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AIRTIGHTNESS AND AIR QUALITY IN PRESERVED WOOD FOUNDATIONS

Final Report

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DISCLAIMER

This study was conducted by Buchan, Lawton, Parent Limited for the Canada Mortgage and Housing Corporation under Part IX of the National Housing Act. The analysis, interpretations and conclusions are those of the consultants and do not necessarily reflect the views of Canada Mortgage and Housing Corporation.

Ce rapport est aussi disponible en français sous le titre *Étanchéité à l'air et qualité de l'air des maisons érigées sur des fondations en bois traité.*

ABSTRACT

Infiltration of soil gas into basements is a cause of indoor air quality problems. Very little research has been conducted on air quality concerns that specifically relate to preserved wood foundations (PWF). This report documents the findings of a field study that examined the air leakage characteristics of preserved wood foundations. The study also investigated the level of "off-gassing" from the chemicals used for wood preservation in PWF basements. The field work involved four types of testing on fourteen homes.

The highlight of this study was the development of a test protocol to determine the air leakage characteristics of the basement portion of a house. The test protocol was then modified to ascertain the leakage of specific cracks in the basement. Unfortunately the testing protocol could not be used to determine the level of below grade air infiltration because the majority of the air leakage into PWF basements was found to be around windows and headers.

The basement wall cavity air was sampled and analyzed for volatile organic compounds. Chemicals encountered were compared to those used in the wood preserving process. All concentrations found were very low and well under the Ontario Ministry of the Environment ambient air quality criteria.

To determine likely below-grade air infiltration paths, samples of wall cavity air, basement air, and air from below sleeper floors were taken and analyzed for radon levels.

Key words for this study would include: preserved wood foundations, air leakage testing, and indoor air quality.

EXECUTIVE SUMMARY

Indoor air quality is an area of increasing concern in today's society. This fact has resulted in an increased level of research on the average Canadian home. Preserved wood foundations have become a common alternative to poured concrete basements. However, very little research has been undertaken on how preserved wood foundation construction techniques affect the indoor air quality of the home.

This study was concerned with two sources of pollutants in the PWF homes; the soil surrounding the house and the chemicals used in the preserving process. Soil gases enter basements through cracks and holes in the air barrier and are affected by various driving forces. The health hazards of soil gases has resulted in an increased desire for construction of airtight basements. Secondly, concerns exist about the potential of chemicals used in the preserving process to "off-gas" fumes into the indoor air. The ability of PWF basements to keep soil gas out has never really been checked.

Canada Mortgage and Housing Corporation has been following developments in these issues with considerable interest. This study was intended to address these concerns through a variety of field testing.

The first step was to develop a protocol to determine the air leakage characteristics of preserved wood foundations. The methodology made use of the natural barrier to air flow provided by the floor assembly between the basement and the first floor. Fans were installed on the ground floor and in the basement. Both areas were depresurrized relative to the outside conditions, and then fan settings were fined tuned so that air pressures were identical in both areas. In this way the air leakage characteristics of PWF basements could be determined. Testing was carried out on thirteen PWF houses and one concrete basement. The error involved in the process was small and in the same order of magnitude as that for the standard house air leakage test. The majority of the air infiltration during testing occurred around windows and headers.

A crack leakage testing protocol was developed for determining crack leakage characteristics. The preserved wood foundations tested did not have significant air flows through below-grade areas when the basement was depressurized. The testing crew detected no flows in these areas. The methodology was used effectively to determine flow through cracks in above-grade components such as headers.

A tracer gas was used to get a better understanding of soil gas entry routes. Radon was chosen as it is naturally present in the ground and can be detected at relatively low levels. Air samples were taken in the basements, wall cavities, and below sleeper floors (where applicable). They were then analyzed for radon concentration. There were considerable variations in radon readings from samples taken in different wall cavities in the same house. High basement radon levels were found where levels were high below sleeper floors.

Samples of basement wall cavity air were taken and tested for a range of volatile organic compounds that could possibly have bben given off by chemical preservatives used on the preserved wood members. All concentrations measured were found to be within acceptable limits.

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INTRODUCTION

Although significant work has been undertaken in an effort to understand the air leakage characteristics of houses, the basement portion of structures has had the least attention. In many ways, the air leakage characteristics of basement structures may be one of the most important aspects of the entire envelope. Significant leakage in other portions of the envelope (although they may contribute to increased energy consumption and possibly accelerated deterioration of components of the envelope and the structure) do not have significant negative implications on the outdoor air quality in the house. Leakage in the foundation area can, in a number of areas of Canada, present a significant problem with the introduction to the dwelling of radon gas and numerous other gases present in the soil. Usually in winter, the foundation is below the neutral pressure plane, and the pressure across the foundation walls and floor will push soil gases into the indoor air.

Research and testing of the airtightness of basements is still in the preliminary stage. Where air leakage research work has been undertaken (both on entire building envelopes and, specifically, on basements), few examples of preserved wood foundations have been involved. The results of wide-scale, routine testing of houses, such as certification tests, undertaken for the enrollment of R-2000 houses, however, has not shown a particular problem with the air sealing of preserved wood foundations.

There is no particular reason why preserved wood foundations should present a particular problem in the area of air leakage, if properly constructed. There are, however, numerous construction details used in the construction of preserved wood foundations, some of which may not be conducive to the long-term integrity of the air barrier system.

A major advantage that preserved wood foundations can have over traditional concrete foundations is the inherent flexibility of the materials involved. If properly constructed, a preserved wood foundation should not suffer from the shrinkage crack problem associated with concrete foundations; hence, it should not require complex control joints. However, where floor structures of concrete are used with preserved wood foundations, the problems with maintaining the integrity of the air barrier may be increased due to the dramatically different characteristics of the materials involved. Some preserved wood foundation systems have relied on poorly installed membranes in the floor area that may not have reasonable service lives.

This report documents the airtightness testing and evaluation of preserved wood foundations (PWF). Prior to this study, no research on the air leakage characteristics of PWF basements is known to have been undertaken.

The primary objective of this project was to determine the airtightness of a sample of preserved wood foundations and to identify major leakage areas. Three seperate techniques were developed to examine and characterize the nature of this leakage.

The first technique involved performing airtightness tests on thirteen PWF full basements, and one PWF crawl space basement. This test was also undertaken on a concrete basement for comparison purposes. A test prtocol was developed that isolated basement air leakage from the air leakage of the rest of the house so that the basement air change rates and equivalent air leakage rates could be determined. Areas of significant leakage were identified by using a smoke pencil and earmarked for further testing.

A second technique was developed to ascertain the air leakage at these individual locations.

The third technique involved the use of a naturally occurring "tracer gas". This "tracer gas", radon, was monitored in an attempt to determine the locations through which the majority of the soil gas was entering each house. Radon was chosen as a tracer gas as it is naturally present in the soil and it can be measured at relatively low concentrations.

A secondary objective of the project was to analyze the gases in the basement wall cavities to determine if there are pollutants present attributable to the wood preservation process. Towards this objective, samples of basement wall cavity air were analyzed for "off-gassing" from the wood preservatives.

2.0 BACKGROUND ON PRESERVED WOOD FOUNDATIONS

A variety of designs have been used in the construction of preserved wood foundations. These designs have evolved since the introduction of preserved wood foundations in Canada in the early 1960's. The houses, in the test program documented here, were of relatively recent design.

The primary source of data on the design of wood foundations is the Canadian Wood Council. Additional information is available from the Council of Forest Industries of British Columbia (COFI) and the Canadian Standards Association (CSA).

The CSA publication CAN3-S406, "Construction of Preserved Wood Foundations" is the basic reference standard cited by the National Building Code (NBC) for the construction of these types of foundations in small buildings. The design details presented in the standard are essentially identical to those presented in the CWC preserved wood publication.

Currently, there are three basic foundation configurations:

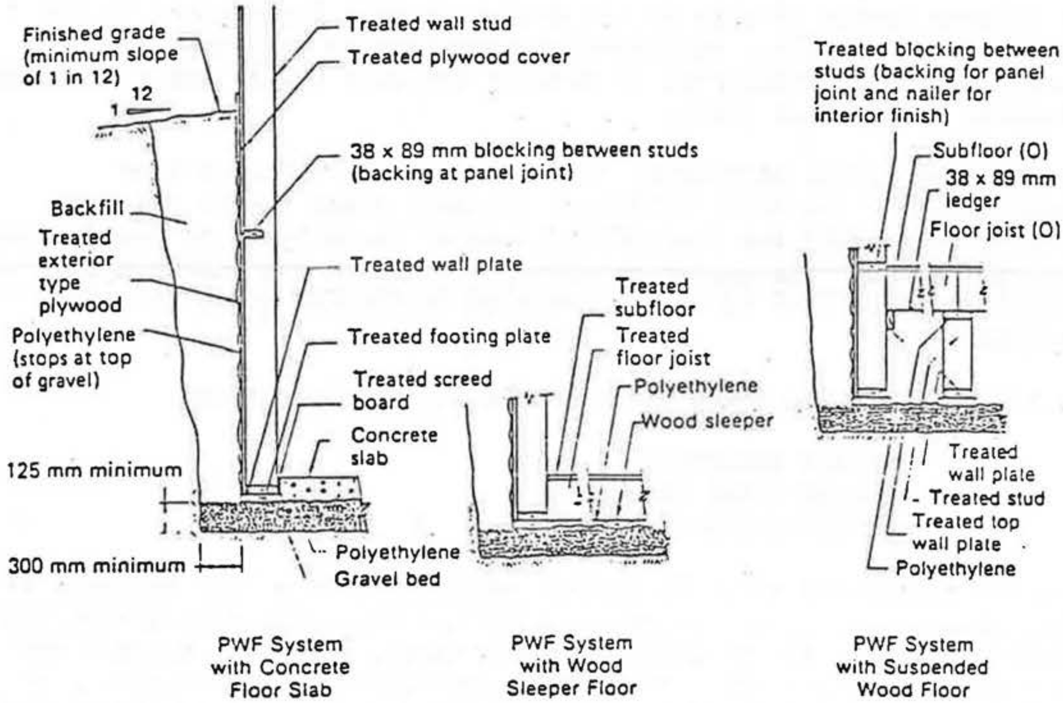
- heated basements
- heated crawl spaces
- unheated crawl spaces

When the foundation space is heated, whether it is a full basement or a crawl space, the foundation walls and floor form a portion of the heated volume envelope. For an unheated crawl space, the floor between the foundation space and the first floor forms part of the envelope. Air leakage characteristics of an unheated crawl space were of little interest directly to this study, although the presence of contamination either from the foundation materials or soil gases was of some interest.

The major difference between heated crawl spaces and full basements is the treatment of the floor assembly. Full basements have either a concrete or wood floor assembly. The wood floor assembly can be either a sleeper floor or a suspended floor. Heated crawlspaces have a suspended wood floor.

The basic details of these system types are shown in Figure 2.1. This information was reproduced directly from the CWC publication, "*Preserved Wood Foundations-CWC Datfile WB-4*".

Figure 2.1



The placement of the moisture barrier material will likely have some effect on the air leakage performance of the system. In all three cases, the below-floor moisture barrier is not generally connected to the exterior wall system, but rather is loose laid against the footing. The primary use for the polyethylene is to retard water vapour flow and reduce surface evaporation from the soil. For this reason often little, if any, care is taken to ensure that coverage is continuous. Overlaps are not sealed and service penetrations are rough.

At present, CSA Standard S406-M83 requires a 0.15 mm polyethylene sheet beneath a suspended wood floor or a concrete floor slab. A suggested improvement of S406, made in 1989, requires that all joints of the polyethylene sheet shall be lapped not less than 300 mm and the sheet shall be sealed to the foundation wall footing around its entire perimeter. It also states that all penetrations of the floor by pipes or other objects shall be sealed against water vapour and soil gas leakage. As the 1989 update has not yet come into effect, houses cannot be assumed to have continuous sealed foundation air/vapour barriers. In fact, it is safe to assume that the primary air barrier in these houses is the wood sheathing in the wall assembly and the concrete slab or wood floor sheathing in the floor assembly.

With heated crawl spaces and in some suspended floor, full basement designs, problems may be encountered with the integrity of the floor air barrier system. If the effective air barrier in the system consists of polyethylene sheeting laid directly on the soil and this sheeting is not properly ballasted with sand or other suitable material, a depressurization test of the basement or crawl space has the potential to seriously damage the air barrier. For this reason, the test houses chosen for this study did not involve these types of designs.

3.0 DEVELOPMENT OF TEST PROTOCOLS

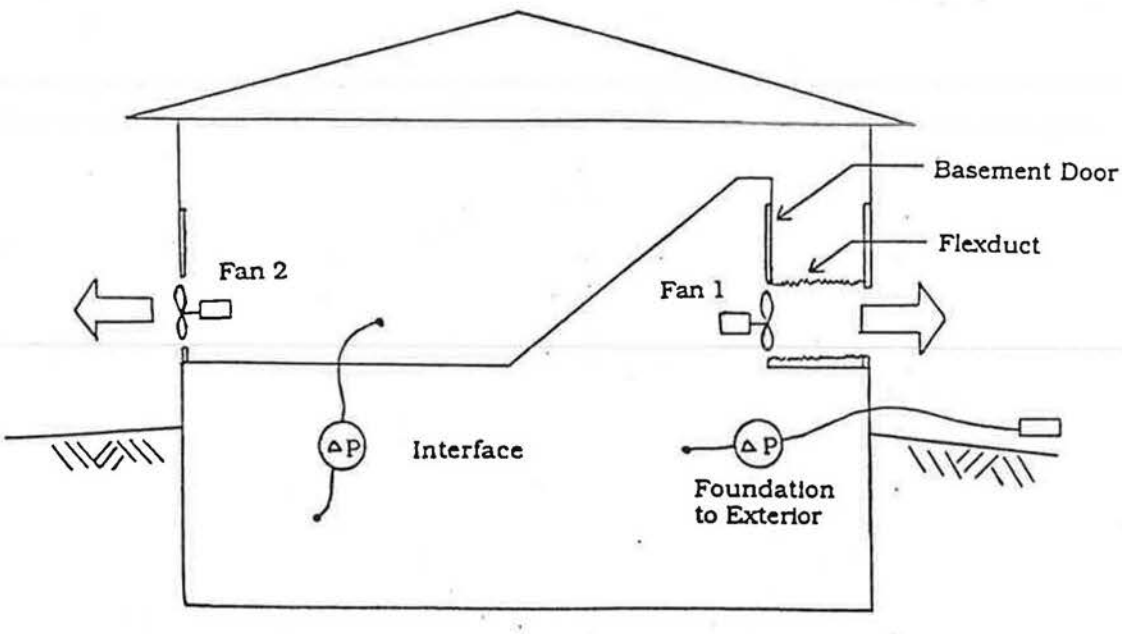
3.1 Airtightness Test Protocol

A protocol for determining the leakage of concrete basements is currently under development. Preliminary data is presently being collected for Canada Mortgage and Housing Corporation under seperate contracts. Two different methodologies are being used to gather this data. The first relies on the measurement of soil gas migration through basement assemblies. The second uses SF_6 as a tracer gas to determine natural air change rates.

Canada Mortgage and Housing Corporation wanted to pursue the development of an alternate method of determining basement air leakage rates concurrently with the previously mentioned studies. To this end, the airtightness test protocol used in the work described in this report was developed by Buchan, Lawton, Parent Ltd for this study. It performed better than initially expected. The only aspect of the test that required refinement during the test program was the method by which the pressure difference at the interface between the basement and the rest of the house was determined.

The general arrangement of the test set-up is illustrated in Figure 3.1.

Figure 3.1



Part of the purpose of the airtightness testing was to develop a protocol that was simple and repeatable. The methodology chosen makes use of the floor above the basement, balancing pressures across this interface to effectively isolate the basement from the rest of the house.

It was realized from the outset that an extremely sensitive device would be necessary to measure the relative pressures in the basement and the rest of the house. It became apparent during the first test that both a Magnahelic guage and an inclined manometer were far too insensitive to accurately measure the pressure difference. A very successful alternative involved using a smoke pencil at an opening in the interface. The smoke gave an obvious, visible indication of the air flow. When equal pressure was reached, the smoke hung in the air or gently wafted back and forth. The accuracy of "smoke flow indicator" was still dependent on the sealing of a majority of the interface leakage areas.

Determining the basement air leakage was accomplished by performing a five-point depressurization test between 10 and 50 pascals on the basement using Fan No. 1, while precisely balancing the pressure across the basement ceiling assembly using Fan No. 2.

The result of repeated testing in the same location gave readings that were very similar. The error involved was similar in magnitude to that of a standard house depressurization test.

Appendix A outlines the required test apparatus and testing protocol.

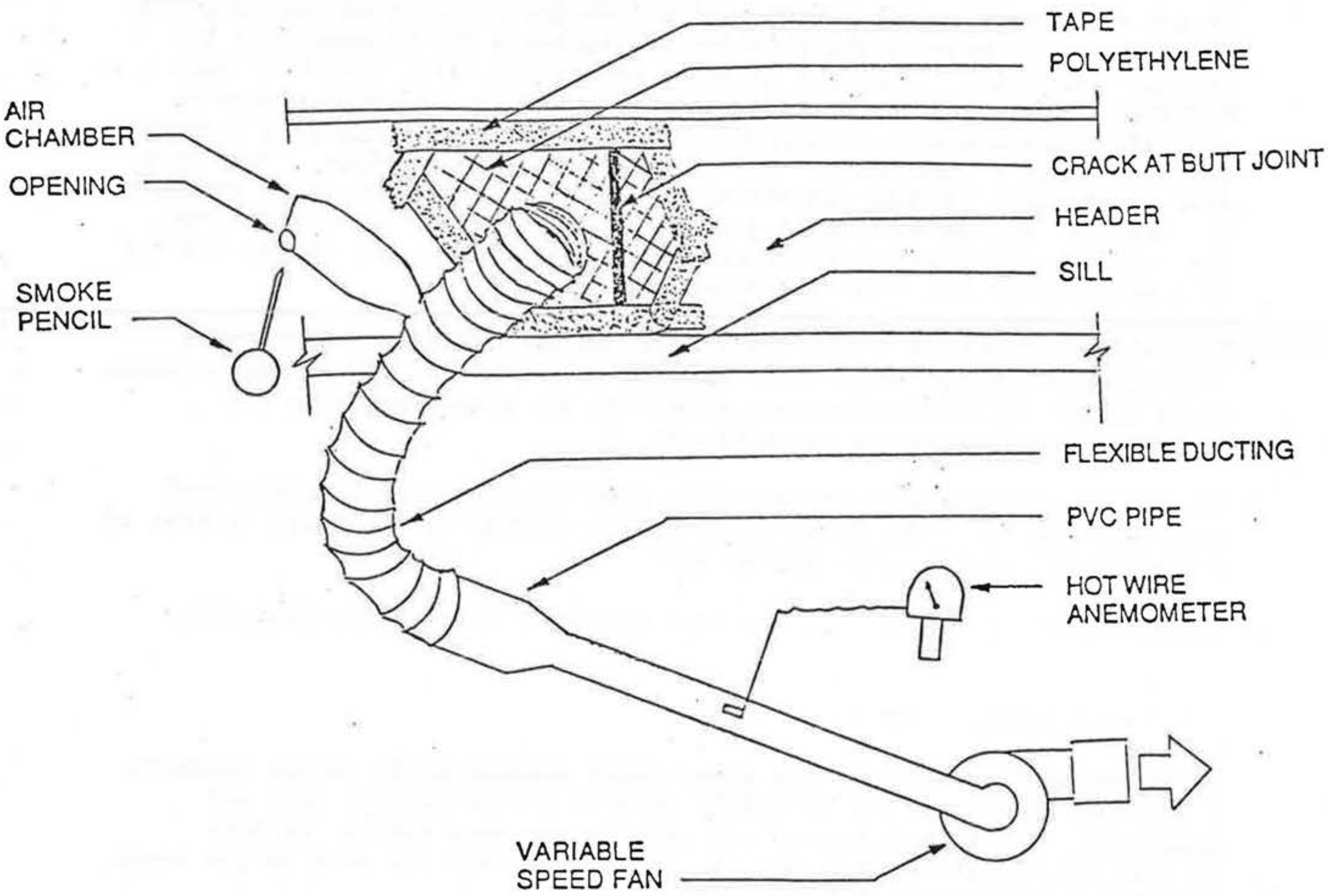
3.2 Crack Leakage Testing Protocol

In an attempt to quantify some major crack leakage areas in the basement, a modified version of the ASTM E783 in-situ window leakage test was developed. The methodology of the testing was very similar to that applied for isolating the basement air leakage from the rest of the house. Figure 3.2 illustrates the test set-up.

The house was depressurized by 50 Pa. The pressure inside the crack chamber was made equal to that of the house by varying the speed of the fan that was drawing air from the chamber. A fairly rigid plastic bag was attached to the chamber to create an area that would have a very low flow pressure due to flow through the crack to the fan. A small hole was cut in the bag so that air could flow between the chamber and the basement. A smoke pencil was used to determine when the two pressures were balanced.

A hot wire anemometer located in the air flow path gave a reading in m/s. The volume of air in L/s was then calculated based on the cross-sectional area pipe at the anemometer. It was found that the smoke pencil pressure balancing was sebsitive enough to be accurate to 0.1 L/s.

Figure 3.2



This test methodology made it possible to have a great deal of sensitivity in monitoring the relative pressures and adjusting the flow from the crack chamber.

The low flow through the cracks that were tested led to anemometer readings that were very low, and therefore had a relatively high degree of error.

Attempts were made to quantify the crack leakage flow from individual cracks at 50 Pa. and to carry out 5 point depressurization testing to determine crack characteristics. The results of the 5 point depressurization testing were not very satisfactory because of the sensitivity of the flow measuring equipment at the very low flow values encountered.

Appendix B outlines the required test apparatus and testing protocol.

3.3 Radon Sampling Protocol

Radon, being one of the main soil gas contaminants, enters basements through cracks and holes in the foundation envelope.

Radon was chosen as the "tracer gas" for the air change testing because it is naturally present in the soil and can be measured at relatively loe levels.

It was anticipated that elevated levels of radon at certain locations would indicate the entry path of radon, and other constituents of the soil gas, into the home.

Air sampling for radon was taken from three locations:

1. the basement;
2. the cavity between the interior and the exterior foundation walls; and
3. below sleeper floors (where applicable).

The initial sampling for radon in wall cavities and sleeper floors used a method of continuous sampling developed specifically for this project. The detector used (R.A.D. M-1 sample pump) measured radon daughters. Unfortunately the system did not perform as expected. All wall cavity readings taken were below the detection limit of the instrumentation, a result that was confirmed as being incorrect through later testing. It is hypothesized that the radon daughters plated out in the wall insulation, tubing and suction pump. Therefore they would not have been carried to the detector.

The details of this initial methodology are included in Appendix C for information purposes only.

The R.A.D. M-1 sample pump was used to test the basement air as well. These results are not under suspicion and thus are included in the results section. The basement radon pump was set in a central location on a solid, level surface. All radon pumps were allowed to sample for a period of four to eight days.

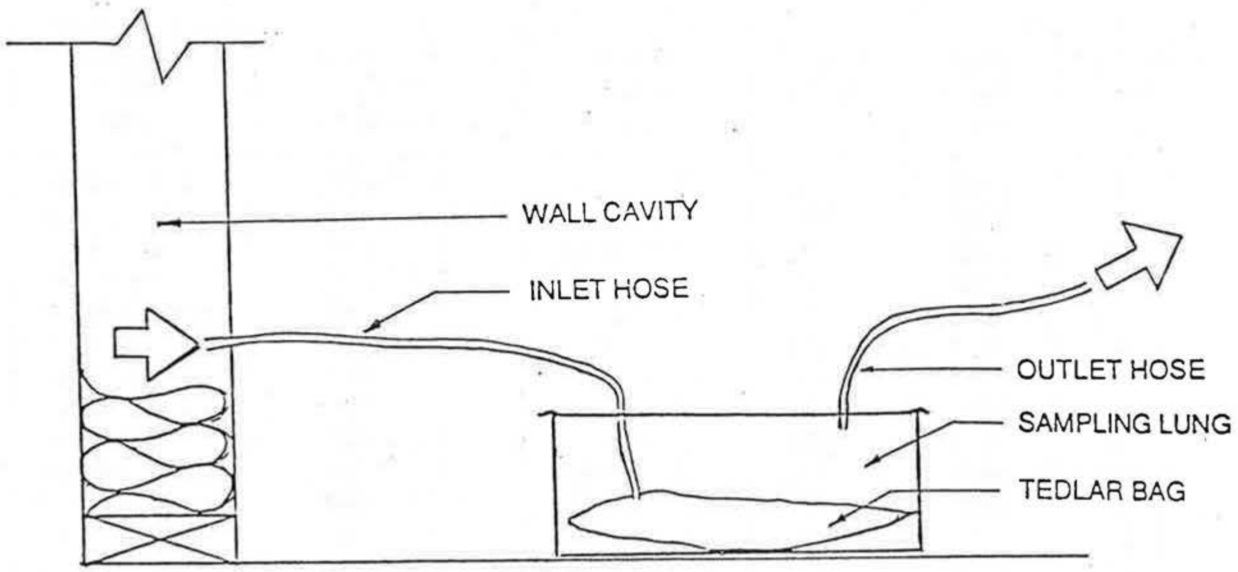
The second radon sampling technique employed the use of a TN-RN 2000 scintillation cell which records the number of decays of radon daughters from radon gas. A filter on the inlet side prevented radon daughters from entering the cell. This allowed only radon gas to enter.

The methodology involved drilling a 10 mm dia. hole into the wall cavity or sleeper floor. A hand pump was used to create a suction that drew the air from the cavity into the sample cell. The cell was set aside for a minimum of three hours to allow the radon decay process to stabilize. At this point the cell was attached to the counter and allowed to run for approximately one hour. The formula provided with the instrument converted the counts to pCi/L.

3.4 Volotile Organic Compounds Sampling Protocol

A three litre sample of air from the wall cavity was tested for volotile organic compounds (VOC's). The sample was taken from the same location as the radon sample using a sampling lung. See Figure 3.3

Figure 3.3



The sampling lung uses a vacuum effect to draw air into a Tedlar bag. The vacuum in the sampling lung was provided by human suction on the outlet hose. It was hoped that an aquarium type pump could be used to inflate the bag, unfortunately preliminary testing showed that the pump suction was inadequate to fully inflate the bag. The inherent rigidity of the Tedlar bags proved to be too much resistance for an aquarium-type pump. The human suction approach performed adequately and yielded an average sampling time of approximately one minute. Once the sample had been drawn into the bag, the valve on the bag was closed and the sample sent to the lab.

A complete list of chemicals related to wood preservatives was submitted to the chemists along with the samples to be analyzed.

4.0 SELECTION OF TEST HOUSES

The thirteen full basement PWF homes tested were built between 1981 and 1991. Seven of the thirteen homes had concrete floors, and six had pressure treated plywood on sleepers. In addition to the PWF full basement houses, one PWF crawl space and one concrete basement were also tested. Table 4.1 summarizes the relevent data for the fifteen homes tested.

Table 4.1

House No.	Year House Built	House Volume (m^3)	House Type	Basement Wall Type	Basement Floor Type
1	1982	722	2 storey	full-PWF	concrete
2	1982	539	2 storey	full-PWF	wood sleeper
3	1982	782	2 storey	full-PWF	concrete
4	1989	295	1 storey	full-PWF	concrete
5	1981	737	2 storey	full-PWF	wood sleeper
6	1987	560	1 storey	full-PWF	concrete
7	1983	824	split level	full-PWF	concrete
8	1988	771	2 storey	full-PWF	concrete
9	1986	688	2 storey	full-PWF	concrete
10	1990	494	2 storey	full-PWF	wood sleeper
11	1990	643	split level	full-PWF	wood sleeper
12	1989	894	2 storey	full-PWF	wood sleeper
13	1989	833	1 storey	crawlspace-PWF	polyethylene
14	1991	1127	2 storey	full-PWF	wood sleeper
15	1972	408	2 storey	full-concrete	concrete

5.0 TESTING RESULTS

5.1 Airtightness Testing Results

The results of the air tightness tests for the thirteen houses with PWF foundations and one house with a concrete foundation are listed in Table 5.1.

Table 5.1

House No.	Equivalent Leakage Area (m^2)				Basement Over Combined as %	House ACH
	Basement	Upper	Combined	House		
1	0.012	0.118	0.130	0.127	9	4.85
2	0.012	0.060	0.072	0.073	17	3.60
3*	0.007	0.015	0.022	0.022	30	0.79
4*	0.012	0.005	0.017	0.015	70	1.15
5	0.033	0.084	0.117	0.116	28	3.98
6*	0.011	0.020	0.031	0.032	35	1.29
7*	0.011	0.018	0.029	0.026	38	0.82
8	0.048	0.041	0.089	0.094	54	3.07
9	0.022	0.095	0.117	0.115	19	4.78
10	0.046	0.056	0.102	0.091	45	4.68
11	0.048	0.110	0.158	0.154	30	5.83
12	0.029	0.076	0.105	0.100	28	2.98
13*	0.013	0.027	0.040	0.046	32	1.52
15	0.032	0.055	0.087	0.088	36	5.83

Notes: * Indicates house built to R2000 standards of air tightness.
House ACH is air changes per hour at 50 Pa of depressurization.
The ELA is calculated according to CGSB-149.10-M86.

The basement equivalent leakage area (ELA) and the upper ELA were summed to yield a combined ELA. This number, when compared to the entire house ELA, substantiated the validity of the test. The percentage difference ranged from 0 per cent to 13 per cent with the mean differnece being 5.2 per cent. The upper ELA was substantially lower for homes built to R2000 standards than for conventional homes. The basement ELA was also lowest for R2000 homes even though two conventional homes had similarly low ELAs.

Smoke pencil investigation revealed that the most significant areas of leakage in all cases were related to the header area, sump pits, and around windows. The homes with the higher basement leakage rates were distinguished from the tighter homes by significantly greater leakage in the above noted areas.

Based on the houses tested, the lower practical limit for the basement ELA is in the range of .01 m^2. Seven of the sample houses were in this range.

With the sample of basements tested, it was not possible to determine that one type of PWF is more prone to air leakage than another because the majority of leakage detected was related to factors not directly associated with the PWF system.

5.2 Crack Leakage Testing Results

During the initial on-site work, numerous attempts were made at crack leakage testing. The only places where detectable flows were found were at headers, around plumbing stacks, and around windows. No detectable flows were found on the PWF walls. For more comprehensive follow on testing, the PWF basement house and the concrete basement house that were chosen were known to be particularly leaky. The PWF area tested was in a coldroom where the plywood exterior wall was still exposed. The house with a concrete foundation selected was built in the late 1950's.

No measureable leaks could be found in the PWF basement walls (i.e. cracks between plywood sheets or at the base of the walls). Tests were carried out on cracks between the top plate and the sill plate, the basement floor & wall joint and a joint in the plywood sheathing. As a point of comparison, testing was also carried out around a vent. Sunlight could be seen in a couple of places along the crack. Table 5.2 gives the results of this testing.

Table 5.2

PWF Basement			
Test No.	Flow 50 Pa.(L/s)	Location	Length of Crack (mm)
1	1.5	-between top plate & first floor sill plate	300
2	1.2	-between top plate & first floor sill plate	200
3	0.4	-between top plate & first floor sill plate	100
4	0.0	-basement floor & wall joint	200
5	0.0	-joint in plywood sheathing	200
6	0.0	-joint between top plate & exterior plywood	200
7	2.5	-crack around vent	75 mm dia. pipe

The house with the concrete foundation was fan depressurization tested and the leakiest basement locations were identified by smoke pencil. The crack locations identified included: a butt joint between header boards; between the header and the sill plate; and between the sill plate and the concrete foundation. Table 5.3 gives the results of this testing.

Table 5.3

Concrete Basement			
Test No.	Flow at 50 Pa. (L/s)	Location	Length of Crack (mm)
1	1.4	-butt joint in header	200
2	1.6	-butt joint & between sill and header	200
3	1.3	-between sill plate & concrete	200
4	0.9	-butt joint in header	150
5	0.0	-between header and floor above	200

Depressurization tests using five pressure-flow readings were attempted at three locations. The value of these results is uncertain as the instrumentation used is not sensitive enough to accurately measure the very low flows. Any localized wind pressure on the outside of the building also had a large effect on the readings. Table 5.4 details the best results that were attained (concrete basement - Test #3).

Table 5.4

House Pressure (Pa)	Flow (L/s)
58	1.4
49	1.3
43	1.3
39	1.3
29	1.0
21	0.9

The calculated ELA was 266 mm^2 which is close to the estimated 1 mm x 200 mm crack size.

The accuracy of the instrumentation comes into question when three house pressure readings in a 10 pascal range yield the same flow reading.

5.3 Radon Sampling Results

The results of the radon testing are given in Table 5.5. The detection limit is 0.2 pCi/L. The table gives two sets of basement radon readings. The first set are the result of the one week continuous radon sampling during April and May when the rest of the field work was done. The second set of basement readings, as well as the wall and floor cavity readings, were taken in October using grab sampling.

Table 5.5

House No.	Radon (pCi/L)				
	Basement		Wall Cavities	Other Wall Cavities Sampled	Floor Cavities
	Long Term	Grab			
1	0.6	3.1	5.7	/	/
2	2.4	1.5	4.7	/	1.5
3	0.2	0.5	0.5	/	/
4	2.0	/	/	/	/
5	/	8.0	28.6	/	/
6	0.4	/	/	/	/
7	0.4	0.6	0.8	/	/
8	1.2	2.0	1.1	0.8,7.1,15.2,3.5	/
9	2.8	6.6	1.9	/	/
10	1.4	8.0	3.6	/	59
11	0.2	1.7	2.1	/	3
12	6.2	9.5	8.8	8.4	440
14	0.4	1.2	0.8	/	/

Note: (/) indicates radon test not performed

It is believed that the second set of basement readings are generally higher because the houses had lower air change rates due to cooler October weather. Also, with the use of a grab sample, the basement readings are very dependent upon the ventilation of the basement prior to taking each sample.

Radon was monitored in the basement, wall cavity, and floor cavity in an attempt to determine the location through which the majority of the soil gas was entering the house. Wall and floor readings varied considerably from house to house and even within the same house.

There appears to be no direct correlation between basement grab results and wall cavity grab results. Some wall cavity results are higher than its corresponding basement result while some wall cavity results are lower. This lack of correlation is understandable when one looks at the five wall cavity results of house 8. The radon levels encountered varied from 0.8 pCi/L to 15.2 pCi/L. These results show that some cavities must be much better sealed from the exterior than others or the radon sources varied considerably around the house.

Where radon levels in cavities were found to be much lower than in the corresponding basement, it is likely due to one of the following three reasons.

1. The cavity was essentially airtight, negating the flow of air to or from either the soil or basement.

2. The cavity was sealed much more tightly on its outside face and from other cavities than on its interior side so that the radon level in the cavity was dependent on the air leakage rate from the basement into the cavity. In this case the reduction in ventilation due to colder weather would have increased the radon level in the basement. The radon level in the cavity may lag behind the radon level in the basement due to low air leakage rates to and from the cavity.

3. The majority of the air leakage in and out of the cavity occurs above grade to the exterior.

Of the five houses with pressure treated sleeper floors, four were tested for radon. It is interesting to note that two of the three highest house basement radon readings (Houses 10 and 12) corresponded to the two highest readings taken below the sleeper floors. The third highest basement radon reading (House 5) has a concrete basement floor; yet this house had the highest wall cavity reading.

The construction of the basement floor (House 2) was unusual. It had a poured concrete floor with polyethylene over top, then air space, sleepers, and regular grade plywood as the flooring. As well, the plywood was riddled with 50 mm diameter vents which essentially made the air below the sleeper part of the basement air. Therefore it is not surprising that the radon level in the basement and under the floor were the same. The radon level below the sleeper floor (House 12) was found to be approximately 440 pCi/L. This was the highest reading taken.

It should be noted that all basement radon readings were found to be well below the Canadian standard of 21 pCi/L.

5.4 Volatile Organic Compound Sampling Results

Twelve air samples were taken from the preserved wood cavities to be analyzed for volatile organic compounds (VOC's). Of the twelve samples, three could not be analyzed due to loss of the sample through shipping damage or defective bags. The fourth sample, House 2, was subjected to analysis by gas chromatography/flame ionization detector (GC/FID). The result of this analysis indicated no compounds were detected at a detection limit of 0.5 micrograms (μg)/sample. The remaining eight samples were analyzed by gas chromatography/mass spectrometry (GC/MS), which has a detection limit of 1.0 nanograms (ng)/sample. Table 5.6 gives a breakdown of the chemicals found for each wall cavity sample.

Table 5.6

V.O.C. Analysis Results
(μg/m³)

House No.	Benzene	Toluene	Ethyl Benzene	Xylene	Terpentines	Total Hydro-carbons	Total V.O.C.'s
3	9.0	88.0	24.8	102.5	553.0	769.5	1546.8
4	5.1	27.0	5.4	22.8	166.9	398.9	626.1
5	6.7	163.5	19.2	79.1	1026.1	620.9	1915.5
7	5.7	55.6	10.6	40.8	207.5	335.8	656.0
8	12.3	103.1	10.2	43.0	412.6	741.5	1322.7
10	4.4	31.9	19.4	87.6	269.6	427.0	839.9
11	5.4	43.7	6.4	33.2	688.8	578.7	1356.2
12	7.0	53.7	26.3	36.1	270.3	415.1	808.5

There are two guideleines with which to compare these results. The indoor air guideline for total VOC's researched by Molhave and used by PWC, suggests a maximum of 5 milligrams/m³. In the absence of guidelines for specific chemicals in the indoor air we reference the Ontario Ministry of the Environment (MOE) 24 hour ambient (outdoor) air quality criteria. These levels are set to protect the health of the general public, vegetation, materials and animals. It is generally expected in the industry that the indoor air should be as good as or better than the outdoor air.

Total volatile organic compounds ranged from 0.6 to 1.9 mg/m³. This compares to typical indoor levels in living areas in houses of 0.01 mg/m³ to 5 mg/m³ (Laboratory Analysis, Ortech International, see report Appendix D).

Specific compounds detected in the wall cavity samples included benzene, toluene, ethyl benzene, xylene, terpentines and hydrocarbons. Benzene levels ranged from 4 to 12 μg/m³. This compares to typical background levels in houses and ambient air of 10 μg/m³ or less (ORTECH). Toluene levels ranged from 27 to 164 μg/m³ which is less than the MOE ambient criteria of 2000 μg/m³. Ethyl benzine levels ranged from 5 to 26 μg/m³ which is less than the MOE ambient criteria of 4000 μg/m³. Xylene levels ranged from 23 to 103 μg/m³ which is less than the MOE ambient criteria of 2300 μg/m³. Terpentines ranged from 167 to 1026 μg/m³ and hydrocarbons from 335 to 769 μg/m³. The MOE criteria do not include levels for terpentines and hydrocarbons.

Every one of the components used in the assembly of the preserved wood foundation (plywood, caulking, insulation, polyethylene and preservatives) will off-gas to some degree. Identifying what percentage of the chemical came from which component is difficult and rather unnecessary considering the low concentrations encountered. The levels encountered in the cavity are considered safe according to guideleines. Any transfer of cavity air into the house willonly dilute the concentration of the chemicals further.

6.0 CONCLUSIONS

The airtightness testing was used to develop a protocol for determining the air leakage characteristics of basements. Very little error is involved when testing is performed according to the protocol.

This protocol can be used for a variety of applications where the air leakage characteristics of a part of the building are desired as well as the air leakage characteristics of the entire structure.

The airtightness testing carried out on 12 PWF full basements, one PWF crawlspace and one concrete basement cannot be used to reach any conclusions about the airtightness characteristics of various PWF design and construction practices since the majority of the air leakage occurred around windows and headers. The method could not be used to seperate air leakage in these locations from air leakage through basement walls and floors.

The PWF foundations were, in general, tightly constructed. Also, in general, the leakage that was detected was in specific locations not directly associated with PWF construction including headers, around windows and around service penetrations.

Some of the houses that underwent basement air leakage testing were constructed prior to the 1983 Standard which requires a 0.15 mm polyethylene sheet beneath a suspended wood floor or a concrete floor slab. The remaining homes were built between the time this standard came into effect and the proposed 1989 update will come into effect. There does not appear to be any correlation between basement airtightness and the year the house was built.

It is not likely that the proposed revisions to the standard will significantly reduce the air leakage in PWF foundations, as the tests showed very tight construction in the areas addressed by the standard update.

As with conventional concrete foundation construction, more work is required to address air seaking of the header area, around windows and around service penetrations.

6.2 Crack Leakage Testing

Crack leakage testing can be used to find the leakage rate at a specific pressure difference for fairly large cracks. During the course of this study, the crack leakage protocol was found not to be sensitive enough to measure air flow around the base of PWF floors or between sheets of plywood sheathing. This technique may be better applied to older buildings with fairly significant crack leakage areas in close proximity to each other.

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6.3 Radon sampling

The radon sampling results show that there can be considerable variation in wall cavity radon reading within any house. This could be caused by variations in soil radon levels, and differences in the effectiveness of the air barriers on the exterior and interior side of each cavity.

High basement radon readings were found in homes with high radon readings below sleeper floors. In these houses it is likely that the soil gas is coming into the basement from below the sleeper floors, although there is not enough evidence to categorically draw this conclusion. The relevance of these results to other homes built in the same timeframe is unknown as too few houses were tested.

6.4 Volatile Organic Compound Sampling

The VOC sampling results indicate there is minor off-gassing in the wall cavities. Chemical levels encountered in the wall cavity were within the strict regulatory guidelines for ambient air. Infiltration of the cavity air into the basement will further dilute the concentration of the VOC's to insignificant levels.