that an airtightness test was seen as being primarily a test of the general quality of construction of the building envelope and not just a test of potential energy conservation qualities. Indeed, it is being increasingly recognized that, in new construction at least, avoidance of interstitial condensation is probably a more compelling incentive for improved airtightness than energy conservation. A recent study[4] has shown that the level of airtightness already achieved in ordinary new Canadian housing is often high enough that further improvements will result in the need for installation of mechanical ventilation. This, of course, is not necessarily undesireable since a perfectly airtight house with a reliable controlled ventilation system would be free of the risks of both interstitial condensation and poor air quality. The point is, however, that, if one starts with one of our ordinary new houses, improving its airtightness, on its own, will save little if any energy since the reduction in air leakage will have to be replaced by ventilation. It is only when heat recovery is added to the ventilation system that energy is saved and this is an additional cost which must be weighed against the value of the energy saved.

Thus, if an airtightness test is conducted primarily to measure the quality of the building envelope, "equivalent leakage area" is a way of expressing the results of the test which seems to relate more closely to this way of thinking of the test.

Equivalent leakage area also relates better than air change rate to the definition of airtightness used in the standard -

> "the degree to which unintentional openings in the building envelope have been avoided".

This is an appropriate point to emphasize the title chosen for the standard. Please note that it is an "airtightness" test and not an "air leakage" test. The committee chose to regard air leakage as the normal accidental exchange of air between the interior and exterior under the action of wind and buoyancy forces - the phenomenon which ASHRAE and AIC refer to, incorrectly or at least incompletely, as "infiltration". This is not what the fan depressurization test measures.

To summarize this point then, CGSB Standard 149.10 seeks to measure "the degree to which unintentional openings in the building envelope have been avoided" and the results are expressed as an equivalent leakage area (ELA).

4.2 The Test Procedure

In establishing a test procedure and a procedure for processing the test data, the committee has strived for precision and reproducibility, envisioning the standard being used in a context where failure to get below some target ELA will have negative consequences, such as denial of an occupancy permit or withholding of a low energy housing program subsidy. It is too early to tell whether these objectives have been achieved.

Briefly, the process involves the following steps:

- All intentional openings in the building envelope, such as windows or chimney flues, are closed or sealed.

- A variable speed fan with a top speed flow capacity of from 1000 to 3000 L/s is sealed into a window or door opening so that it will blow outwards. The fan will have been previously calibrated to obtain a correlation between its speed and flow or between the pressure drop at its inlet orifice and flow. Sometimes a calibrated inlet nozzle is used to measure flow through the fan.

- The fan speed is then varied to create a number of interior/exterior pressure differences ranging from 10 Pa to 50 Pa. The fan flow required to create each pressure difference is recorded.

- The flow readings are corrected for differences between the atmospheric pressure and interior temperature of the house and the pressure and temperature at which the fan was calibrated, and for the difference between interior and exterior temperatures. This latter correction is required because interior air flow through the fan is being measured but it is really exterior air flow through the envelope that we are interested in.

- To the corrected flow and pressure difference readings, a curve is fitted to the form -

$$Q = C \quad p^n$$

where: Q = flow (L/s),
C = a constant, and
P = interior/exterior pressure difference (Pa).
n is an exponent between 0.5 and 1.0

The curve fitting is done using the least squares method modified to give less weight to the low pressure difference values because these are the most difficult to make accurately. Statistical analysis tests are applied which invalidate the test if the fit of the curve is not within prescribed limits.

o The regression coefficients C and n are then used in the following formula to calculate the equivalent leakage area:

$$ELA = 0.001157 \quad {}_{o} \cdot C \cdot 10^{n-0.5}$$

where: ELA = equivalent leakage area (m^2)
$_o$ = density of the exterior air (kg/m^3)

Committee member William Jones of Ontario Hydro derived this formula[5] by equating the flow at 10 Pa from the fitted curve to the flow through a sharp-edged orifice at 10 Pa. 10 Pa is used because it is the test pressure closest to the pressures the house will actually experience.

Figure 1 shows a typical test set-up and Figures 2 and 3 show typical processed test results.

4.3 Experience in Using the Standard So Far

Achieving reliable ELA values has been a problem. In some cases where the test is being used to monitor the results of sealing work, the ELA has appeared to increase after sealing even though the flow at 50 Pa has decreased. This is attributed to the fact that the ELA value derived from the above formulae is strongly influenced by the results at low test pressures and these, in turn, are strongly influenced by the wind. Thus ELA's derived from test results taken on other than calm days must be regarded with some suspicion even if the results have passed all the required statistical tests. Often it is not possible to delay testing to wait for calm conditions. The committee may have to consider revisions to the procedure to make the results less sensitive to wind influence on low pressure difference readings. Perhaps dropping some of the lower pressure readings would accomplish this.

Another issue has been the aforementioned quest for a correlation between the results of an airtightness test and the normal air leakage experienced by the house. While some researchers[6,7] claim to have found such a correlation, we are not aware of any research into this issue which was **both rigorous**, in terms of the method and length of time of air leakage measurements, and **broad-based**, in terms of the number and variety of houses studied. Indeed, we have reason to be skeptical about the derivation of any generalized correlation since, in using the fan depressurization test to track the results of air sealing work, we have become aware of one shortcoming of the method, which seems obvious in retrospect. The fan depressurization test tests all of the leaks in the envelope in parallel; but many of those leaks will act in series under normal wind and buoyancy forces. Once one of the leaks in a series is sealed, sealing the others will have no effect on normal air leakage; but each sealing effort shows up as an improvement in an airtightness test, whether or not it is redundant in its effect on normal air leakage. Since the arrangement of parallel and series leakage paths is likely to vary from house to house quite randomly, is it likely that a generalized correlation exists?

I hasten to add that this latter point does not negate the value of the fan depressurization test as long as one bears in mind its primary purpose, which is to act as a quality control check on the envelope.

5. POSSIBLE FUTURE APPLICATION OF CGSB STANDARD 149.10

I mentioned earlier that improvements in the airtightness of our new houses would not likely yield substantial direct reductions in energy consumption. This does not mean that such improvements should not be strived for. The most important reason to do so is to reduce the incidence of interstitial condensation in the building envelope - a significant and apparently increasing problem, as we increasingly tend to operate our houses in a "flueless" mode without an active chimney flue to depressurize the house and reduce exfiltration. Another is to make heat recovery capabilities in ventilation systems more effective when and if it becomes economic to incorporate such facilities on a widespread basis.

There are two ways to encourage the building industry to adopt better practices in operations affecting airtightness - the "carrot" approach and the "stick" approach. Both can make use of CGSB Standard 149.10.

The "carrot" approach is already being used in the federal government subsidy program for low energy houses I mentioned earlier. This is the "R2000" Program, operated by the Department of Energy, Mines and Resources, in which a builder qualifies for a grant if his house meets certain criteria including an airtightness criterion. However, this program thus far has affected only a small number of houses.

The "stick" approach - incorporation of airtightness requirements in building regulations - has not been used yet and may not be for some time. There is reluctance on the part of provincial building code authorities to implement requirements perceived as being related to energy conservation and not to the traditional objectives of building regulations - health and safety. The fact that, in the six years since it was published, only one province in ten has implemented the "Measures for Energy Conservation in New Buildings" is eloquent testimony to this observation. Thus, although the "Measures" committee is contemplating incorporating a requirement for an airtightness test according to the CGSB Standard (with an appropriate criterion) in the next edition of the "Measures", it will have little immediate effect.

On the other hand, it is being increasingly recognized that the vapour barrier requirements in the National Building Code and its provincial offspring, with their emphasis on preventing vapour diffusion and their failure to effectively address the real cause of interstitial condensation (i.e. outward air leakage), are not very relevant in terms of protecting the structure from this growing menace. Perhaps, therefore, we can hope that airtightness test requirements and criteria might be incorporated in building codes proper rather than in energy conservation supplements. I know of no such plans at present; but these things take time. Our consensus approach to standards writing and implementation has many advantages; but speed is not one of them.

6. SUMMARY

My summary can be quite brief. We are very close to having in place a standard method for measuring the airtightness of houses which we believe addresses the relevant issues in this area and, with a few refinements, will yield accurate, reproducible results; but it is unlikely that this standard method will be used in any broad regulatory way in the near future.

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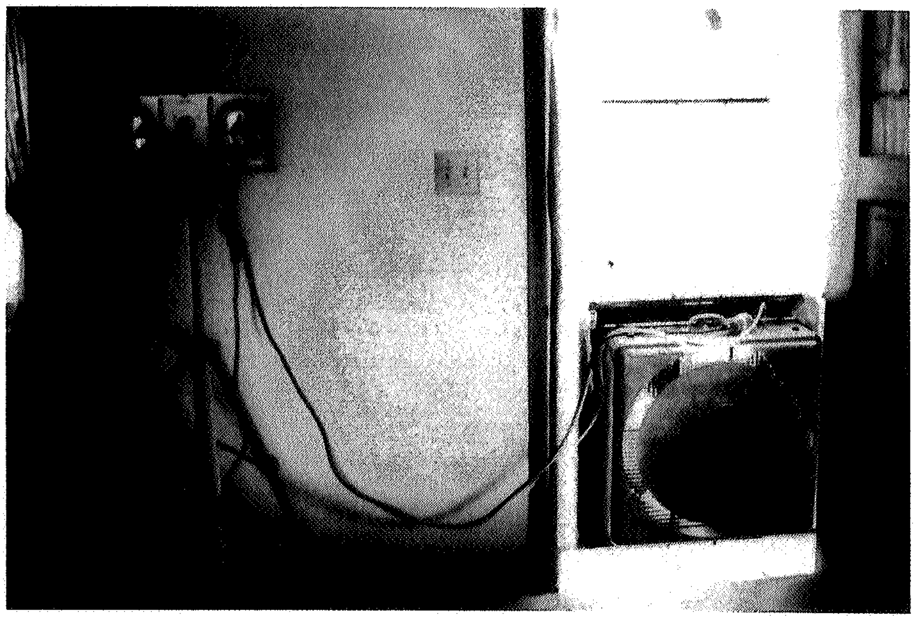


FIGURE 1

Depressurization fan installed in an exterior doorway; speed control and gauge unit on left. Disk in fan orifice reduces flow for tighter houses.

AIRTIGHTNESS TEST RESULTS (as per CGSB Draft 6)

85 KING ST.
AUG. 16,1983 — Ext.Temp.= 23.8 C
Bar.Press. = 102 KPa — Wind Speed = 4 km/h

PRESS. (PA)	TI (C)	MEAS'D.	FLOW(L/S) ADJ'D.	FITTED	RELATIVE ERROR(%)
10.0	24.0	675.00	678.11	670.18	1.17
15.0	24.2	850.00	853.63	865.42	1.38
20.0	24.2	1050.00	1054.49	1037.56	1.61
30.0	24.2	1300.00	1305.55	1339.83	2.63
40.0	24.2	1625.00	1631.94	1606.32	1.57
50.0	24.2	1835.00	1842.84	1849.02	0.34

C = 156.898007 n = .630573117

E.L.A. = 0.2682 m^2 Volume = 461 m^3

Q @ 10Pa = 670.18 L/S Q @ 50Pa =1849.02 L/S

Air Change per Hour @ 50Pa = 14.439

SXX= 2.10046194E+13 SXY= 1.32449483E+13

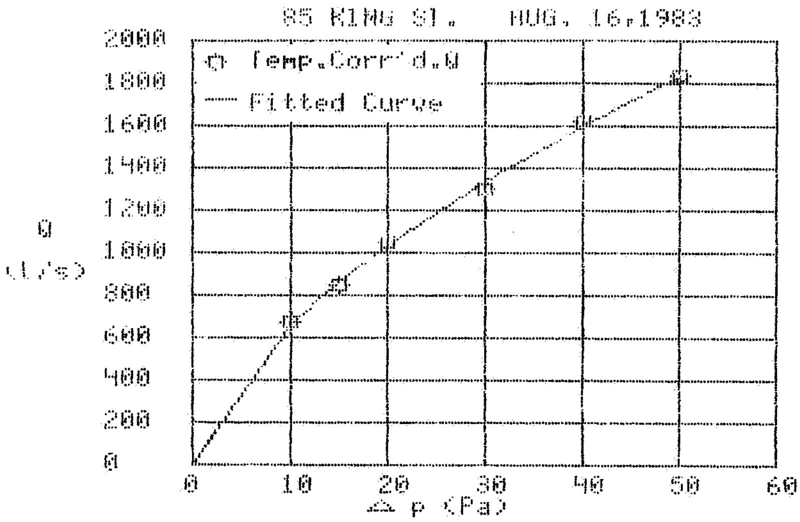
SYY= 8.37553855E+12 SYX= 24.2277571

Correlation Coefficient= .998588337

Relative Standard Error = 2.16%

FIGURE 2

Processed data from a typical airtightness test of a 2-storey, pre-war house.



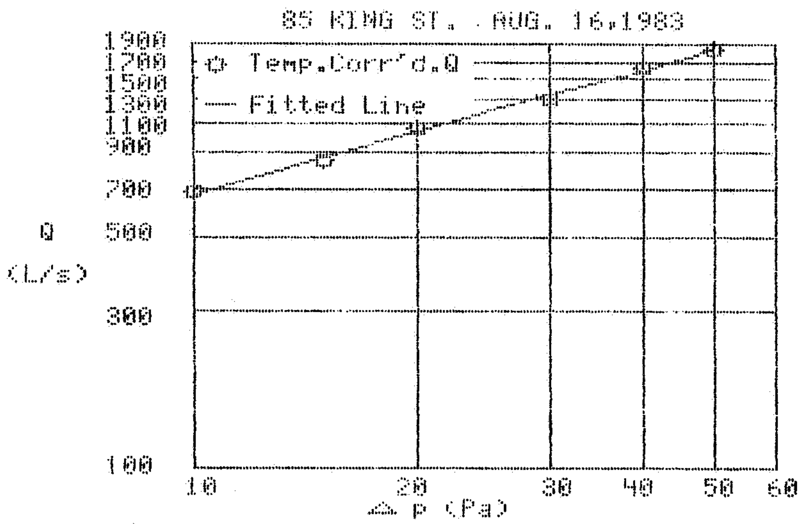


FIGURE 3

Plots of typical results from an airtightness test of a 2-storey, pre-war house.