SURVEY OF MOISTURE LEVELS IN ATTICS

APPENDIX A - Methodology Details

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APPENDIX C - Forest Products Laboratory Detailed Model Inputs

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Appendix A

METHODOLOGY DETAILS

APPENDIX A-1

AIRTIGHTNESS TEST

APPARATUS

Attic Blower

- Retrotec door fan

House Blower

- Minneapolis blower door

Instrumentation

- 3 four-wall pressure taps with one litre pressure averaging can and capillary tubes
- 2 General Eastern Electronic pressure transducers (0-0.25 inches H_2O output 01-5 V)
- Fluke digital volt meter and switch
- 2 Magnahelic pressure gauges for measuring fan flow pressures

Ductwork

- sheet metal square to round transition piece with flanges weather-stripped with closed cell foam
- 2 adjustable fiberglass extension poles
- 15 and 25 foot lengths of 20" diameter PVC flex duct
- various lengths of 20" diameter lay flat tubing constructed of polyethylene plastic sheet

PROCEDURE

Set-up

- Take instrument case into house and plug in electronic transducers. Place fan controllers beside instrument case.
- Seal intentional openings, close all windows, open interior doors, as per conventional fan test.
- Place four-wall pressure averaging kit in attic, tossing pressure taps towards the eaves and gable ends.
- Run two independent four wall taps outside building, as per conventional fan test.
- Connect attic pressure tap to transition piece. Fit square side of transition into attic. Support transition securely with adjustable

extension poles. Run plastic hose from attic transition to instrument case.

- Connect large flex-duct to transition piece.
- Install attic fan in bottom of doorway.
- Install house fan above attic fan.
- Route two exterior pressure taps through blower door assembly and tape shut. Connect one to the attic zone transducer and the other to the house zone transducer.
- Connect attic zone transducer and house zone transducer. Turn on digital multi-meter. Check transducer calibration. Re-calibrate using oil-filled manometer if necessary.
- Connect flex duct to attic blower.
- Connect fan flow pressure gauges and fan controllers.
- Close fan apertures on both blowers. Record initial transducer output for attic zone. Toggle transducer switch to house zone and record initial output.
- Calculate target transducer output values corresponding to 10, 20 and 30 Pa for house transducer and attic transducer. Recalculate target pressures for the second part of the test.
- Record target transducer values for first and second parts of test on field data sheet.

1-Pressurize Attic

- Open attic fan aperture to full or nearly full configuration. Open house fan aperture to a medium configuration. Toggle transducer switch to attic zone, turn on attic fan. Pressurize attic until target transducer output is achieved (10 Pa). Wait until transducer output is stable.
- Toggle transducer switch to house zone, turn on house blower ands de-pressurize house. Adjust blower speed until target transducer output is reached (initial transducer output recorded during set-up).
- Toggle transducer switch to attic blower and readjust attic flow.
- Repeat last two steps until stable target transducer outputs have been achieved.
- Repeat last three steps for 20 and 30 Pa; attic fan capacity permitting.

2-Depressurize House

- Go outside, close attic fan aperture to a nearly closed configuration.
- Toggle transducer switch to house, turn on house fan. Adjust fan speed until target transducer output is achieved (-10 Pa).
- Toggle between zones until stable targeted transducer outputs have been achieved as in the first part of the test.

APPENDIX A-2

AIR CHANGE TEST

APPARATUS

Tracer Gas

- pressurized canister 0.01% SF_6, balance air
- regulator
- electronic mass flow meter

Injection Apparatus

- one 10 manifold constructed of 0.25" diameter copper tubing sections connected to 1" copper tubing vessel
- outlets connected by PVC hose of varying lengths to spray nozzles (oil furnace type)

Sampling Apparatus

- four aquarium-type air pumps
- four long PVC hoses
- four 60 litre sampling bags (garbage bags)
- 10 cc evacuated blood collection tubes ('vacu-tainers')
- 35 ml syringes

PROCEDURE

Sample and Injection Location

- Four sample pumps to be located at centroid of attic quadrants.
- Injection nozzles to be evenly distributed around the four sampling pumps.

Set-Up

- Hang sample pumps from rafters. Gang pump plug-in ends together and run one extension cord through attic hatch to floor of house.
- Run hoses from pumps through attic hatch to floor of house.
- Locate injection nozzles throughout attic. Route feed hose to injection manifold through attic hatch.
- Fit temporary attic hatch made of cardboard and seal with tape.

- Plug in extension cord feeding pumps and check each of four sampling hoses to ensure pumps are functioning. Correct if necessary. Unplug extension cord feeding pumps.
- Connect manifold injection hose to mass flow meter and mass flow meter to tracer gas tank.
- Open tank, adjust flow rate to 1900 cc/min. Note start time of injection.
- Record outdoor temperature, indoor temperature, attic temperature.
- Evacuate sampling bags and fit bags with PVC hose and hose connector. Plug connector, arrange all bags nearby sampling hoses.
- After period of one hour from start of injection, plug in sampling pumps and allow 1-2 minutes to bleed lines.
- Unplug sampling bags and connect to sampling tubes.
- Make sketch of attic plan with pump numbers and locations, injection point locations and 2 sets of air sample identification numbers per pump.
- One-half hour after connecting bags to pumps, purge sampling syringe several times and draw 17 ml sample from each bag. Inject 17 ml sample into corresponding vacu-tainer.
- Disconnect each bag from tube, evacuate bag of air and reconnect bag to tube.
- One half hour after reconnecting tube, draw second set of samples.

Dual Zone Tracer Gas

- Set up attic sampling and injection apparatus as for conventional test substituting 99.5 per cent CO_2 tracer gas for attic. Use rotameter-type flow metering.
- Add fifth sampling pump to centre of attic volume.
- Add 1 per cent SF_6 mixture and mass flow meter set up to provide single point injection into return air grille of heating system. Optionally, use multi-point injection to various rooms.
- Measure CO_2 concentration in attic prior to test.
- Route all sampling lines outside to sampling stations.
- Inject CO_2 at approximately 15000 cc/min., and SF_6 at 1500 cc/min.

- Connect fifth sampling hose to CO_2 analyser during stabilization period, adjust CO_2 flow rate to target steady-state concentration of approximately 4000 ppm. Commence filling sample bags.
- Using timing similar to conventional test, draw SF_6 samples from bags; connect bags to CO_2 analyser; take readings. Deduct from readings background CO_2 concentration recorded prior to test.
- Analyse samples for SF_6 concentration.

APPENDIX A-3

MOISTURE MONITORING

APPARATUS

Moisture Sensor

- Delmhorst moisture pins with 6 m extension wires
- T-type thermocouples with 6 m extension leads

Instrumentation

- Delmhorst moisture meter with surface probe and adapter for permanent pin connectors
- T-type thermocouple reader
- electric psychrometer
- BLP humidity samplers
- terminal block mounting connectors for all moisture sensors installed in attic

SENSOR INSTALLATION DETAILS

The majority of the attics were instrumented with six moisture sensors. The sensors were placed in lumber on the gables (if applicable), in the rafters (or upper truss member) supporting the sheathing, and in the joists (beneath the insulation). A typical installation would include one sensor in each gable, two sensors located in the top truss at opposite ends of the attic and two sensors in the bottom joists located directly below the upper sensors. All moisture pins were driven to a depth of 1/4 lumber thickness. The pins were inserted parallel to plank grain, spaced at 2 cm according to the manufacturer's directions. Exposed T-type thermocouples were mounted on the lumber adjacent to the pins. These were fastened by covering the thermocouple junction with a thin piece of foam and stapling the foam to the lumber. Each thermocouple and moisture pin was equipped with approximately six metres of lead wire. A labelled terminal block was mounted to the attic lumber in close proximity to the attic hatch. The leads from the various sensors were routed through this panel and connected to screw-type connectors exposed for easy measurement with the moisture meter adapter probe and thermocouple reader. Figures A-3.1 and A-3.2 show the sensor mounting detail and terminal block assembly respectively.

Figure A-3.1 **Moisture Sensor Installation Details**

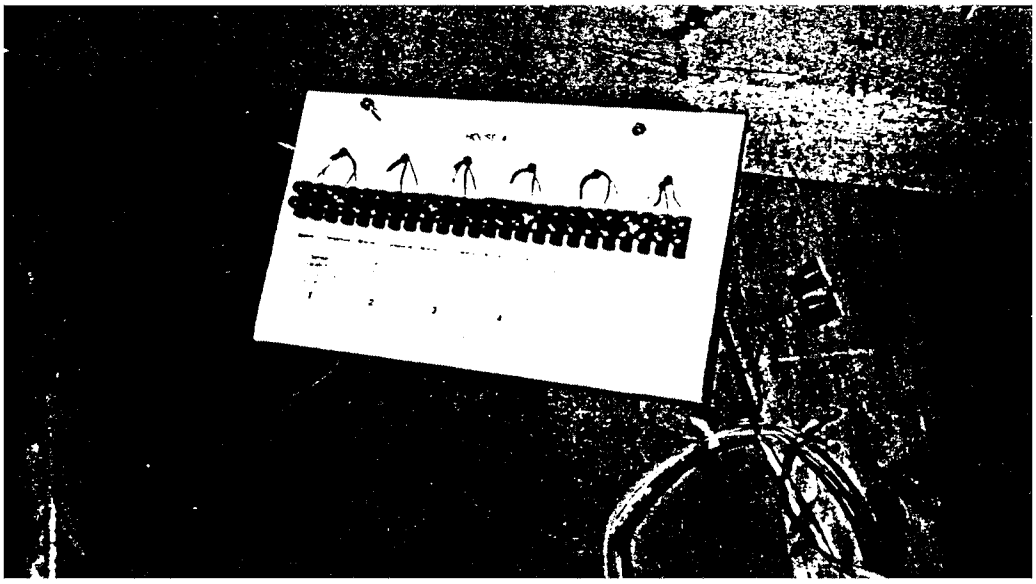
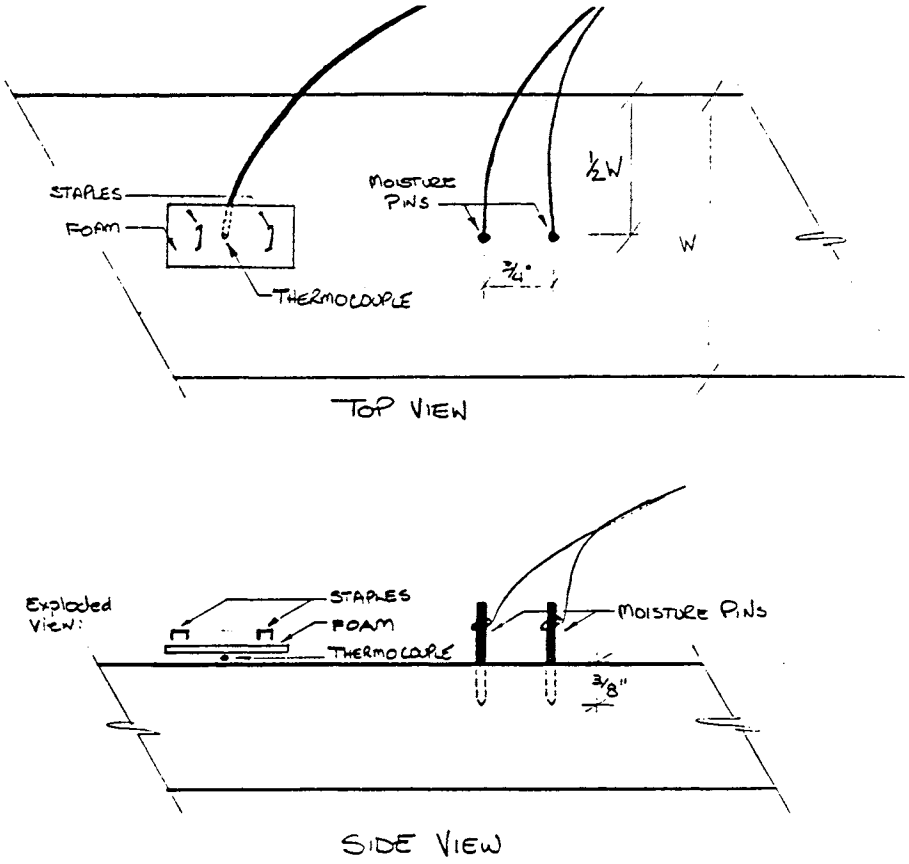


Figure A-3.2 **Example Terminal Block**



MONTHLY SITE VISIT PROCEDURES

Humidity Measurements

- Measure relative humidity of attic air with minimum disturbance of attic by placing a functioning psychrometer in attic and closing attic hatch. Allow time for psychrometer to stabilize.
- Retrieve previous month's humidity sampler from house space and re-deploy new humidity sampler.
- Retrieve psychrometer from attic. Record attic wet bulb and dry bulb temperature and calculate relative humidity.
- Record house wet bulb and dry bulb temperatures and calculate relative humidity.

Moisture Monitoring

- Using the moisture meter equipped with terminal leads, probe all moisture pins at the terminal block from the attic hatch and record moisture values.
- Using the thermocouple reader, read all the thermocouple outputs on the terminal connection block.
- Using the Delmhorst moisture meter with surface probe, record average moisture levels for sheathing, top truss, webbing and bottom joist lumber.
- Close attic hatch.
- Record date, time, snow cover on roof and humidity sampler I.D.

APPENDIX A-4

ERROR CALCULATIONS

House Characterization

Venting Area:

Generally,

$$A = n L_1 L_2 p$$

where
n = number of vents
$L_{1,2}$ = dimensions [cm]
p = percentage open (0.6)

As the shape of openings were very rough and vents were blocked to varying degrees by insulation, the following estimates of the component errors were made:

$$\delta L_{1,2} = \pm 10\%$$
$$\delta p = \pm 10\%$$

The component errors were summed in quadrature to yield the accuracy, dA:

$$dA = \sqrt{(0.1^2 + 0.1^2 + 0.1^2)}$$
$$dA = 0.17 \text{ or } 17\%$$

Air Tightness - Accuracy

Equivalent Leakage Area:

Generally,

$$ELA = 0.0013\ Cr\ 10^{n-0.5}$$

$$= \frac{0.0013}{\sqrt{(10)}}\ Cr\ 10^{n}$$

$$= \frac{0.0013}{\sqrt{(10)}}\ Q_{10}$$

$$= 0.0004\ Q_{10}\ [m^2]$$

where
$C_{r,n}$ = flow coefficient and exponent of depressurized volume.
Q_{10} = flow through depressurized volume @ 10 Pa [L/s]

ventilation ELA, (also applies to house ELA results)

$$VELA = 4\,(Qa - Qh)$$

$$= 4\,(Ca\ p_a^{na} - Ch\ p_h^{nh})$$

where $C_{a,\,h}$ & $N_{a,\,h}$: calibration data for attic and house zone fans.

$p_{a,\,h}$: how pressures measured through attic and house fans.

$$dVELA = \sqrt{([\delta a^2 + \delta p_a^2] + [\delta h^2 + \delta p_h^2])}$$

where $\delta_{a,\,h}$: manufacturer's stated fan calibration accuracies for the attic and house fans.

$\delta p_{a,\,h}$: accuracies of flow pressure gauges for attic and house fans.

δ_a = 0.05 (Retrotec)

δ_h = 0.10 (Minneapolis)

$\delta p_{a,\,h}$ = 0.05 (Magnahelic, based on mean flow pressure of 50 Pa)

$$dVELA = \sqrt{([0.05^2 + 05^2]) + ([0.1^2 + 0.05^2])}$$

$$= \sqrt{0.005 + 0.0125}$$

$$= 0.13 \text{ or } 13\%$$

Interface ELA

In part 1 of the test, interface ELA was measured with the house fan:

$$dIELA_1 = \sqrt{(0.125)} = .11 \text{ or } 11\%$$

Air Tightness - Measurement Error

Considerable measurement error was prevalent when trying to measure the pressure difference of 10 Pa between the house and attic zones. The sources of this error were the transducers, their calibration, and the effects of wind-induced pressure fluctuations.

Including wind effects, the pressure drop was measured as follows:

$$dp_{ha} = dp_{ho} - dp_{ao} + dpw$$

where
- h : house zone
- a : attic zone
- o : outdoor zone
- w : wind effects

The measurement error,

$$dp_{ha} = \sqrt{(\delta ph^2 + \delta pa^2 + \delta pw^2)}$$

Estimating the component errors:

The general eastern transducers had an error ±2 per cent of full-scale which was 0.25 inches H_2O. This corresponded to ±2 Pa, or ±10 per cent in the applied range. An additional calibration error of ±0.2 per cent was also included.

$$\delta h = \pm 12\%$$
$$\delta a = \pm 12\%$$
$$\delta w = \pm 10\% \text{ (estimate of } \pm 1 \text{ Pa)}$$

The components were summed in quadrature to yield the measurement error, dELA

$$dELA = \sqrt{(0.12^2 + 0.12^2 + 0.1^2)}$$
$$= 0.2 \text{ or } 20\%$$

Air Change Measurement

Air Change Rate:

$$I = \frac{Q \times 1\,000\,000}{Cs \times V} \quad \text{[a.c.h.]}$$

where Q = the gas injection rate [L/h]
Cs = the steady state concentration of tracer gas [p.p.m.]
V = the volume of the attic [L]

For the above variables, the component errors were taken as:

δQ = ±1% (Matheson mass flow meter specifications)
δCs = ±3% (G.C. lab estimate)
δV = ±10% (based on ±5% estimated error in length measurements)

$$dI = \sqrt{(0.01^2 + 0.03^2 + 0.1^2)}$$

$$= \pm 11\%$$

Interface Leakage:

$$I_i = \frac{Th}{Ta} \frac{Ca}{Ch} Qa$$

where $T_{h,a}$ = absolute house and attic temperature [K]
$C_{h,a}$ = steady state house and attic tracer gas concentrations [p.p.m.]
Q_a = flow rate through attic

Compiling the component errors, δQa followed the exact same analysis as above, but δQ and δCs values were modified for the use of rotameters and the Nova absorption equipment.

$$\delta Q = \sqrt{(0.05^2 + 0.05^2 + 0.1^2)}$$
$$= \pm 12\%$$

$\delta Th,a$ = ±1% (thermocouple reader specifications)
δCh = ±3% (as before)
δCa = ±5% (from Nova specifications)

Summing Component Errors:

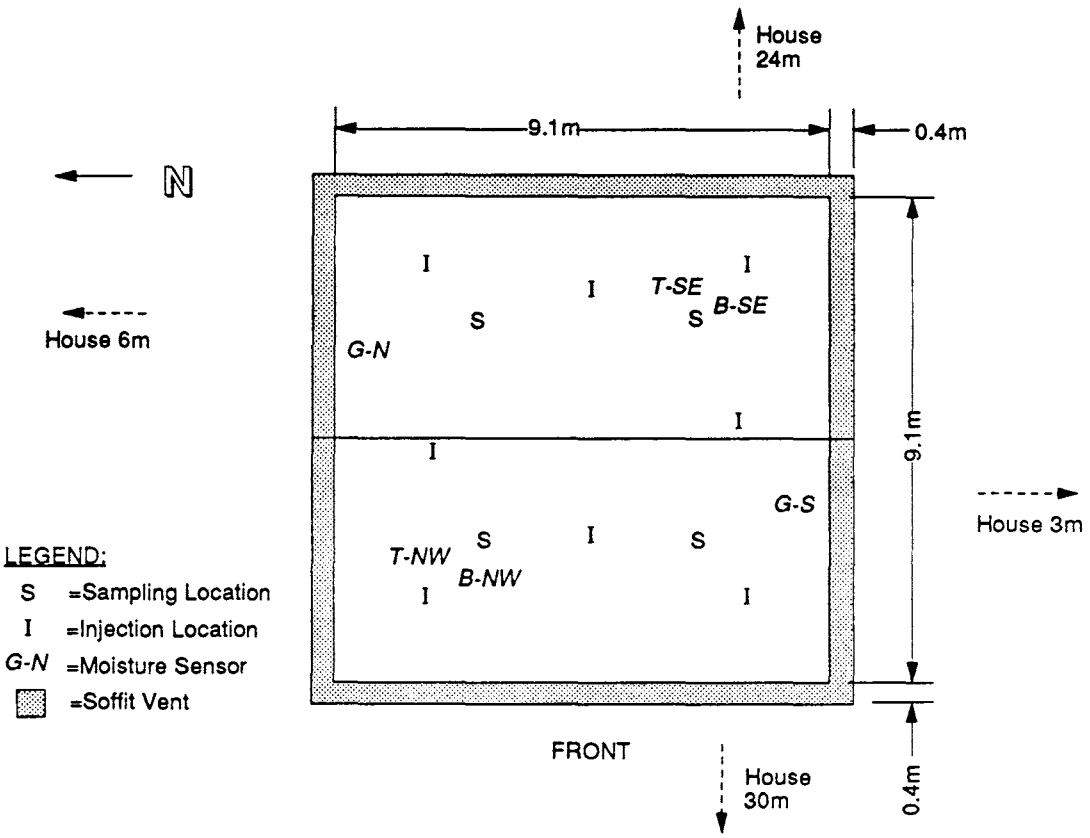
$$\delta I_i = \sqrt{(0.12^2 + 0.01^2 + 0.03^2 + 0.05^2)}$$
$$= \pm 14\%$$

Appendix B

RESULTS

HOUSE O-1
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	1.3 m	Types:	soffit
Age:	1970	Volume:	53 m^3	Free venting area (approx.):	2300 cm^2
Type:	2 storeys	Ceiling area:	84 m^2		
Roof		Insulation:	RSI 3.3 glass fibre batts		
Type:	gable	Vapour barrier:	yes		
Sheathing:	plywood				
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	fir				

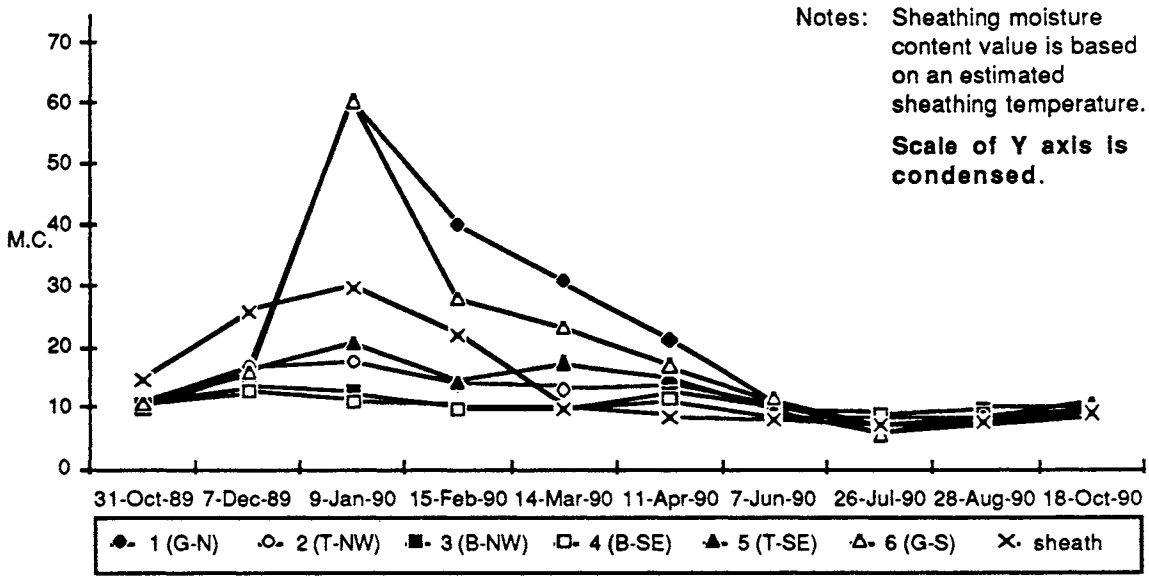
Air Change Data

Test	*Date*	*Average Wind Speed (kph)*	*Wind Direction*	*Outside Temp (T_O) (°C)*	*Attic Temp (T_a) (°C)*	*House Temp (°C)*	*Attic Air Change (ACH)*	*Average Interface Leakage (L/s)*
1	24-Jan-90	24	S	5	10	20	6.5	N/A
2	26-Jul-90	7	W	31	52	26	2.6	N/A

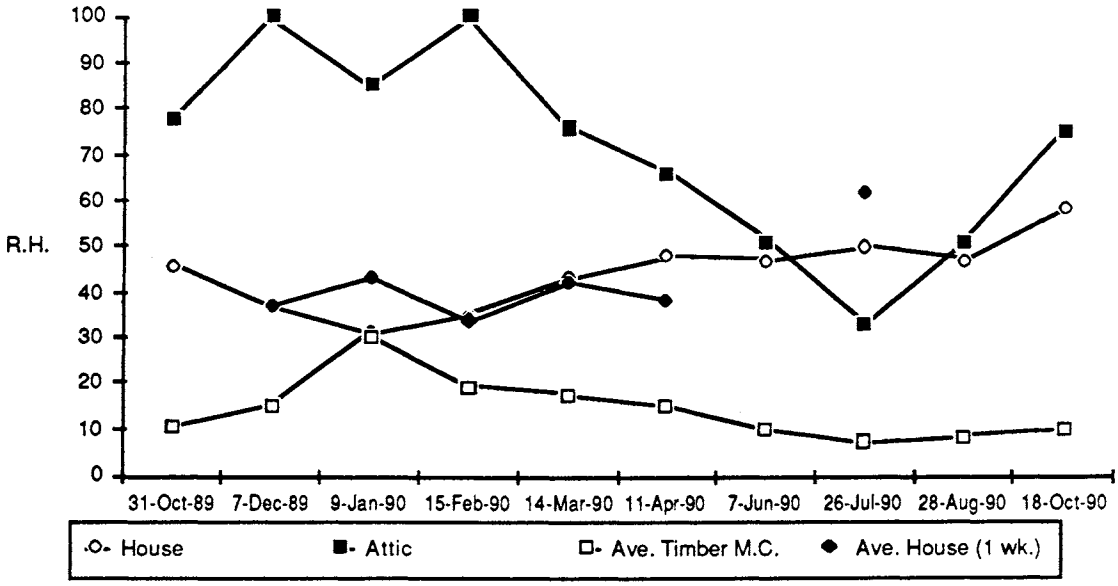
Attic Air Tightness Data

Wind Speed During Test kph	*Attic Ventilation ELA cm^2*	*Interface ELA cm^2*
18	1700	330

Moisture Curves: House O-1

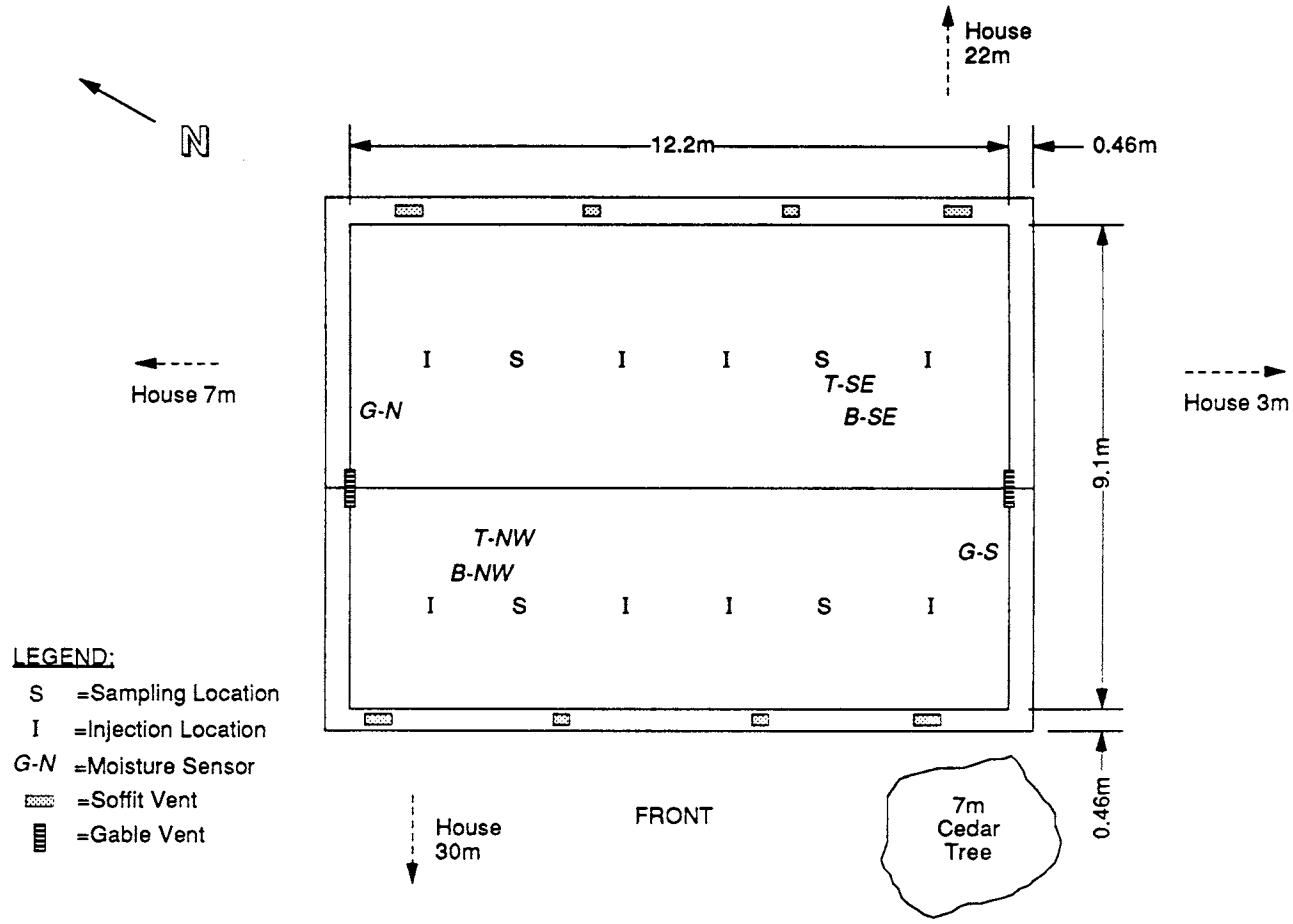


Relative Humidity and Average Lumber Moisture Content Curves: House O-1



HOUSE O-2
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	1.4 m	Types:	soffit gable
Age:	1968	Volume:	82 m^3	Free venting area (approx.):	2700 cm^2
Type:	1 storey	Ceiling area:	112 m^2		
Roof		Insulation:	RSI 2.8 glass fibre roof board		
Type:	gable	Vapour barrier:	yes		
Sheathing:	plywood				
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	S-P-F				

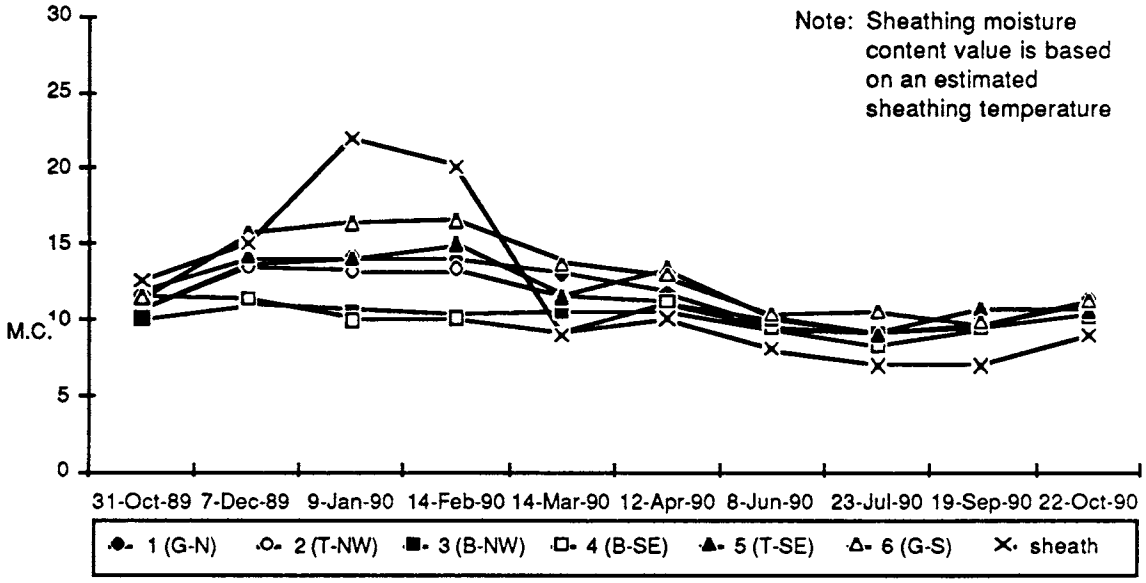
Air Change Data

Test	Date	Average Wind Speed (kph)	Wind Direction	Outside Temp (T_o) (°C)	Attic Temp (T_a) (°C)	House Temp (°C)	Attic Air Change (ACH)	Average Interface Leakage (L/s)
1	22-Jan-90	6	ENE	-12	2	19	3.1	N/A
2	23-Jul-90	15	NE	21	21	20	1.6	N/A

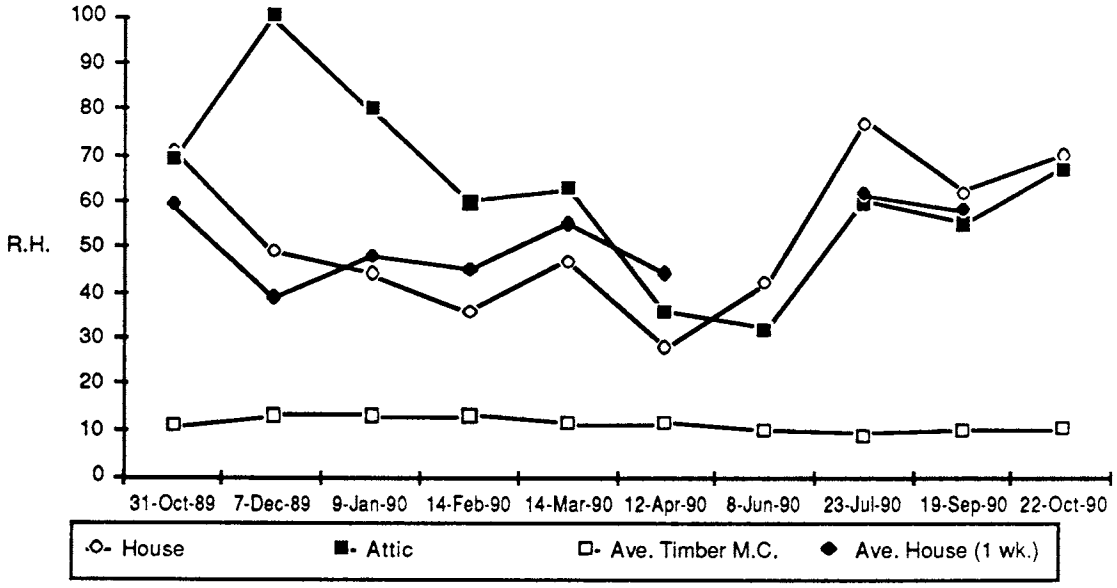
Attic Air Tightness Data

Wind Speed During Test kph	Attic Ventilation ELA cm^2	Interface ELA cm^2
11	2500	460

Moisture Curves: House O-2

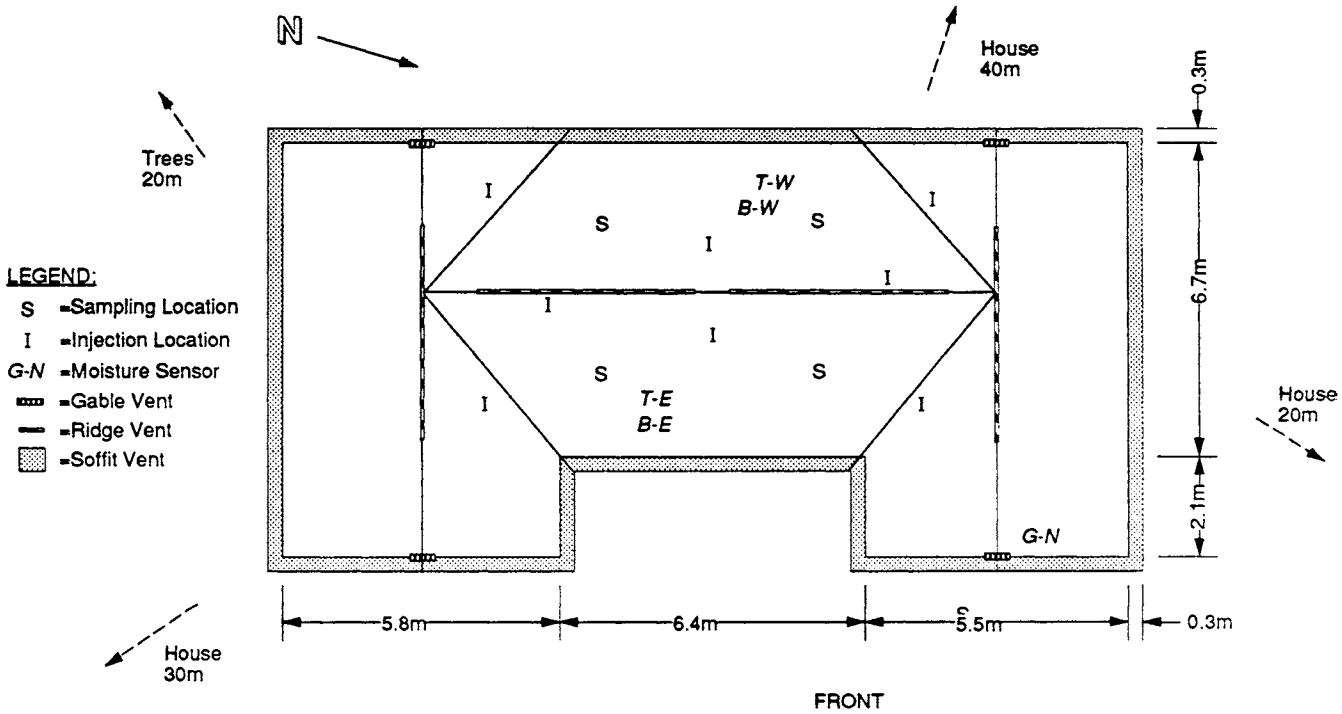


Relative Humidity and Average Lumber Moisture Content Curves: House O-2



HOUSE O-3
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	3.0 m	Types:	soffit
Age:	1987	Volume:	202 m^3		gable
Type:	1 storey	Ceiling area:	149 m^2		ridge
Roof		Insulation:	RSI 5.0 blown glass fibre	Free venting area (approx.):	29,000 cm^2
Type:	H gable	Vapour barrier:	yes	**Further Relevant Information**	
Sheathing:	plywood				House built to the R-2000 Specifications
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	S-P-F				

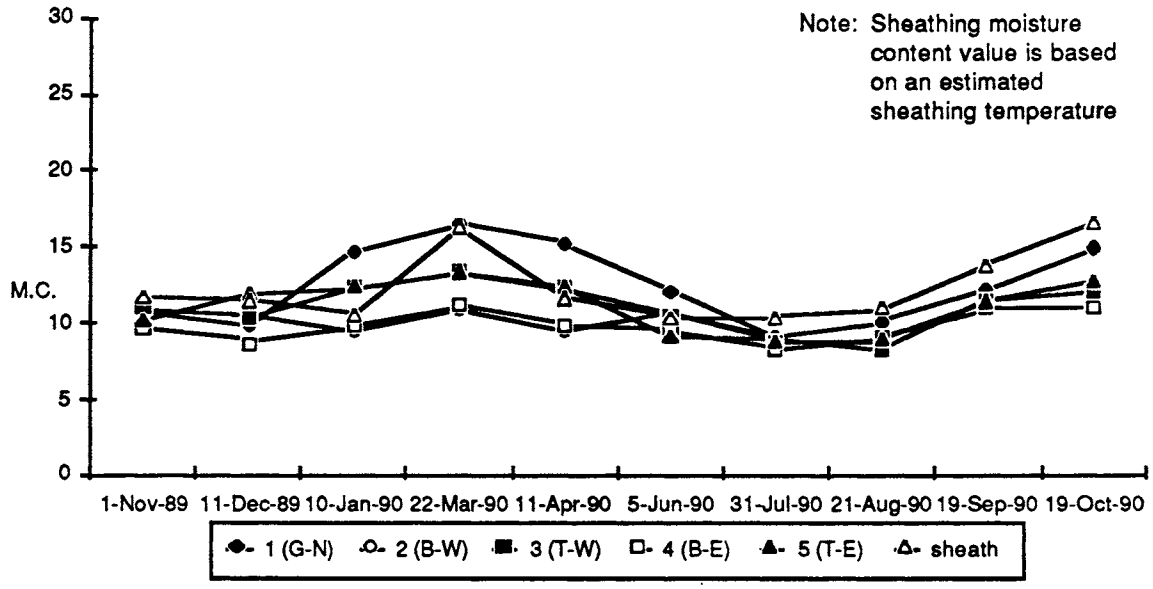
Air Change Data

Test	Date	Average Wind Speed (kph)	Wind Direction	Outside Temp (T_o) (°C)	Attic Temp (T_a) (°C)	House Temp (°C)	Attic Air Change (ACH	L/s)	Average Interface Leakage (L/s)
1	23-Jan-90	11	SW	-2	5	18	15	840	N/A
2	31-Jul-90	20	N	20	26	21	14.5	812	N/A
3	1-Aug-90	23	NW	25	25	21	11.3	633	N/A
4	3-Aug-90	17	W	27	35	22	14.1	789	N/A
5	22-Mar-90	20	SSW	11	15	19	14	784	-
6	17-Aug-90	22	SSW	31	38	24	15.3	857	40

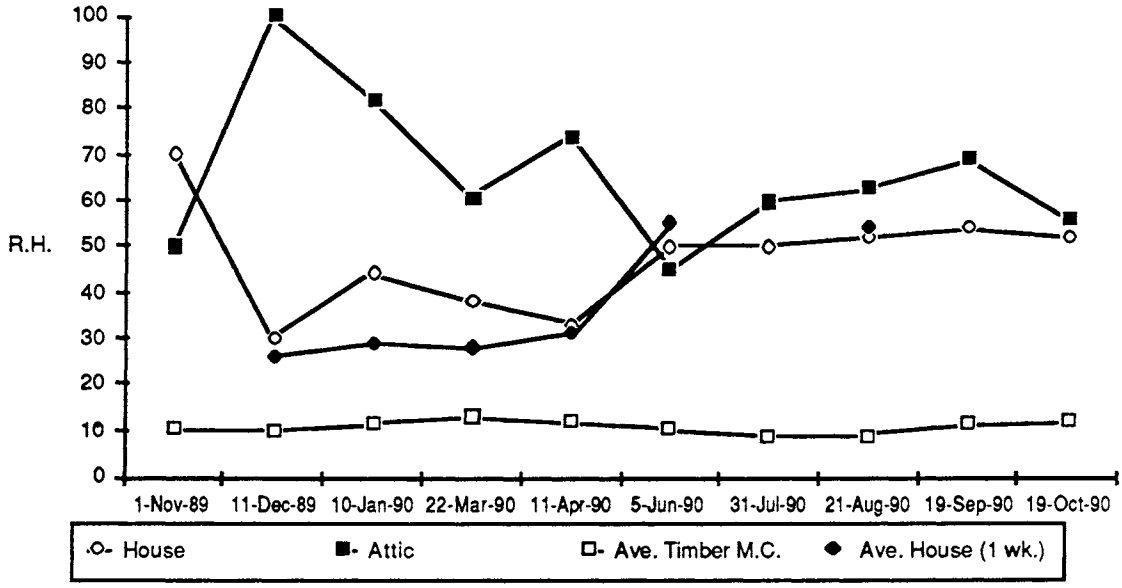
Attic Air Tightness Data

Wind Speed During Test kph	Attic Ventilation ELA cm^2	Interface ELA cm^2
27	attic test not done -- unable to pressurize	

Moisture Curves: House O-3

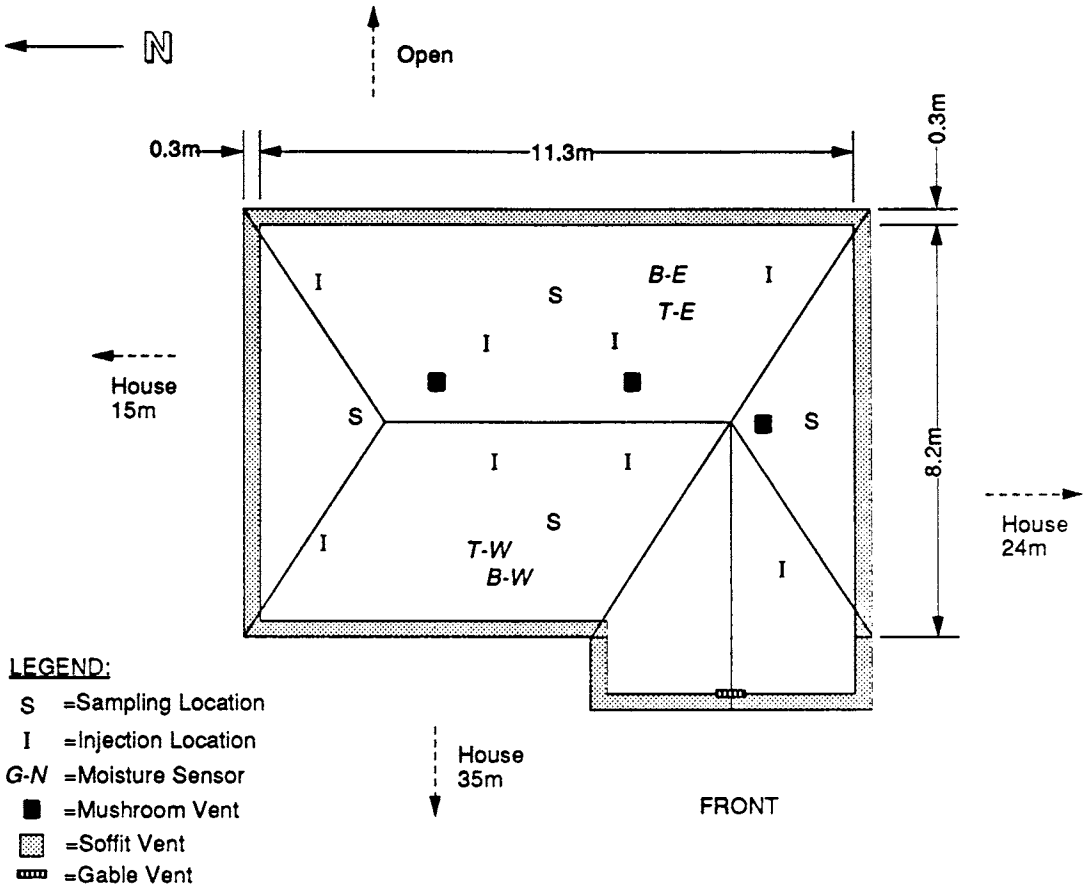


Relative Humidity and Average Lumber Moisture Content Curves: House O-3



HOUSE O-4
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	1.8 m	Types:	soffit 3 mushroom gable
Age:	1987	Volume:	70 m^3	Free venting area (approx.):	3900 cm^2
Type:	2 storeys	Ceiling area:	89 m^2		
Roof		Insulation:	RSI 5.0 blown glass fibre		
Type:	hip, gable	Vapour barrier:	yes		
Sheathing:	plywood				
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	S-P-F				

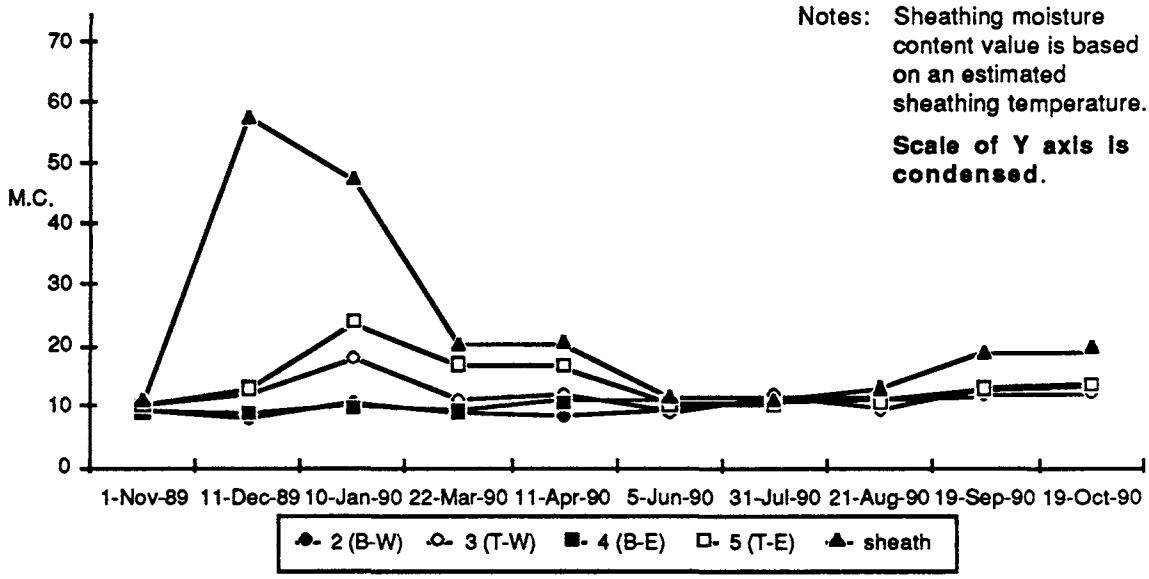
Air Change Data

Test	Date	Average Wind Speed (kph)	Wind Direction	Outside Temp (T_O) (°C)	Attic Temp (T_a) (°C)	House Temp (°C)	Attic Air Change (ACH	L/s)	Average Interface Leakage (L/s)
1	23-Jan-90	10	SW	-2	9	22	6	115	N/A
2	31-Jul-90	28	NNW	16	24	18	8.3	159	N/A
3	1-Aug-90	24	NW	27	30	26	6.5	125	N/A
4	3-Aug-90	19	W	31	48	20	14	268	N/A
5	22-Mar-90	15	SSE	6	10	19	13.6	261	10.2
6	9-Aug-90	15	SSW	26	33	23	17	326	32

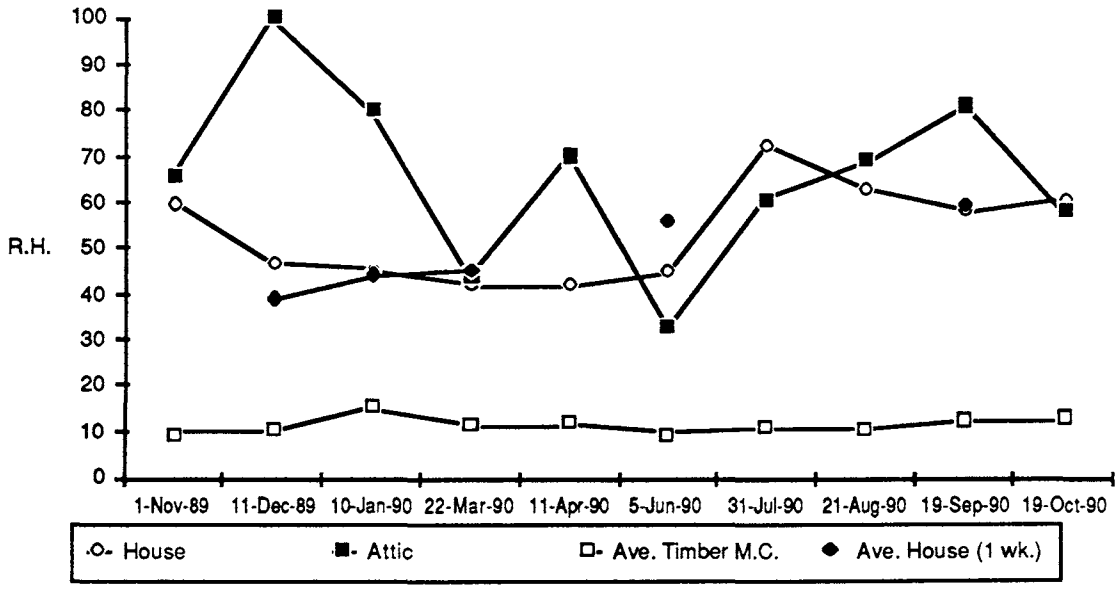
Attic Air Tightness Data

Wind Speed During Test kph	Attic Ventilation ELA cm^2	Interface ELA cm^2
27	3600	250

Moisture Curves: House O-4

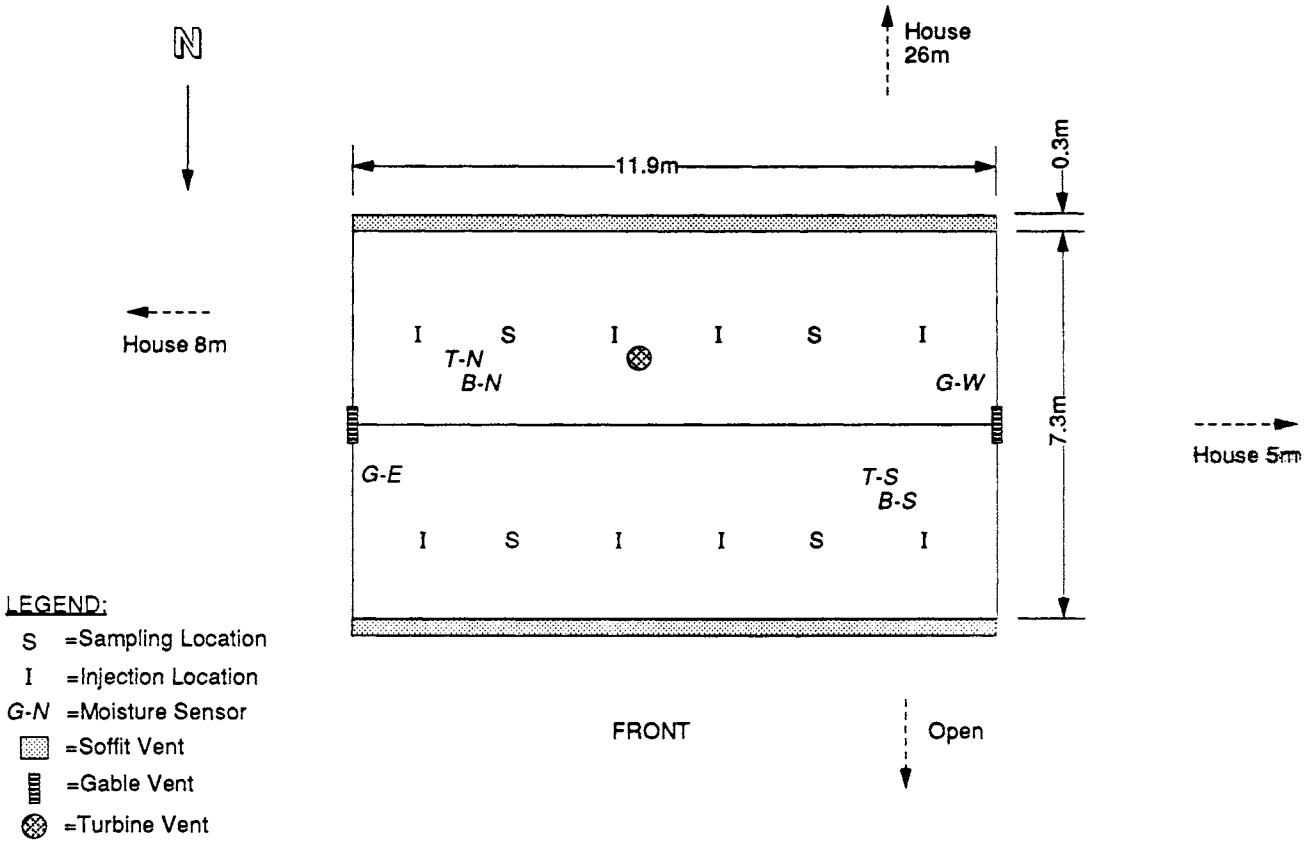


Relative Humidity and Average Lumber Moisture Content Curves: House O-4



HOUSE O-5
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	1.3 m	Types:	soffit gable turbine
Age:	1972	Volume:	61 m^3	Free venting area (approx.):	3400 m^2
Type:	1 storey	Ceiling area:	87 m^2	**Further Relevant Information**	
Roof		Insulation:	RSI 3.3 glass fibre batt		Bathroom fan vented into attic
Type:	gable, mansard	Vapour barrier:	yes		
Sheathing:	waferboard				
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	S-P-F				

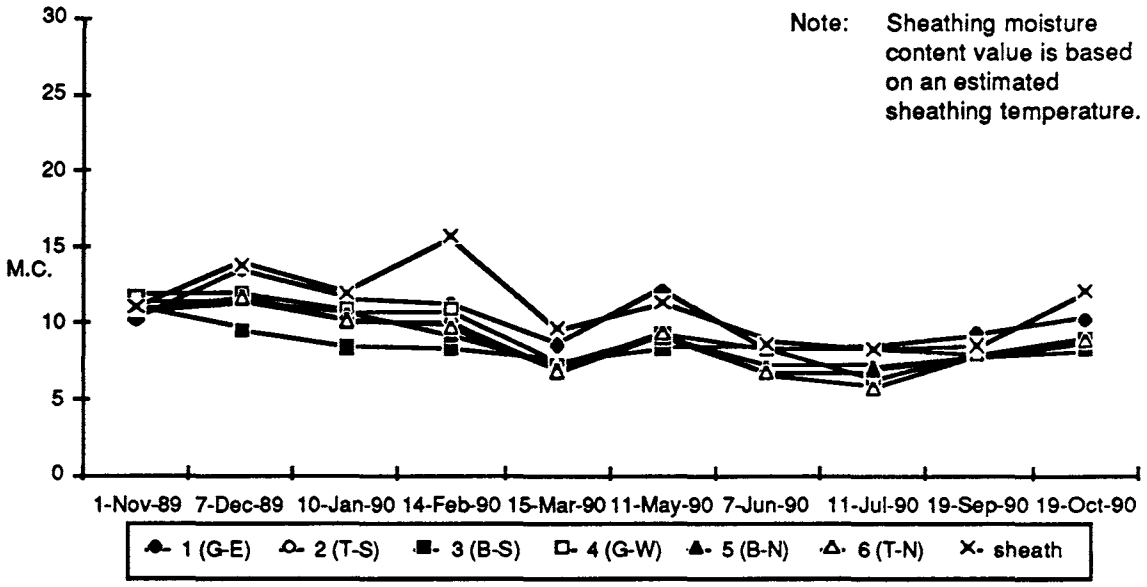
Air Change Data

Test	Date	Average Wind Speed (kph)	Wind Direction	Outside Temp (T_O) (°C)	Attic Temp (T_a) (°C)	House Temp (°C)	Attic Air Change (ACH)	Average Interface Leakage (L/s)
1	14-Feb-90	6	NW	-7	6	19	14.2	N/A
2	11-Jul-90	13	WNW	24	35	20	6.2	N/A

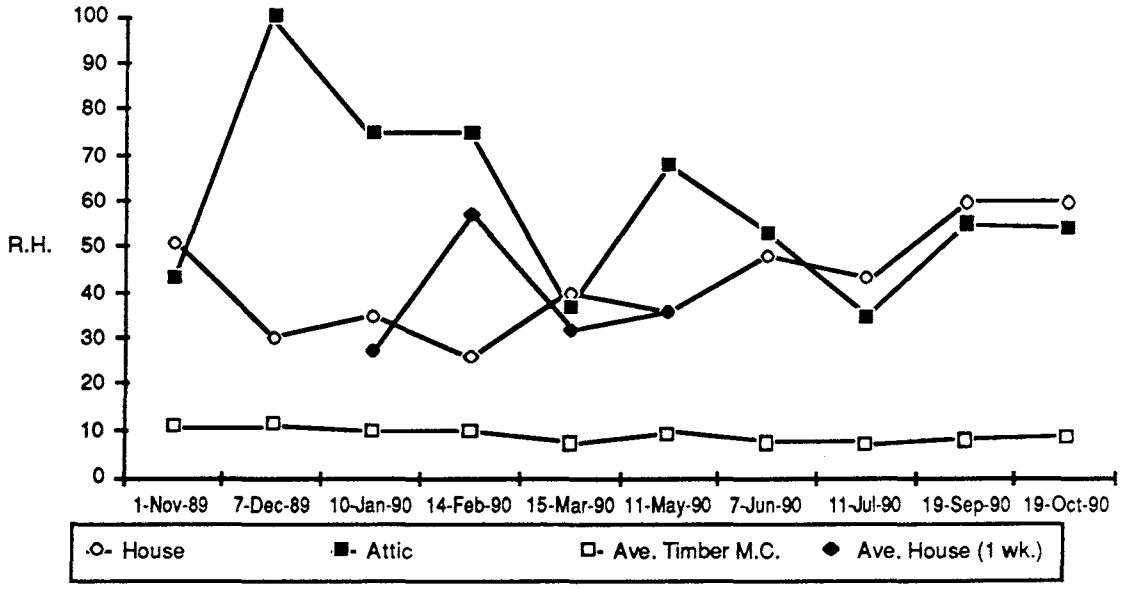
Attic Air Tightness Data

Wind Speed During Test kph	Attic Ventilation ELA cm^2	Interface ELA cm^2
12	2500	300

Moisture Curves: House O-5

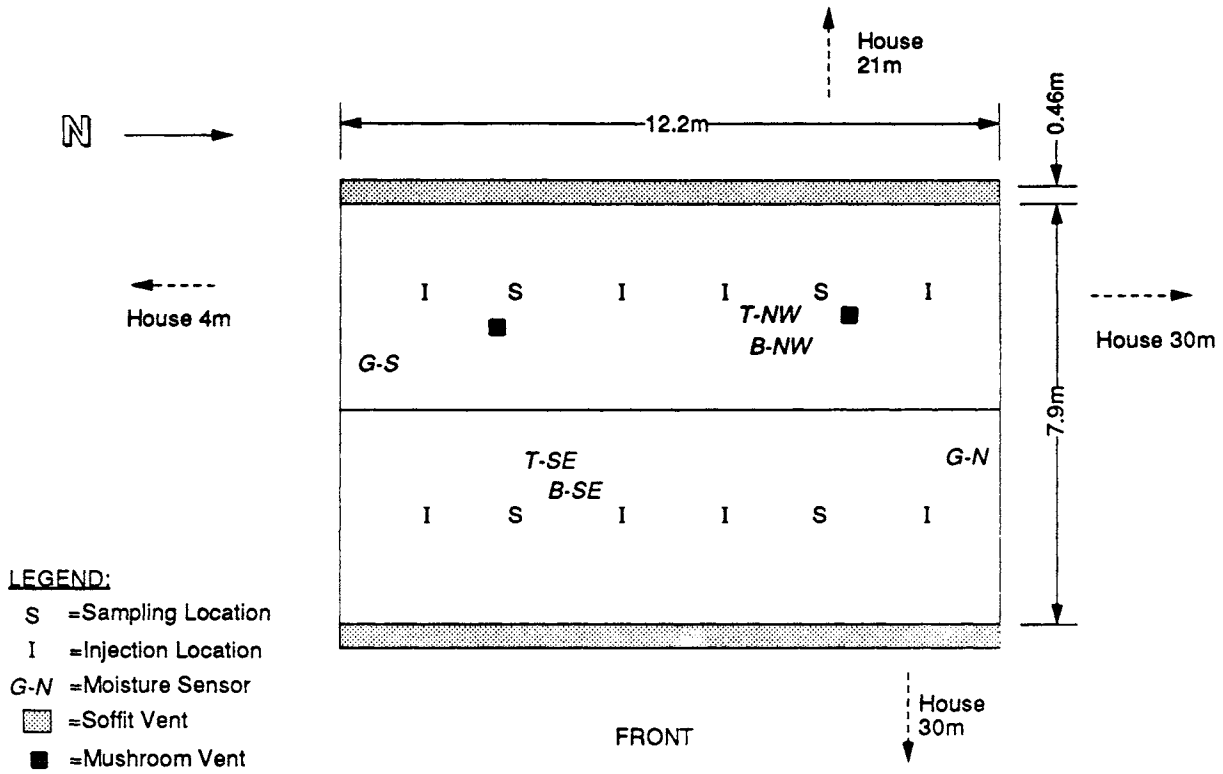


Relative Humidity and Average Lumber Moisture Content Curves: House O-5



HOUSE O-6
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	1.5 m	Types:	soffit 2 mushroom
Age:	1988	Volume:	79 m^3	Free venting area (approx.):	6100 cm^2
Type:	2 storeys	Ceiling area:	97 m^2		
Roof		Insulation:	RSI 7.6 blown glass fibre		
Type:	gable	Vapour barrier:	yes		
Sheathing:	waferboard				
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	S-P-F				

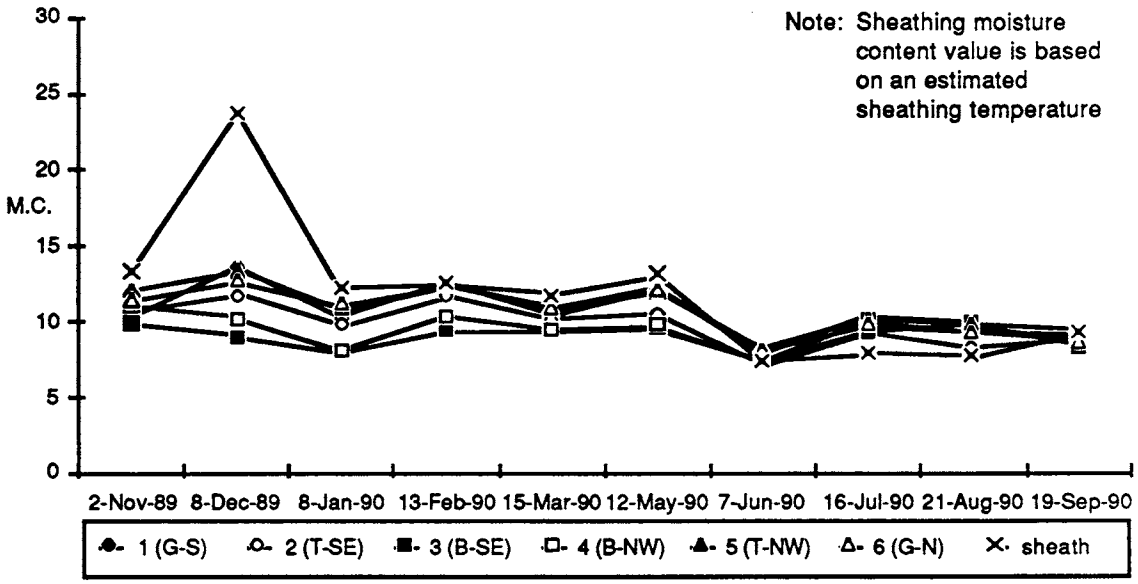
Air Change Data

Test	*Date*	*Average Wind Speed (kph)*	*Wind Direction*	*Outside Temp (T_o) (°C)*	*Attic Temp (T_a) (°C)*	*House Temp (°C)*	*Attic Air Change (ACH)*	*Average Interface Leakage (L/s)*
1	13-Feb-90	10	S-W	-3	2	18	5.8	N/A
2	16-Jul-90	26	SW	25	30	20	19	N/A

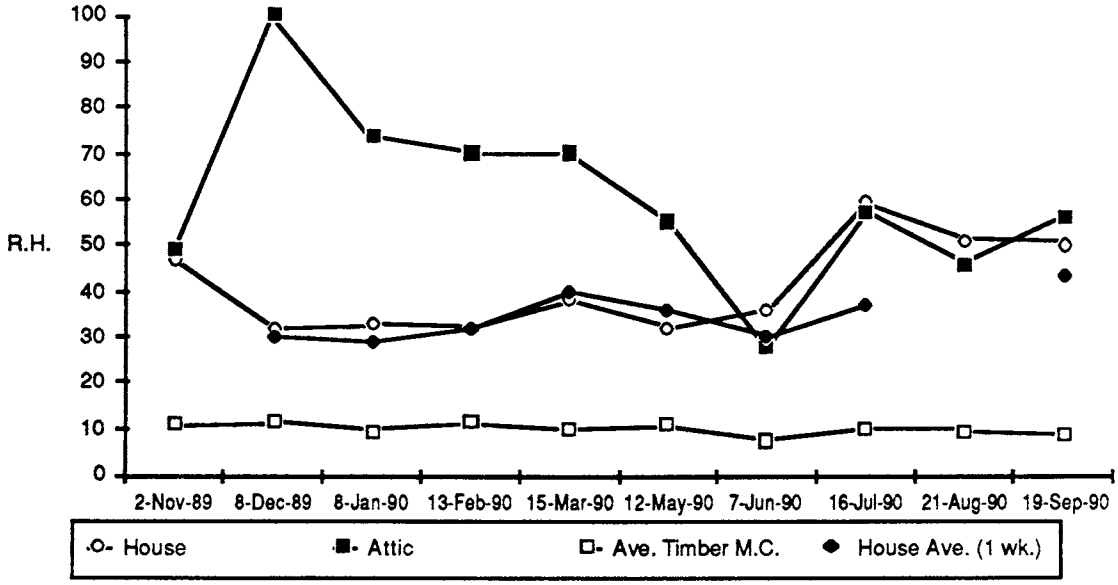
Attic Air Tightness Data

Wind Speed During Test kph	*Attic Ventilation ELA cm^2*	*Interface ELA cm^2*
12	4700	330

Moisture Curves: House O-6

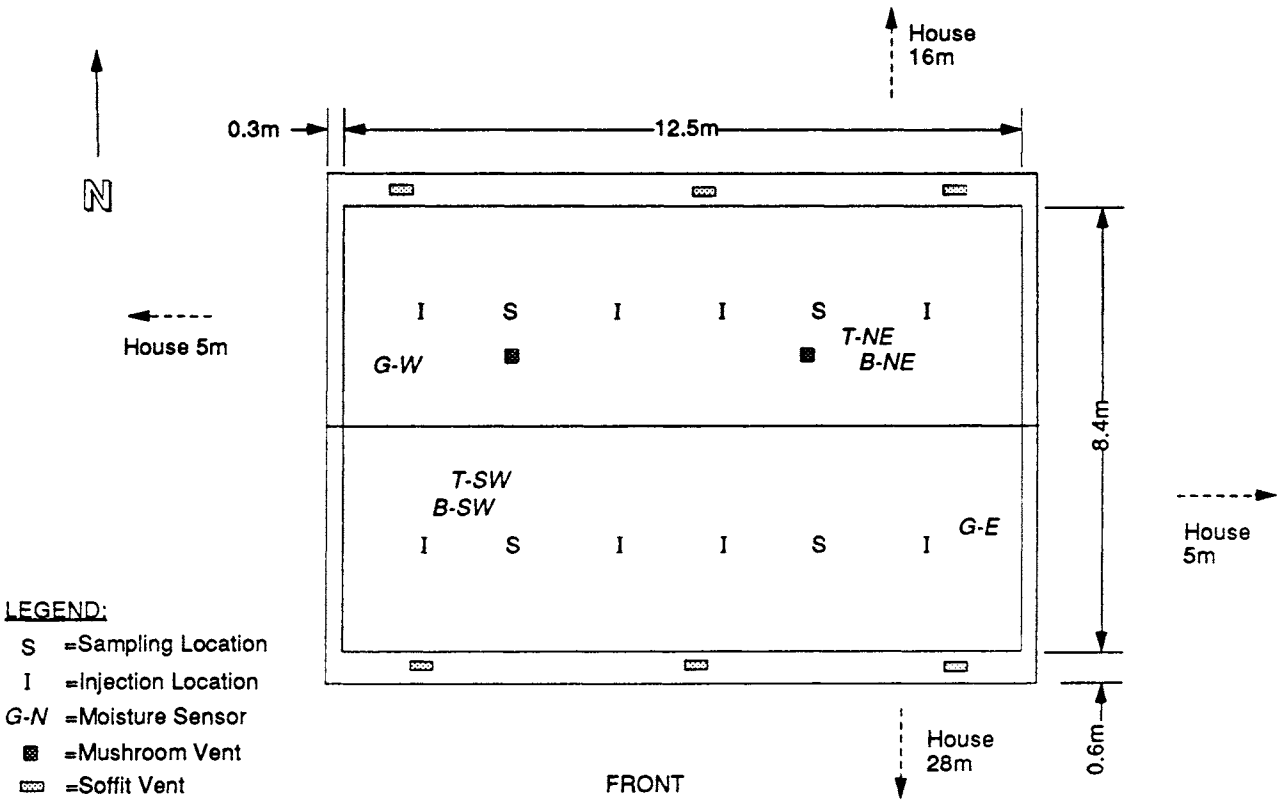


Relative Humidity and Average Lumber Moisture Content Curves: House O-6



HOUSE O-7
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	1.4 m	Types:	6 soffit 2 mushroom
Age:	1968	Volume:	82 m^3	Free venting area (actual.):	1500 cm^2
Type:	1 storey	Ceiling area:	105 m^2		
Roof		Insulation:	RSI 3.1 glass fibre batt		
Type:	gable	Vapour barrier:	yes		
Sheathing:	plank				
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	S-P-F				

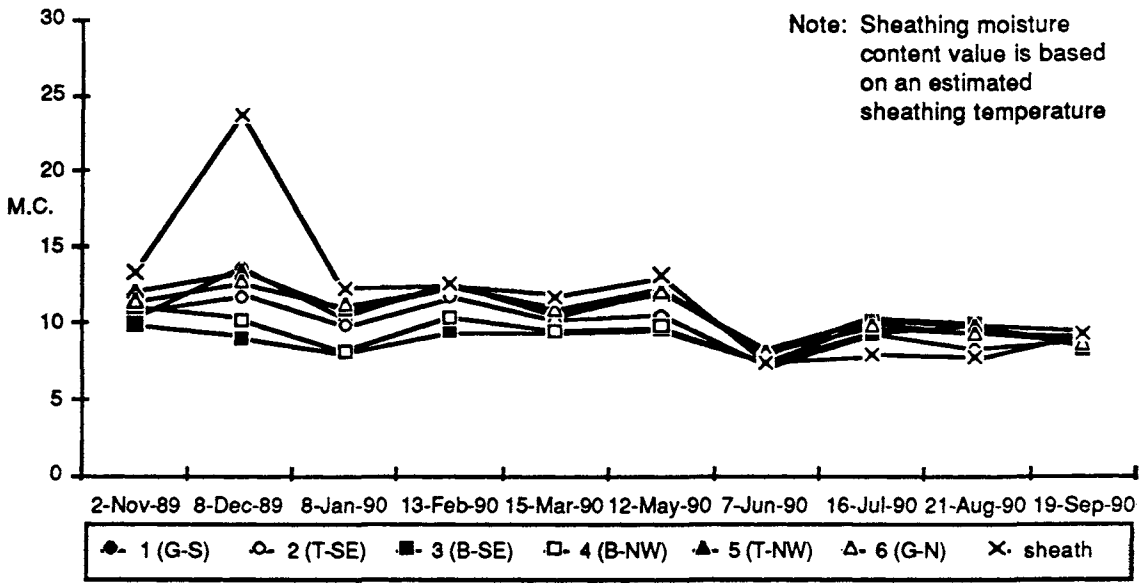
Air Change Data

Test	Date	Average Wind Speed (kph)	Wind Direction	Outside Temp (T_o) (°C)	Attic Temp (T_a) (°C)	House Temp (°C)	Attic Air Change (ACH)	Average Interface Leakage (L/s)
1	14-Feb-90	19	NW	-3	0	20	4.4	N/A
2	18-Jul-90	30	SW	31	42	29	3.8	N/A

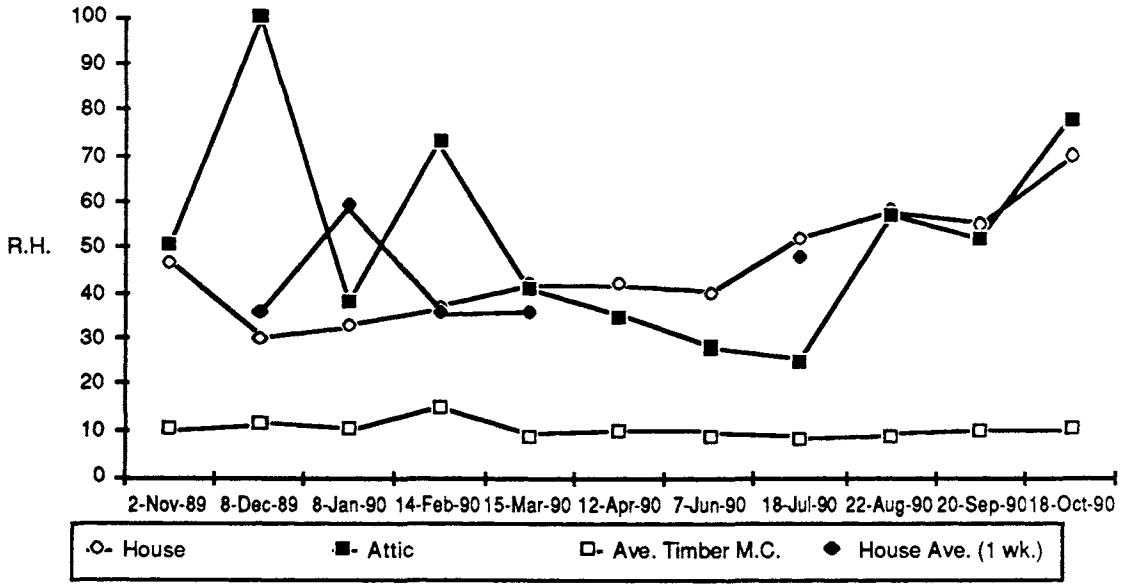
Attic Air Tightness Data

Wind Speed During Test kph	Attic Ventilation ELA cm^2	Interface ELA cm^2
6	2300	400

Moisture Curves: House O-7

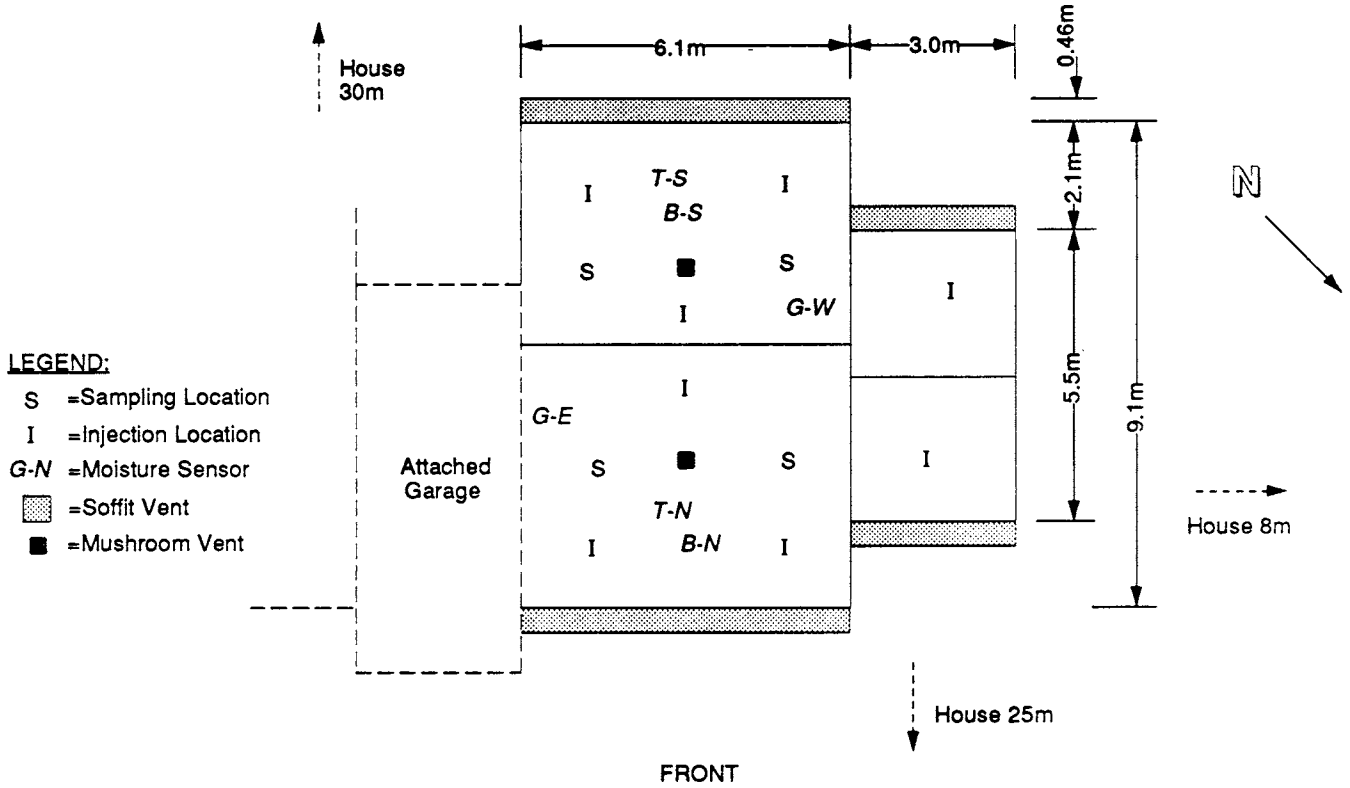


Relative Humidity and Average Lumber Moisture Content Curves: House O-7



HOUSE O-8
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	1.6 m	Types:	soffit 2 mushroom
Age:	1971	Volume:	56 m^3	Free venting area (approx.):	2500 cm^2
Type:	2 storeys	Ceiling area:	74 m^2		
Roof		Insulation:	RSI 5.5 glass fibre batt		
Type:	gable	Vapour barrier:	no		
Sheathing:	plywood				
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	S-P-F				

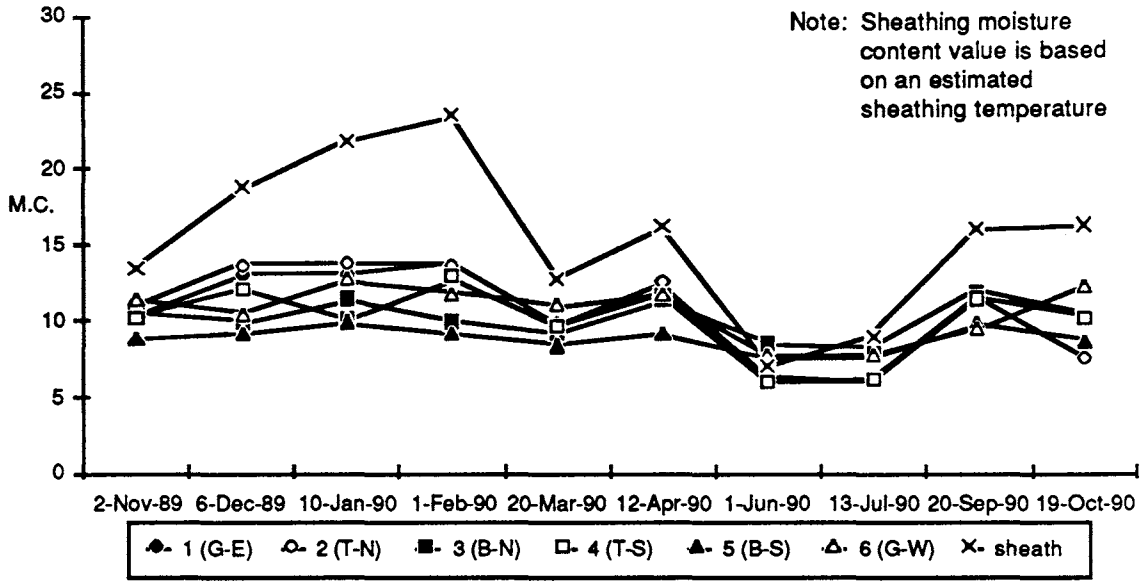
Air Change Data

Test	Date	Average Wind Speed (kph)	Wind Direction	Outside Temp (T_o) (°C)	Attic Temp (T_a) (°C)	House Temp (°C)	Attic Air Change (ACH	L/s)	Average Interface Leakage (L/s)
1	1-Feb-90	15	S	0	7	18	11.7	184	N/A
2	1-Jun-90	30	SW	28	37	22	16.8	264	N/A
3	13-Jul-90	9	SE	25	41	24	4.3	67	N/A
4	18-Jul-90	20	SSW	30	37	21	33	518	N/A
5	20-Mar-90	15	N	4	11	18	5.9	93	11.3
6	7-Aug-90	6	W	20	24	21	4.5	71	7.1

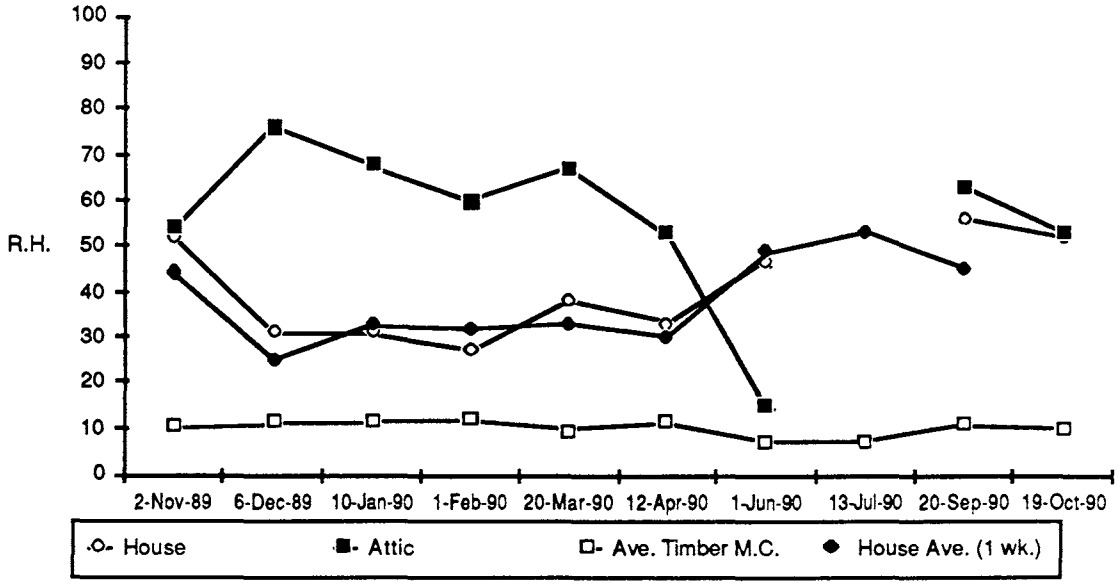
Attic Air Tightness Data

Wind Speed During Test kph	Attic Ventilation ELA cm^2	Interface ELA cm^2
10	5100	280

Moisture Curves: House O-8

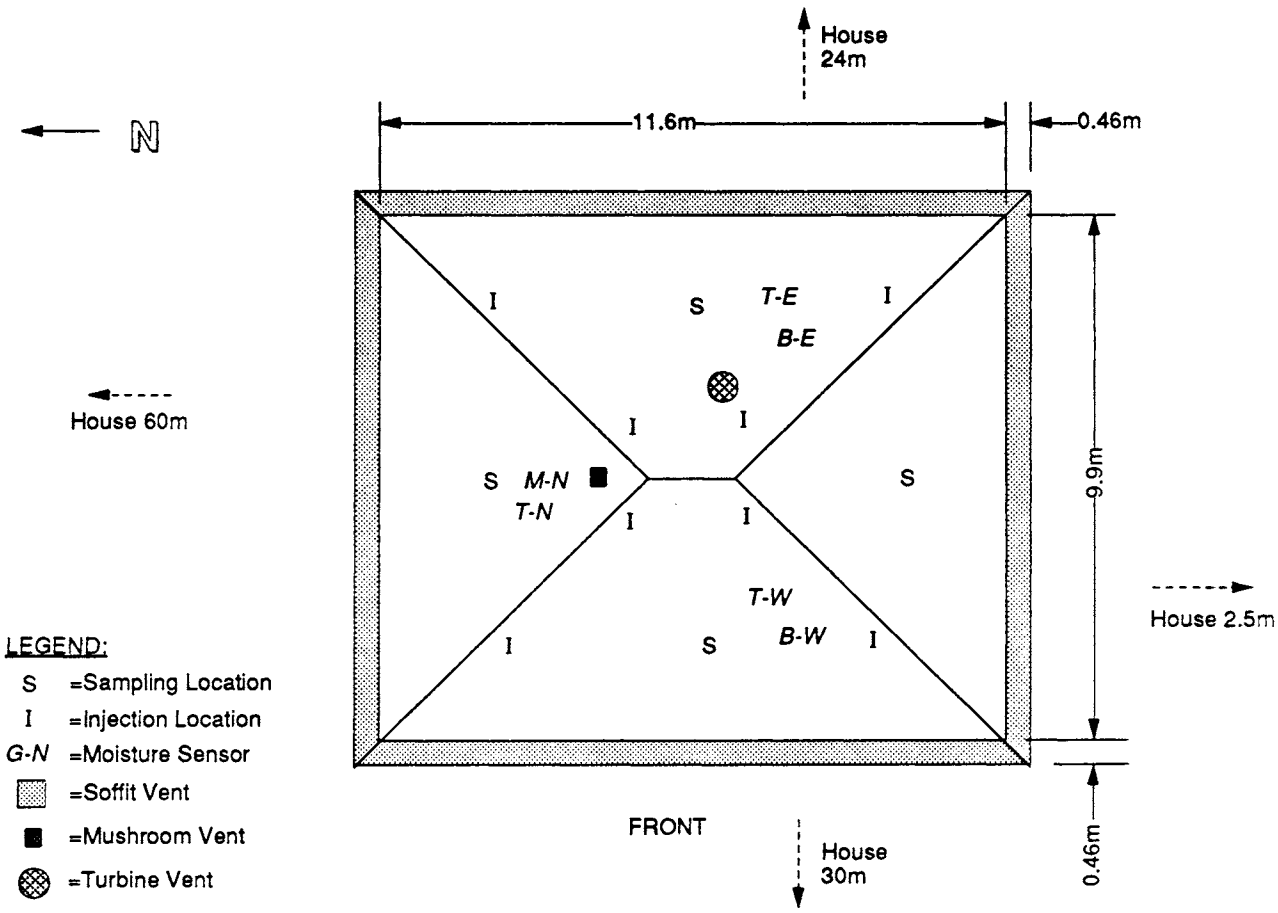


Relative Humidity and Average Lumber Moisture Content Curves: House O-8



HOUSE O-9
HOUSE CHARACTERISTICS

Site Plan



LEGEND:

S =Sampling Location

I =Injection Location

G-N =Moisture Sensor

=Soffit Vent

=Mushroom Vent

=Turbine Vent

House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	1.8 m	Types:	soffit mushroom turbine
Age:	1960	Volume:	78 m^3	Free venting area (approx.):	6200 cm^2
Type:	1 storey	Ceiling area:	111 m^2		
Roof		Insulation:	RSI 3.3 glass fibre with RSI 3.1 blown cellulose		
Type:	hip	Vapour barrier:	none		
Sheathing:	plank				
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	S-P-F				

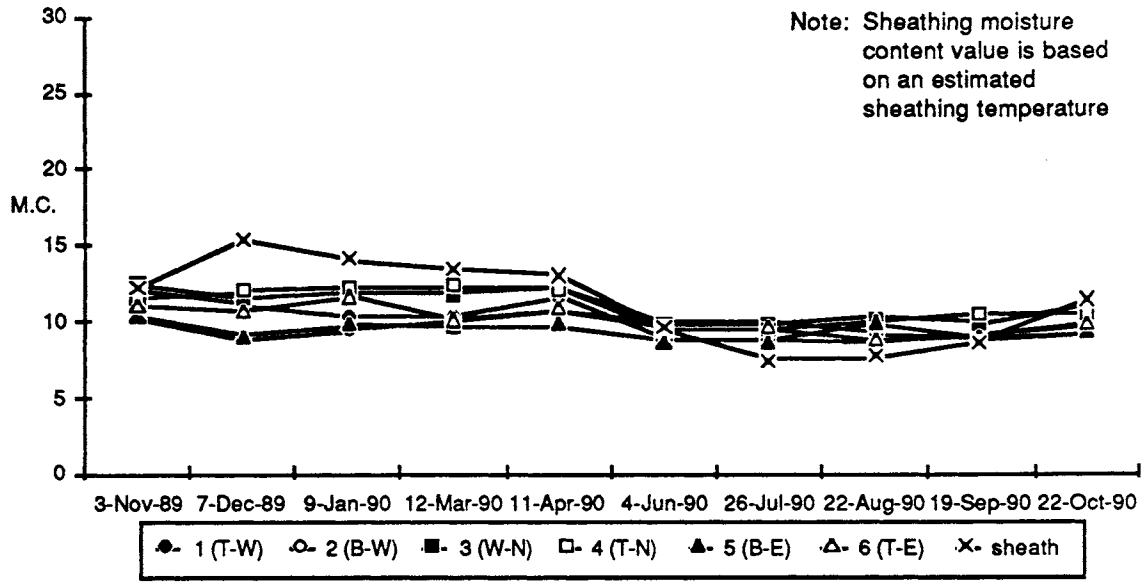
Air Change Data

Test	*Date*	*Average Wind Speed (kph)*	*Wind Direction*	*Outside Temp (T_O) (°C)*	*Attic Temp (T_a) (°C)*	*House Temp (°C)*	*Attic Air Change (ACH)*	*Average Interface Leakage (L/s)*
1	12-Mar-90	15	ENE	6	11	19	8.9	N/A
2	26-Jul-90	9	W	26	27	21	3	N/A

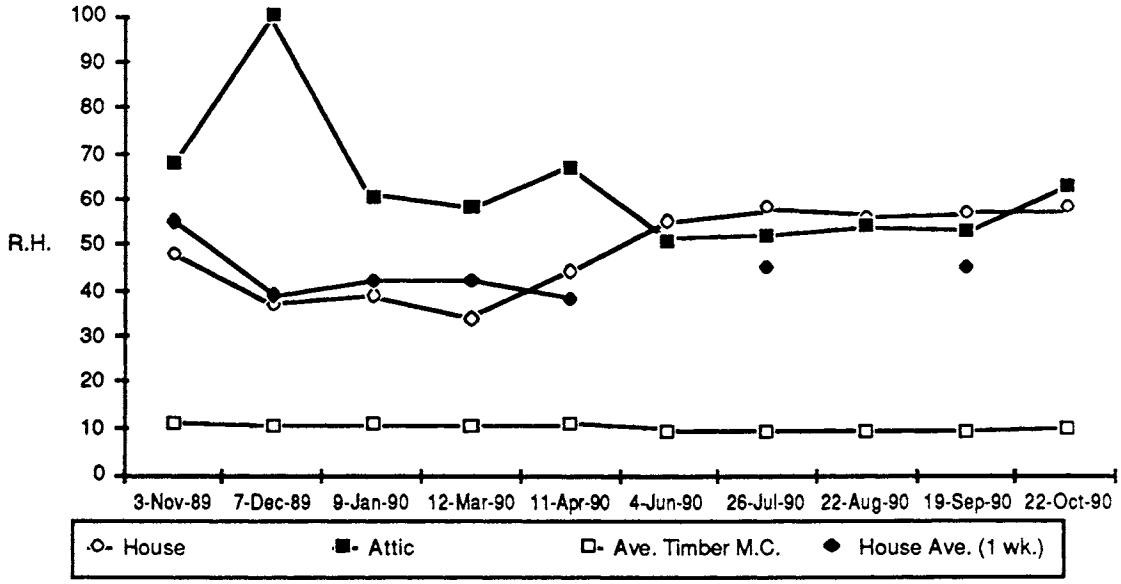
Attic Air Tightness Data

Wind Speed During Test kph	*Attic Ventilation ELA cm^2*	*Interface ELA cm^2*
8	3900	450

Moisture Curves: House O-9

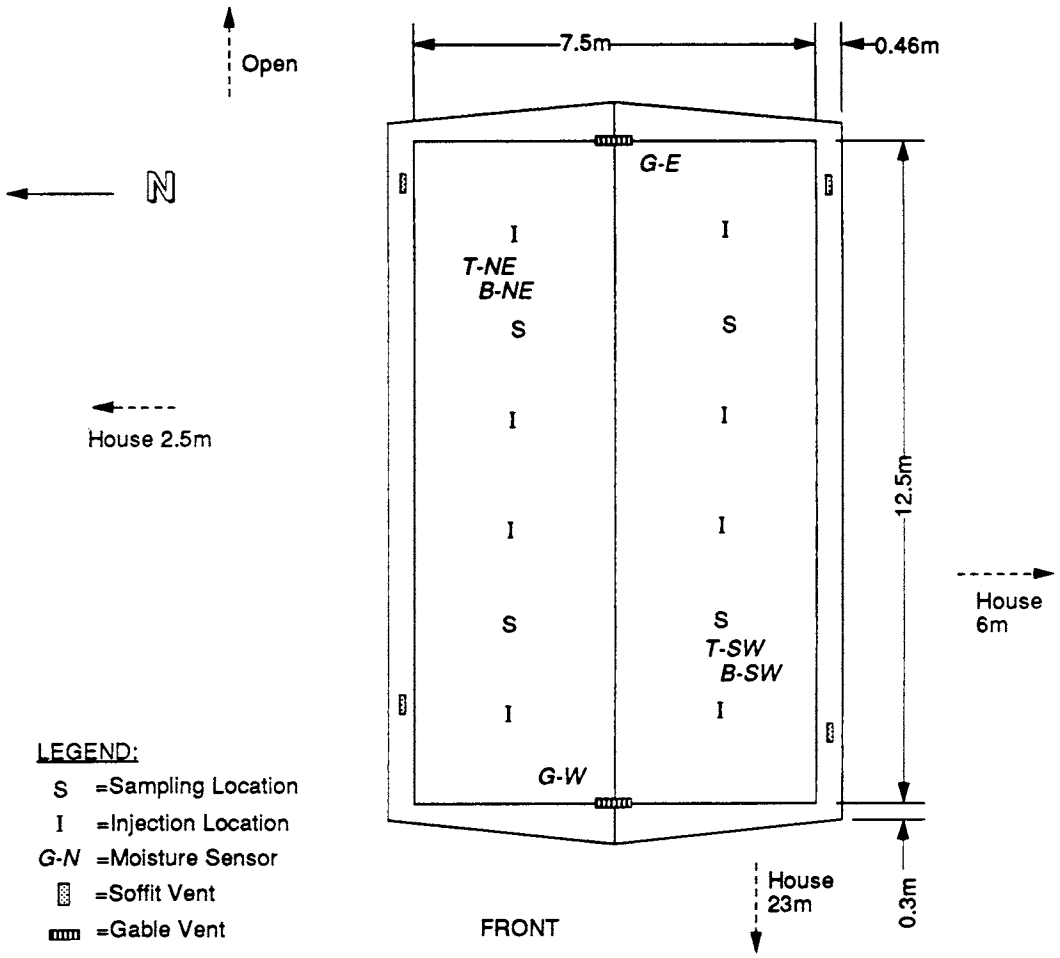


Relative Humidity and Average Lumber Moisture Content Curves: House O-9



HOUSE O-10
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	1.8 m	Types:	soffit
Age:	1960	Volume:	92 m^3		gable
Type:	1 storey	Ceiling area:	93 m^2	Free venting area (actual.):	1900 cm^2
Roof		Insulation:	RSI 5.0 blown cellulose loose fill		
Type:	gable	Vapour barrier:	none		
Sheathing:	plank				
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	S-P-F				

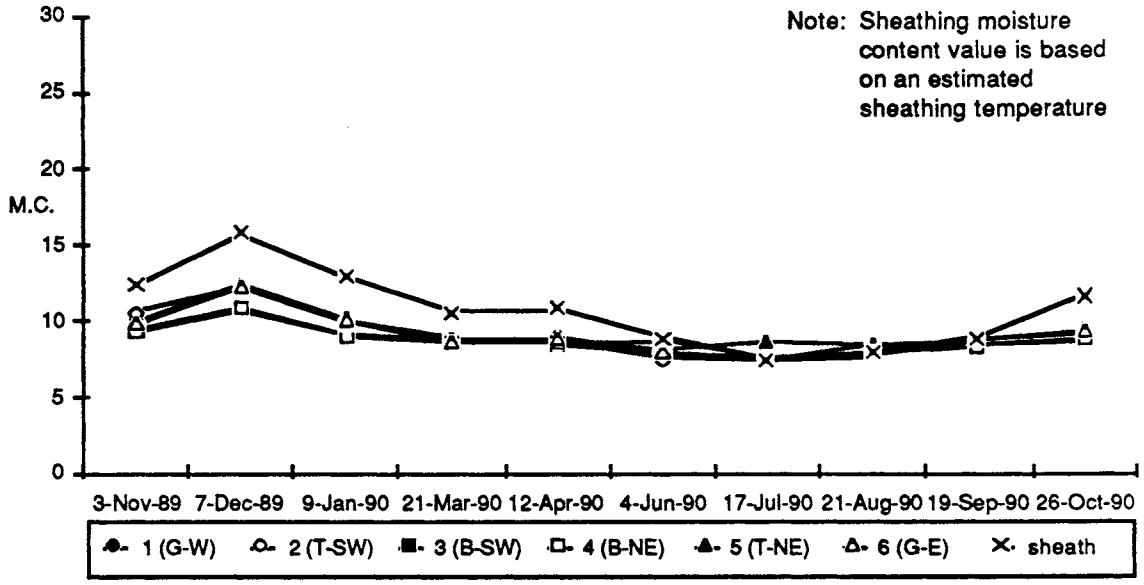
Air Change Data

Test	Date	Average Wind Speed (kph)	Wind Direction	Outside Temp (T_o) (°C)	Attic Temp (T_a) (°C)	House Temp (°C)	Attic Air Change (ACH	L/s)	Average Interface Leakage (L/s)
1	18-Jan-90	19	SSW	4	7	16	3	77	N/A
2	17-Jul-90	20	SW	26	35	25	1.9	48	N/A
3	19-Jul-90	26	W	25	40	24	1.6	41	N/A
4	20-Jul-90	11	W	20	22	20	1.1	28	N/A
5	21-Mar-90	30	W	6	21	18	3.5	89	3.3
6	2-Aug-90	17	WSW	28	49	20	1.6	41	0.9

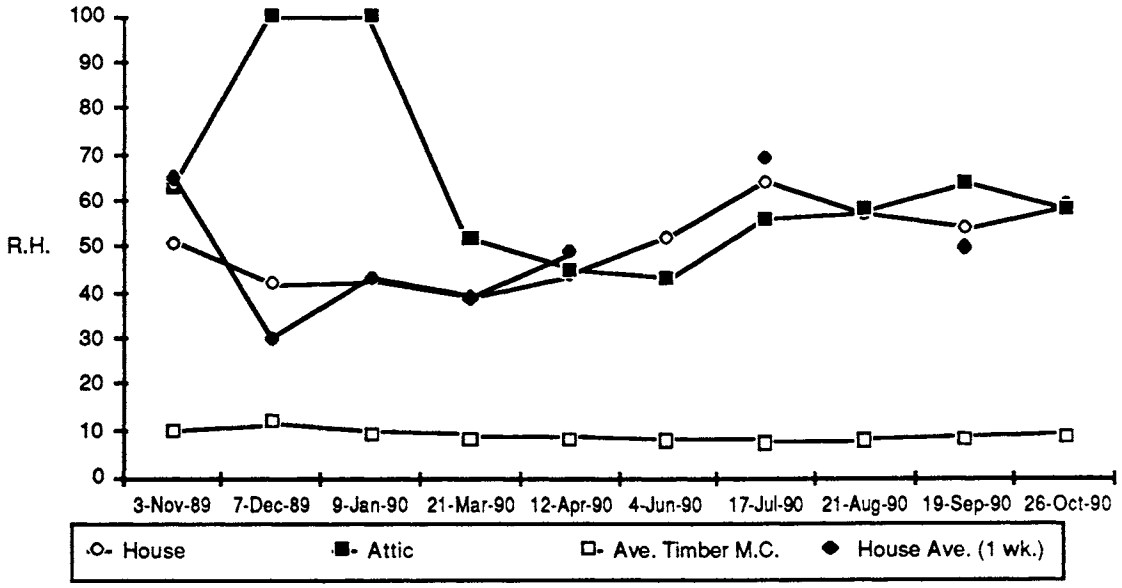
Attic Air Tightness Data

Wind Speed During Test kph	Attic Ventilation ELA cm^2	Interface ELA cm^2
15	2200	280

Moisture Curves: House O-10

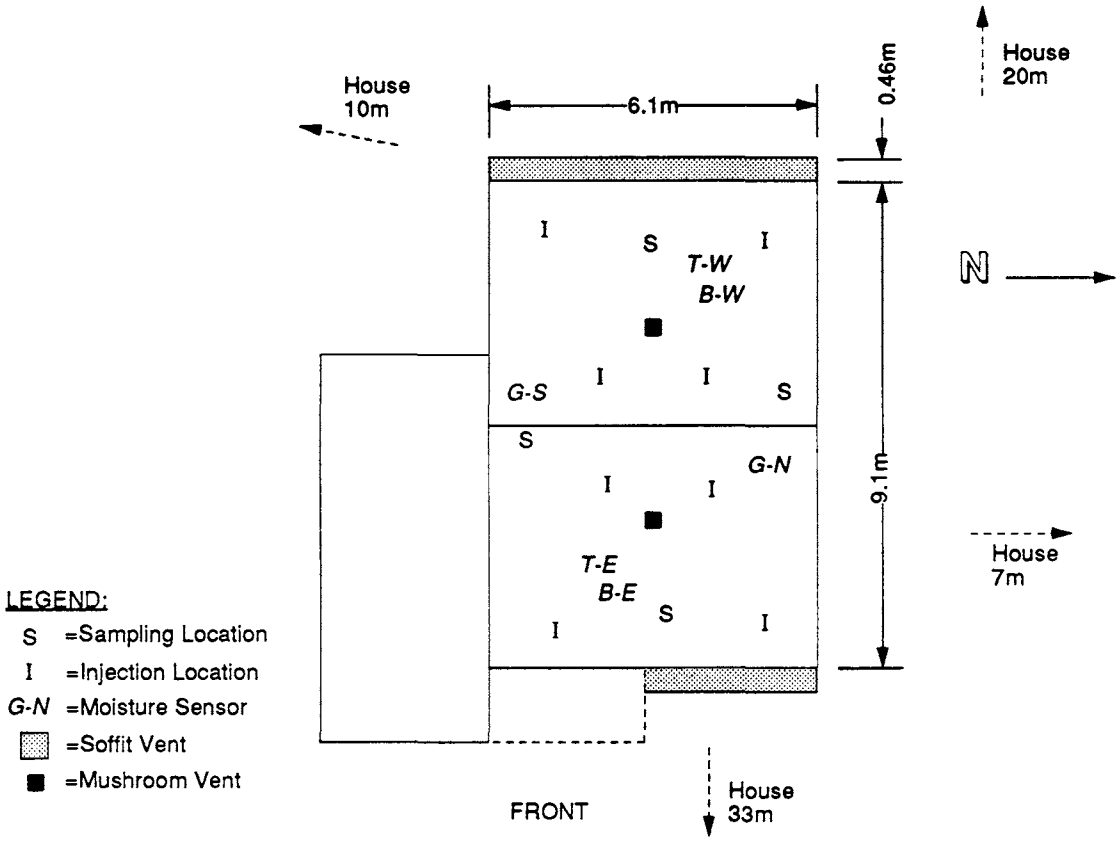


Relative Humidity and Average Lumber Moisture Content Curves: House O-10



HOUSE O-11
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	1.6 m	Types:	soffit 2 mushroom
Age:	1985	Volume:	50 m^3	Free venting area (approx.):	2300 cm^2
Type:	2 storeys	Ceiling area:	55.7 m^2		
Roof		Insulation:	RSI 5.0 blown glass fibre		
Type:	hip	Vapour barrier:	yes		
Sheathing:	waferboard				
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	S-P-F				

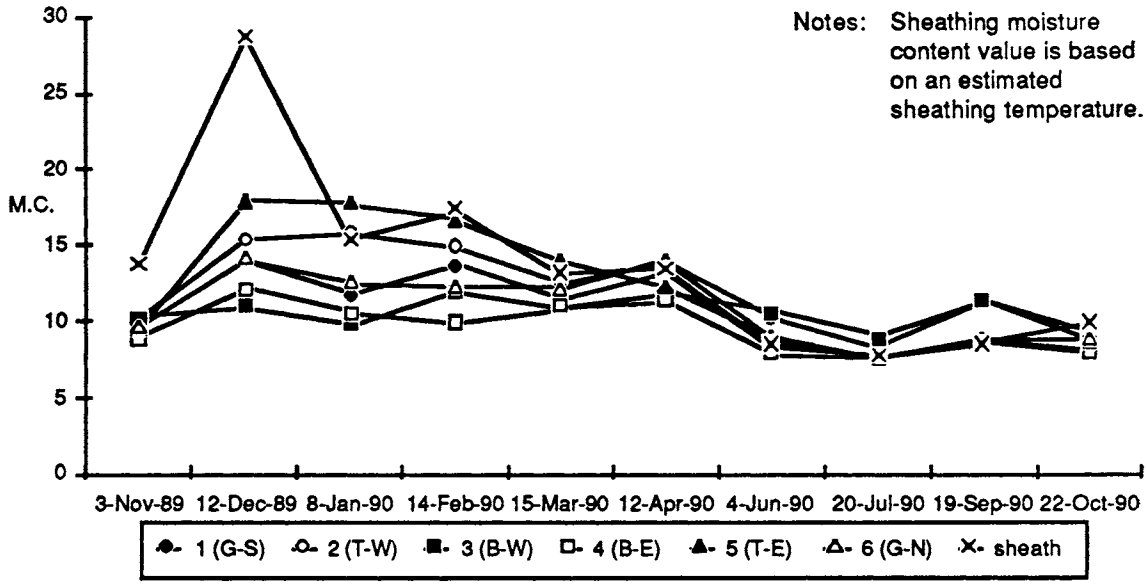
Air Change Data

Test	Date	Average Wind Speed (kph)	Wind Direction	Outside Temp (T_o) (°C)	Attic Temp (T_a) (°C)	House Temp (°C)	Attic Air Change (ACH)	Average Interface Leakage (L/s)
1	24-Jan-90	30	SSW	5	9	19	11.4	N/A
2	20-Jul-90	13	SW	19	24	22	2.6	N/A

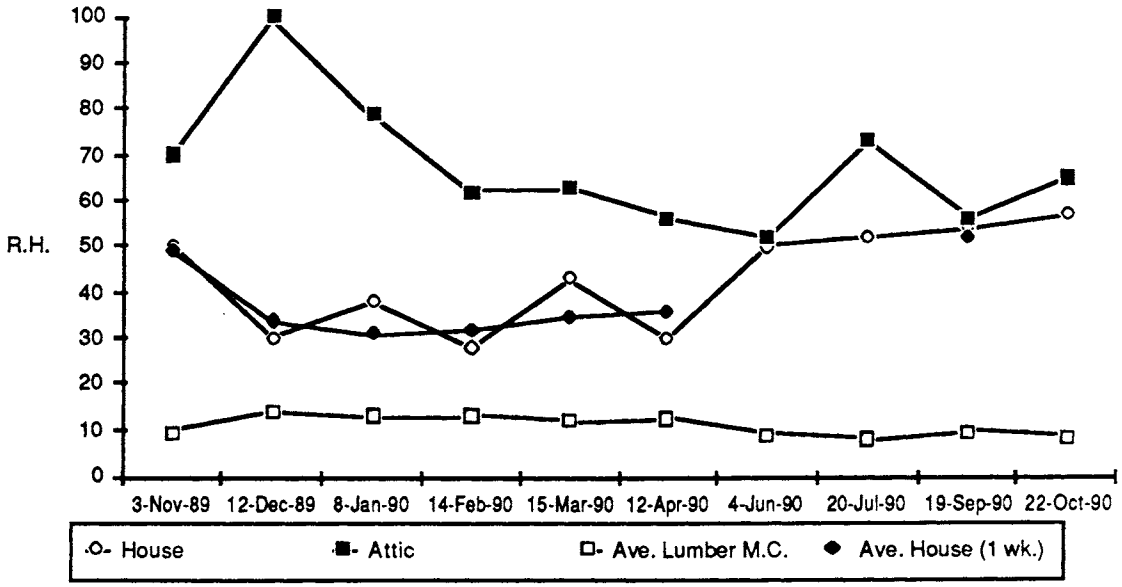
Attic Air Tightness Data

Wind Speed During Test kph	Attic Ventilation ELA cm^2	Interface ELA cm^2
32	1300	350

Moisture Curves: House O-11

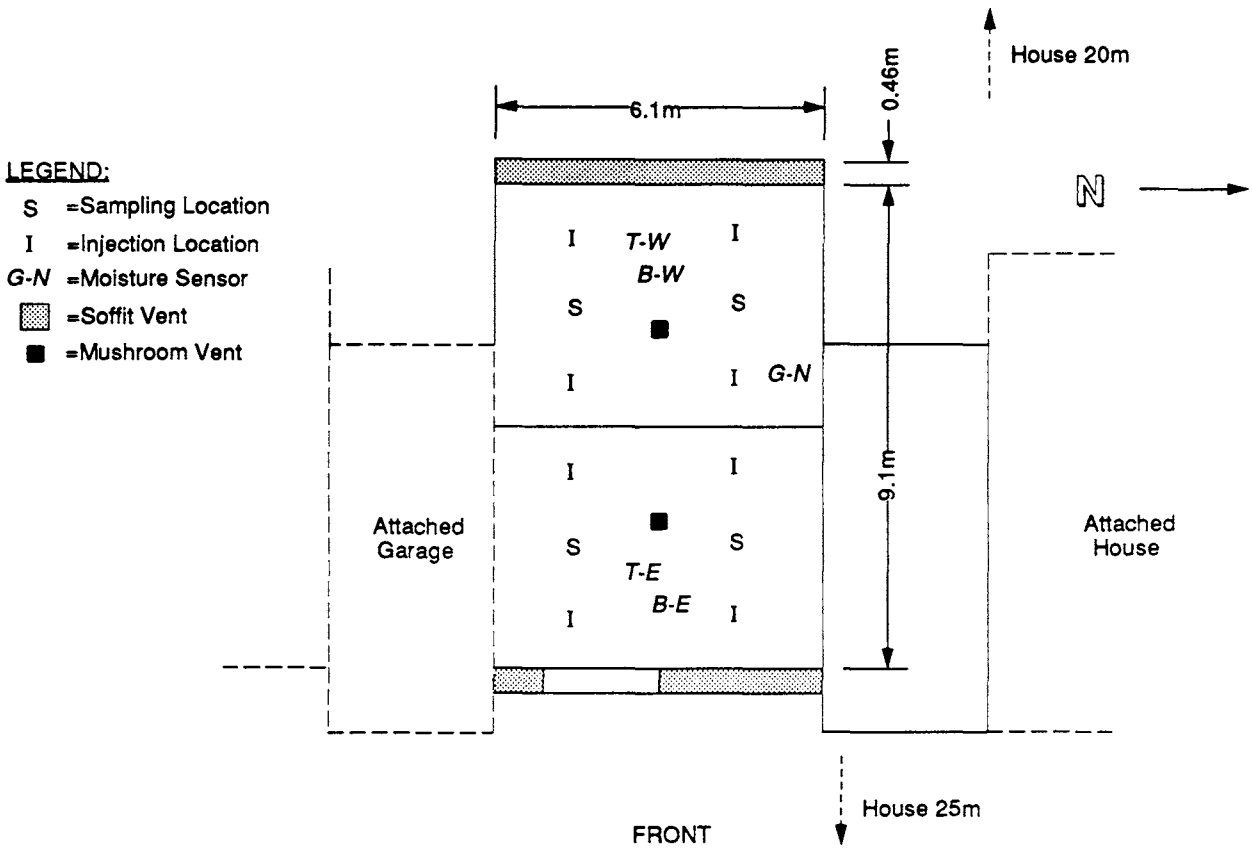


Relative Humidity and Average Lumber Moisture Content Curves: House O-11



HOUSE O-12
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	1.75 m	Types:	soffit 2 mushroom
Age:	1972	Volume:	56 m^3	Free venting area (approx.):	2200 cm^2
Type:	2 storey	Ceiling area:	56 m^2		
Roof		Insulation:	RSI 3.3 glass fibre batt		
Type:	gable	Vapour barrier:	none		
Sheathing:	plywood				
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	S-P-F				

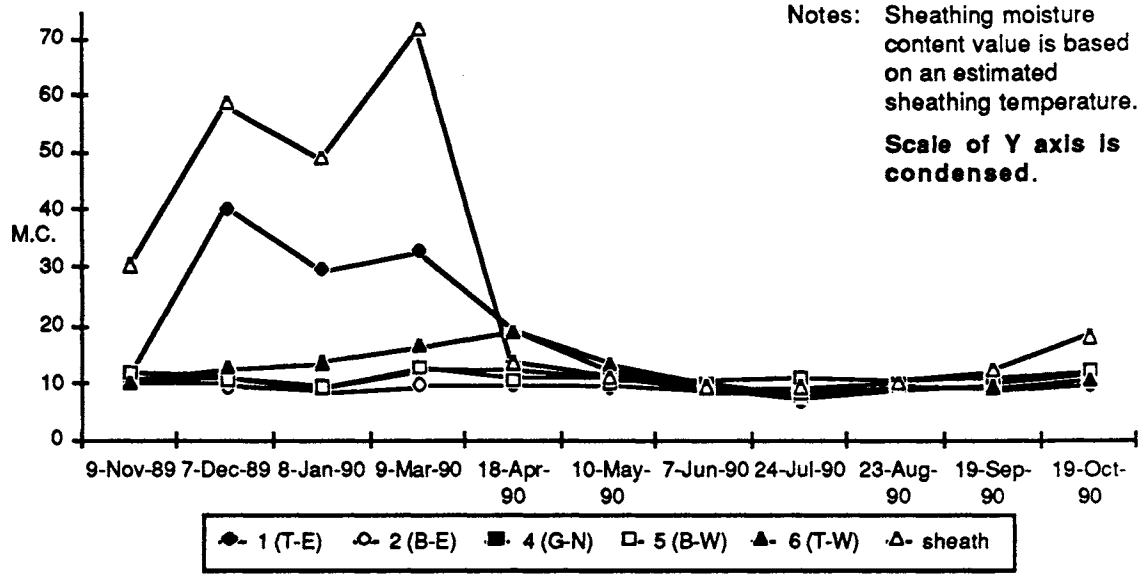
Air Change Data

Test	Date	Average Wind Speed (kph)	Wind Direction	Outside Temp (T_o) (°C)	Attic Temp (T_a) (°C)	House Temp (°C)	Attic Air Change (ACH	L/s)	Average Interface Leakage (L/s)
1	15-Jan-90	11	NNE	-11	2	18	3.7	58	N/A
2	17-Jan-90	12	ENE	-1	6	18	5	78	N/A
3	24-Jul-90	8	SSW	27	47	21	2.8	44	N/A
4	25-Jul-90	11	W	20	29	20	1.9	30	N/A
5	9-Mar-90	5	ENE	4	12	20	3.2	50	13.4
6	30-Jul-90	22	S	31	41	20	6.2	97	7.3

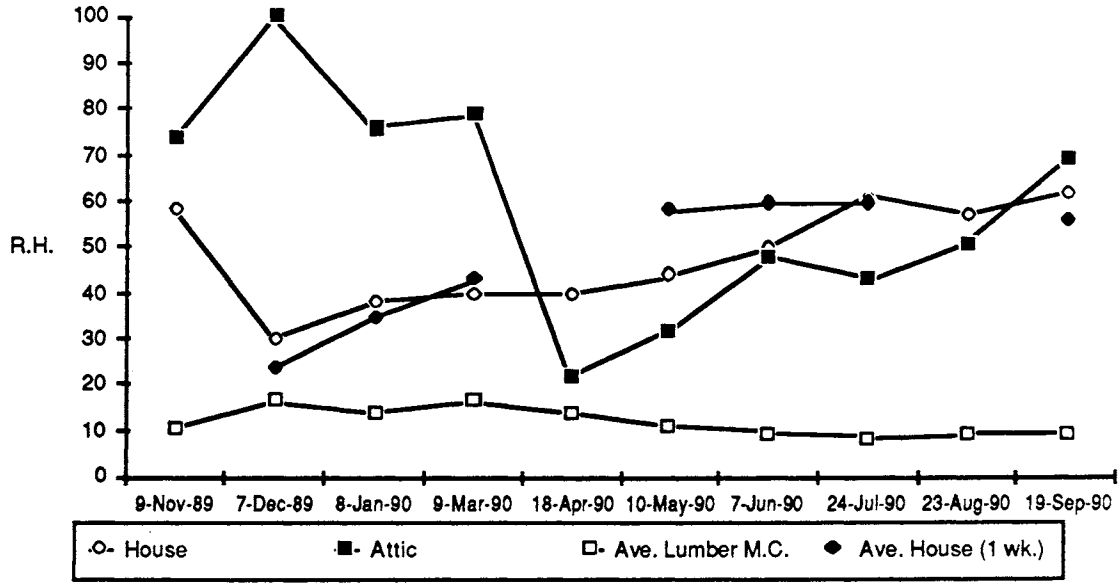
Attic Air Tightness Data

Wind Speed During Test kph	Attic Ventilation ELA cm^2	Interface ELA cm^2
28	2400	-

Moisture Curves: House O-12

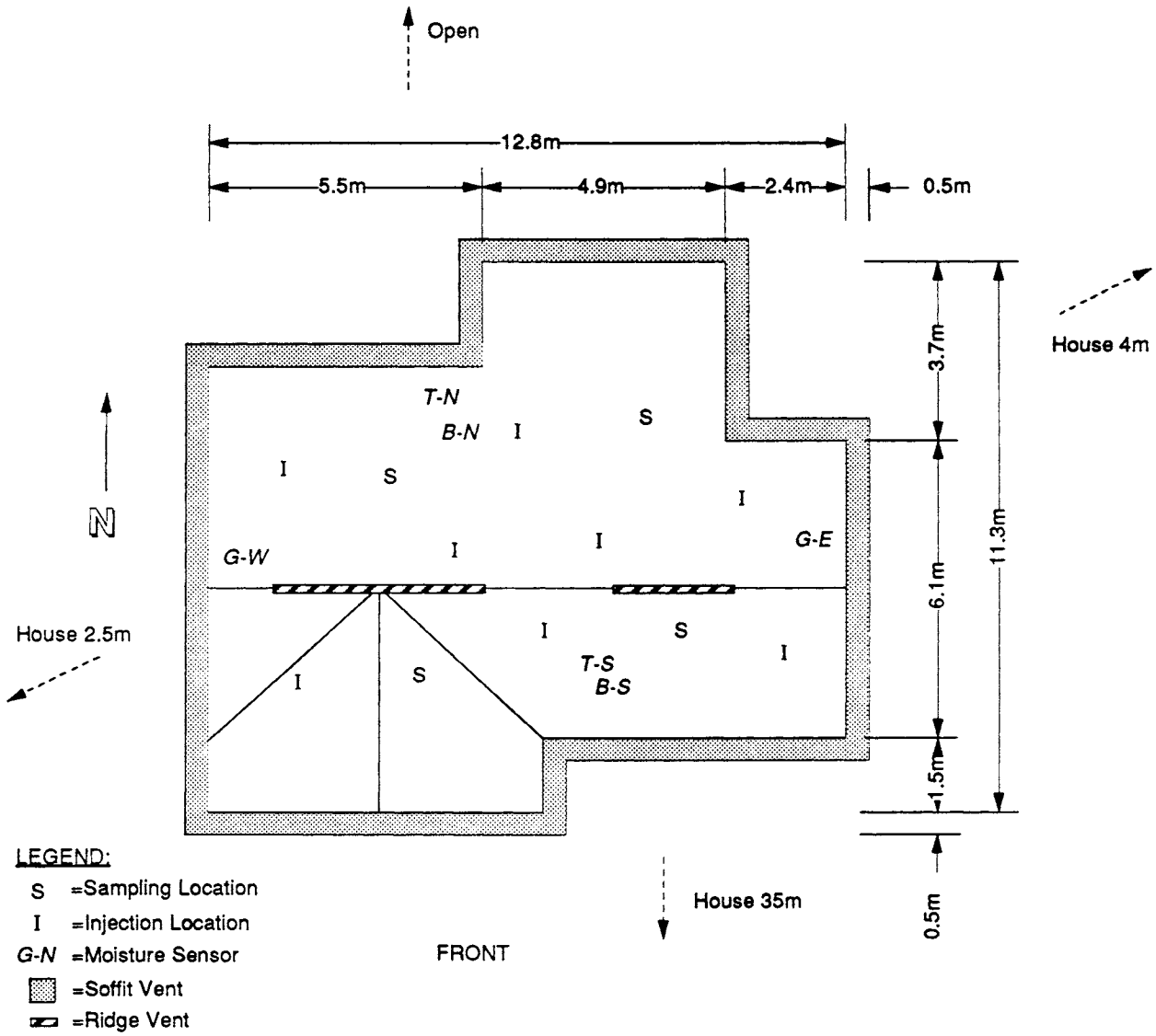


Relative Humidity and Average Lumber Moisture Content Curves: House O-12



HOUSE O-13
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	1.9 m	Types:	soffit ridge
Age:	1985	Volume:	116 m^3	Free venting area (approx.):	8500 cm^2
Type:	2 storeys	Ceiling area:	114 m^2		
Roof		Insulation:	RSI 7.0 glass fibre batt		
Type:	hip	Vapour barrier:	yes		
Sheathing:	plywood				
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	S-P-F				

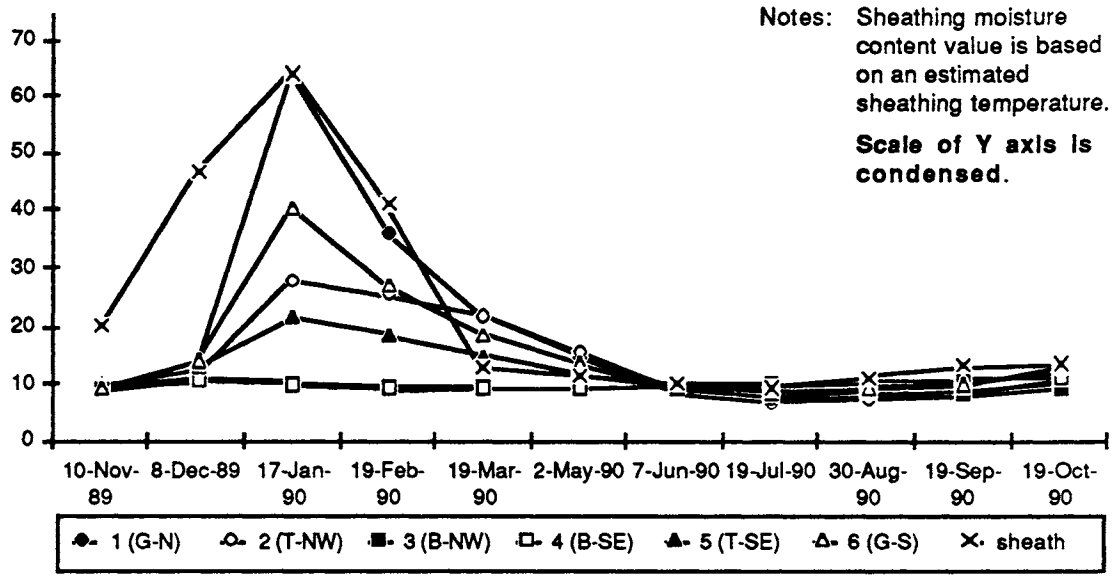
Air Change Data

Test	Date	Average Wind Speed (kph)	Wind Direction	Outside Temp (T_O) (°C)	Attic Temp (T_a) (°C)	House Temp (°C)	Attic Air Change (ACH)	Average Interface Leakage (L/s)
1	19-Feb-90	37	W	-3	1	18	12.6	N/A
2	19-Jul-90	24	WSW	27	36	24	11.4	N/A

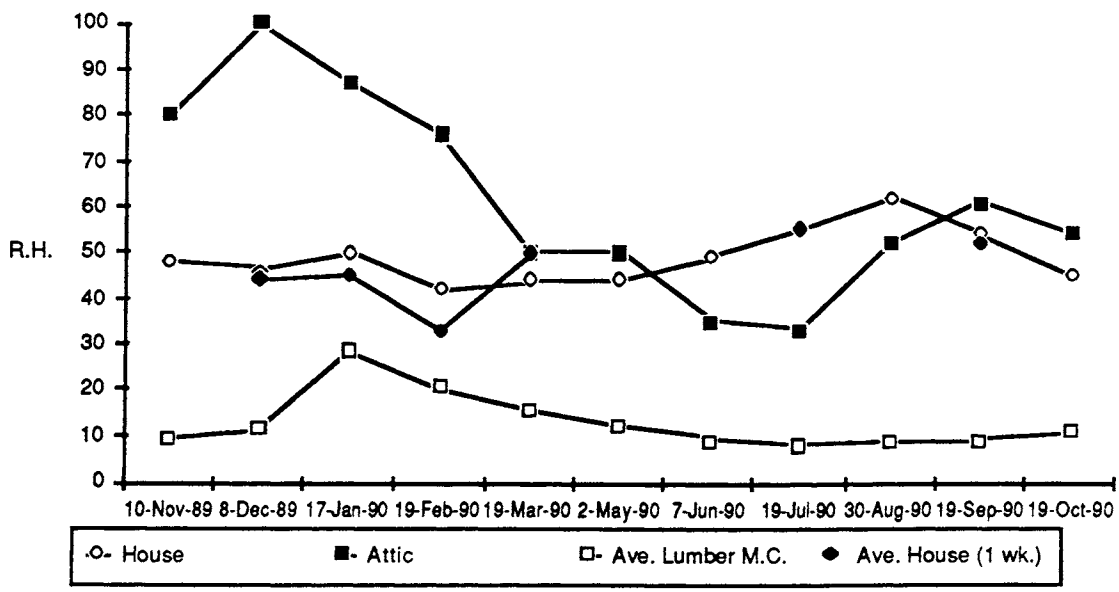
Attic Air Tightness Data

Wind Speed During Test kph	Attic Ventilation ELA cm^2	Interface ELA cm^2
8	2900	400

Moisture Curves: House O-13

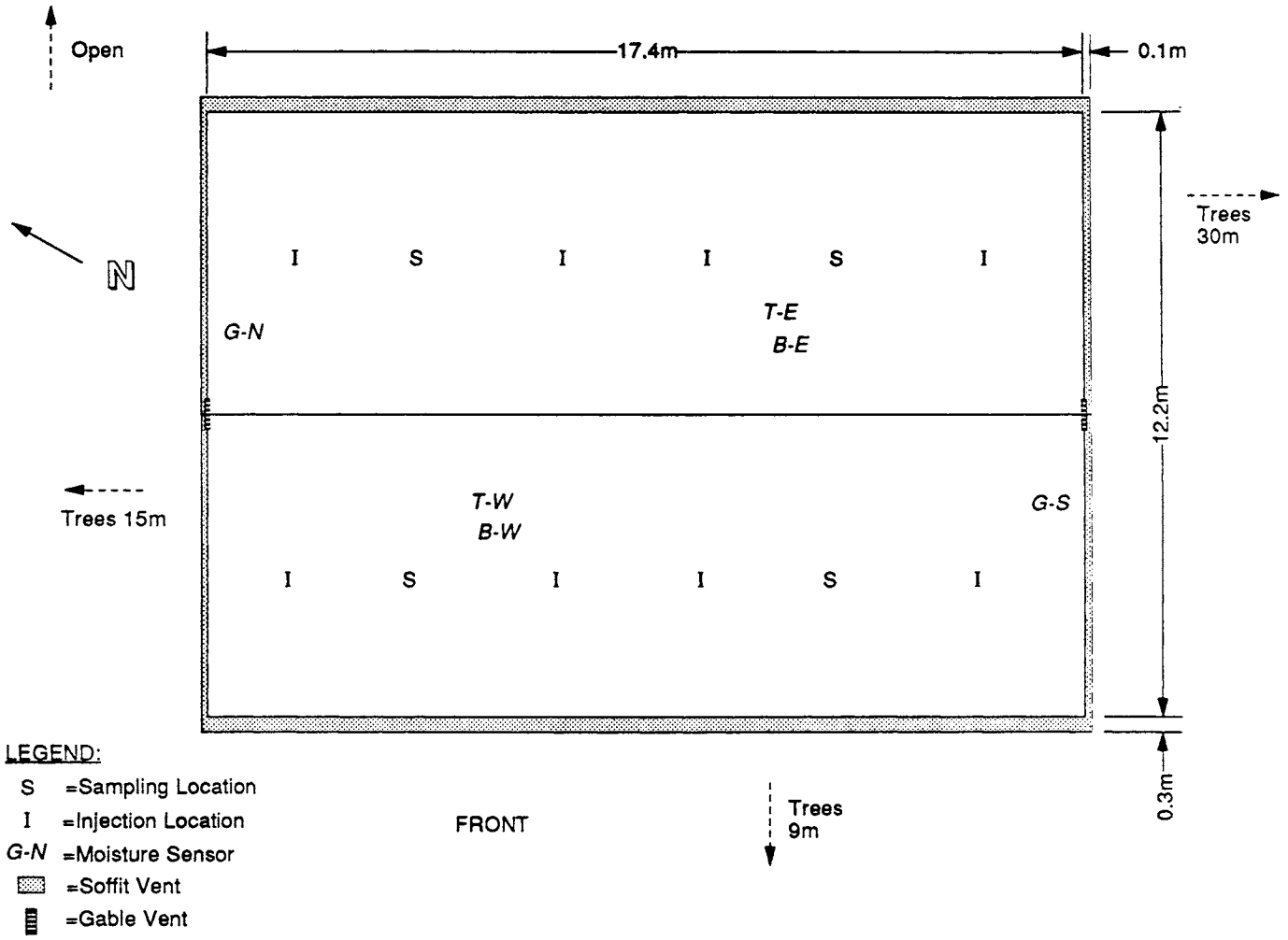


Relative Humidity and Average Lumber Moisture Content Curves: House O-13



HOUSE O-14
HOUSE CHARACTERISTICS

Site Plan



LEGEND:

S =Sampling Location

I =Injection Location

G-N =Moisture Sensor

=Soffit Vent

=Gable Vent

House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	2.2 m	Types:	soffit gable
Age:	1987	Volume:	237 m^3	Free venting area (approx.):	7000 cm^2
Type:	1 storey	Ceiling area:	212 m^2	**Further Relevant Information**	
Roof		Insulation:	RSI 7.0 blown cellulose fibre		Building built to the R-2000 Specifications
Type:	gable	Vapour barrier:	yes		
Sheathing:	waferboard				
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	S-P-F				

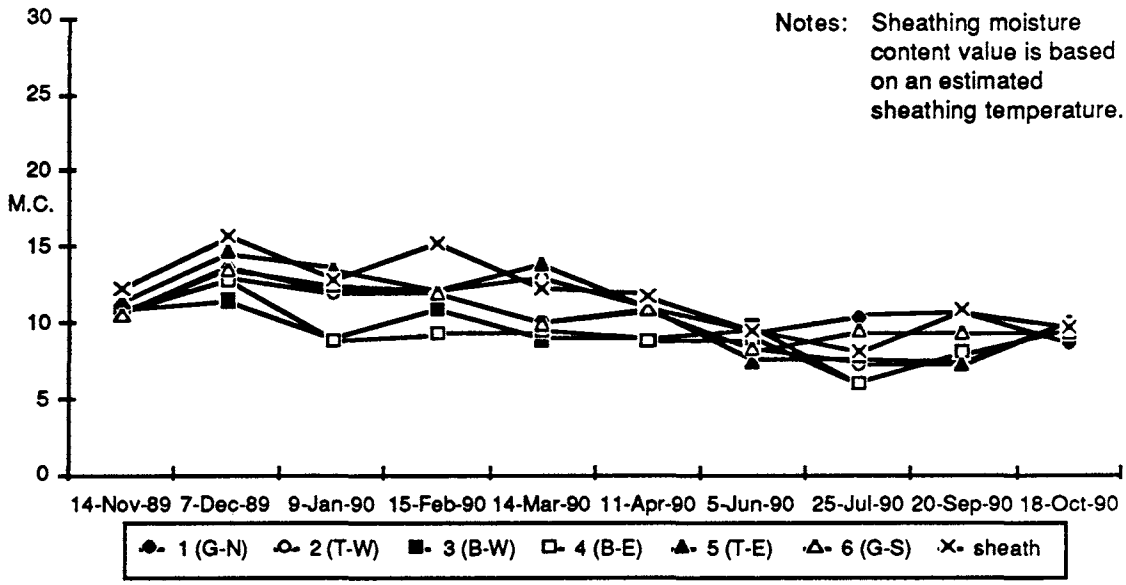
Air Change Data

Test	Date	Average Wind Speed (kph)	Wind Direction	Outside Temp (T_o) (°C)	Attic Temp (T_a) (°C)	House Temp (°C)	Attic Air Change (ACH)	Average Interface Leakage (L/s)
1	15-Feb-90	26	NE	-7	-5	15	2.2	N/A
2	25-Jul-90	13	W	30	50	20	1.9	N/A

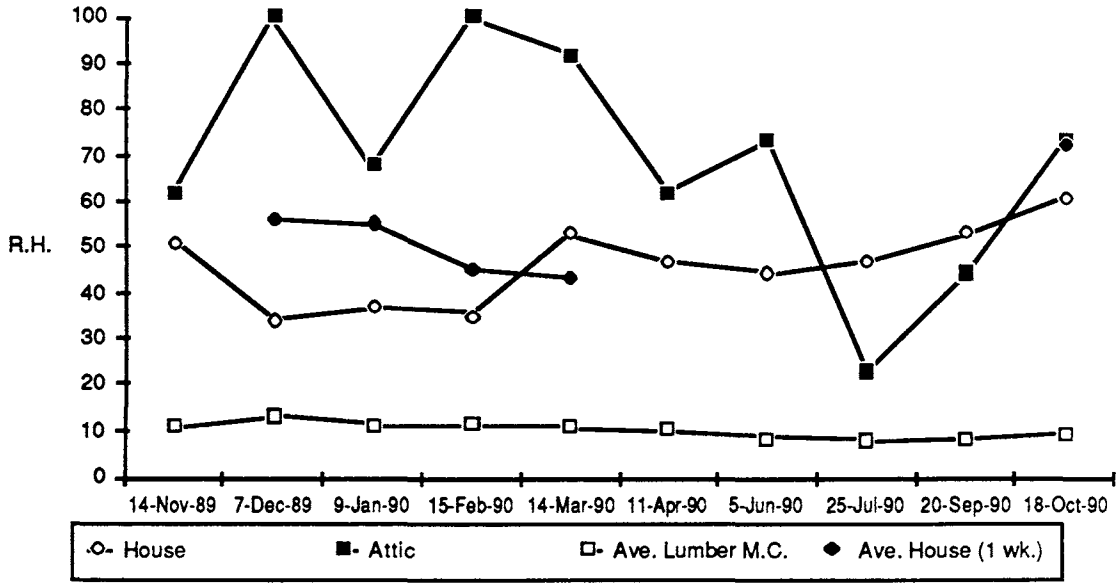
Attic Air Tightness Data

Wind Speed During Test kph	Attic Ventilation ELA cm^2	Interface ELA cm^2
15	5700	20

Moisture Curves: House O-14

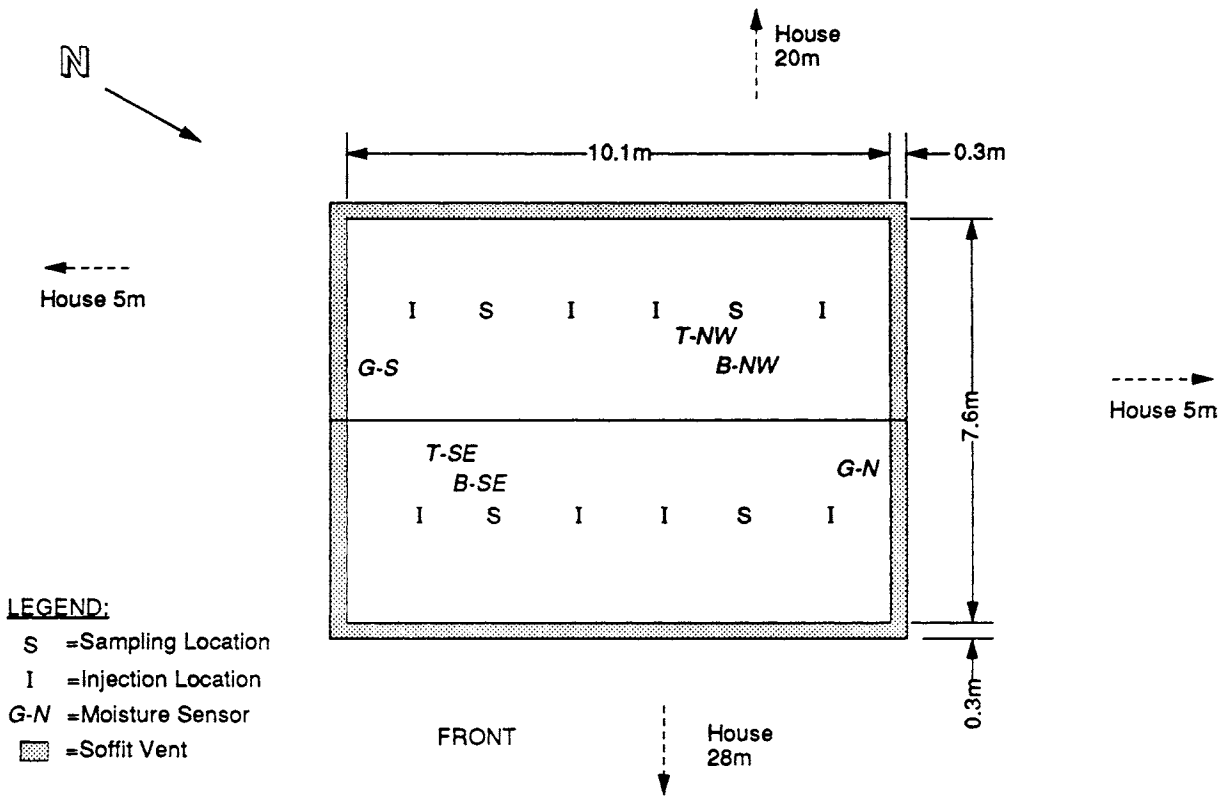


Relative Humidity and Average Lumber Moisture Content Curves: House O-14



HOUSE O-15
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Ottawa	Ceiling to ridge height:	1.5 m	Types:	soffit
Age:	1968	Volume:	63 m^3	Free venting area (approx.):	3600 cm^2
Type:	2 storeys	Ceiling area:	77 m^2		
Roof		Insulation:	RSI 3.3 glass fibre batt		
Type:	gable	Vapour barrier:	yes		
Sheathing:	plywood				
Exterior finish:	asphalt shingles				
Sheathing species:	CSP				
Lumber species:	S-P-F				

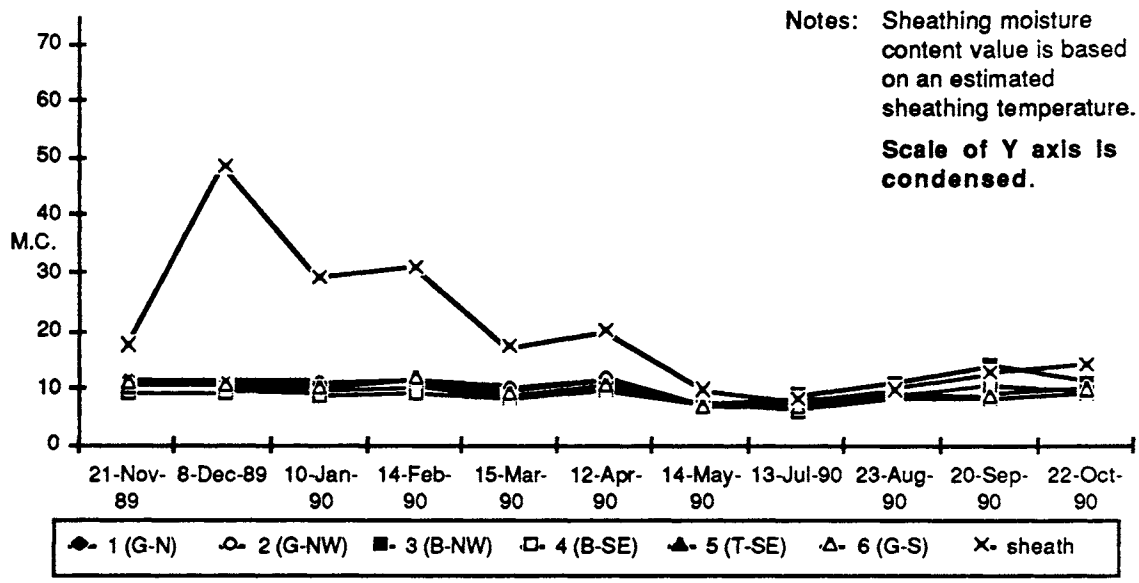
Air Change Data

Test	*Date*	*Average Wind Speed (kph)*	*Wind Direction*	*Outside Temp (T_o) (°C)*	*Attic Temp (T_a) (°C)*	*House Temp (°C)*	*Attic Air Change (ACH)*	*Average Interface Leakage (L/s)*
1	19-Jan-90	20	W	-10	-3	17	13.4	N/A
2	14-May-90	7	NNW-SW	17	39	20	7.2	N/A

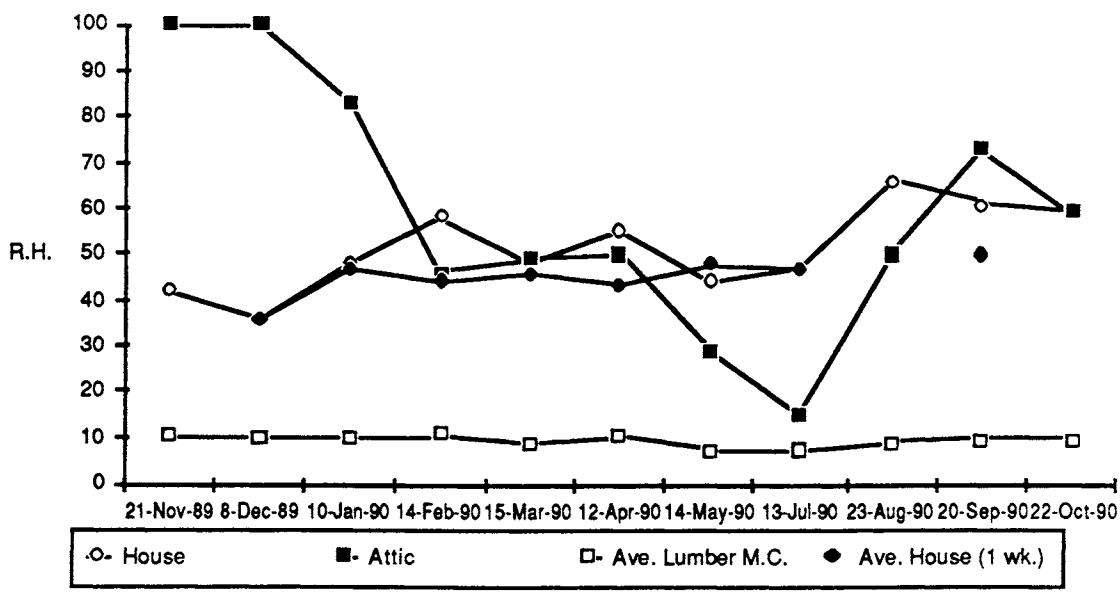
Attic Air Tightness Data

Wind Speed During Test kph	*Attic Ventilation ELA cm^2*	*Interface ELA cm^2*
11	5500	220

Moisture Curves: House O-15

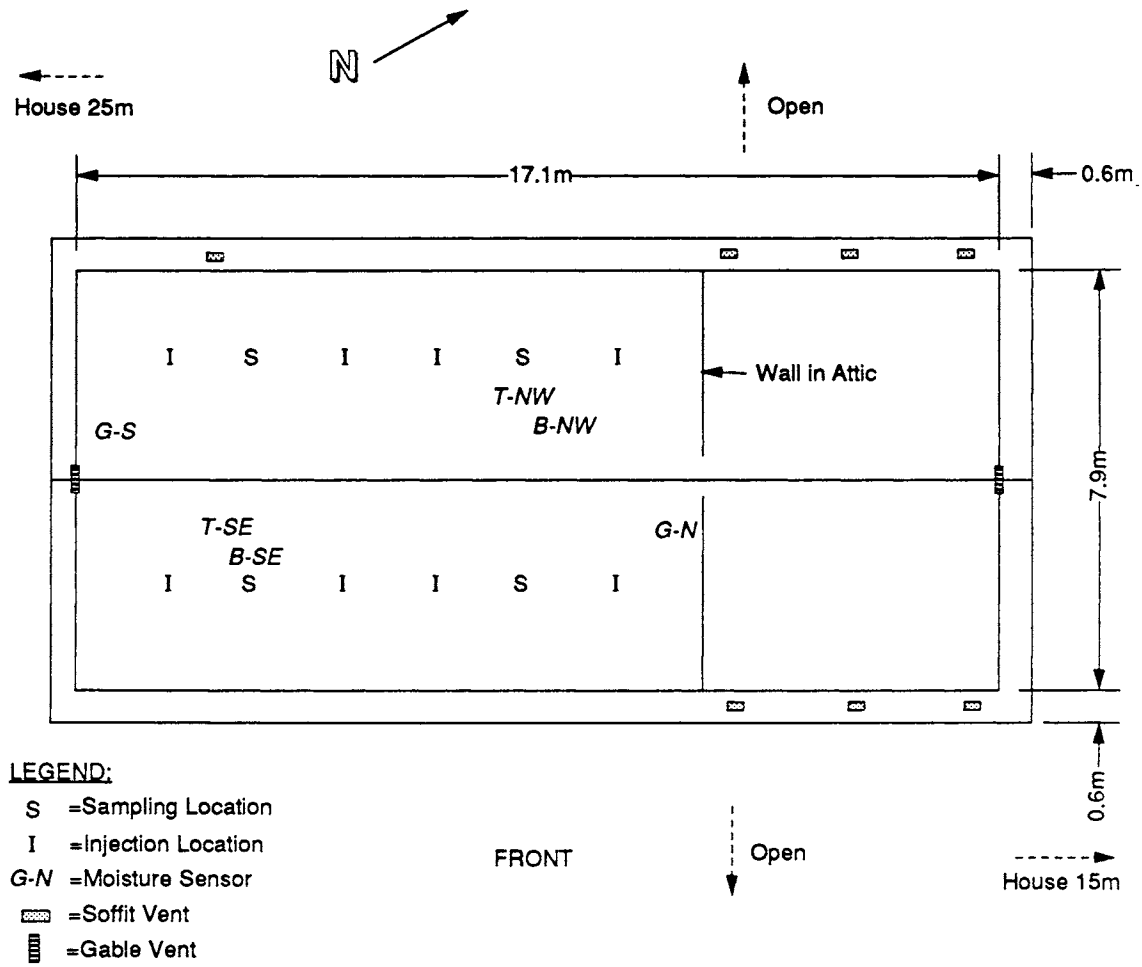


Relative Humidity and Average Lumber Moisture Content Curves: House O-15



HOUSE M-1
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Charlottetown	Ceiling to ridge height:	1.4 m	Types:	soffit gable
Age:	1971	Volume:	124 m^3	Free venting area (actual.):	1400 cm^2
Type:	1 storey	Ceiling area:	157 m^2		
Roof		Insulation:	RSI 5.0 blown cellulose fibre		
Type:	gable	Vapour barrier:	4 mil poly		
Sheathing:	tongue & groove				
Exterior finish:	asphalt shingles				
Sheathing species:	spruce				
Lumber species:	spruce				

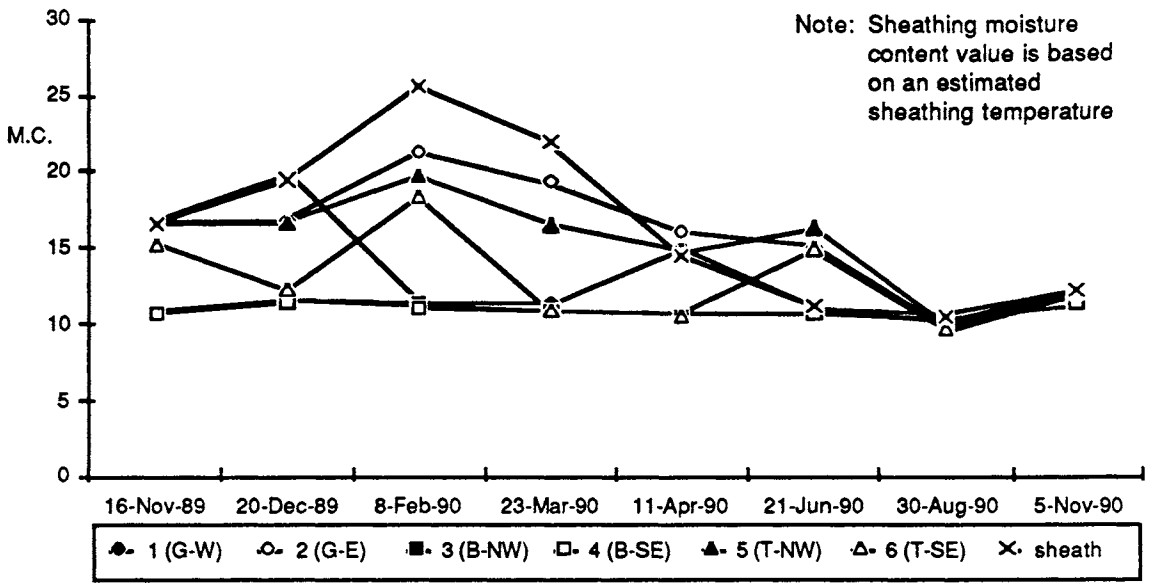
Air Change Data

Test	*Date*	*Average Wind Speed (kph)*	*Wind Direction*	*Outside Temp (T_o) (°C)*	*Attic Temp (T_a) (°C)*	*House Temp (°C)*	*Attic Air Change (ACH)*	*Average Interface Leakage (L/s)*
1	8-Feb-90	15	ENE	-5	9	18	2.2	N/A
2	17-Jun-90	17	SSW	25	28	18	1.2	N/A

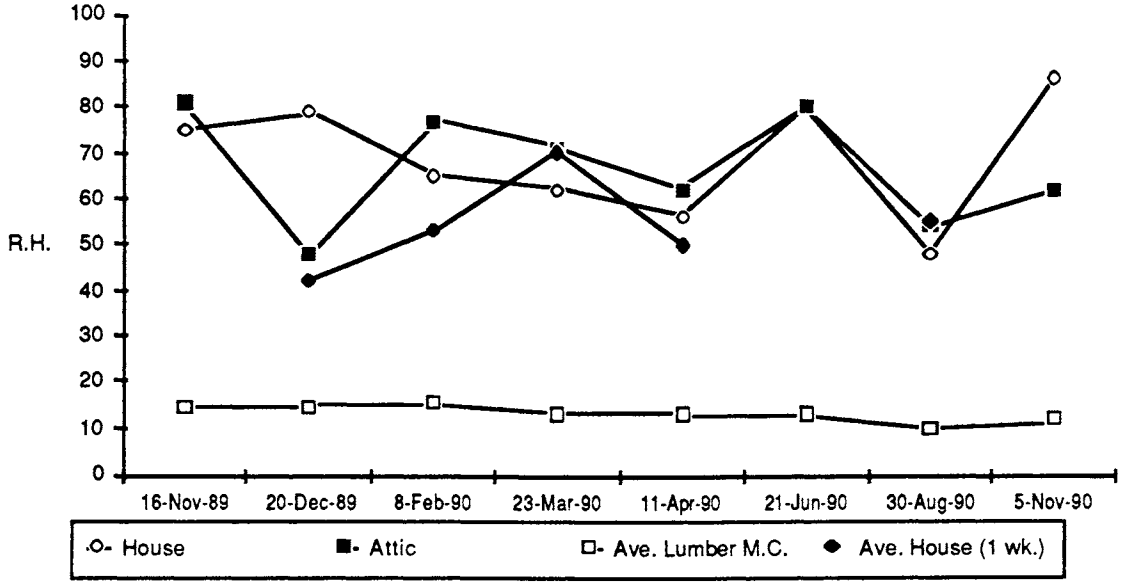
Attic Air Tightness Data

Wind Speed During Test kph	*Attic Ventilation ELA cm^2*	*Interface ELA cm^2*
25	1900	330

Moisture Curves: House M-1

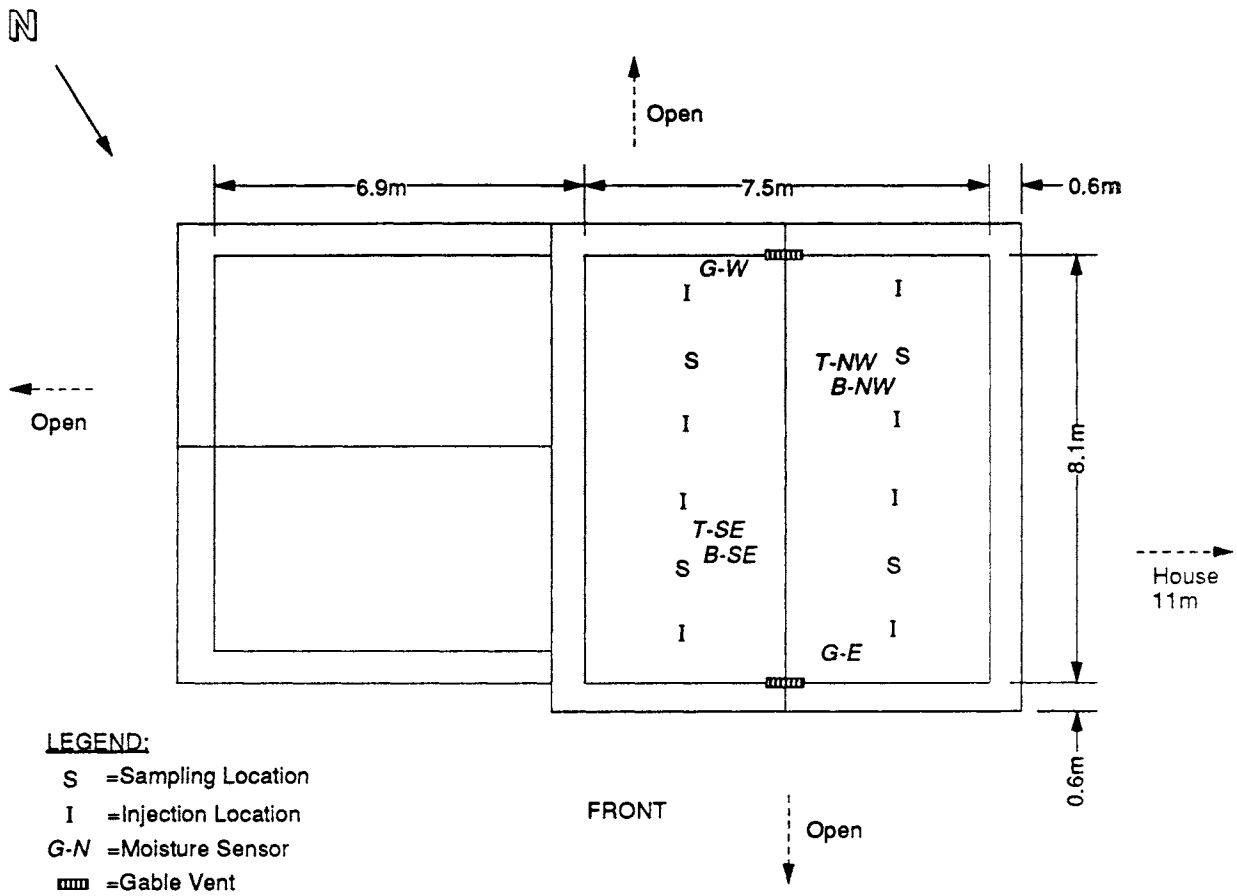


Relative Humidity and Average Lumber Moisture Content Curves: House M-1



HOUSE M-2
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Charlottetown	Ceiling to ridge height:	1.6 m	Types:	gable
Age:	1979	Volume:	57 m^3	Free venting area (actual.):	570 cm^2
Type:	split level	Ceiling area:	60 m^2		
Roof		Insulation:	RSI 5.0 glass fibre batts		
Type:	gable	Vapour barrier:	yes		
Sheathing:	plywood				
Exterior finish:	asphalt shingles				
Sheathing species:	fir				
Lumber species:	spruce				

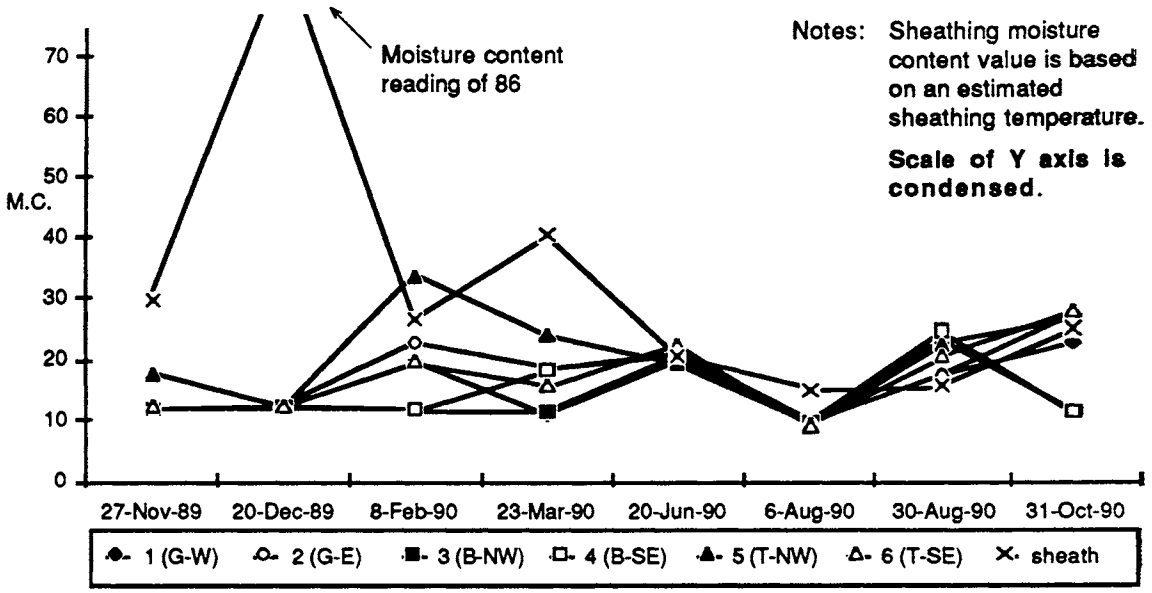
Air Change Data

Test	Date	Average Wind Speed (kph)	Wind Direction	Outside Temp (T_o) (°C)	Attic Temp (T_a) (°C)	House Temp (°C)	Attic Air Change (ACH)	Average Interface Leakage (L/s)
1	8-Feb-90	18	NW	-2	12	19	2.6	N/A
2	20-Jun-90	9	N	15	17	21	2.4	N/A

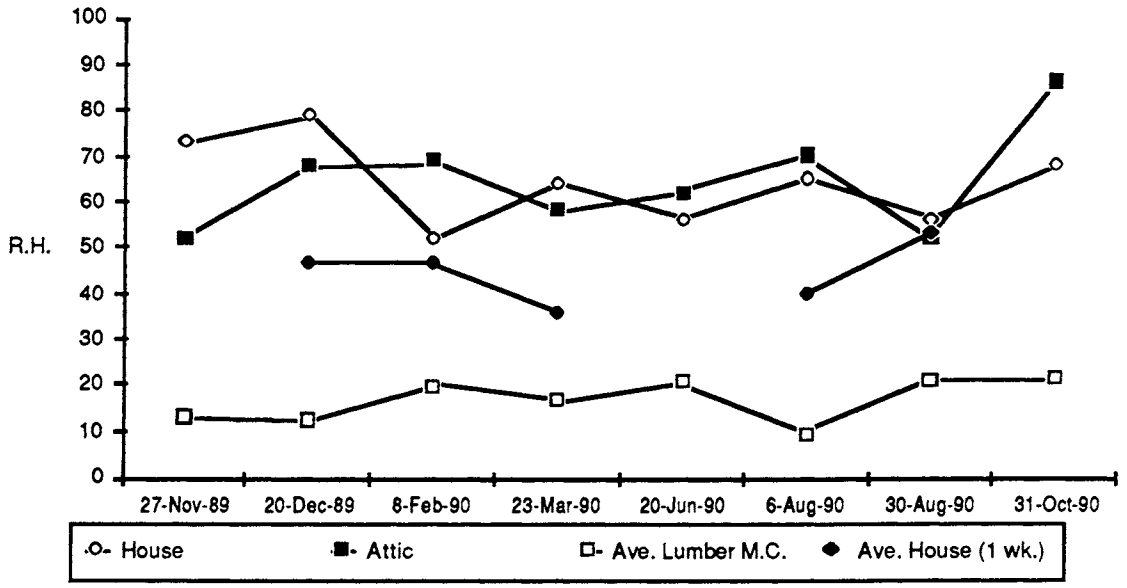
Attic Air Tightness Data

Wind Speed During Test kph	Attic Ventilation ELA cm^2	Interface ELA cm^2
10	820	280

Moisture Curves: House M-2

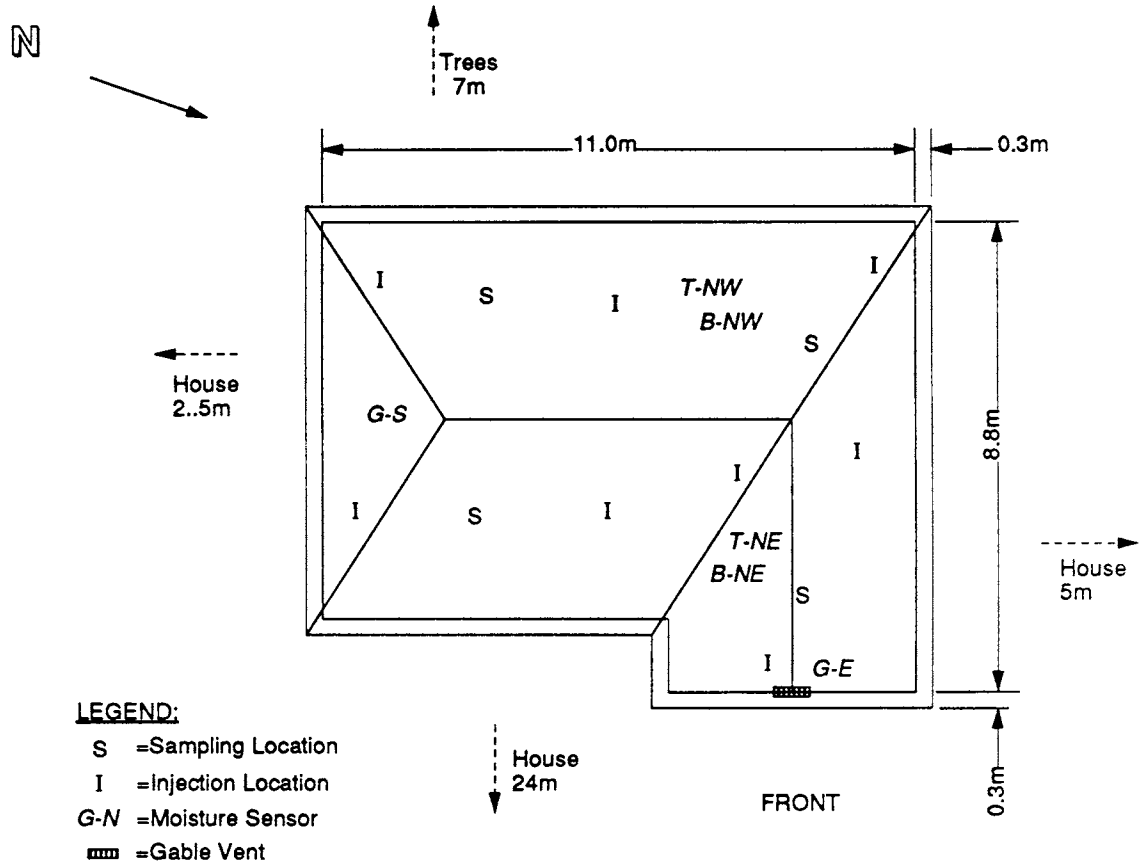


Relative Humidity and Average Lumber Moisture Content Curves: House M-2



HOUSE M-3
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Charlottetown	Ceiling to ridge height:	2.0 m	Types:	gable
Age:	1956	Volume:	85 m^3	Free venting area (actual):	320 cm^2
Type:	1 storey	Interface area:	97 m^2		
Roof		Insulation:	RSI 4.0 rock wool loose fill		
Type:	gable & hip (L-shaped)	Vapour barrier:	none		
Sheathing:	plank				
Exterior finish:	asphalt shingles				
Sheathing species:	spruce				
Lumber species:	spruce				

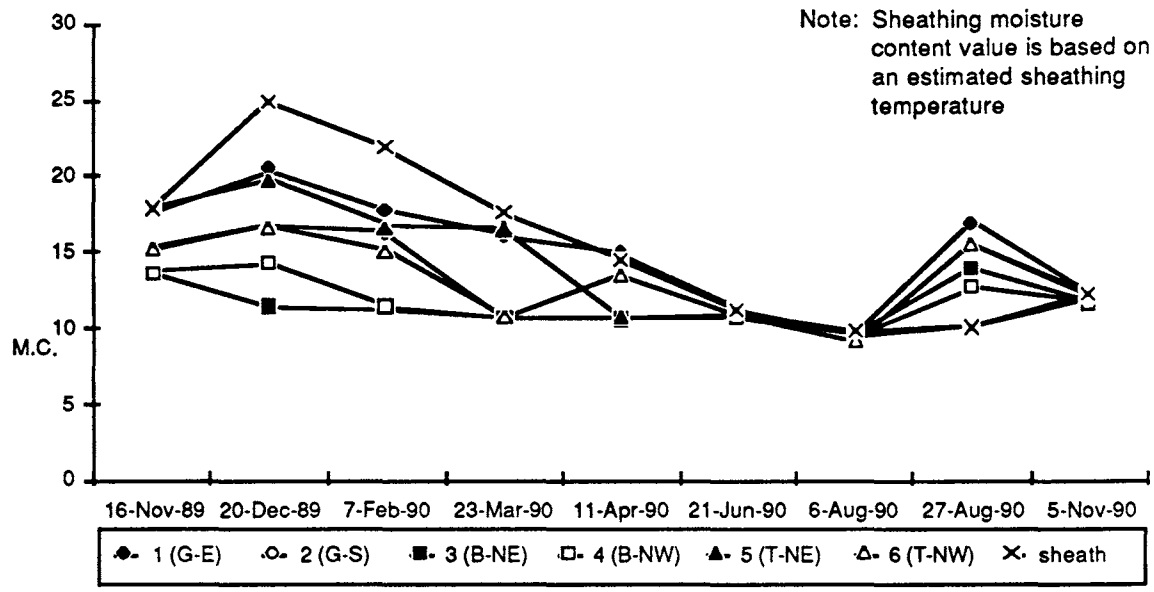
Air Change Data

Test	*Date*	*Average Wind Speed (kph)*	*Wind Direction*	*Outside Temp (T_O) (°C)*	*Attic Temp (T_a) (°C)*	*House Temp (°C)*	*Attic Air Change (ACH)*	*Average Interface Leakage (L/s)*
1	7-Feb-90	22	SSW	-7	7	18	6.2	N/A
2	21-Jun-90	11	N	14	16	20	1.9	N/A

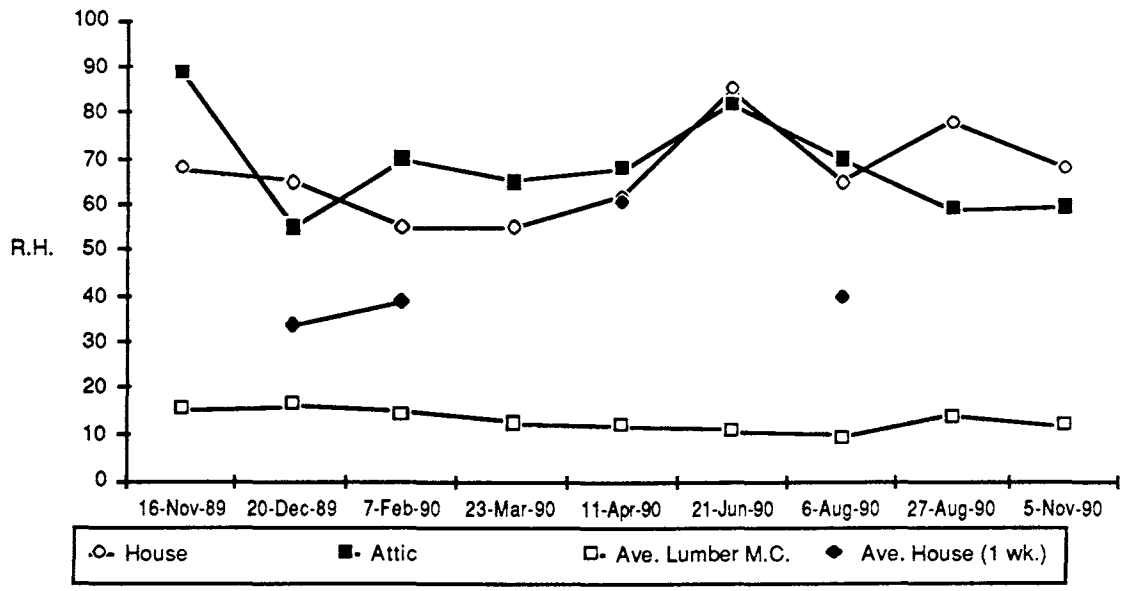
Attic Air Tightness Data

Wind Speed During Test kph	*Attic Ventilation ELA cm^2*	*Interface ELA cm^2*
13	2100	400

Moisture Curves: House M-3

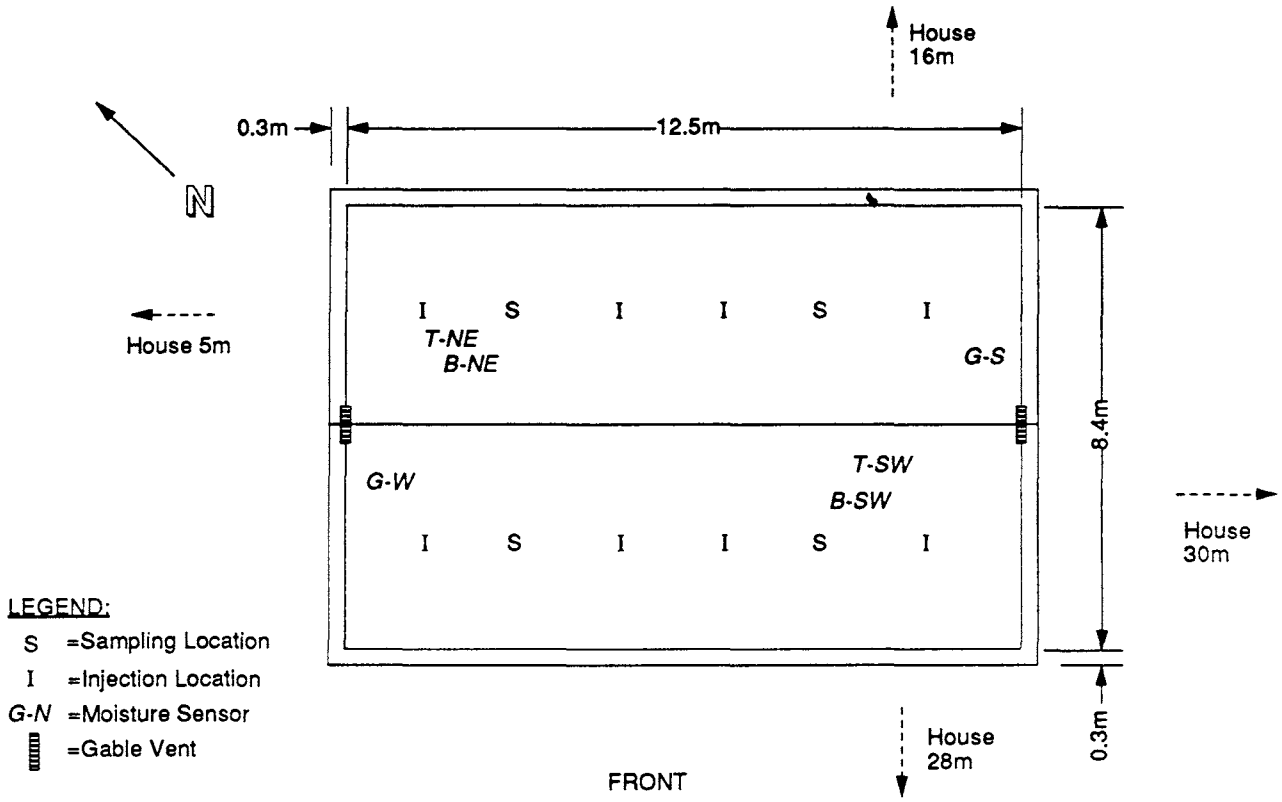


Relative Humidity and Average Lumber Moisture Content Curves: House M-3



HOUSE M-4
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Charlottetown	Ceiling to ridge height:	1.5 m	Types:	gable
Age:	1964	Volume:	113 m^3	Free venting area (actual):	1000 cm^2
Type:	1 storey	Ceiling area:	136 m^2		
Roof		Insulation:	RSI 3.0 rock wool loose fill		
Type:	gable	Vapour barrier:	4 mil poly		
Sheathing:	plank				
Exterior finish:	asphalt shingles				
Sheathing species:	spruce				
Lumber species:	spruce				

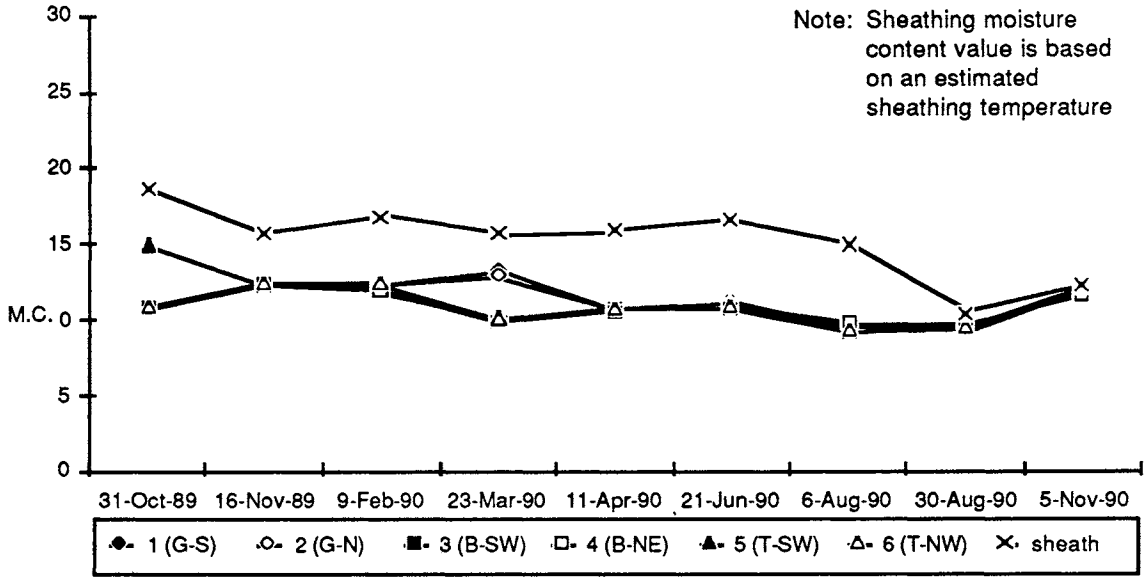
Air Change Data

Test	Date	Average Wind Speed (kph)	Wind Direction	Outside Temp (T_O) (°C)	Attic Temp (T_a) (°C)	House Temp (°C)	Attic Air Change (ACH)	Average Interface Leakage (L/s)
1	9-Feb-90	22	S	1	1	19	6.7	N/A
2	17-Jun-90	15	S	24	33	18	2.1	N/A

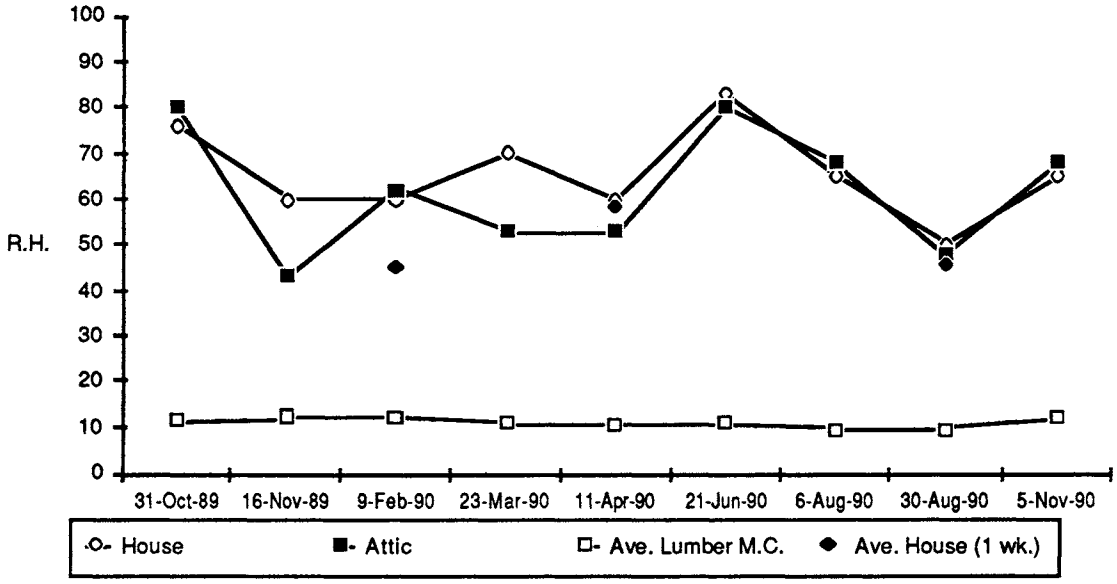
Attic Air Tightness Data

Wind Speed During Test kph	Attic Ventilation ELA cm^2	Interface ELA cm^2
13	3100	380

Moisture Curves: House M-4

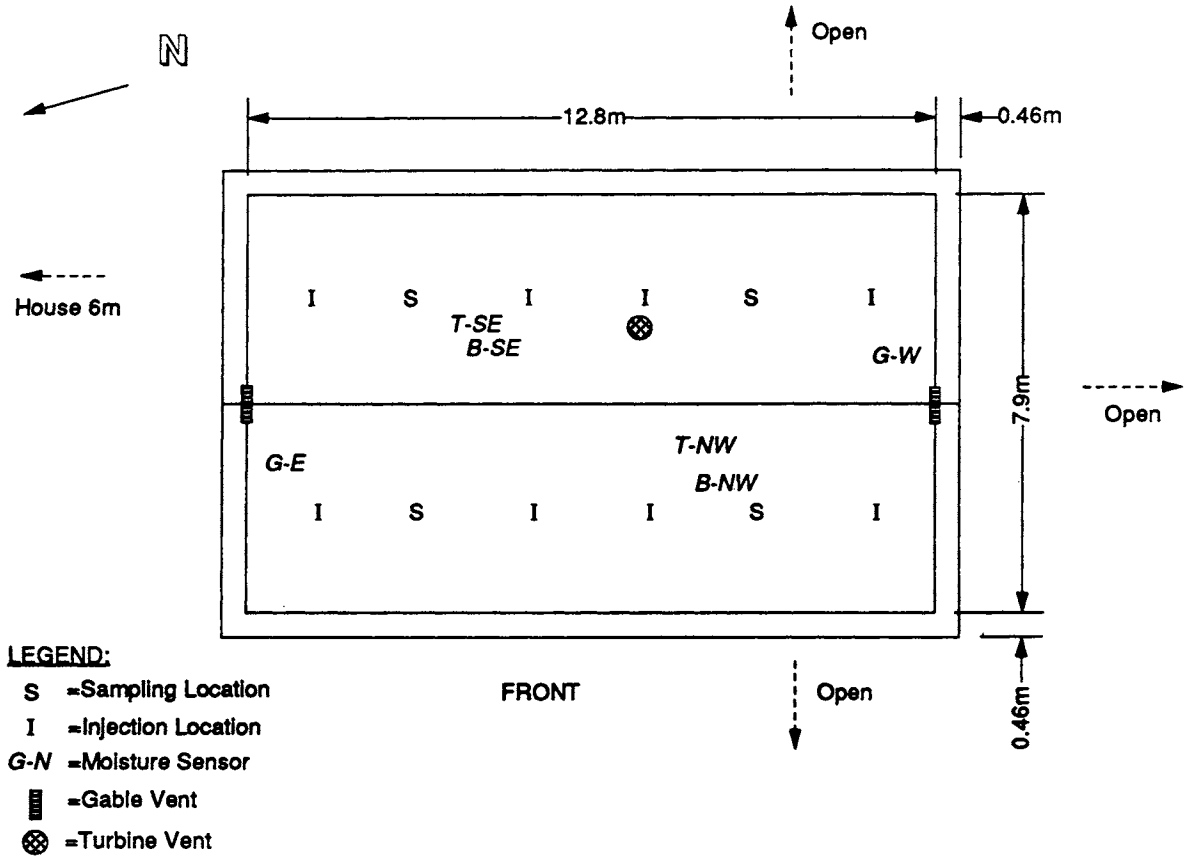


Relative Humidity and Average Lumber Moisture Content Curves: House M-4



HOUSE M-5
HOUSE CHARACTERISTICS

Site Plan



House Data

General		Attic		Venting	
Location:	Charlottetown	Ceiling to ridge height:	1.2 m	Types:	gable turbine
Age:	1975	Volume:	67 m^3	Free venting area (actual):	1600 cm^2
Type:	1 storey	Ceiling area:	101 m^2		
Roof		Insulation:	RSI 3.3 glass fibre batts with RSI 3.0 rock wool loose fill		
Type:	gable				
Sheathing:	plank				
Exterior finish:	asphalt shingles				
Sheathing species:	spruce	Vapour barrier:	4 mil poly		
Lumber species:	spruce				

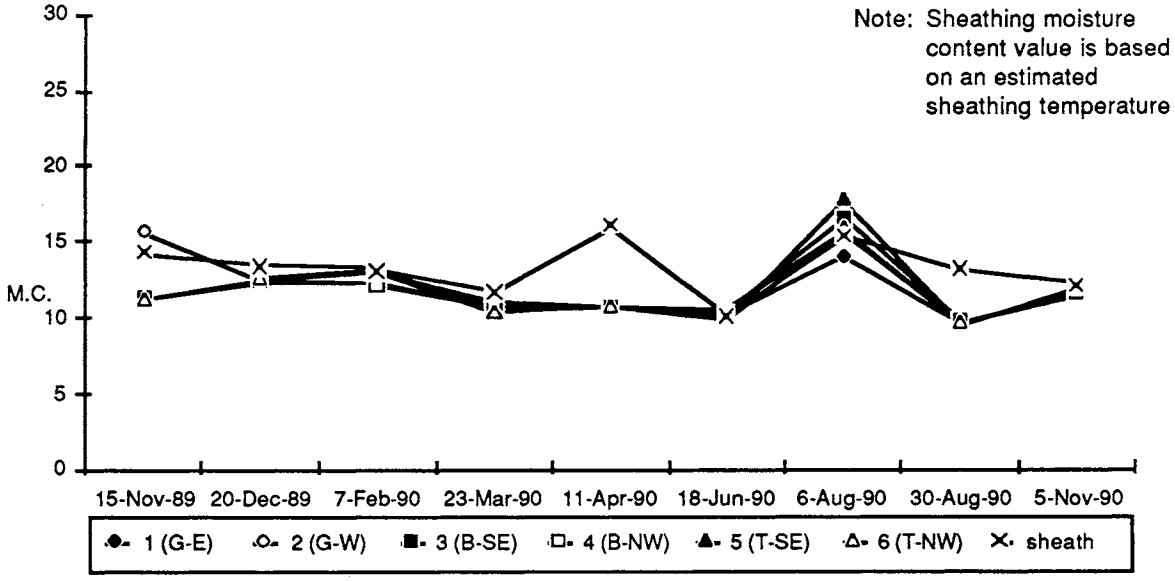
Air Change Data

Test	Date	Average Wind Speed (kph)	Wind Direction	Outside Temp (T_O) (°C)	Attic Temp (T_a) (°C)	House Temp (°C)	Attic Air Change (ACH)	Average Interface Leakage (L/s)
1	7-Feb-90	11	SSW	-7	2	18	9.5	N/A
2	18-Jun-90	28	SW	20	27	18	23	N/A

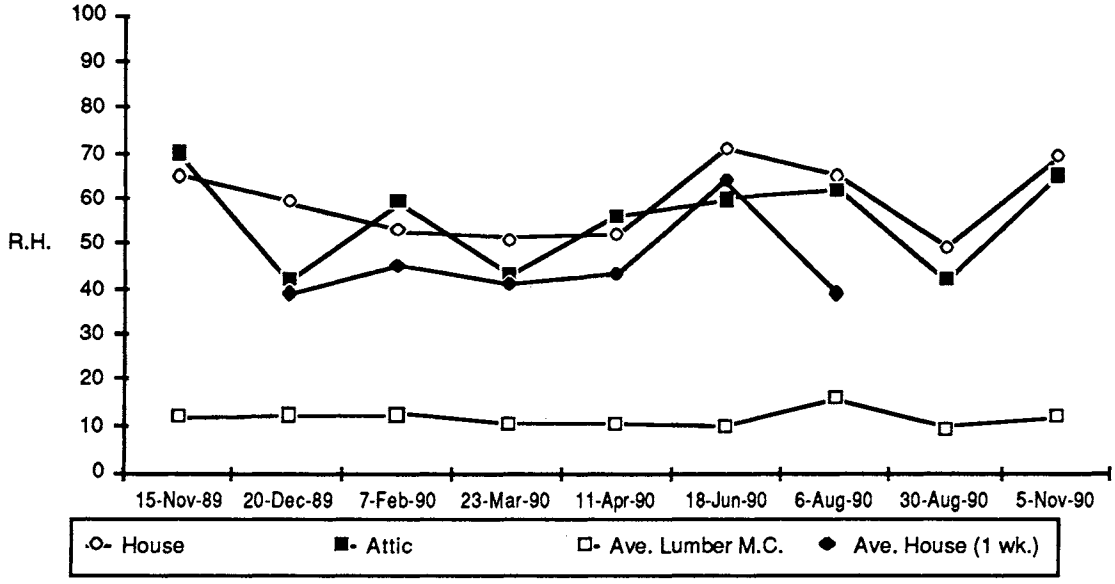
Attic Air Tightness Data

Wind Speed During Test kph	Attic Ventilation ELA cm^2	Interface ELA cm^2
25	1600	460

Moisture Curves: House M-5



Relative Humidity and Average Lumber Moisture Content Curves: House M-5



Appendix C

FOREST PRODUCTS LABORATORY DETAILED MODEL INPUTS

BUILDING DATA

Building length	[ft]
Building width	[ft]
Grade to ceiling height	[ft]
Roof overhang	[ft]
Roof pitch	[rise/run]
Interface flow/house exfiltration	[h^{-1}]
Windshade factor	[0-1]
Absorptivity	(0.9)
House air change rate	[ach]
R ceiling	[h.ft sq F/BTU]
R end walls	[h.ft sq F/BTU]
R roof	[h.ft sq F/BTU]
House temperature	[R]
RH house	[%]
Sheathing M.C. "A"	[%]
Sheathing M.C. "B"	[%]
Attic exhaust fan rate	[cfm]
Attic air change	[ach]
Vent area/ceiling area	[ft^2]

FILE FORMATS

All input files ASCII format. Records 24 numbers, comma separated. Records delimited by a CR/LF sequence. No file name convention required.