RESEARCH REPORT

Air Leakage Performance of 11 Log Houses in Eastern Ontario & Western Quebec

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AIR LEAKAGE PERFORMANCE OF 11 LOG HOUSES IN EASTERN ONTARIO & WESTERN QUEBEC

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Air Leakage Performance of 11 Log Houses in Eastern Ontario & Western Quebec

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EXECUTIVE SUMMARY

This report contains the results of air tightness testing of 11 log homes of various construction details, sizes and ages in the region of Eastern Ontario & Western Quebec.

Two other air tightness studies one from Idaho 1993 and the other Minnesota 1990 agreed that it was possible to air seal a log home to a minimum standard, that the quality of the assembly appeared to play a role, air infiltration was a bigger problem than air leakage, lateral joints were not always the major air leakage areas but rather, corner, window/door assemblies and log to framing connections.

Although the small sample prevents drawing scientific conclusions, the report indicated the following:

Sealing (chinking) the exposed face of the log joints increased air tightness about an order of magnitude compared to a double line of caulking between logs. The same was generally true for air sealing joints at window and door openings. It should be noted that the test method may have had some influence on this finding as it was not possible to place the test box tight against the internal air seals.

The air tightness of round V-scribe and hand hewn log construction was tighter than expected indicating that craftsmanship is a factor in developing air tightness.

Tightening down gasketed walls with through bolts can maintain air tightness as shrinkage occurs.

Various techniques for accommodating settlement appear to be working well.

RÉSUMÉ

Ce rapport présente les résultats d'essais d'étanchéité à l'air concernant 11 maisons en pièce sur pièce de construction, de taille et d'âge différents situées dans l'Est ontarien et l'Ouest québécois.

Deux autres études d'étanchéité à l'air (Idaho 1993 et Minnesota 1990) concluaient que l'étanchéité à l'air des maisons en pièce sur pièce pouvait être conforme à des normes minimales, que la qualité de l'assemblage semblait avoir un rôle à jouer, que l'infiltration d'air constituait un problème plus important que l'exfiltration d'air, que les joints latéraux n'étaient pas toujours à l'origine des principales fuites d'air, mais qu'il fallait plutôt regarder du côté des angles, des assemblages des portes et fenêtres et des jonctions entre les pièces de bois et l'ossature.

Comme l'échantillon était petit, il est difficile de tirer des conclusions scientifiques, mais le rapport laisse néanmoins entrevoir ceci :

Le scellement (colmatage) de la face exposée des joints des pièces augmente l'étanchéité à l'air par environ un ordre de grandeur comparativement à une double épaisseur de mastic de calfeutrage entre les pièces. La même observation vaut généralement pour les joints d'étanchéité à l'air réalisés autour des portes et fenêtres. Il faut noter que la méthode d'essai a peut-être influé sur ces résultats puisqu'il n'a pas été possible d'assurer l'étanchéité du caisson d'essai lorsqu'il a été placé contre les joints internes.

L'étanchéité à l'air de la charpente de pièces rondes trusquinées en V et dressées à la main s'est avérée meilleure que prévu, un signe que la qualité d'exécution revêt une certaine importance pour l'obtention d'une bonne étanchéité à l'air.

En resserrant les joints d'étanchéité des murs au moyen de boulons traversants, il est possible de maintenir l'étanchéité à l'air en dépit du retrait du bois.

Les diverses techniques permettant de composer avec les effets du tassement semblent être efficaces.

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1. Introduction

It became apparent that, during the course of developing air sealing details for log homes, there was insufficient data on the actual air leakage performance of these types of buildings. The work described in this report is intended to some extent to fill this information gap and to provide a degree of confirmation that the air leakage details for log buildings make sense.

The work involved carrying out air leakage tests of eleven log homes in eastern Ontario and western Québec. Five of the homes were further investigated using more detailed tests to determine the leakage characteristics of specific log wall components. The air testing was carried out by Bill Boles of Boles Construction and staff from Buchan, Lawton Parent Ltd. The detailed tests were carried out by Buchan, Lawton, Parent Ltd. Considerable effort was made to ensure the houses were all prepared in the same way for testing and to use the same procedure for the testing in order to permit the comparison of the test results.

2. Literature Search

A literature search was conducted to identify air leakage evaluation work that had been undertaken. Contacts included a review of an extensive literature search done by the Canadian Housing Information Centre; review of documents at CHIC for further references to other sources; a search of the library materials of the Canadian Log Builders Association, International; a search using the Internet for log building information; a review of publications by the National Association of Home Builders; and an on-line search of periodicals and publication using a commercial search company (EasySearch).

Very little information appeared to exist. The reports that were reviewed were interesting, but inconclusive. The studies generally agreed that it was possible to air seal a log home to a minimum standard, that the quality of the assembly appeared to play a role, air infiltration was a bigger problem than air leakage, lateral joints were not always air leakage areas, and corner, window and door assemblies, and locations where log construction joined to the framing system were often the major air leakage and infiltration sites.

Two specific reports contained significant information on air leakage:

Klossner, Stephen R., *Energy Related Performance Testing of Minnesota Log Homes,* Minnesota Department of Public Service, June, 1990.

> This report surveyed the exterior envelope characteristics of 25 Minnesota log homes. Homes were blower door tested and surveyed by infrared thermography to determine areas of major heat loss.

Roos, Carolyn et al., *The Thermal Performance and Air Leakage Characteristics of Six Log Homes in Idaho,* U.S. Department of Energy, August, 1993.

> This study included monitoring of energy consumption, blower door tests, site audits, heat flux through log walls, indoor and outdoor temperatures, solar flux and envelope tightness and modelling of the thermal performance using SUNCODE-PC, a thermal simulation program.

Limited information was also discovered in:

Canadian Log Builders Association, *1995 Log Building Standards for Residential, Handcrafted, Interlocking, Scribe-fit Construction*

Chambers, Robert W., *Radomske Explains, "Shrink-Fit Grooves" at AGM*, Log Building News. 8.

Chambers, Robert W., *Energy and Log Homes*, Log Building News 4, August, 1990

Friedman, Ray, *The Emseal Choice,* Log Building News 9, 1992, pg. 7

Gorman, Thomas M., *The Thermal Performance of Log Home Walls,* Ph.D, University of Idaho, October, 1995.

Radomske, Del, *Overscribing the Lateral Groove to Create a Compression-Fit Notch,* Log Building News 11, 1993.

3. Field Air Leakage Testing

Field air leakage tests of eleven log homes were carried out in eastern Ontario and western Québec. These tests were carried out on log homes where it was expected that reasonable effort had been undertaken to eliminate air leakage.

Testing followed the standard CGSB air leakage testing protocol. Following each air test, a thorough qualitative assessment of the air leakage paths in each building was carried out using smoke pencils.

The work involved in the field testing of log houses went far beyond a "standard" R-2000 air tightness test. Takeoffs, volume calculations and a HOT2000 run were prepared for each house, as well as, conducting a blower door test. While the house was depressurized, the field personnel investigated and documented where the sealing details were and were not effective.

Table 3.1 provides a précis of the results of the field testing for each of the eleven houses.

Table 3.1 Building Summaries

House No: 1 Whitney, Ontario

House Description

- 1 storey with loft
- 65 m^2 (700_sq.ft.)
- 340 m^3
- 3 years old

Type of Wall Construction

- *main floor:* round v-scribe logs
- *second floor kneewall:* framed 2.5' 2x6 insulated, a/v_barrier
- *ceiling:* cathedral dimensional wood

Foundation

- block, R12 glass fibre, 6_mil poly, no finish
- poured concrete floor

Wall Seal

round v-scribe logs insulated with glass fibre

Joint, Corner, & End Seals

v-scribe insulated with glass fibre

Door & Window Frame Seal

sealant, compressed foam, vapour & air barriers

Gable & Eave Seal Details

conventional frame construction

Air Leakage at 50 Pa / NLA

3.7 ACH

3.5 ACH after sealing

1.5 cm^2/m^2

Air Leakage Comments & Observations

- *basement:* leakage at bottom of wall, around windows, basement door (door seal ineffective), receptacles, between joists (header area)
- *main floor:* significant leakage adjacent to corners (sealing inside corners only appeared to move leakage over a few inches); minor leakage at lateral log joints; leakage at windows and doors, log floor joists & beams
- *loft:* leakage where frame kneewall rests on top log, windows and receptacles

House No: 2 Wilno, Ontario

House Description

- bungalow
- 71 m^2 (768 sq.ft.)
- 330 m^3
- 2 years old

Type of Wall Construction

- *main floor:* hewn dovetail logs with few lateral joints +/- 7 logs per wall
- *ceiling:* gypsum board, 6 mil poly

Foundation

- block
- no insulation and no interior finish
- poured concrete floor

Wall Seal

hewn logs with insulation, bead board and elastomeric chinking

Joint, Corner, & End Seals

dovetail with double bead sealant

Door & Window Frame Seal

sealant, compressed foam, vapour & air barriers

Gable & Eave Seal Details

conventional wood frame construction

Air Leakage at 50 Pa / NLA

2.1 ACH

1.0 cm^2/m^2

Air Leakage Comments & Observations

- *basement:* significant leakage at windows; slight leakage at other penetrations (unfinished basement)
- *main floor:* leakage at corners and windows; lateral permachink joints were air tight, connection of permachink air barrier across corners required

House No: 3 Renfrew County, Ontario

House Description

- 1 storey
- summer use only
- 70 m^2 (750 sq.ft.)
- 210 m^3
- 10 years old

Type of Wall Construction

- *main floor:* round v-scribe logs
- *ceiling:* cathedral beamed

Foundation

- slab-on-grade with one course concrete block

Wall Seal

round v-scribe logs insulated with glass fibre
lateral joints appear relatively tight on interior

Joint, Corner, & End Seals

v-scribe insulated with glass fibre

Door & Window Frame Seal

windowshorizontal sliders, no weatherstrip on main wood door

Gable & Eave Seal Details

conventional wood frame with ridge pole

Air Leakage at 50 Pa / NLA

6.6 ACH
1.9 cm^2/m^2

Air Leakage Comments & Observations

- summer cottageunheated in winter, poor quality windows and doorslittle concern for air leakage
- small logs therefore more lateral joints
- *main floor:* significant leakage at corners; leakage at lateral joints, windows and log wall/frame gable intersection

House No: 4 Killaloe, Ontario

House Description

- bungalow
- 86 m^2 (930 sq.ft.)
- 500 m^3
- 8 corners to accommodate log lengths
- 2 years old

Type of Wall Construction

- *main floor:* round v-scribe cedar logs
- *ceiling:* 3/5 flat, 2/5 cathedral

Foundation

- block
- no insulation and no interior finish
- lower level drive-in access
- poured concrete floor
- 8.75' height

Wall Seal

round v-scribe logs insulated with glass fibre

Joint, Corner, & End Seals

v-scribe insulated with glass fibre

Door & Window Frame Seal

sealant and compressed insulation

Gable & Eave Seal Details

conventional wood frame construction

Air Leakage at 50 Pa / NLA

5.6 ACH

2.7 cm^2/m^2

Air Leakage Comments & Observations

- *basement:* leakage at woodstove, basement doors, windows, & top of block wall/sill plate interface (unfinished basement)
- *main floor:* leakage at corners (particularly at dining room jog), windows and doors, top log/gable end frame wall intersection, lateral joints, chimney, partition/exterior wall intersection and ceiling plumbing and electrical penetrations

House No: 5 Golden Lake, Ontario

House Description

- 2 storey
- 223 m^2 (2400 sq.ft.)
- 850 m^3
- 4 years old

Type of Wall Construction

- *main floor:* hewn dovetail logs
- *second floor:* 2x6 frame, insulated, poly air/ vapour barrier, gypsum board interior and plywood exterior
- second floor surrounded by cantilevered balcony on beams

Foundation

- block, 2x2 frame, 1.5" EPS, 6 mil poly, (utility room not completed)
- faced with stone above grade
- basement walkout on SE side

Wall Seal

hewn logs with insulation, bead board and elastomeric chinking

Joint, Corner, & End Seals

dovetail with double bead sealant

Door & Window Frame Seal

exterior faced with elastomeric chinkingno valence

Gable & Eave Seal Details

conventional wood frame construction

Air Leakage at 50 Pa / NLA

4.3 ACH

2.2 cm^2/m^2

Air Leakage Comments & Observations

- *basement:* leakage at windows
- *main floor:* significant leakage at corners, and filler log between floor joists; leakage at windows (through units not at installation)
- *second floor:* leakage at window installation; major leakage at chimney (gap around chimney); leakage at electrical penetrations through frame construction
- little eave ventilation but two roof-top turbine ventssuspect turbines draw house air through large ceiling penetrations
- significant portion of air leakage in house seems to be from frame construction details & window units, leakage at log wall corners and log floor joists only part of problem

House No: 6 Franktown, Ontario

House Description

- 2 storey
- 160 m^2 (1720 sq. ft.)
- 610 m^3
- approximately 5 years old

Type of Wall Construction

- *main floor:* round v-scribe logs
- *second floor kneewall:* framed 2' 2x6 insulated, a/v barrier
- *ceiling:* gypsum board, 6 mil poly

Foundation

- poured concrete walls
- crushed gravel floor
- insulated header space
- some walls glass fibre insulated with poly covering

Wall Seal

round v-scribe logs insulated with glass fibre

Joint, Corner, & End Seals

v-scribe insulated with glass fibre

Door & Window Frame Seal

sealant with compressed insulation

Gable & Eave Seal Details

conventional wood frame construction

Air Leakage at 50 Pa / NLA

1.9 ACH

1.2 cm^2/m^2

Air Leakage Comments & Observations

- *basement:* significant leakage in header and where no air barrier has been installed, through gravel floor, and at basement doors and windows
- *main floor:* significant leakage at each corner, around beam end extending through walls, and around windows; minor leakage through log joints; no leakage detected through cracks within logs
- *second floor:* (framed construction) significant leakage noted around chimney through ceiling; leakage under baseboards, attic hatch, electrical outlets
- moisture problems noted in skylight and wood blackened at corners of log walls

House No: 7 Wakefield, Québec

House Description

- 1.5 storey
- 156 m^2 (1680 sq. ft.)
- 580 m^3
- 1 year old

Type of Wall Construction

- *main floor:* hewn dovetail logs
- *second floor:* 1 m hewn dovetail
  remaining framed wall
- *ceiling:* gypsum board, 6 mil poly

Foundation

- poured concrete
- no insulation on walls
- insulated header space (no poly)
- windows and mechanical penetrations foamed
- floor drains not trapped (covered with tape)

Wall Seal

hewn logs with insulation, extruded polystyrene and elastomeric chinking

Joint, Corner, & End Seals

dovetail with double bead sealant

Door & Window Frame Seal

sealant and glass fibre insulation

Gable & Eave Seal Details

conventional wood frame construction

Air Leakage at 50 Pa / NLA

1.9 ACH

1.1 cm^2/m^2

Air Leakage Comments & Observations

- *basement:* significant leakage at sill plate and gasket at top of concrete foundation wall, around beam pockets, and at window lintel joints; leakage where metal chimney connects to concrete block stack (mastic dried and cracked)
- *main floor:* significant leakage at joints between log and chinking material, framed walls butting up to log walls, around all window and door frames (glass fibre insulation) and at corners
- *second floor:* leakage at log to framed wall connection
- condensation and mould in basement

House No: 8 Pakenham, Ontario

House Description

- 1.5 storeyhalf one storey with cathedral ceiling and half two storey
- 200 m^2 (2150 sq. ft.)
- 820 m^3
- Confederation log home

Type of Wall Construction

- *main floor:* milled dovetail logs
- *second floor:* 2x6 framed walls insulated & covered with 2x12 boards on outside face
- *ceiling:* half cathedral with dimensioned lumber finish

Foundation

- poured concrete with one course of block on top (header inset)
- no air/vapour barrier installed in header space
- no air sealing between window frames and block work

Wall Seal

milled logs with two lines of sealant on protruding tongues and line of gasket in depression between tongues

walls installed on threaded rod

Joint, Corner, & End Seals

dovetail with triple gaskets

Door & Window Frame Seal

glass fibre insulation, frame securely attached to 2x6 which slides freely on a dowel

Gable & Eave Seal Details

conventional wood frame construction

Air Leakage at 50 Pa / NLA

2.2 ACH

1.2 cm^2/m^2

Air Leakage Comments & Observations

- *basement:* leakage at headers and beam pockets, leakage at windows
- *main floor :* significant leakage at window frame to log connection, and at access to through bolt adjustment nut at butt end joints

- In cases where the logs fit squarely and compressed the foam gasket and butyl tape, there was virtually no leakage. In cases where the logs did not compress the sealing materials, there was significant leakage.

House No: 9 Spencerville, Ontario

House Description

- 1.5 storeyhalf one storey with cathedral ceiling and half two storey
- 150 m^2 (1600 sq. ft.)
- 770 m^3
- 5 years old

Type of Wall Construction

- *main floor:* milled round log flat on top and bottom
- *second floor:* framed wall insulated, poly, gypsum board interior and dimensioned wood exterior
- *ceiling:* half cathedral with dimensioned lumber finish

Foundation

- concrete block
- no insulation
- insulated header space (no poly)
- no gasket installed at sill plate
- poured concrete floor

Wall Seal

butyl sealant placed between milled round logs with exterior and interior chinking
walls installed on threaded rod

Joint, Corner, & End Seals

butyl gaskets

Door & Window Frame Seal

insulation and gasketing
trim on windows and doors attached with two nails for easy removal to permit periodic resealing

Gable & Eave Seal Details

conventional wood frame construction

Air Leakage at 50 Pa / NLA

1.8 ACH
0.9 cm^2/m^2

Air Leakage Comments & Observations

- *basement:* significant leakage at sill plate, where no gasket has been installed, and at header spaces

- *main floor:* significant leakage where interior walls butted into exterior walls; leakage where sealant used to seal polyethylene ceiling air/vapour barrier to the outside log wall had dried and released; no leakage was detected between logs
- *second floor:* framed walls
- home resealed one year ago

House No: 10 Danford Lake, Québec

House Description

- 2 storey
- 110 m^2 (1200 sq. ft.)
- 390 m^3

Type of Wall Construction

- *main floor:* milled round log with double tongue on top and recess on bottom
- interior partition walls are log and extend through exterior walls
- *second floor:* combination of log as well as framed walls

Foundation

- concrete block
- no insulation
- no gasket between sill plate and foundation wall
- insulated header space (no poly)
- poured concrete floor

Wall Seal

butyl sealant applied to two upper tongues of milled round log

Joint, Corner, & End Seals

double line of butyl gaskets
caulking applied at corners and ceiling junctions (dried and cracked)

Door & Window Frame Seal

compressed insulation

Gable & Eave Seal Details

log walls on gable ends carried up to top of cathedral ceilingsealed using caulking
ridge poles and queen purlins extend through gable ends

Air Leakage at 50 Pa / NLA

10.4 ACH
4.9 cm^2/m^2

Air Leakage Comments & Observations

- *basement:* significant leakage at header area, leakage and water damage at fireplace foundation which partially extends through exterior wall, leakage at exterior door
- *main floor and second floor:* significant air leakage at stone fireplace, around windows and doors and at electrical outlets; leakage common at horizontal joints between logs
- It appears that, when the logs dried, the butyl caulking separated from the tongues and is no longer providing an air seal.

House No: 11 Perth, Ontario

House Description

- 2 storey with basement
- 150 m^2(1600 sq. ft.)
- 540 m^3
- 2 years old

Type of Wall Construction

- *main floor:* hewn dovetail
- *second floor:* lower portion of perimeter wall- is 0.5 m hewn dovetail upper portion -framed wall

Foundation

- concrete block
- header inset to foundation wall
- inside wall: framed, insulated but no vapour barrier

Wall Seal

milled logs with two lines of sealant on protruding tongues and line of gasket in depression between tongues

walls installed on threaded rod

Joint, Corner, & End Seals

dovetail with triple gaskets

Door & Window Frame Seal

glass fibre insulation, frame securely attached to 2x6 which slides freely on a dowel

Gable & Eave Seal Details

conventional wood frame construction

Air Leakage at 50 Pa / NLA

2.7 ACH

1.7 cm^2/m^2

Air Leakage Comments & Observations

- *basement:* leakage at header (despite being wrapped with poly as per the log kit supplier's specs!)
- *main floor:* significant leakage at all corners (substantial gaps open to the exterior) leakage at butt joints, horizontal joints, and corner joints (house built during heavy rain much of butyl tape did not adhere)
- *second floor:* air leakage noted at log to framed wall connection significant leakage at attic hatch and chimney through ceiling

4. Blower Door Calibration

The blower door air leakage testing was carried out using two blower doors. The fan units for these doors were calibrated to ensure comparable results were obtained. Using the results from calibrated blower doors will also permit the direct comparison of the results of this work with the air leakage information used in the development of the energy code for other types of buildings.

The calibration of the blower door fans was performed by Buchan, Lawton, Parent Ltd in its in-house calibration facility.

The results of the calibration testing indicated that both fans were accurate to within 5 per cent across all flows and pressure differences. This is considered to be quite acceptable and well within the tolerances permitted for blower doors.

5. Comparative Study

At the completion of the air leakage testing, the test results were examined to identify whether there were trends, construction techniques of particular concern or techniques which appeared to work well. Because of the limited size of the sample and the desire to test the broad range of log wall construction types, it was difficult to draw any sweeping conclusions. However, some comments can be made:

1. It is possible to build log homes with acceptable air tightness characteristics. In the homes where particular attention was paid to the air sealing details, it was possible to achieve an air leakage rate that was less than 2_air changes per hour at 50_Pa pressure (ACH). The normalized leakage area (NLA) in more than half the houses was less than 2_cm^2/m^2 and one home had an NLA of less than 1_cm^2/m^2.

2. Good levels of air tightness were observed for each example of the three types of log walls (round, hewn and milled). The lowest air leakage rates for each type were:
   - round v-scribe: 1.9_ACH,
   - hewn with dovetail corners: 1.9_ACH, and
   - milled: 1.8_ACH.

3. When the log homes were depressurized, leakage through the log walls was identified using smoke penciling. In a number of the houses, significant leakage was observed at the following locations:
   - the corners;
   - the transitions between log walls and the other building components, such as gable ends and knee walls;
   - around doors and windows; and
   - other wall penetrations, such as floor joists and electrical receptacles.

   Generally, leakage at the lateral joint between the logs was minor or undetectable. As well, cracks in individual logs were rarely a source of air leakage.

4. In many instances where higher leakage rates were detected, the log wall portions of the homes did not perform poorly. Other aspects of the building construction appeared to contribute significantly to air leakage, including:
   - header spacesthe header spaces were either completely uninsulated or stuffed with glass fibre insulation but no vapour barrier;
   - at ceiling and roof penetrations; and
   - at basement wall penetrations.

5. Two seals or barriers to air movement, such as two strips of butyl or a double bead of sealant, appeared to be much more effective than one.

6. The home with the highest rate of air leakage to wall area and the leakiest wall section test results had not been adequately designed to accommodate settlement (the stone fireplace and some of the structure inhibitted settlement). The vertical components in the house that

act as pillars and prevent the even settlement of logs will cause increased air leakage between the logs, as well as other problems.

7. Although some of the homes had low air leakage rates, none of them had exhaust fans. This could contribute to high moisture levels and problems with mold, mildew and rotting over the life time of the building.

8. When compared with the results of the American data listed in the references cited in Section 2, the Canadian homes appeared to have a similar spread in the range of air tightness results (between 1.8 and 10.7 air changes per hour at 50 Pa pressure). The average for the Canadian homes was lower, 3.9 ACH compared with 5.3 ACH for the six American log homes tested in Idaho.

6. On-Site Component and Assembly Testing

In five of the houses, specific components and assemblies, such as windows, doors and corner details, were isolated and subjected to a standard ASTM air leakage test. The work was carried out following the completion of the air leakage testing and provided more detailed information for quantitatively assessing the air leakage characteristics of log wall assemblies.

Whole house depressurization testing was useful for finding areas of significant air leakage with a smoke pencil. The quantifiable results of the blower door air leakage tests provided an indication of the leakage characteristics of the entire log home. However, they did not provide a quantifiable measure of the leakage through the log components alone since all building envelope components have an effect on the results of the air testing.

Log home section air leakage testing was carried out at the five homes in order to get an understanding of the quantifiable air leakage through various log assemblies. Characterizing leakage through these assemblies was intended to help determine which details were working well for different types of log homes.

Testing was carried out in accordance with the test standard ASTM E 283 *Standard Test Methods for Rate of Air Leakage Through Exterior Windows, Curtain Walls, and Doors.* For each section tested, an enclosure was built on the interior face. This enclosure was sealed to the log components as well as was practically possible. A window test rig (sealed fan system with air flow measurement equipment) was used to depressurize the enclosure to a maximum of 75 Pascals. Between four and six pressure differences between the enclosure and the space around it were recorded along with the corresponding air flow. The mathematical relationship between pressure differential and the air leakage rate was then determined for each enclosure. The calculated value of the air flow rates are shown in Table 6.1. They are presented at a 75 Pascal pressure differential for comparison purposes.

In the case of windows, the tests were repeated with polyethylene sheeting placed over the exterior of the window and attached to the window frame. This sealed off the window and made it possible to net out the leakage through the window assembly in the test results. The window leakage value, therefore, would indicate the leakage through the rough opening and the log assemblies surrounding the window but not through the window itself.

Log wall components are unlike the typical components tested according to ASTM Standard E 283. In the standard, the base assumption is that the enclosure is sealed to the principle air barrier of the house and, by doing so, defines the specific area to be tested. In the case of log homes, there are usually multiple air barriers within the wall system (for example logs that are chinked on the inside and outside face). Therefore air leakage is likely to be more widespread than the area defined by the enclosure.

The following chart summarizes the results of the log section leakage testing at the five houses where testing was carried out.

Table 6.1 Log Component and Assembly Air Leakage Testing

Houses 6 to 10

Test Location	**Section** Height (m)	Width (m)	Area (m2)	**Maximum Test Pressure** (Pa)	**at 75 Pa Depressurization** Flow (L/s)	Flow per Unit Area $L/(s*m^2)$
House No. 6:	no sealant between round v-scribed logs					
Corner	1.1	1.0	1.1	N/A	2.3	2.1
Window	1.6	1.2	1.9	N/A	10.8	5.6
Window*	1.6	1.2	1.9	N/A	11.2	5.8
House No. 7:	polystyrene and chinking between hewn logs					
Wall	1.2	0.9	1.1	N/A	0.4	0.4
Corner	1.4	1.0	1.4	N/A	3.5	2.5
House No. 8:	double line of caulking and gasket between milled logs					
Wall #1	1.5	1.6	2.4	N/A	5.2	2.2
Wall #2	1.5	1.0	1.4	N/A	9.4	6.6
Wall #3	1.5	0.3	0.5	N/A	5.6	12.4
Corner	1.4	1.5	2.1	N/A	5.1	2.4
Window	1.5	1.6	2.4	45	12.5	5.2
Window*	1.5	1.6	2.4	N/A	15.6	6.5
House No. 9:	double line of caulking between milled logs and chinking on both sides					
Wall	1.5	1.5	2.3	N/A	0.7	0.3
Corner	1.3	1.0	1.3	N/A	0.6	0.5
Window	1.5	1.7	2.6	N/A	5.3	2.1
Window*	1.5	1.7	2.6	N/A	2.2	0.9
House No. 10:	double line of caulking between milled logs					
Wall #1	1.1	1.1	1.2	55	11.2	9.3
Wall #2	1.1	1.1	1.2	22	24.3	20.1
Window	1.6	1.5	2.4	35	19.3	8.0
Window*	1.6	1.5	2.4	34	17.5	7.3

Note: Window* indicates that the window unit itself had been netted out of the test.

The strategy employed during the testing was to test the air barrier closest to the interior of the building. In order to minimize extraneous leakage from within the house into the enclosure, the following preparations were carried out for each test:

- the enclosure was taped to the surface of the logs;
- cracks in the face of the logs were taped where they extended into the enclosure; and,
- cracks between logs around the perimeter of the enclosure were sealed with tape and play dough.

Because of a concern about the extent of the leakage coming into the enclosure via the space between logs, either from the interior or exterior face, a series of tests were carried out at House No. 8 to attempt to quantify this extraneous leakage. A large enclosure was prepared and tested. The width of the enclosure was then reduced to less than a third of its original width and retested. Although the size of the interior air barrier was greatly reduced, the same number of cracks between logs were maintained through the three tests. Comparing the results of these tests (Wall #2 and Wall #3 under House No. 8) made it possible to gain a greater understanding of the extent of the extraneous leakage during testing at this house.

The results presented in Table 6.1 must be discussed in the context of:

- the wall system used and the way it was installed and maintained;
- the air barrier component that the enclosure was intended to be sealed to; and,
- notes regarding how well it was possible to seal the enclosure.

7. Results of the Component Testing by House

House No. 6

This round v-scribed log home had no sealants on the inside or outside face between logs. Considerably more leakage was occurring at the corners than at wall sections during smoke pencil testing. Water staining marks in corners may also be attributable to greater air leakage in these locations. However, the saddle notch corner detail was found to be reasonably air tight during the corner assembly enclosure test.

Smoke pencil testing showed that there was substantial air leakage where the joints in the logs abutted the window frame. The compressed glass-fibre insulation in the notched sections was seen in the cross-section at the window openings. The caulking around the outside face of the window frame had dried and cracked, and was in need of replacement. Smoke pencil testing from outside the house showed that there was movement of air into the spaces between logs where they abutted the window.

One of the windows in the log home was tested for air leakage. A window testing enclosure was installed on the face of the logs surrounding the window. Play dough and air barrier tape were used to seal into the crannies between logs. The rate of air leakage at the window section was almost triple that of the corner section at this house. The second window area test, netting out leakage through the window unit itself, was not appreciably different from the one with the window unit included. This result indicated that the leakage through the casement window unit was not appreciable.

House No. 7

In this hewn log home, inner and outer wythes of extruded polystyrene were used to fill the space between the logs and provide a backer for the elastomeric chinking air barriers on each face. Mineral fibre batt insulation was used to fill the space between the wythes.

The enclosures were sealed to the face of the rectangular logs and elastomeric chinking with tape and play dough. Therefore, the air barrier tested consisted of the logs and the interior layer of chinking material.

The smoke pencil testing showed that some leakage was occurring wherever the elastomeric chinking adjoined the logs. However, the enclosure air leakage testing showed this leakage to be relatively small. No sealant had been used down the interior face of the dovetail log corner or at log joints on the exterior face. Leakage was found to be considerably greater in the corner section enclosure test.

House No. 8

The joints in the milled logs at this home were sealed by two rows of caulking on the tongues of the milled log and a gasket in the hollow between them. This recently built home had not had the through bolts tightened for more than six months.

The smoke pencil testing indicated more air leakage was occurring in areas with larger spaces between the logs. It was expected that tightening the through bolts to compress the foam gasket and butyl tape would have improved the test results for the wall sections in House No. 8.

The enclosures were sealed to the face of the rectangular milled logs and into the flat section of the space between logs with tape and play dough. No practical attempt could be made to seal any sloped section of the space between logs prior to the butyl tape. The tested air barrier consisted of the logs and the interior strips of butyl tape between them.

The results of wall test #2 and wall test #3 provided a measure of the rate of air leakage directly from the interior of the home into the enclosure. The third test was carried out in the same area as the second test with the same enclosure height, but with a width that was slightly less than a third of the second enclosure. The air flow rates show that the smaller section had more than half the amount of leakage than the larger section did. Therefore the leakage around the enclosure was considerable.

It is also interesting to note that the leakage was much greater at wall section #2 where the spaces between logs were larger than they were at wall section #1 or the corner section. (Wall section #3 was a dissimilar size from all other sections and therefore cannot be directly compared.)

Smoke pencil testing showed that there was considerable leakage at the joints in the logs where they butted up against windows. The relatively high air leakage rate from the window area enclosure confirmed that this was the case. The space between the window and the stud framing was shimmed and filled with glass-fibre batt insulation. The frame was secured to dowels on both sides and the dowels moved freely in the wall cavity.

The second window area test, netting out leakage through the window unit itself, was not appreciably different from the one with the window unit included. This indicates that the leakage through the casement window unit was not appreciable.

House No. 9

The logs used to build this home were cut on a lathe to make them dimensionally the same and cut flush on the top and bottom face for stacking. Butyl caulking was used between the logs and they were chinked on the inside and outside face with Permachink. The logs were secured in place using spikes, with a countersunk space above the nail to accommodate the nail rising when the logs dried. The house was built five years ago and rechinked one year ago.

Smoke pencil testing did not reveal any leakage between the lateral joints in the logs. The wall section and corner section enclosure leakage tests substantiated this observation. Leakage rates were at the low end for all the enclosure tests included in the study. When the house was depressurized to 50 Pascals pressure, the pressure inside both enclosures remained the same as the pressure inside the house. This would indicate that the leakage found during testing was almost entirely from inside the house, around the perimeter or the enclosures rather than through the sections themselves.

The window units were attached directly to an extended wooden frame. The space between the frames and the logs were chinked inside and outside. A space had been left below the window to allow for settlement. This space was also chinked.

At the window used for the enclosure test, smoke pencil testing showed that there was some leakage in the space between the frame and a log at the base of the window where chinking was missing. The vertical sliding windows themselves were noted to leak substantially.

The window and surrounding log section tested with the enclosure at this house was found to be far less leaky than similar sections at the other houses. Installing polyethylene sheeting to the window frame in order to net out the leakage through the window unit cut the leakage through the section to less than half the original amount. This was the only house with sliding windows and the only one where netting out leakage through the window unit made the test results appreciably different.

House No. 10

The air sealing between the milled logs in this home was done using butyl caulking applied to the two upper tongues of each log. The walls and windows of this approximately ten year old house had not been resealed in any way since it was built.

Smoke pencil testing showed that there was significant leakage occurring between the logs throughout the house. The result of the wall section air leakage testing at this house were far worse than at any other house where section testing took place.

The second wall section tested was located next to a stone fireplace that extended through the building envelope. The differential settlement of the logs, caused by the wall being supported at one end by the fireplace, had caused large cracks in this area. As a result, the fireplace had been removed and reinstated a few years ago. Leakage through the wall section next to the fireplace was found to be double that at a more representative wall location.

The space between the window frames and the logs had been filled with glass-fibre insulation. No air sealing methods had been used at the windows. The enclosure testing showed that the window and surrounding wall section area leakage was slightly higher at this house than at any other. The second window area test, netting out leakage through the window unit itself, was not appreciably different from the one with the window unit included. This result indicates that the leakage through the casement window unit was not appreciable.

8. Discussion of the Results of the Component Testing

The following comments are based upon the enclosure testing at this statistically small sample of homes, the review of the techniques utilized within them, and observations from the smoke pencil testing.

1. Sealing the space between the logs leads to reduced air leakage.

2. Overall, wall sections tested with face sealing techniques between logs were found to have lower air leakage rates than sections where sealing had been carried out within the wall only. The reasons for this appear to be:
   - The face sealing of the joints can be visually inspected after they are installed. Unlike sealants within wall cavities, quality control is not time dependent and they are not affected by the weather at the time of construction. They can also be corrected where necessary after construction is completed, and be resealed during and after settlement.
   - The enclosure method of testing sections may provide a better seal to a principle air barrier where there is an air barrier on the interior face. For instance, where the logs are sealed by two rows of caulking on the tongues and a gasket in the hollow between them, the enclosure method attempts to seal to the air barrier at the inner row of caulking. This may not be the principle air barrier.

3. Where gasket systems are installed, frequent tightening of through bolts will improve air sealing, particularly in the first few years when settlement is greatest.

4. Evaluating techniques for air sealing at windows, those that used an interior air seal were again found to have far less air leakage. Chinking on the interior face appeared to be the most effective way of air sealing. However, it must be recognized that resealing will be required over time as settlement occurs.

5. Various methods of allowing for settlement without causing stress on window units had been used. All appeared to work well.