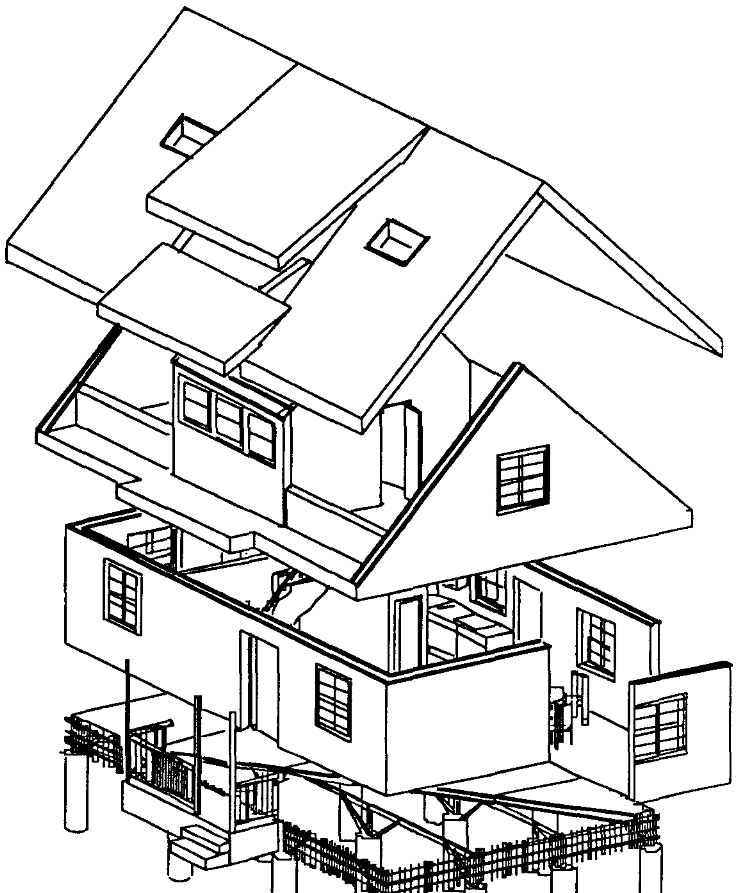
Stressed Skin Insulating Core Panel Demonstration House Thermal Testing Report



University of Oregon

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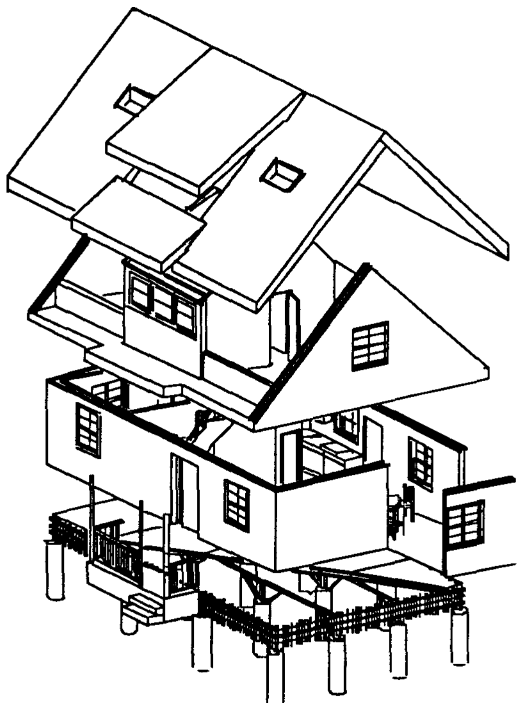

Energy Studies in Buildings Laboratory
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1.0 EXECUTIVE SUMMARY

A series of building diagnostic tests was performed on a Stressed Skin Insulating Core (SSIC) Panel Demonstration House by the Energy Studies in Buildings Laboratory (ESBL) between April and June of 1994. This SSIC Panel Demonstration House, which featured innovations in the use of SSIC Panels, was designed by the ESBL to have an energy performance 40% better than a home conforming to the Oregon Energy Code and to have a lower first cost than an architecturally equivalent conventionally constructed house. The diagnostic testing was conducted to assess the thermal performance of the SSIC Panel Demonstration House compared to design objectives. Results of these tests were also compared to results from diagnostic tests performed by the ESBL on six units of housing utilizing various types of panelized wall construction. In addition, results were compared to the theoretical performance of a reference house of the same architectural design as the SSIC Panel Demonstration House, but built with stick frame construction.

The building diagnostic tests included fan de-pressurization tests and tracer gas tests to determine airtightness and infiltration, smoke leakage tests to identify areas of leakage, coheating tests to determine the building thermal transmittance value (UA) and thermographic imaging to identify areas of heat loss due to conductance and infiltration. A summary of results are provided in Table 1-1.

SSIC Panel House Building Diagnostic Test Results		
Infiltration	Closed (ACH)	Open (ACH)
Fan Pressurization Test, ACH50/N	0.053	0.086
Tracer Gas Test	0.039	0.087
Thermal Transmittance	(Btu / h F)	
Coheating Test	133	
Theoretical UA	155	

Table 1-1
Summary of Building Diagnostic Tests

Building diagnostic tests to establish infiltration and airtightness indicate the SSIC Panel Demonstration House is extremely airtight. Results of the fan de-pressurization tests indicate that the SSIC Panel Demonstration House has an air change rate of 0.053 ACH in the "closed' condition and 0.086 ACH in the "open" condition. Estimates of natural infiltration rates were made using the Lawrence Berkeley Laboratory (LBL) model. "Closed" and "open" refer to whether intentional penetrations through the envelope were sealed or left open, respectively. Intentional penetrations through the envelope include all Fresh Air 80 vents, all dryer inlet and outlet vents, conduit penetrations for the data logger, the Envirovent outlet and the condensate drip for the Envirovent. Results from closed tests are considered to be a better assessment on the quality of construction; whereas, results of open tests are considered to be a better assessment of actual airtightness.

The estimates of natural infiltration rates from the fan de-pressurization test compare well to infiltration rates determined through concentration decay tracer gas tests. Tracer gas results indicate an infiltration rate of 0.039 ACH in closed conditions and 0.087 in open conditions. Results of both the fan de-pressurization test and the tracer gas tests in both open and closed conditions are below the recommended air change rate of .10 ACH specified by the Bonneville Power Administration's (BPA) Super Good Cents (SGC) program for advanced leakage control (SGC, p 4.3, 1991)

Effective Leakage Areas (ELA_4) from the fan de-pressurization results were also compared to a theoretical effective leakage area for the reference house calculated using ASHRAE values. The reference house is of the same architectural design as the SSIC Panel Demonstration House is built with standard frame construction. The effective leakage area of the SSIC Panel Demonstration House was 43% less in open conditions than the theoretical effective leakage area of the reference house (see Figure 4-1).

In addition the ELA of the SSIC Panel Demonstration House was compared to the effective leakage areas of six apartments designed to meet Bonneville Power Administration's Super Good Cents program. These units, referred to as University Housing, were recently tested by the ESBL. The University Housing units featured manufactured panel walls including one unit constructed of SSIC panels, two units constructed of open panels and three units constructed of closed panels. When compared to the University Housing Units, the SSIC Panel Demonstration House had an ACH_{50} that was 80% less than the average ACH_{50} for all six University Housing units, Figure 4-3, and an ELA_4 that was 81% less than the average ELA_4 for the six University Housing units, Figure 4-4. Even when ELA_4 was normalized by crack length of windows and doors and joint length of panels to account for differences in design, the normalized ELA_4 of the SSIC Panel Demonstration House was 75% less than the averaged normalized ELA_4 of the six University Housing Units, Figure 4-5.

Smoke leakage tests were performed on the SSIC Panel Demonstration House under pressurized conditions. Common areas of leakage included bathroom and kitchen vents, the hinge side of all windows, some electrical outlets and some Envirovent registers. Slight leakage was also detectable between the wall and window frame; and small cracks in the finished wall were detectable in these areas. No leakage was detectable at any panel joint in the walls, floor or ceiling.

Thermographic imaging did not detect any significant areas of heat loss in the Demonstration House. Common areas of conductive losses included panel-to-panel joints, panel-to-floor joints, panel-to-ceiling joints, headers above windows and doors, electrical outlets, Fresh Air 80 vents, around door openings and door frames, and around window openings and window frames. Possible losses due to infiltration occurred around door and window openings.

Results of the coheating test indicate that the Demonstration House had a measured UA value of 133 Btu/h °F. Heat loss due to infiltration was estimated to be 7.5 Btu/h °F using tracer gas results in closed conditions; consequently the measured UA value less infiltration was 125.5 Btu/h °F. The measured UA value - infiltration was 19% lower than the theoretical UA value and 22% lower than the theoretical UA value of the reference house. In addition, results of coheating tests were compared to results of the coheating tests performed on the University Housing apartments. Coheating results were normalized by dividing UA less infiltration by surface area. Because the University Housing apartments were built on slab-on-grade foundations, normalizing by surface area may not reflect the actual U value because heat loss through the slab-on-grade is dependent upon perimeter. Normalized results indicate that the SSIC Panel Demonstration

House performed 40% better than the best performing University Housing apartment and 50% better than the average U value of the University Housing units.

Overall, results of the building diagnostic test performed on the SSIC Panel Demonstration House indicate a high level of thermal performance and air-tightness. The SSIC Panel Demonstration House was confirmed to have an energy performance 40% better than housing meeting the Oregon Energy Code. In addition, diagnostic tests indicate that the SSIC Panel Demonstration House would probably perform better than a reference house of the same architectural design but of frame construction insulated to levels equivalent to the SSIC Panel Demonstration House.

2.0 INTRODUCTION

The University of Oregon, Energy Studies in Buildings Laboratory (ESBL) constructed a Stressed Skin Insulating Core (SSIC) Panel Demonstration House in Springfield, Oregon in 1994. A series of building diagnostic tests were performed by the ESBL between April and June of 1994. The objective of the testing was to assess the thermal performance of the SSIC Panel Demonstration House. Results of the diagnostic tests were compared to results from diagnostic tests performed by the ESBL on six units of housing utilizing panelized wall construction (University Housing). In addition, results were compared to the theoretical performance of a reference house of the same architectural design as the SSIC Panel Demonstration House, but built with stick frame construction.

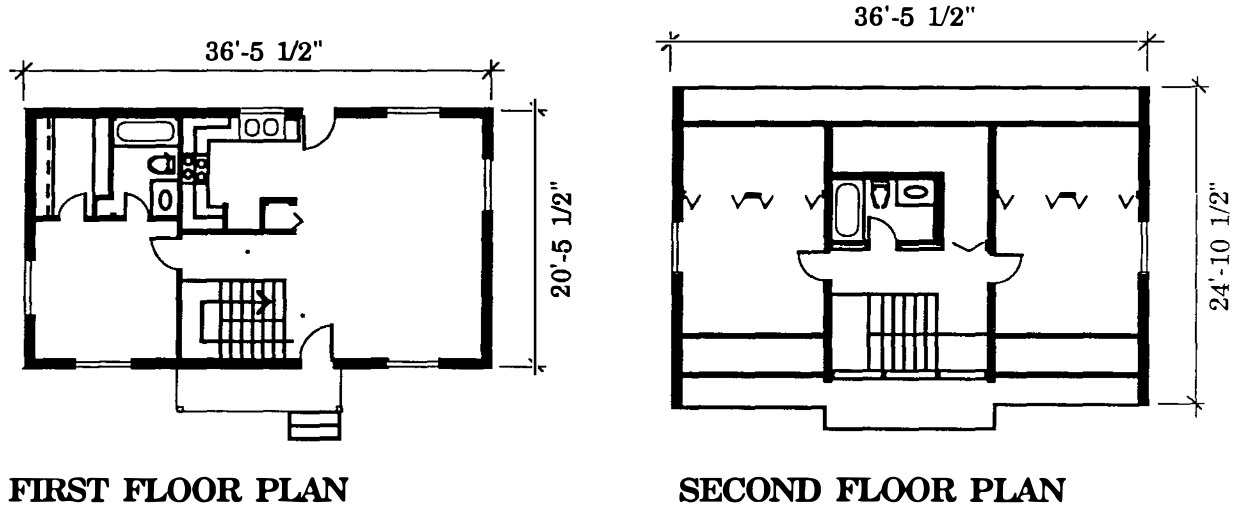

Figure 2 - 1
First and Second Floor Plans

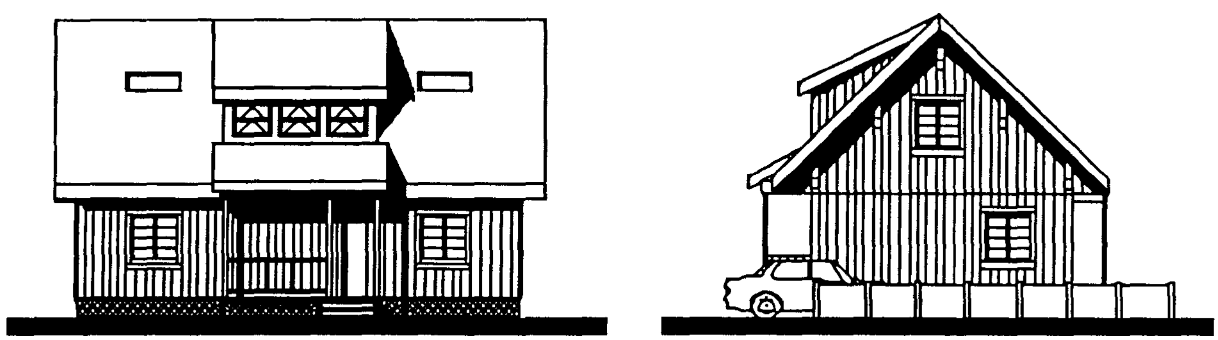

Figure 2 - 2
South and East Elevations

The building diagnostic tests included fan de-pressurization tests and tracer gas tests to determine airtightness, smoke leakage testing to identify areas of leakage, coheating tests to determine the building thermal transmittance value (UA), and infrared testing to identify areas of heat loss due to conductance and infiltration.

SSIC Panel Demonstration Construction

The SSIC Panel Demonstration House features an integrated floor and foundation system that makes use of the two-way spanning capability of the SSIC panels. The floor panels are 6 3/8 inch SSIC panels with skins of 7/16" oriented strand board (OSB) with a 5 1/2 inch core (R21) of expanded polystyrene (EPS). The walls of the house are 8 5/16 inch thick SSIC panels that include an interior skin of 7/16" OSB, an exterior skin of 5/8 inch Duratemp siding and a 7 1/4 inch EPS core (R28). The roof of the house is formed of 10 1/8 inch thick SSIC panels made with 7/16 inch OSB skins and a 9 1/4 inch EPS core (R36). Interior surfaces of the walls and roof are finished with 1/2 inch fiber reinforced gypsum board. Windows are low-e argon-filled vinyl windows (R3.33). Skylights are clear tempered safety glass with heat mirror with an R value of 3.66 and doors are R5 insulated fiberglass. Sections, elevations and construction details are provided in Appendix 7.1

HVAC Controls

Four Fresh Air 80 inlet vents were installed in the house to provide ventilation in conjunction with an Envirovent ventilating water heater. Due to the high level of airtightness of the SSIC Panel construction, mechanical ventilation is required to provide adequate air quality. The Envirovent ventilating water heater extracts heat from exhaust air to provide hot water heating and supplemental heating and cooling to air. Primary heating is provided with four electric resistance wall heaters located in the living area, the master bedroom and the two upstairs bedrooms.

Reference House

Throughout the report, the SSIC Panel Demonstration House is compared to a theoretical reference house of the same architectural design, but with traditional wood frame construction. The reference house was designed to have a similar level of thermal performance as the Demonstration House; consequently, the reference house is also design to be 40% better than Oregon Energy Code. To meet the same levels of insulation, the reference house utilized advanced framing techniques. The reference house walls are constructed of 2 by 8 lumber at 24 inches on center with R-26 insulation. The floor and foundation system is a conventional crawl space foundation insulated to a level of R-30. In order to allow the appropriate amount of batt insulation, 2 x 10 inch joists were necessary. The roof system of the reference house was designed with 2 by 12 inch rafters at 24 inch on center with plywood sheathing. Again, the size of the lumber was necessary to allow for R38 insulation and roof ventilation as specified by the BPA's Super Good Cents program. Sections and details for the reference house are also provided in Appendix 7.1.

	SSIC Demonstration House		Reference House	
	Construction	R-Value of EPS	Construction	R Value of Batt Insulation
Wall	8 5/16 inch SSIC Panel	R-28	2x8 inch Framing, 24 inch o.c.	R-26
Roof	10 1/8 inch SSIC Panel	R-36	2x12 inch rafters, 24 inch o.c.	R38
Floor	6 3/8 inch SSIC Panel	R-21	2x10 inch joists	R-30
Foundation	Trestle foundation		Crawl space	
Windows	Low-e, argon-filled	R-3.33	Low-e, argon-filled	R-3.33
Doors	Insulated fiberglass	R-5	Insulated fiberglass	R-5

Table 2-1
Comparison of Insulation Levels for the SSIC Panel Demonstration House and the Stick Framed Reference House

University Housing Units

The performance of the Demonstration House was also compared to the performance of six units of student housing in three duplexes at the University of

Oregon, referred to as University Housing throughout the remainder of this report. The University Housing units utilized open, closed and SSIC panel wall panelization strategies. The units were constructed approximately six months earlier than the Demonstration House and ESBL performed a series of building diagnostic tests on these units similar to the tests conducted on the SSIC Panel Demonstration House.

Although the testing was similar, the comparison of results was complicated by many factors. These factors include different weather conditions during different times of the year, different construction crews, and different testing crews. In addition, fan pressurization equipment differed but coheating equipment was the same. The University Housing duplexes also vary in size, design and configuration.

The University Housing Units were designed to meet BPA Super Good Cents energy performance levels. All units feature R5 insulation under slab, R15 insulation around slab perimeter, R38 insulated vaulted ceiling and R49 insulated flat ceiling, vinyl, U - .35, (R -2.86) low-e, argon-filled windows, U-.19 (R5.26) doors, R 4 insulation around pipes, bimetallic controls for stack ventilation, and insulated headers. The manufactured walls all have insulation R values of 26 except for the 1 story SSIC panel unit, which has and insulation R value of 23. However, each unit does differ in the ratio of window aperture to floor area and the amount of thermal mass.

All the University Housing units used field installed trusses and sheathing for roofs. The 1 1/2 story units also used panelized dormers having framing and roofing constructed in the factory. Plans, sections, elevations and a description of the construction of each University Housing unit is provided in Appendix 7.1

Unit	Construction	Wall	Slab on Grade	Slab Perimeter	Roof
1	1 story SSIC	R23	R5 under 4"concrete slab	R15	R38 Vaulted / R49 Flat
2	1 story Closed Panel	R26	R5 under 4"concrete slab	R15	R38 Vaulted / R49 Flat
3	1 1/2 story Open Panel	R26	R5 under 4"concrete slab	R15	R38 Vaulted / R49 Flat
4	1 1/2 story Open Panel	R26	R5 under 4"concrete slab	R15	R38 Vaulted / R49 Flat
5	2 story Closed Panel	R26	R5 under 4"concrete slab	R15	R49 Flat
6	2 story Closed Panel	R26	R5 under 4"concrete slab	R15	R49 Flat

Table 2-2
Comparison of Insulation Levels of University Housing Apartments

3.0 METHODOLOGY

A series of building diagnostics were performed to establish the thermal performance of the SSIC Panel Demonstration House. Diagnostic tests included fan de-pressurization tests, tracer gas tests, and smoke leakage tests. In addition, thermographic imaging and coheating tests were performed.

The units were also instrumented to monitor long term total electrical consumption and electrical consumption for space heating. Comfort criteria were measured with ambient air temperature probes, mean radiant temperature probes, and a relative humidity sensor. A weather monitoring station, established by the ESBL, also provides information on temperature, relative humidity, wind speed, wind direction and vertical and horizontal irradiance. The weather station, located at the University Housing, is approximately two miles from the SSIC Panel Demonstration House; consequently, weather data, especially wind, conditions may vary.

3.1 AIR INFILTRATION

Fan De-Pressurization Testing

Infiltration testing was performed by fan de-pressurization (blower door testing). A Minneapolis blower door Model 3 with magnehelic pressure gauges was used to obtain air-flow rates at negative house pressure differentials. A log-log plot of multipoint test data was created, and a line of best fit was drawn. From the line of best fit data, the air-flow rate at 50 pascals (CFM_{50}) and the air-flow rate at 4 pascals (CFM_4) were determined to establish air changes per hour at 50 pascals, (ACH_{50}) and effective leakage areas (ELA_4).

Fan de-pressurization tests were performed on the Demonstration House in two different modes: "closed" condition, all intentional penetrations through the envelope closed or taped, and "open" conditions, all intentional penetrations through the envelope open. Intentional penetrations through the envelope include all Fresh Air 80 vents, all dryer inlet and outlet vents, the conduit penetration for the data logger, the Envirovent outlet and the condensate drip for the Envirovent. Results from closed tests are considered to be a better assessment on the quality of construction; whereas, results of open tests are considered to be a better assessment of actual airtightness.

Tracer Gas Infiltration Testing

Infiltration rates were also determined using a concentration decay tracer gas test. Tracer gas tests using Sulfur Hexaflouride (SF_6) were performed on the Demonstration House in both open and closed modes. The tracer gas was introduced into each room of the house and mixed with four fans for approximately 30 to 60 minutes to ensure a homogeneous mix. The decay of the SF_6 gas was monitored using a Miran 203 specific vapor analyzer. Uniformity of mixture was verified by taking readings using the Miran Vapor Analyzer in four separate zones. Measurements were taken until a drop of 5 ppm in gas concentration occurred. The infiltration rate of the house was then determined by a regression analysis of the natural log of the average house concentration versus elapsed time.

Smoke Leakage Testing

In addition to fan de-pressurization tests, air leakage was visually inspected by smoke testing. Smoke tests were performed by pressurizing the house to +20 Pa relative to the outside pressure using the fan pressurization equipment. Leakage paths were then established using a titanium tetrachloride smoke pencil. Major and minor leakage areas of infiltration were noted based on visual examination of the speed and quantity of escaping smoke.

3.2 THERMAL TRANSMITTANCE (UA)

Thermographic Imaging

Evaluation of thermal insulation quality and air leakage pathways was made using the Inframetrics 600L IR system. The Model 600L IR performs real-time analysis of static or dynamic thermal patterns. The scanner includes an electronics control module to adjust variables such as surface emittance. The system also features an infrared camera with closed circuit cooling, a VCR and a 4 inch color monitor. One thorough scan of the thermal envelope was performed from the inside of the unit. In addition, the east, south and west exteriors of the house were also scanned. The scans were completed with the house in a thermally undisturbed state, ie. the heating system had been at the same set point for at least 24 hours. The thermographic scans were recorded on 3.5 hours of video tape for later analysis.

Coheating Tests

Overall thermal transmittance (UA) was determined with a coheating test. The test involves the use of five electrical resistance heaters controlled and monitored by a CR 21X data logger and IBM 386 to maintain the house at a constant temperature for a period of 24 hrs. Electrical energy consumption was monitored using infrared optical meter sensors for the duration of the test.

The house was divided into five thermal zones, each controlled by a copper-constantan thermocouple. These thermocouples were connected to the CR-21X and IBM 386. The IBM 386 controlled a relay that switched the heaters on or off depending on whether the temperature in the zone drifted below or above the control point of 75°F. Interior temperatures at five locations as well as the ambient outdoor air temperature were monitored constantly. Monitoring was performed for a period of 24 hrs; however, data for analysis was taken from 3:00 am to 5:30 am, with readings taken every 6 minutes.

Theoretical UA values were calculated for both the Demonstration House and the reference house to compare to the coheating results. Estimates of heat loss due to infiltration were made using fan de-pressurization results to allow a better comparison of measured results to theoretical results.

4.0 RESULTS

Results of building diagnostic tests of the SSIC Panel Demonstration House are presented in this section. Building diagnostic tests include testing related to infiltration and thermal transmittance. Infiltration tests include fan de-pressurization tests, tracer gas tests and smoke leakage tests. Thermal transmittance tests include thermographic imaging and coheating tests.

4.1 AIR INFILTRATION

Fan De-Pressurization Results

Four pressurization tests were performed in closed conditions and two tests were performed in open conditions. The average air change rate per hour at 50 pascals (ACH_{50}) in closed conditions was 1.39 air changes of house volume per hour, ACH; whereas, the average ACH_{50} in open conditions was 2.27 ACH. An estimation of the natural infiltration rate at 4 pascals, considered to be normal house conditions, was made using the Lawrence Berkeley Laboratories (LBL) model. LBL estimates of the natural infiltration rates indicated an average air change rate of .053 ACH in closed conditions and .086 ACH in open conditions. Both estimates are well below the minimum air change rate of .35 ACH in BPA Super Good Cents construction standards. In addition, the estimated ACH is also below the air change rate of 0.10 specified for advanced air leakage control packages utilizing mechanical ventilation. (SGC Appendix C, p c.26 1991). A summary of results of the fan de-pressurization tests is presented in Table 4-1. Individual fan de-pressurization tests are provided in Appendix 7.3.

Error for fan de-pressurization results of ACH_{50} was estimated to be 5% based on correlation of curve fit data. A larger error of 10% was estimated for ELA_4 and estimates of natural infiltration based on greater inaccuracy of pressure gauges at lower pressure differentials. However, estimates of natural infiltration rates from fan de-pressurization results did compare well to tracer gas results.

Test	Fresh Air Vents	CFM50	CFM4	ACH50	ELA	SLA	ACH50/N (LBL Model)
		(cfm)	(cfm)	(ach)	(sq. in.)		(ach)
BDT1-1A	Closed	238	67	1.34	18.92	0.98	0.051
BDT1-1B	Closed	251	48	1.41	13.62	0.71	0.053
BDT1-2A	Closed	249	36	1.40	10.29	0.53	0.053
BDT1-2B	Closed	251	39	1.41	11.17	0.58	0.053
Average	**Closed**	**247**	**48**	**1.39**	**13.50**	**0.70**	**0.053**
BDT2-1A	Open	402	77	2.27	21.91	1.4	0.086
BDT2-1B	Open	404	75	2.28	21.15	1.1	0.086
Average	**Open**	**403**	**76**	**2.27**	**21.53**	**1.25**	**0.086**

Notes:

ELA_4 – Effective leakage area at a specific pressure

SLA – Specific Leakage Area, ELA_4 (ft) *10,000/House (ft^2)

Table 4-1:
Fan De-Pressurization Results

An estimate of effective leakage area at 4 pascals was made for the reference house (ASHRAE, 23.15). The minimum leakage areas, specified in Table 3 of ASHRAE Fundamentals Chapter 23, were used to determine overall effective leakage area based on the assumption that the Reference house would be new construction. The effective leakage area of the Demonstration House is compared to the theoretical effective leakage area of the reference house in Figure 4-1. In addition, the theoretical distribution of air leakage for the reference house is shown in Figure 4-2.

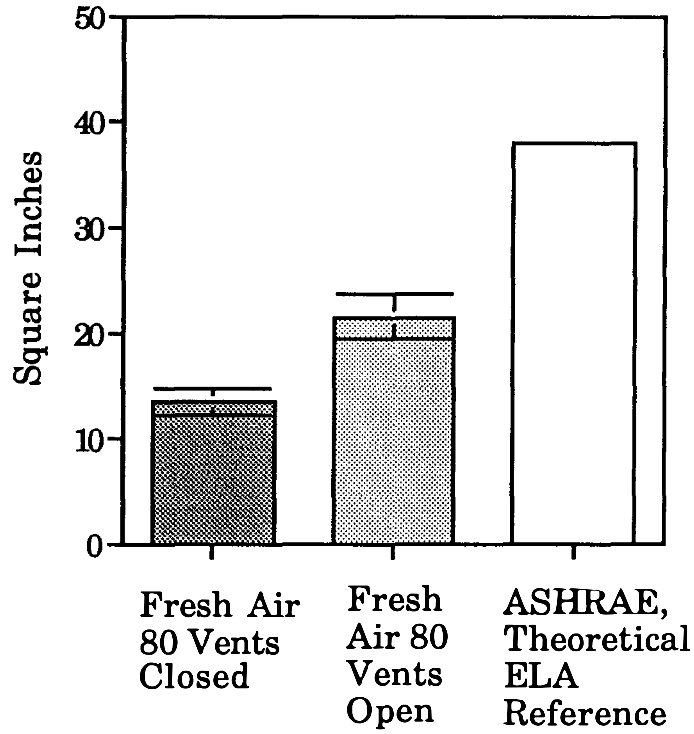

Figure 4-1
Comparison of Effective Leakage Areas of the SSIC Panel Demonstration House in Open and Closed Conditions to the Theoretical Effective Leakage Area of the Reference House

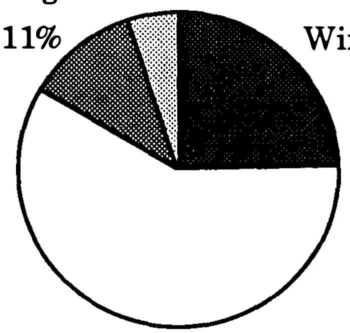

Figure 4-2
Theoretical Distribution of Air Leakage for the Reference House
Total Theoretical Leakage Area is 38 Square Inches

The airtightness of the SSIC Panel Demonstration House was also compared to the performance of the University Housing apartments. ACH_{50}, ELA_4, and the LBL estimate of natural infiltration of the Demonstration House was compared to the same parameters measured at the University Housing apartments in Figure 4-3, Figure 4-4 and Figure 4-5, respectively. All three figures indicate that the SSIC Panel Demonstration House is more airtight than all the University Housing units including the SSIC panel unit of the University Housing Apartments. In addition, when effective leakage areas were normalized by the crack length of windows and doors and the length of all panel-to-panel joints, panel-to-floor joints, panel-to-ceiling joints, and ceiling-to-ceiling joints to account for differences in design, the Demonstration House remains the most airtight (see Figure 4-6) .

The superior performance of the SSIC Panel Demonstration House as compared to University Housing SSIC panel unit may be due to the use of SSIC panels for the walls, floors and ceiling unlike the University Housing SSIC panel unit where only wall panels were employed. Other factors in the different levels of performance include different construction crews, different component manufacturers, and different weather conditions when testing was performed.

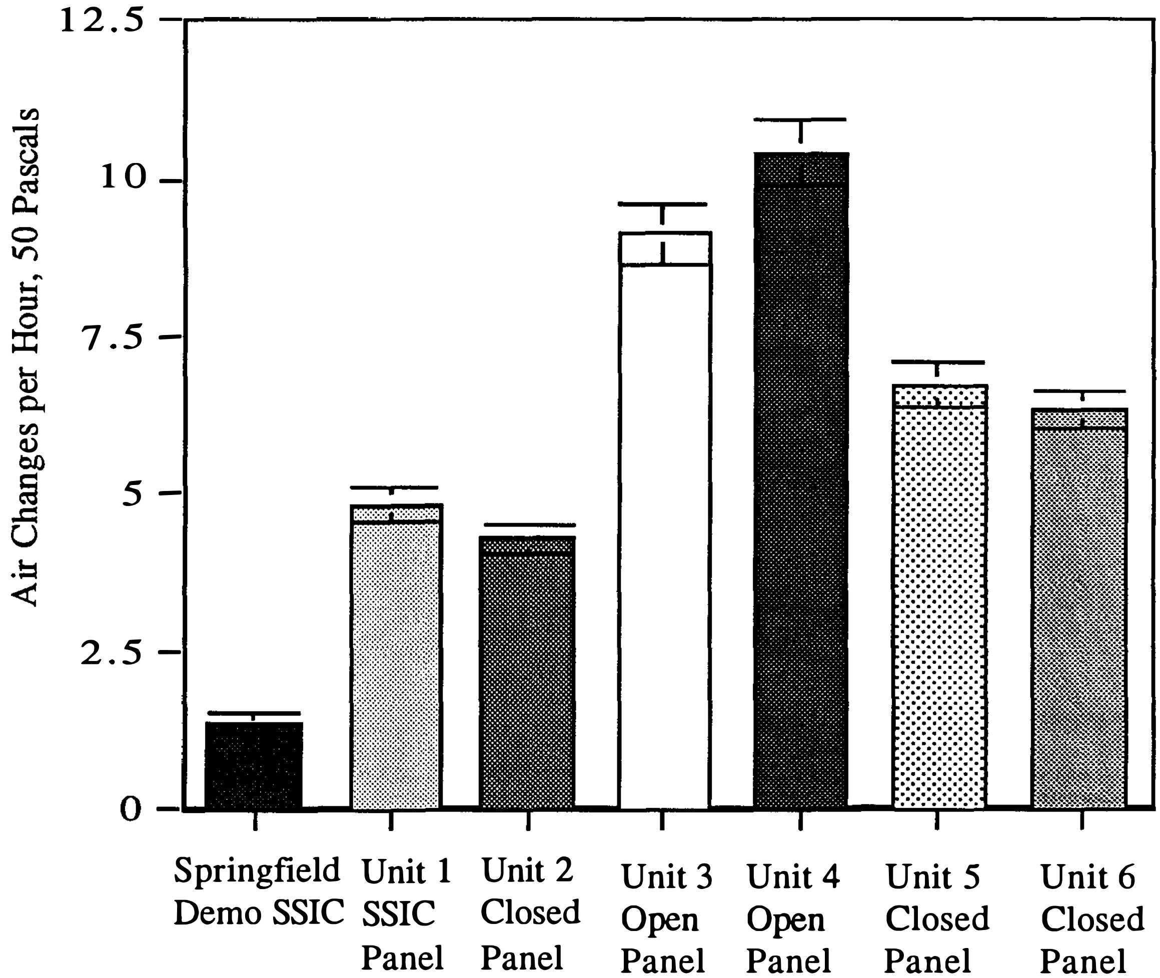

Figure 4-3
Comparison of Air Changes per Hour at a House Pressure of 50 Pascal of the SSIC Panel Demonstration House to University Housing Apartments

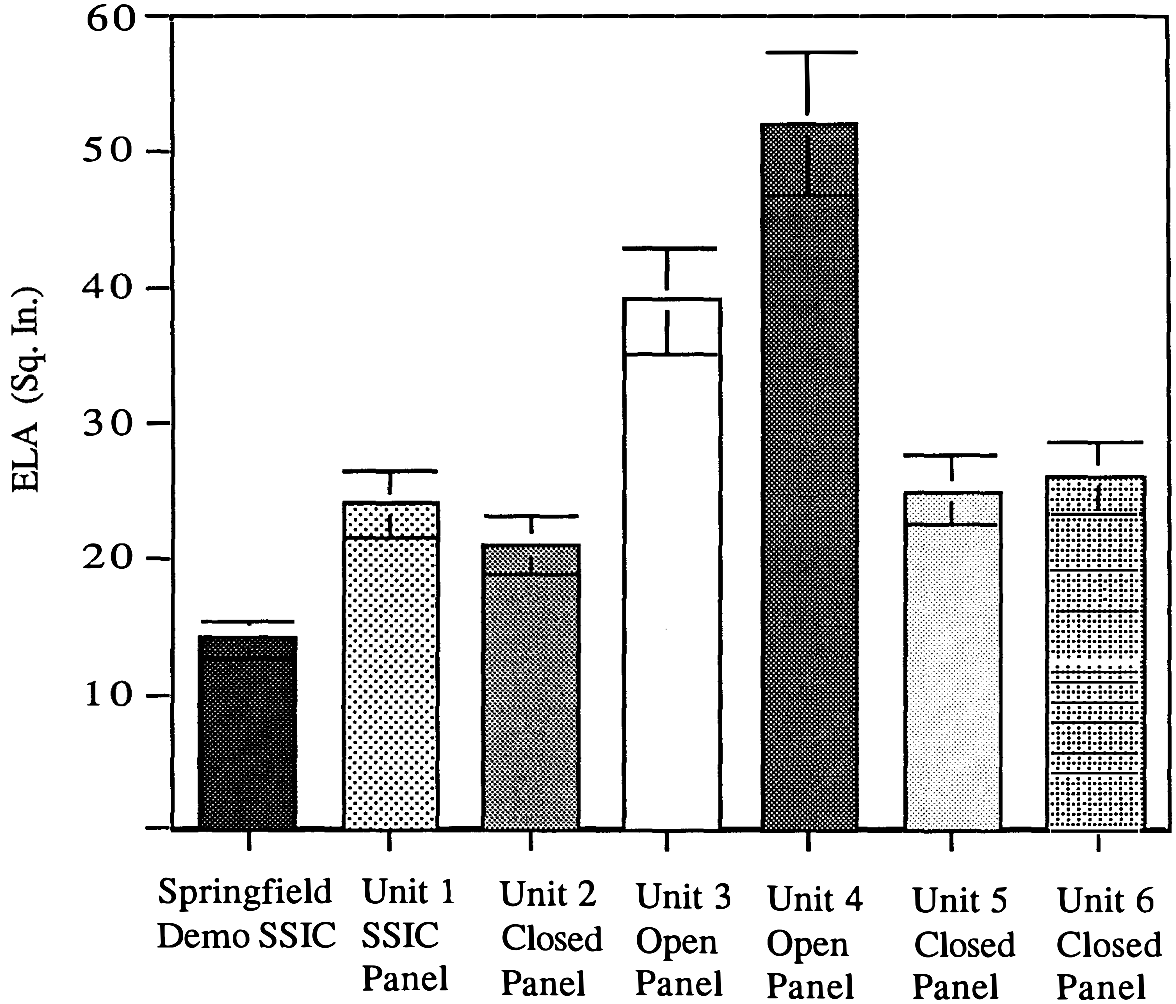

Figure 4-4
Comparison of Effective Leakage Area of the SSIC Panel Demonstration House
University Housing Apartments

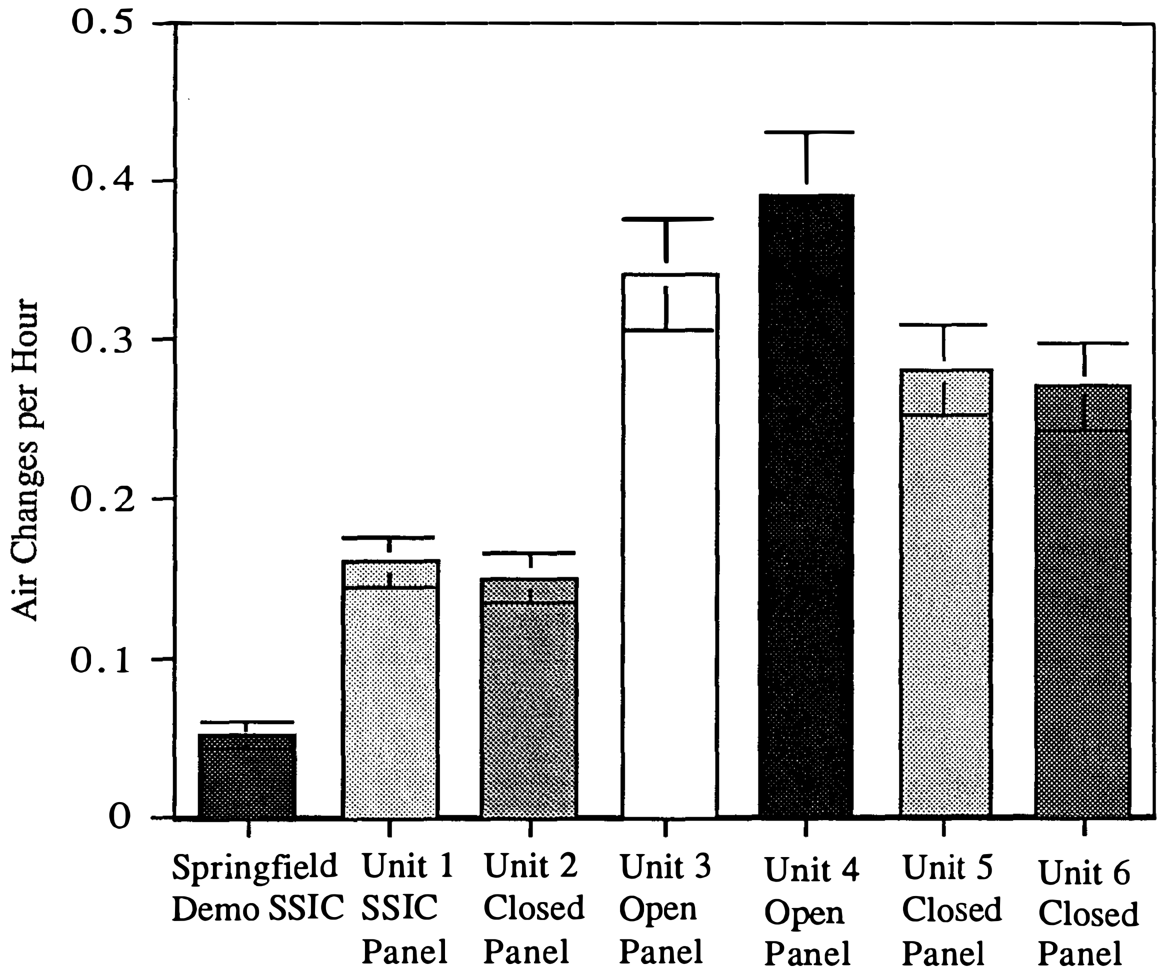

Figure 4-5
Comparison of LBL Estimates of Natural Infiltration of the SSIC Panel Demonstration House to University Housing Apartments

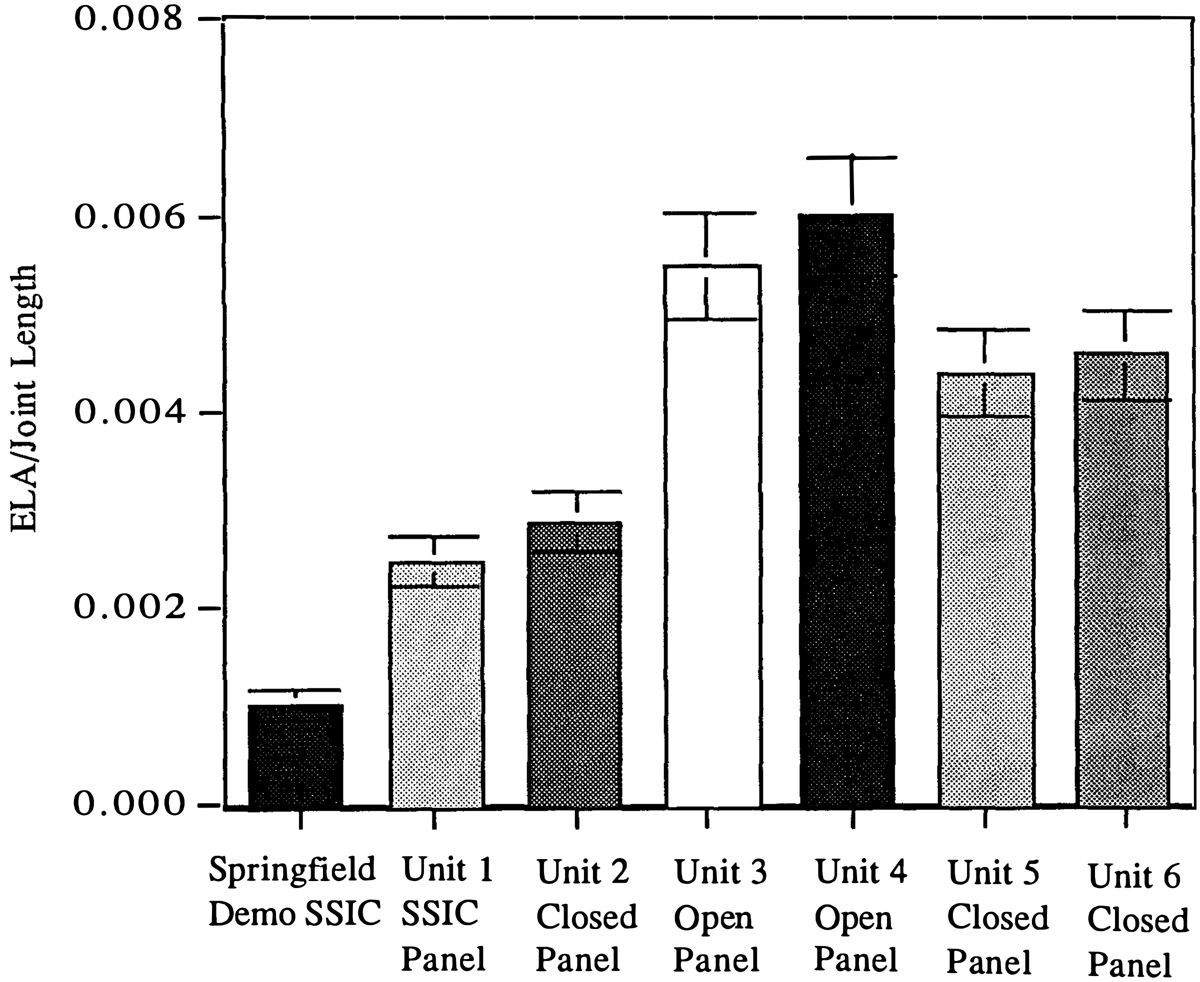

Figure 4-6

Comparison of Effective Leakage Area Normalized by Joint Length of Windows, Doors, Ceiling Joints and all Panel Joints of the SSIC Panel Demonstration House to the University Housing Apartments

Tracer Gas Testing

In addition to fan de-pressurization tests, concentration decay tracer gas tests were performed to measure natural infiltration rates. Tracer gas tests were performed in open and closed positions (See the definition for "open and "closed" on p. 11). The average infiltration rate in closed conditions was .039 ACH, and the average infiltration rate in open conditions was .087 ACH. The range of error for the infiltration tests was estimated to be 10% based on the correlation the line of best fit to data.

Test	Fresh Air Vents	Wind Speed	Wind Direction	Indoor Temp	Outdoor Temp	Infiltration
		Mph	Degrees	F	F	ACH
TGT1-1A	Closed	1.16	0.91	70	67.5	0.032
TGT1-1B	Closed	3.46	359.60	77.0	80.0	0.044
Average	Closed					0.039
TGT1-2A	Open	*	*	69.5	72.0	0.082
TGT1-2B	Open	1.99	179.20	74.5	70.0	0.069
TGT1-2C	Open	4.86	359.53	80.0	81.0	0.111
Average	Open					0.087

Table 4-2
Results of Concentration Decay Tracer Gas Test for the SSIC Panel Demonstration House

* Data was not recorded

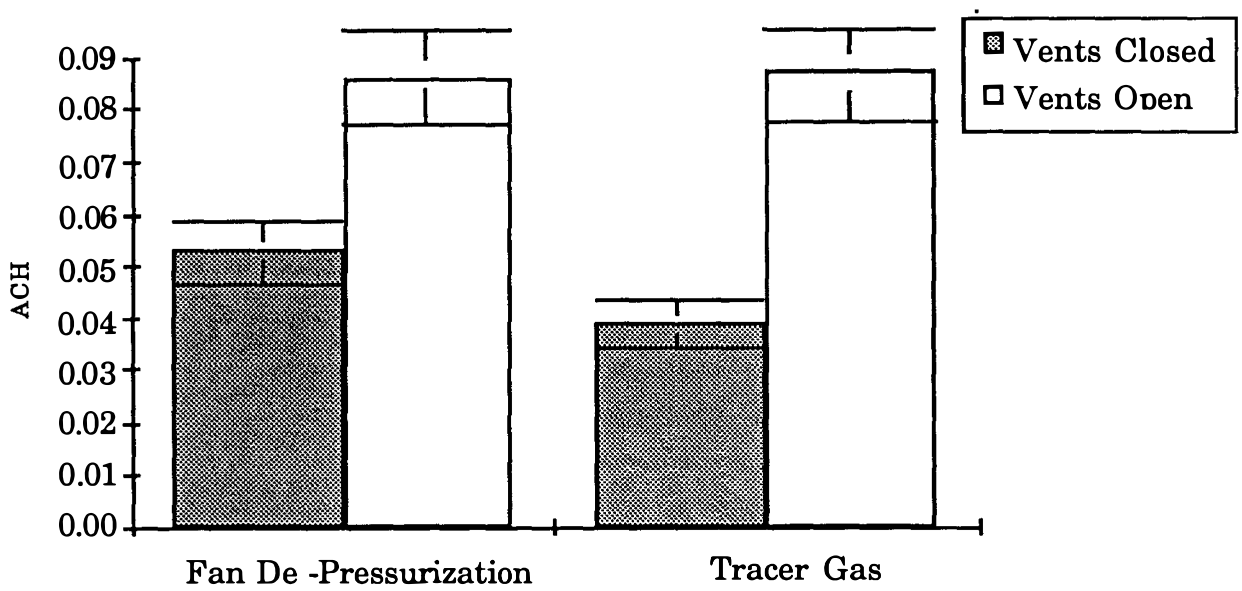

Figure 4-7
Comparison of Tracer Gas Results to Fan De-Pressurization Results For the SSIC Panel Demonstration House

Results of the tracer gas test are compared to LBL estimates of natural infiltration at 4 pascals from the fan de-pressurization tests, Figure 4-7. In closed conditions the average estimate of natural infiltration from fan de-pressurization results using the LBL model was 0.053 ACH compared to tracer gas results of 0.039 ACH, a difference of 0.014 ACH. In open conditions the average estimate of natural infiltration from fan de-pressurization results was .086 ACH compared to tracer gas results of .087 ACH. Tracer gas results are considered to be a more direct measure of natural infiltration; however, they measure infiltration at a specific moment in time having specific wind and temperature conditions.

Smoke Leakage Testing

Leakage paths through the envelope were visually identified using titanium tetrachloride smoke while the house was pressurized to 30 pascals. Common areas of leakage included bathroom and kitchen vents, the hinge side of all windows, some electrical outlets and some Envirovent registers. Slight leakage was also detected between the wall and window frame; small cracks in the finished wall were detected in these areas. No leakage was detected at any panel joint in the walls, floor or ceiling. A detailed list of leakage areas is presented in Table 4-3 .

ROOM	SEVERE LEAKAGE	MODERATE LEAKAGE	SLIGHT LEAKAGE
Kitchen	Exhaust hood	Light switch and electrical outlet, north wall, near door	
	Heat recovery vent for refrigerator, 2" diameter, south wall		
	Bottom 2 inches on west side of the door, 3 inches on bottom corner and top corner of east side of the door	Moderate leakage 3 inches on east side of the bottom of the door	Slight leak between window frame and wall on bottom, east corner small crack detectable
Living Area		Moderate to slight leakage on hinge sides of all windows	Slight leak between window frame and wall on north, east and south windows, slight cracks detectable
			All electrical outlets on north, south and east walls
Master Bedroom, 1st Floor		West wall electrical outlet	East partition wall, electrical outlet
		South wall electrical outlet, moderate to slight leaks	South window, hinge sides
		Leakage through envirovent register	West window, uncapped operating mechanism

Table 4-3
Smoke Leakage Testing Results

ROOM	SEVERE LEAKAGE	MODERATE LEAKAGE	SLIGHT LEAKAGE
Closet			Partition wall electrical, cable and phone outlets
			South wall electrical outlet
			West wall electrical outlet
Bathroom 1st floor	Bathroom vent		Partition wall electrical outlet
West Bedroom, 2nd floor		West window, hinge side	Window operating mechanism, uncapped
			Top corners of skylight
		West wall electrical outlets	South wall, slight to no leakage
			East partition wall, slight leakage on southern outlet
Bathroom 2nd floor	Vent		
East Bedroom, 2nd Floor	East window, hinge side	East wall electrical outlet	East window, operating mechanism, uncapped
			South partition wall electrical outlet
Envirovent Room			All electrical outlets

Table 4-3 (continued)
Smoke Leakage Testing Results

4.2 THERMAL TRANSMITTANCE

The thermal transmittance section includes results from thermographic imaging and coheating tests. Thermographic imaging, or infrared scanning, provides a qualitative assessment of heat loss through conduction and infiltration through the envelope. Coheating test provides a quantitative assessment of heat loss due to thermal transmittance and heat loss due to infiltration. Theoretical UA values were also calculated to compare to measured UA values.

Thermographic Imaging

The interior of the Demonstration House was thoroughly scanned using an Inframetrics 600L IR system. Common areas of conductive losses included panel-to-panel joints, panel-to-floor joints, panel-to-ceiling joints, headers above windows and doors, electrical outlets, Fresh Air 80 vents, and areas around door openings and door frames, and around window openings and window frames. Possible losses due to infiltration occurred around door and window openings.

Infrared scans of panel joints indicated that heat loss varied relative to the type of panel and joint. For example, temperature differentials detected by the thermographic scans of ceiling joints appeared to be much less than temperature differentials of floor joints. The better performance of roof panel joints compared to wall panel joints is most likely a reflection of panel thickness. The roof panels are 10 1/8 inch thick with additional roofing layers compared to the wall panels which are 8 5/16 inch thick. Both roof panels and some wall panels utilize 2x framing members. Unlike the roof joints and some of the wall joints, floor panel joints utilized an OSB spline rather than a 2x spline. Heat loss at floor panel joints was only detectable at the edges of the floor panels approximately 2 to 3 feet from the wall, and was not detectable in the center of the floor. Heat loss at the floor panel joints may have been greater at the edges of the floor panels due to exposure to wind or an increase in framing at the perimeter. The temperature below the center of the floor system may also be slightly greater than the ambient temperature due to shielding effects of the building. An additional factor affecting heat loss through the panel joints only at the perimeter may be the alignment of wall panel joints, and consequently splines, to the floor panel joints and splines. This alignment of splines may contribute to thermal bridging.

The infrared scans also detected heat loss at the Envirovent registers. The thermal gradient detected at the registers may have been due to the connection of ductwork from the outside or to the natural convection of air within the house.

The south, east and west exteriors of the facades were also scanned. Common areas of heat loss detected from the exterior included all panel joints, window and door headers and punctures through the envelopes for ducts and vents. Areas of heat loss and possible exfiltration were detectable at the intersection of roof panels and west wall panels at the peak of the gable. An area of heat loss was also detected at the intersection of the roof panel to 2nd floor framing on the south side of the west wall. In addition, a small area of more intense heat loss was detected at the intersection of the overlooks with the west wall panels and the roof panels. Areas of heat loss are shown in Figures 4-8 through Figures 4-16. A detailed table of areas of heat loss identified with the infrared camera is provided in Appendix 7.7

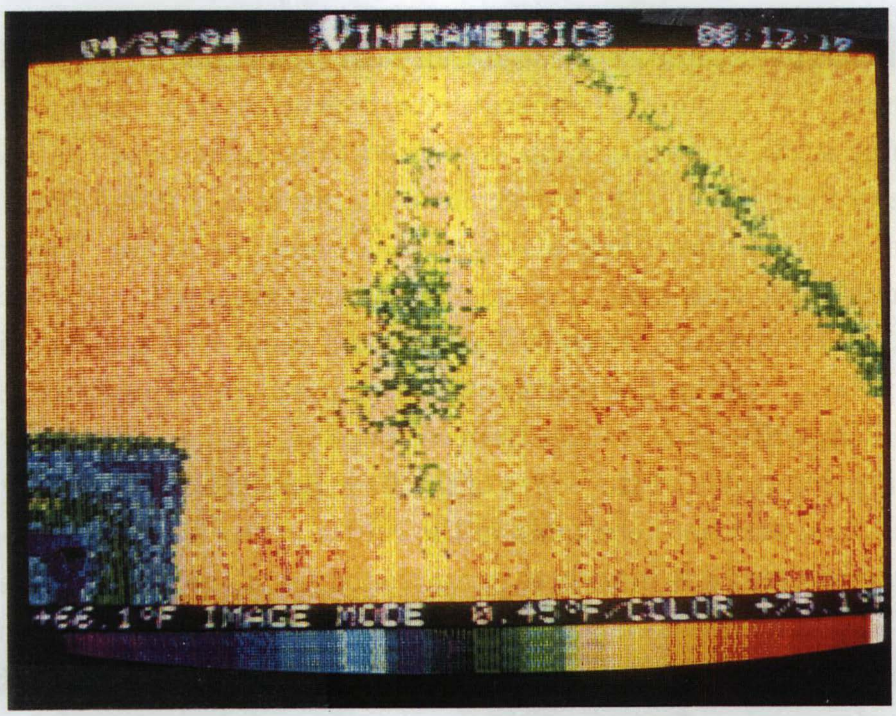

Figure 4-8
Heat Loss at SSIC Panel Panel to Panel Joint,
Heat Loss is More Extensive than Typical of Panel Joints

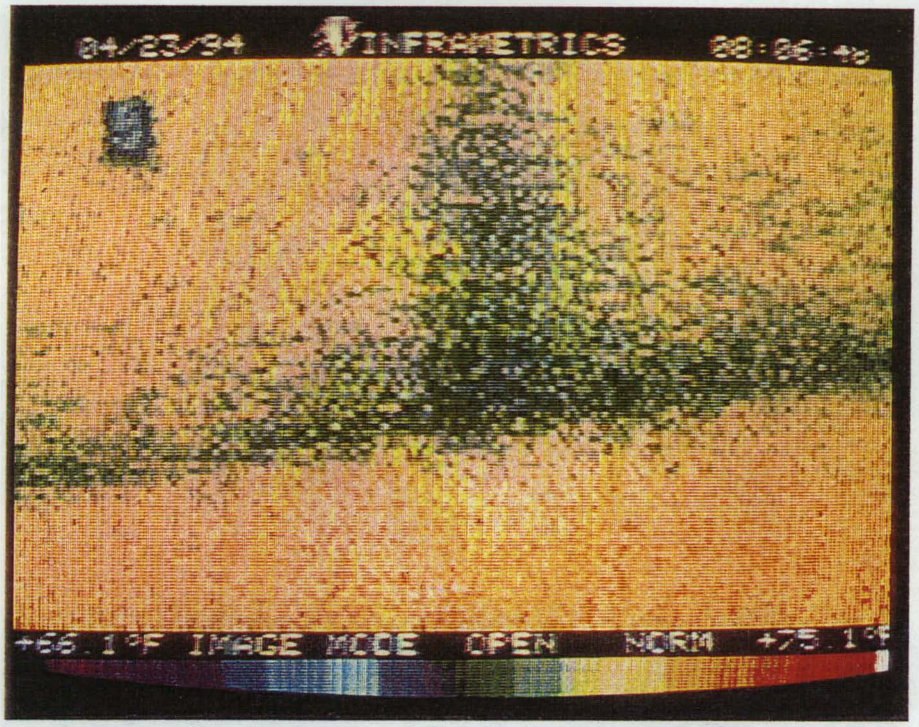

Figure 4-9
Heat Loss at Panel to Panel Joint and Wall to Floor Plant Joint,
Heat Loss through Electrical Outlet also Visible

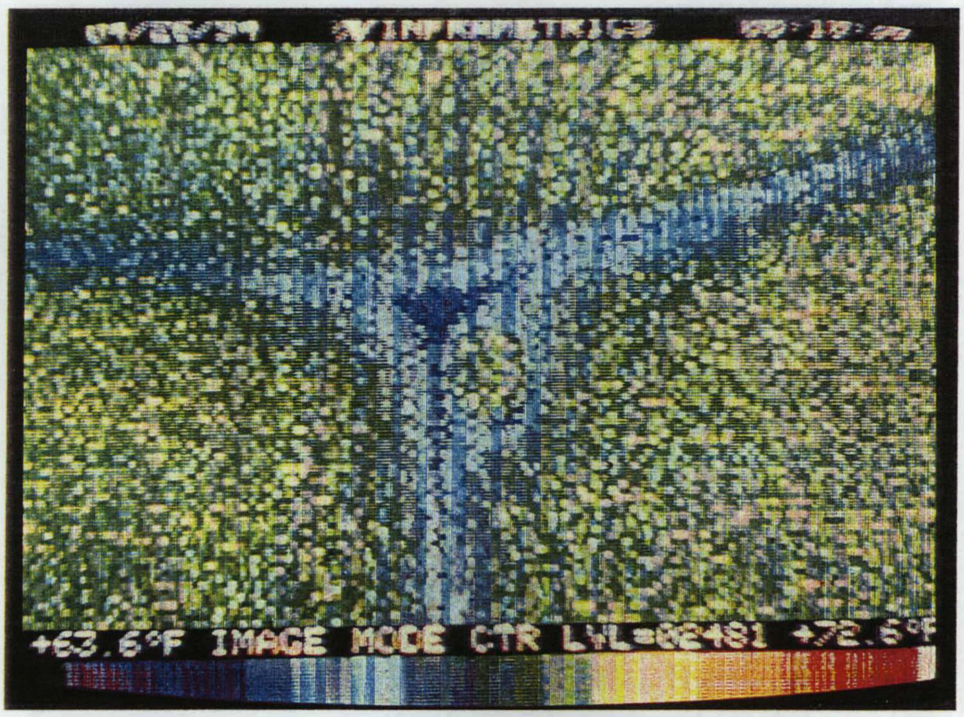

Figure 4-10
Heat Loss at Intersection of Panels and 2nd Floor Framing,
Heat Loss through Fresh Air Vent also Visible

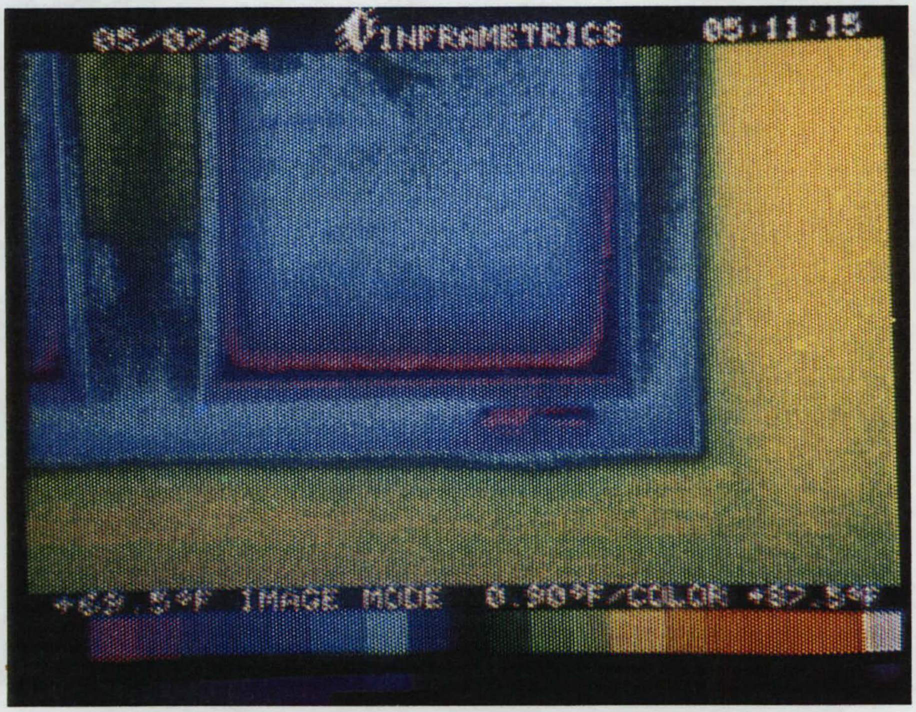

Figure 4-11
Heat Loss through Window Opening and Window Frame,
Heat Loss through Window Operating Mechanism

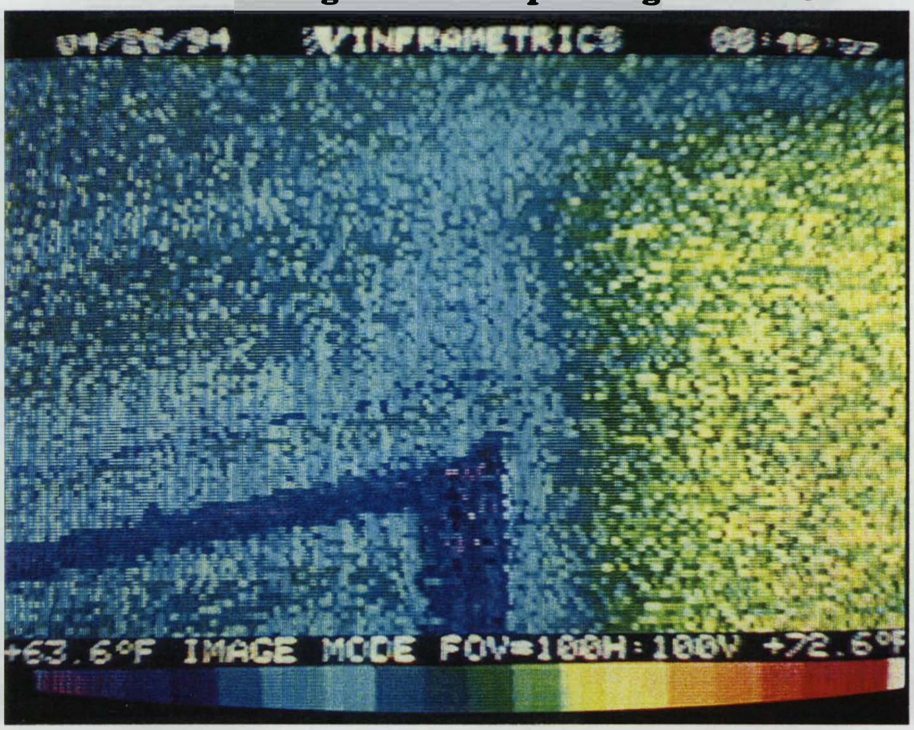

Figure 4-12
Heat Loss through Header above North Door

Figure 4-13
Exterior View of Heat Loss through Panel to Panel Joints, Fresh Air 80 Vents, and 2nd Floor Framing

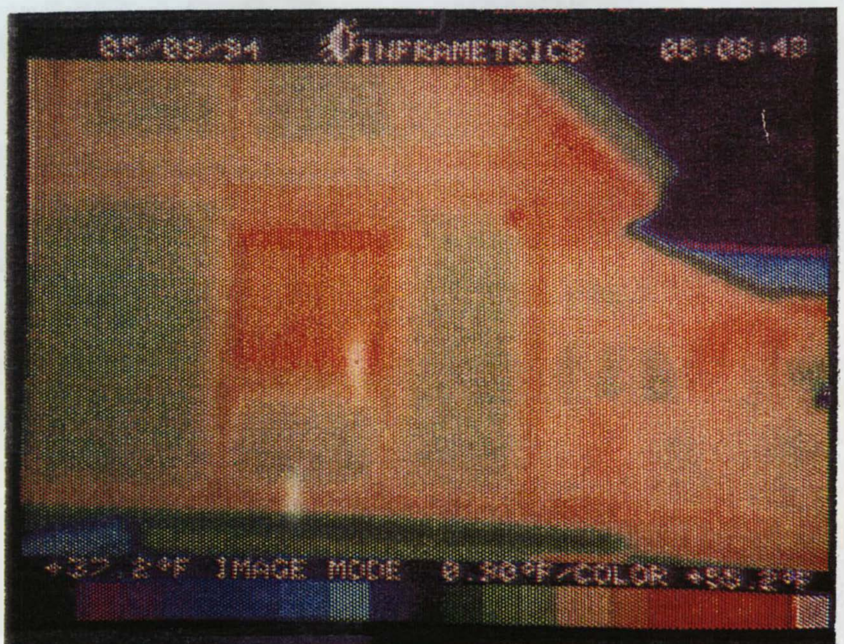

Figure 4-14
Exterior View of Heat Loss, East Elevation of Demonstration House. Heat Loss is Visible through Panel to Panel Joints, 2nd Floor Framing, Fresh Air 80 Vents and Window Openings

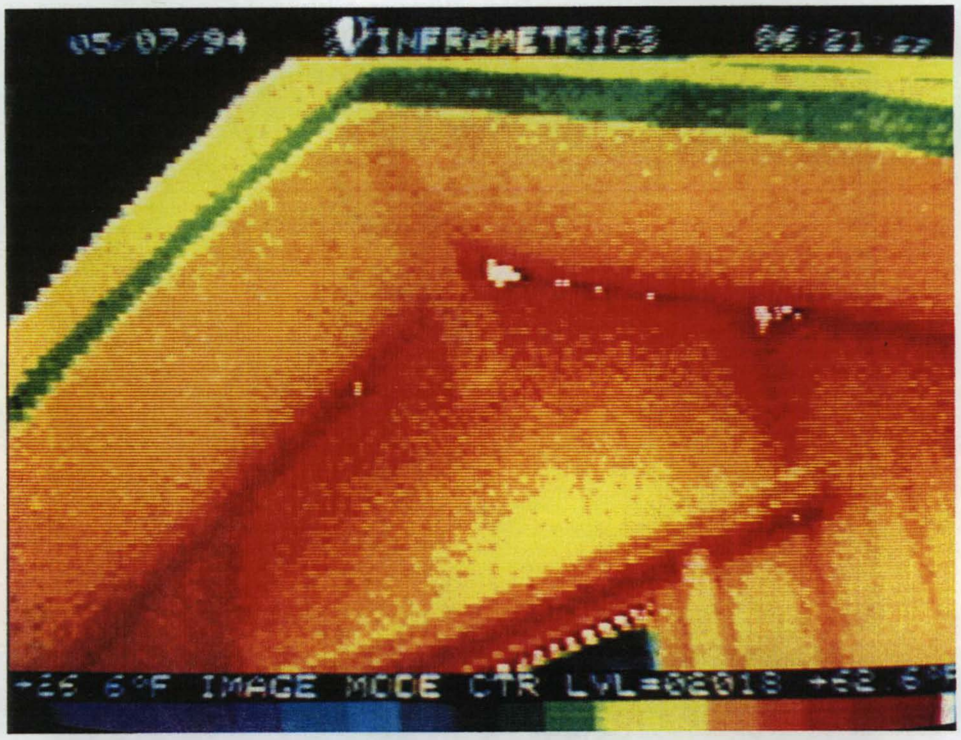

Figure 4-15
Heat Loss under Eaves on West Elevation of Demonstration House.
Heat Loss is More Extensive at Gable and Intersection of Panel Joints and Roof

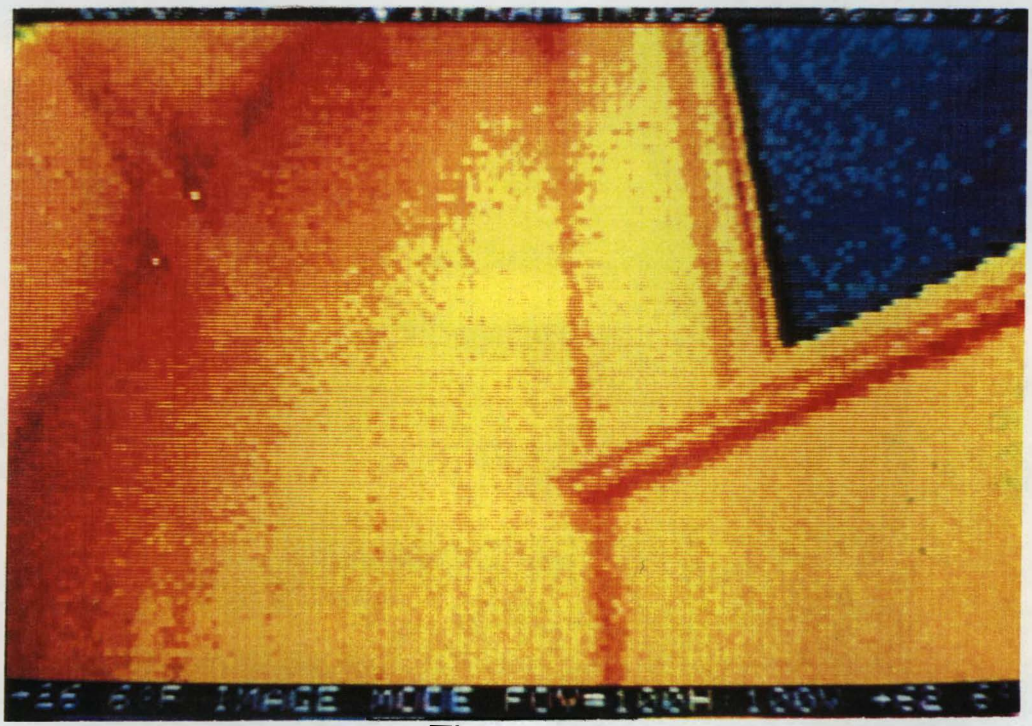

Figure 4-16
Heat Loss on West Elevation of Demonstration House at Panel Joints around 2nd Story Window and Around Overlook under Eaves

Coheating Results

Results of the coheating test indicate that the Demonstration House had a measured UA value of 133 Btu/h °F. Heat loss due to infiltration was estimated to be 7.5 Btu/h °F using averaged infiltration rates from tracer gas results in closed conditions; consequently the measured UA value less infiltration was 125.5 Btu/ °F. The measured UA value less infiltration was 19% lower than the theoretical UA value and 22% lower than the theoretical UA value of the reference house. The reference house was designed to have a comparable level of insulation as the Demonstration House. The distribution of insulation between the SSIC Panel Demonstration House and the reference house is different as can be seen when the distribution of heat loss for the Demonstration House, Figure 4-17, is compared to the distribution of heat loss for the Reference house, Figure 4-18.

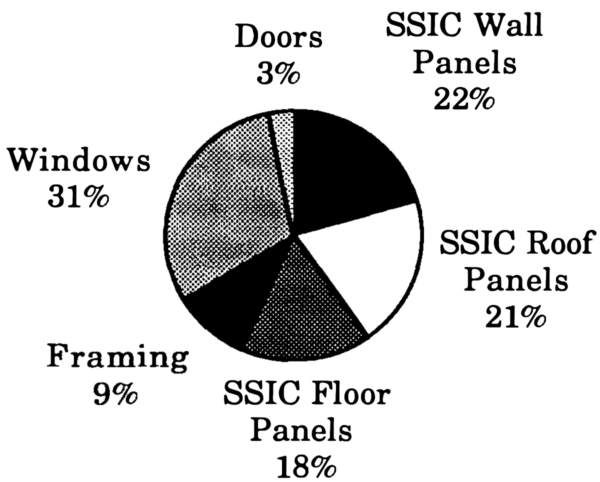

Figure 4-17
Theoretical Distribution of Heat Loss for the SSIC Panel Demonstration House
Total Theoretical UA is 155 Btu/h °F

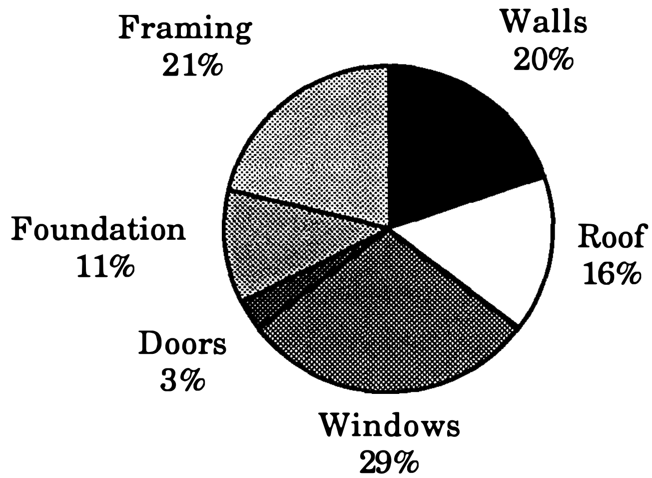

Figure 4-18
Theoretical Distribution for the Stick Framed Reference House
Total Theoretical UA is 161 Btu/h °F

The SSIC Panel Demonstration House was also compared to the University Housing SSIC panel unit for an indication of how the SSIC Panel Demonstration House compares to houses meeting the Oregon Energy Code. Table 4-4 compares the performance of the SSIC Panel Demonstration House to all six units of University Housing. For a more direct comparison of heat loss due to thermal transmittance, estimates of heat loss due to infiltration were made using fan depressurization results. For the Demonstration House, the average of tracer gas results in closed conditions was used to estimate heat loss due to infiltration. Overall thermal transmittance was normalized by dividing measured UA values less estimated infiltration losses by the surface area of the Demonstration House, Figure 4-19. When compared to all six University Housing units, the Demonstration House has an overall U value at least 40% less than each University Housing Unit. Surface area for the six University Housing units includes the area of the concrete slab. Because heat loss through a concrete slab is primarily dependent upon perimeter, dividing by surface area of the slab does not accurately model the overall U value of the University Housing units.

The estimated error for the SSIC Panel Demonstration House coheating test as well as the University Housing coheating tests was 20%. Because each coheating test was performed on six different nights with different wind conditions and temperature conditions, error was estimated to be within 20%. For the

Demonstration House, the average ΔT for the coheating test was measured to be 28.6 °F. The average wind speed was 1.4 mph during the hours of testing. For the University Housing coheating tests, the range of ΔT indoor to outdoor was from 20.3 °F to 51.3 °F, and wind varied from 1.4 mph to 7.6 mph. In addition, temperature data was measured from on site; whereas wind data was taken from the Solar Monitoring Lab located approximately .5 miles away from the University Housing Apartments and 2 miles from the SSIC Panel Demonstration House The measurements of wind data are taken at an approximate height of 45 feet.

The different wind and temperature conditions affect heat loss due to infiltration. In a report by the Florida Solar Energy Center (FSEC), "Side-by Side Evaluation of a Stressed-Skin Insulated-Core Panel House and a Conventional Stud Frame House", a plot of 17 nights of energy consumption versus temperature indicated energy consumption, a reflection of heat loss due to conductive and infiltration losses, varied by as much as 15% under the same ΔT. Consequently, error associated with the coheating tests was estimated to be 20%.

Unit	Surface Area	UA Value as Measured	Estimated Infil. Loss	UA - Infil. UA	UA Theoretical	UA-Infil. UA / Surface Area	Estimate of R-Value of Overall Envelope
	(sq. ft.)	(Btu\h F)	(Btu\h F)	(Btu\h F)	(Btu\h F)	(Btu\h F Ft^2)	(Ft^2 h F\ Btu)
Springfield SSIC Demo House	3732	133	7	126	155	0.034	30
Unit 1 SSIC Panel	2388	174	18	156	136	0.065	15
Unit 2 Closed Panel	2388	180	16	164	134	0.069	15
Unit 3 Open Panel	1965	198	37	161	113	0.082	12
Unit 4 Open Panel	2182	186	46	140	129	0.064	16
Unit 5 Closed Panel	1796	129	28	101	112	0.056	18
Unit 6 Closed Panel	1796	136	27	110	112	0.061	16

Note: Infiltration loss was estimated by multiplying the LBL estimate of natural infiltration times the volume of each unit and by 1 hr to establish an Air volume. The air volume was then multiplied by the specific heat of air and the density of air to establish the heat capacity of the air lost due to infiltration in each unit

Table 4-4
Coheating Comparison

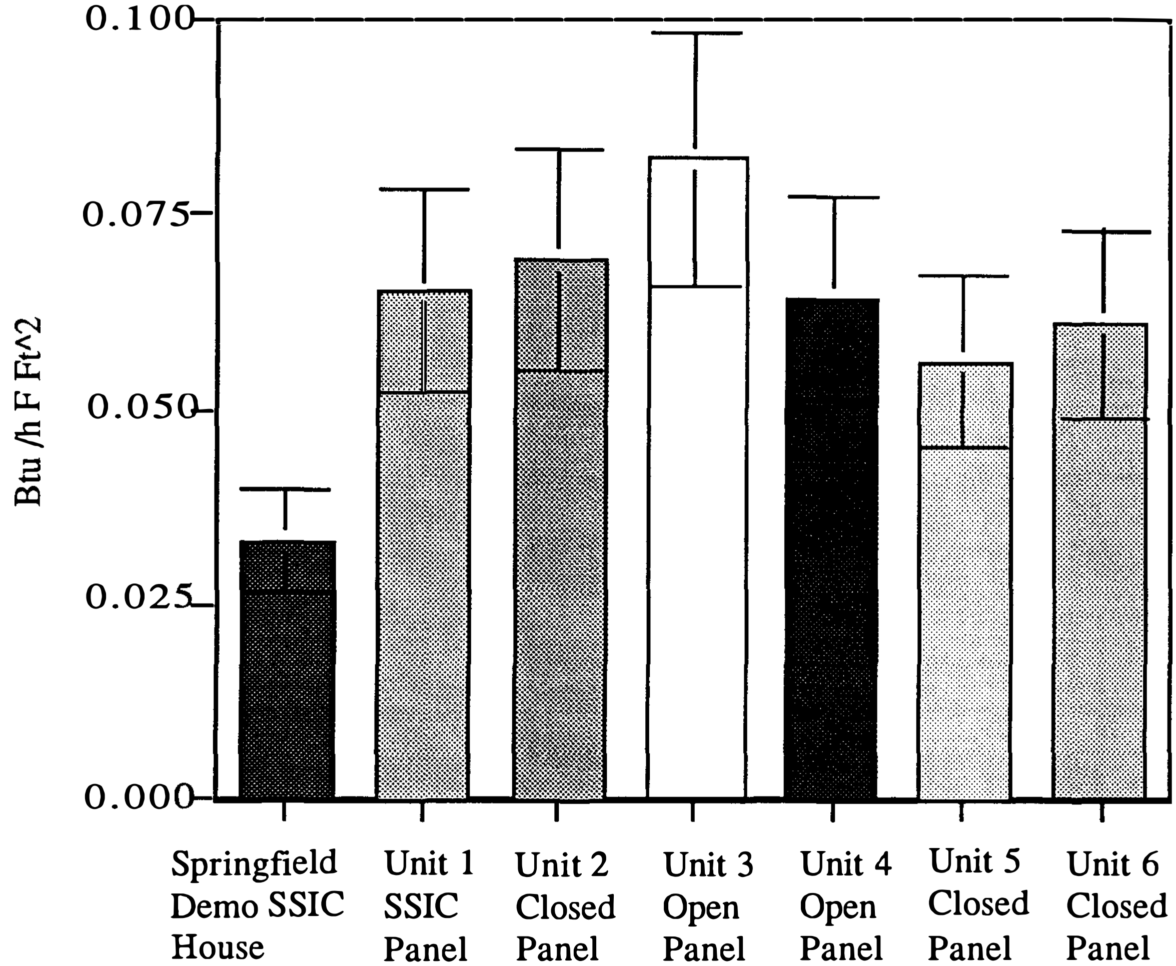

Figure 4-19
Comparison of Coheating Results for the SSIC Panel Demonstration House and University Housing Units
(UA as Measured) - (Infiltration) Divided by Surface Area

4.3 SUMMARY OF RESULTS

Overall, the results of the building diagnostic tests performed on the SSIC Panel Demonstration House indicate a high level of thermal performance and air-tightness. Results of the fan de-pressurization tests indicate that the SSIC Panel Demonstration House has an air change rate of approximately 0.053 ACH in the closed condition and 0.086 ACH in the open condition. Estimates of natural infiltration rates were made using the LBL model. The estimates of natural infiltration rates compares well to infiltration rates determined through concentration decay tracer gas tests. Tracer gas results indicate a natural infiltration rate of 0.039 ACH in closed conditions and 0.087 in open conditions. Results of both tests in both open and closed conditions are well below the recommended air change rate of .10 ACH to meet Super Good Cents advanced air leakage control. (SGC, p 4.1, 1991)

Effective leakage areas from the fan de-pressurization results were also compared to a theoretical effective leakage area for the reference house. The Demonstration House was 43% more airtight in open conditions than the theoretical reference house, Figure 4-1. The Demonstration House had an ACH_{50} 80% less than the average ACH_{50} for all six University Housing units and an ELA_4 81% less than the average ELA_4 for the six University Housing units. Even when ELA_4 was normalized by crack length of windows and doors, and joint length of panels to account for differences in design, the normalized ELA_4 of the Demonstration House was 75% less than the averaged normalized ELA_4 of the six University Housing Units.

Smoke leakage tests were performed on the SSIC Panel Demonstration House under pressurized conditions. Common areas of leakage included bathroom and kitchen vents, the hinge side of all windows, some electrical outlets, and some Envirovent registers. Slight leakage was also detected between the wall and window frame; small cracks in the finished wall were detectable in these areas. No leakage was detected at any panel joint in the walls, floor or ceiling.

Thermographic imaging did not detect any significant areas of heat loss in the Demonstration House. Common areas of conductive losses included panel-to-panel joints, panel-to-floor joints, panel-to-ceiling joints, headers above windows and doors, electrical outlets, Fresh Air 80 vents, around door openings and door frames, and around window openings and window frames. Possible losses due to infiltration occurred around door and window openings.

Results of the coheating test indicate that the Demonstration House had a measured UA value of 133 Btu/h°F. Heat loss due to infiltration was estimated to be 7.5 Btu/h°F using the average tracer gas results in closed conditions; consequently the measured UA value less infiltration was 125.5 Btu/h°F. The measured UA value less estimates of heat loss due to infiltration was 19% lower than the theoretical UA value and 22% lower than the theoretical UA value of the reference house. Overall thermal transmittance was normalized by dividing measured UA values less estimated infiltration losses by the surface area of the Demonstration House, Figure 4-19. When compared to all six University Housing units, the Demonstration House has an overall U value at least 40% less than each University Housing unit. When compared to the University Housing units, the SSIC Panel Demonstration House meets the design goal of performing 40% better than housing meeting the Oregon Energy Code.

Overall, the coheating results indicate that the Demonstration House exhibits superior thermal performance as compared to the University Housing units which were designed to meet Oregon Energy Code. The superior performance may be attributed to the higher overall R value of the Demonstration House. In addition, the use of SSIC panels for the entire envelope may have contributed to a more airtight envelope with less thermal defects then the University Housing which only employed SSIC panels for the walls. Other factors affecting the performance of the SSIC Panel Demonstration House as compared to the University Housing units include the utilization of SSIC panels for a foundation system versus slab on grade for the University Housing, differences in contractors, differences in building component manufacturers and differences in building design. In addition, testing conditions differed between the Demonstration House and the University Housing units, including different weather conditions, different testing personnel, and in the case of fan de-pressurization tests, different equipment.

5.0 REFERENCES

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Rudd, Armin and Chandra Subrato, Side- by Side Evaluation of a Stressed-Skin Insulated-Core Panel House and a Conventional Stud-Frame House, Florida Solar Energy Center, Cape Canaveral Florida, January 14, 1994.

Wattsun 5 Reference Manual. Washington State Energy Office. Olympia WA. 1991.

6.0 ACKNOWLEDGEMENTS

This project was funded by the U.S. Department of Energy contract #DE-FC51-94R020277. The SSIC Panel Demonstration House was designed by Rudy Berg, John Briscoe, G.Z. Brown, Mike Elliot, Patrick Gay, Ron Kellet, Bret Mitchel, Sam Pierce, Richard Rapp, Richa Wilson of the ESBL, Center for Housing Innovation, University of Oregon. George Lei played an important role in the instrumentation and data collection for the project and conducted preliminary analysis of fan de-pressurization and coheating data. Armin Rudd and David Beal of the Florida Solar Energy Center provided assistance in selecting testing equipment, developing testing protocol and providing equipment.

7.0 APPENDICES

7.1 PLANS, SECTIONS AND ELEVATIONS

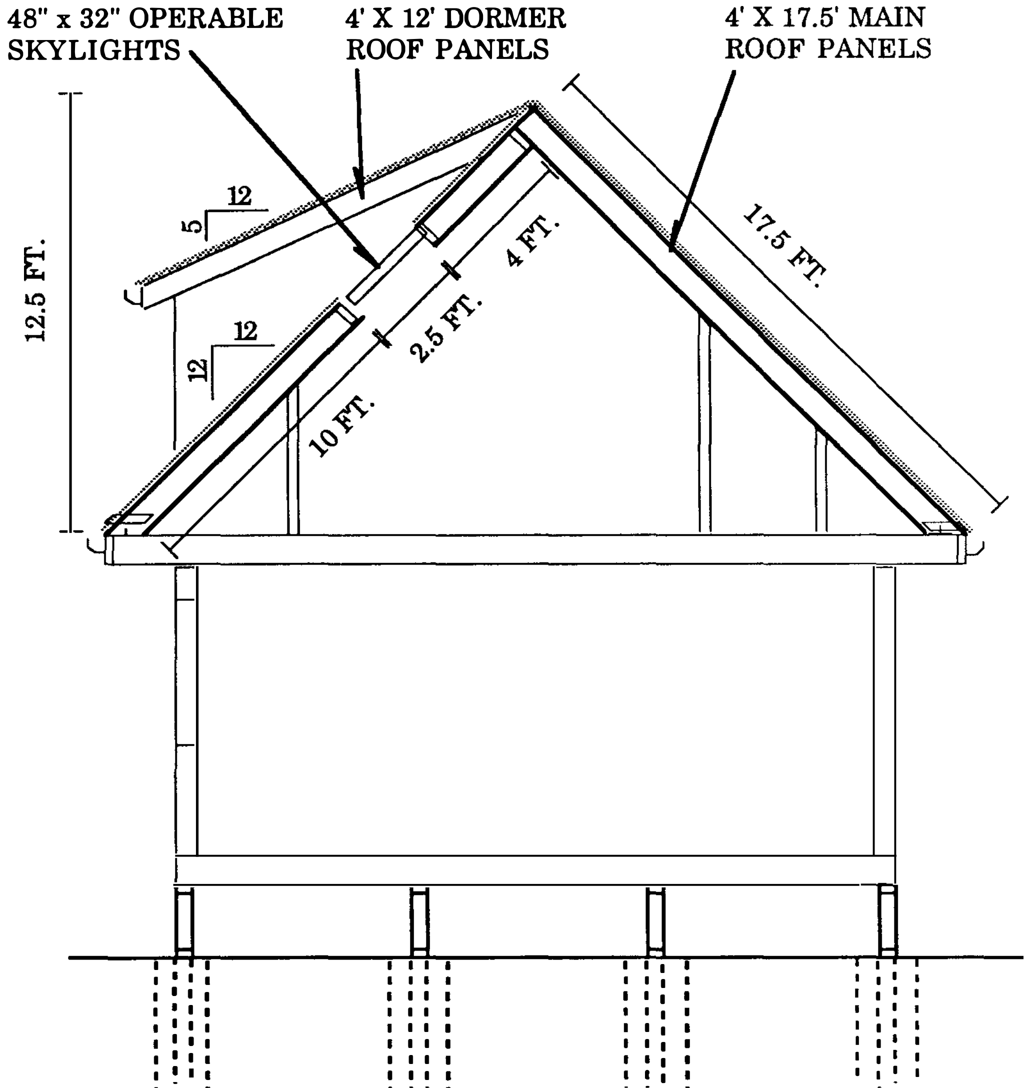


Figure 7.1-1
Demonstration House Roof Section through Skylight

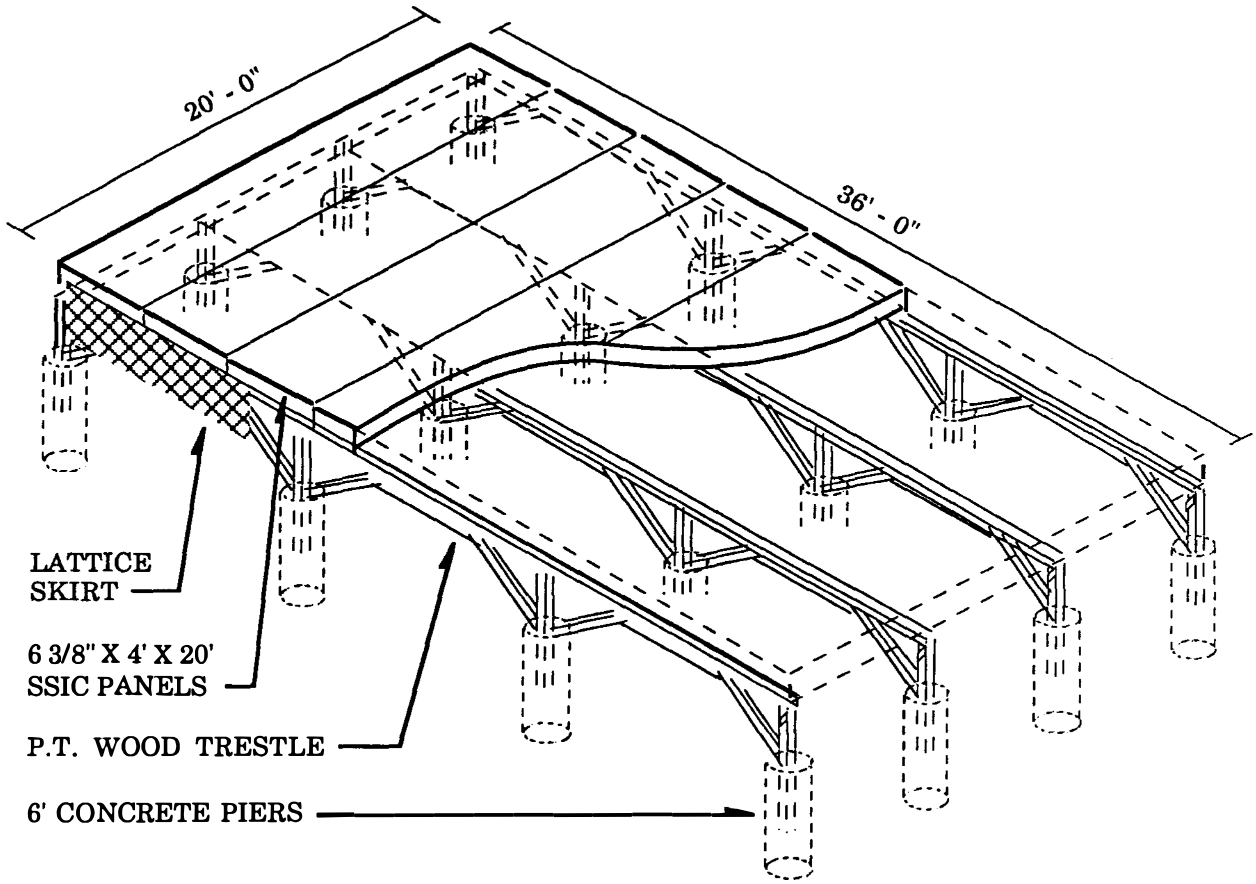


Figure 7.1-2
Demonstration House Floor and Foundation System

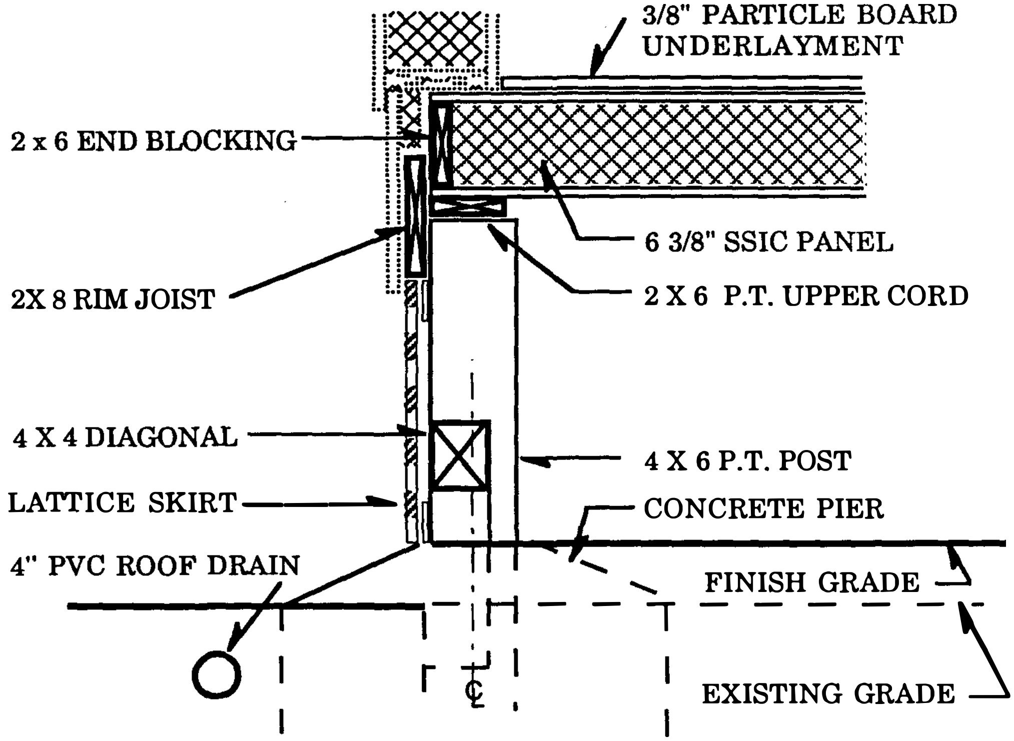


Figure 7.1 - 3
Demonstration House Floor and Foundation Section

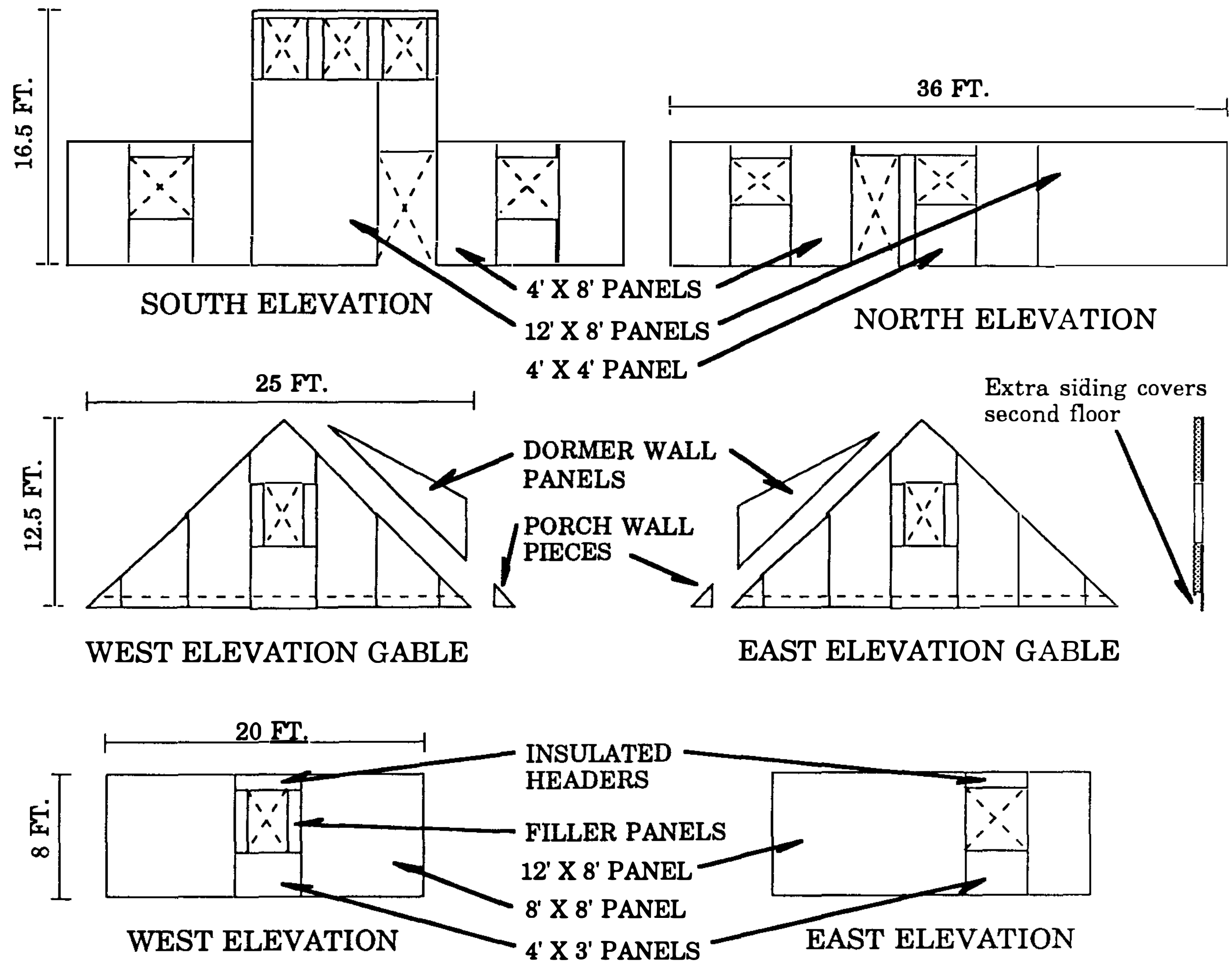


Figure 7.1-4
Demonstration House Wall Panel Layout

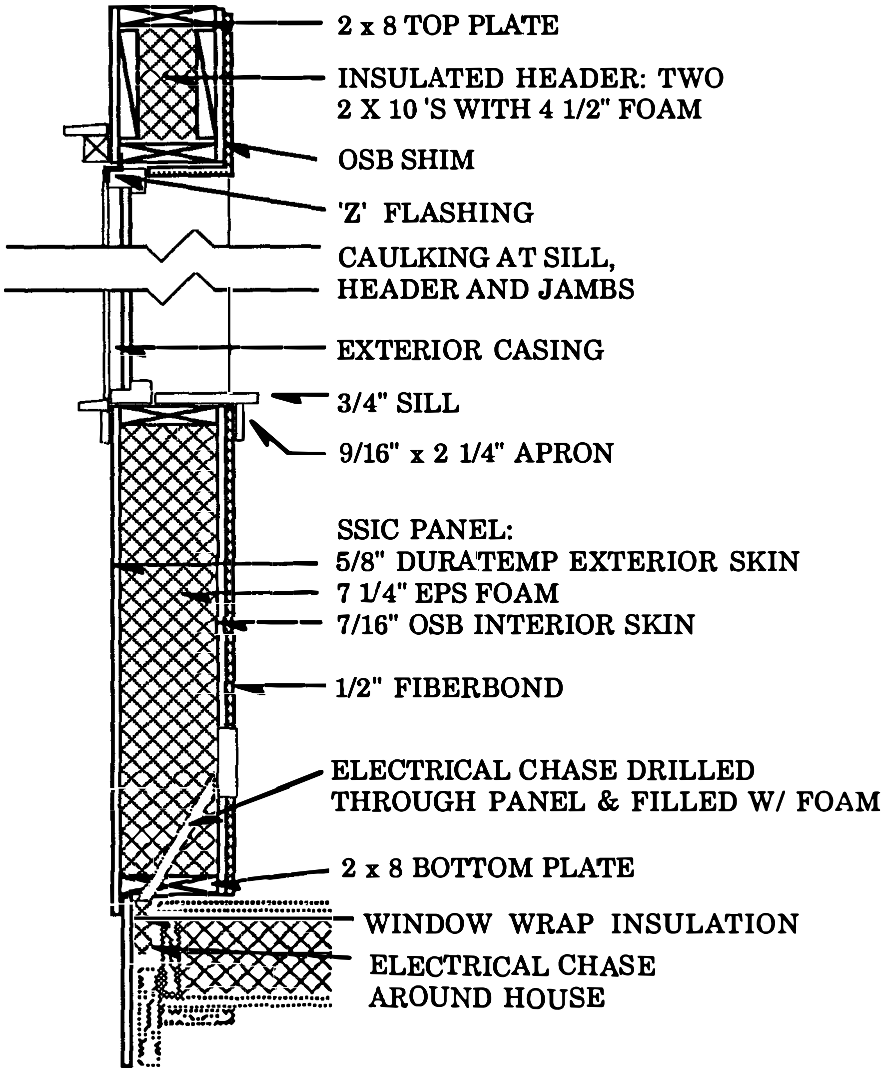


Figure 7.1-5
Demonstration House Wall Section through a Window

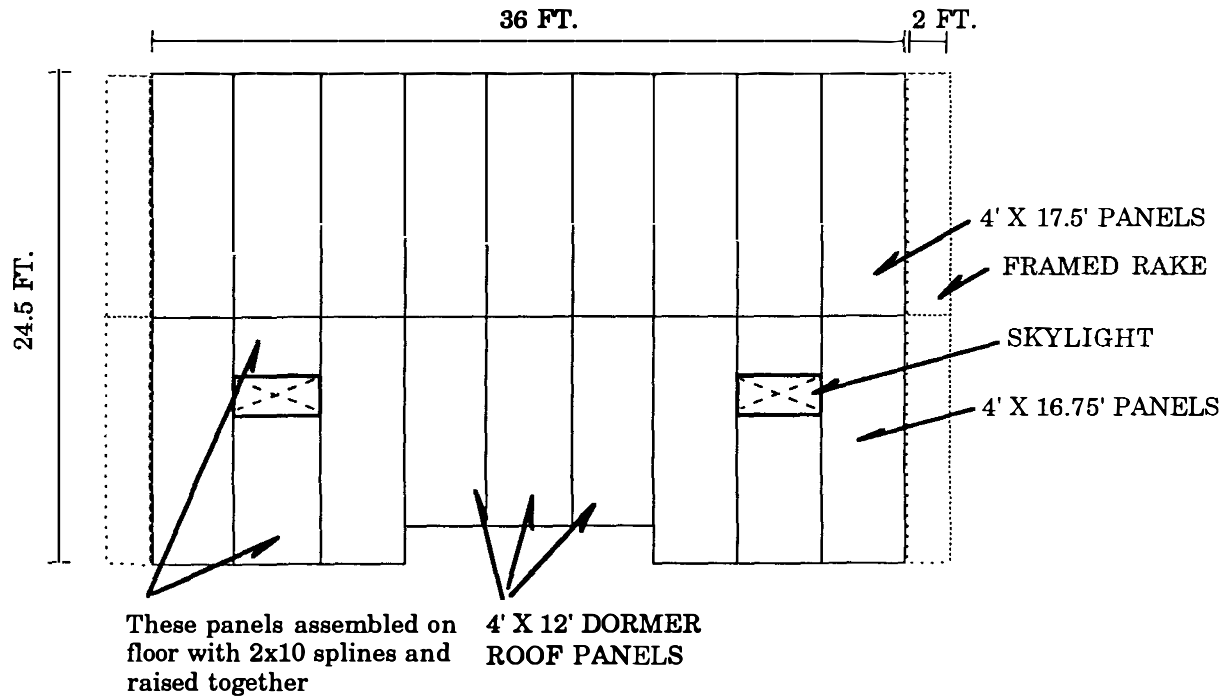


Figure 7.1-6
Demonstration House Roof Panel Layout (Plan View)

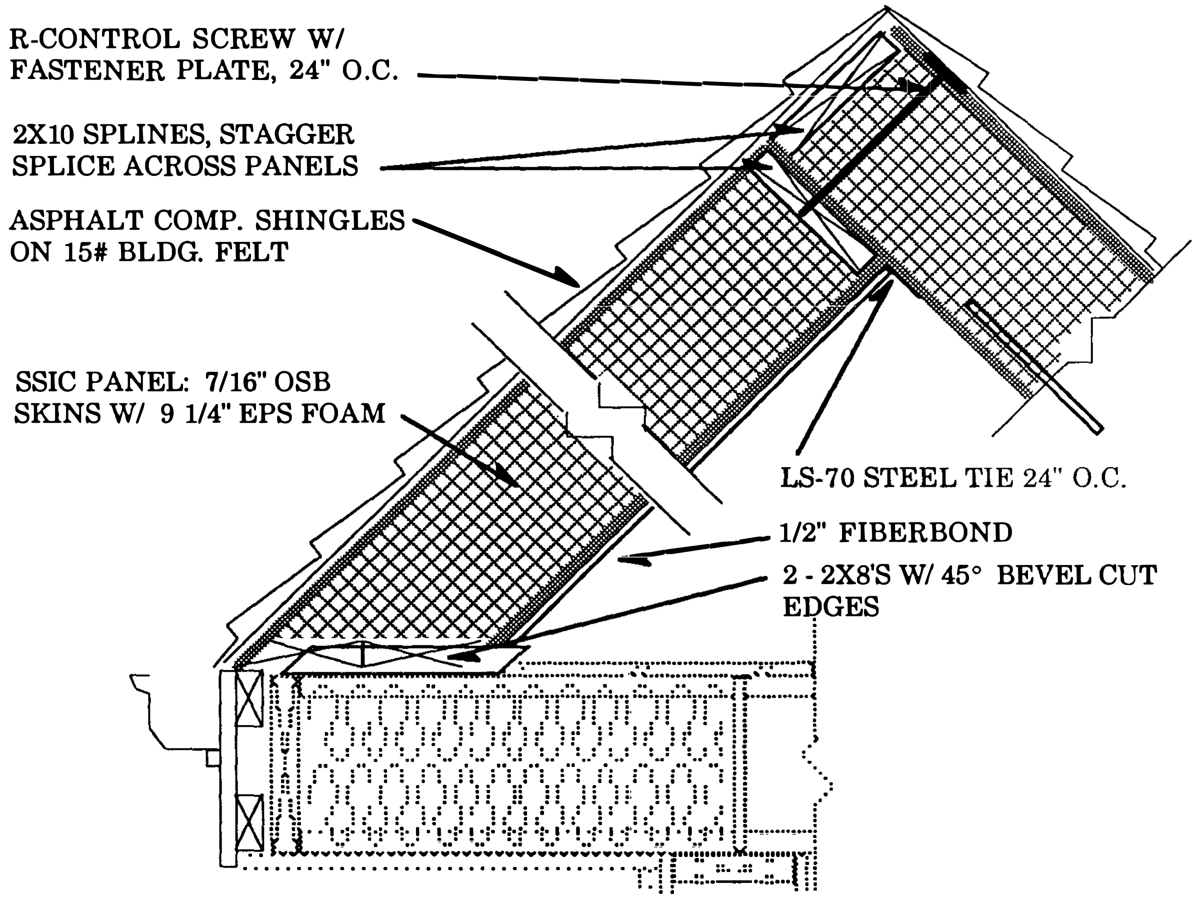


Figure 7.1-7
Demonstration House Typical Eaves and Ridge Details

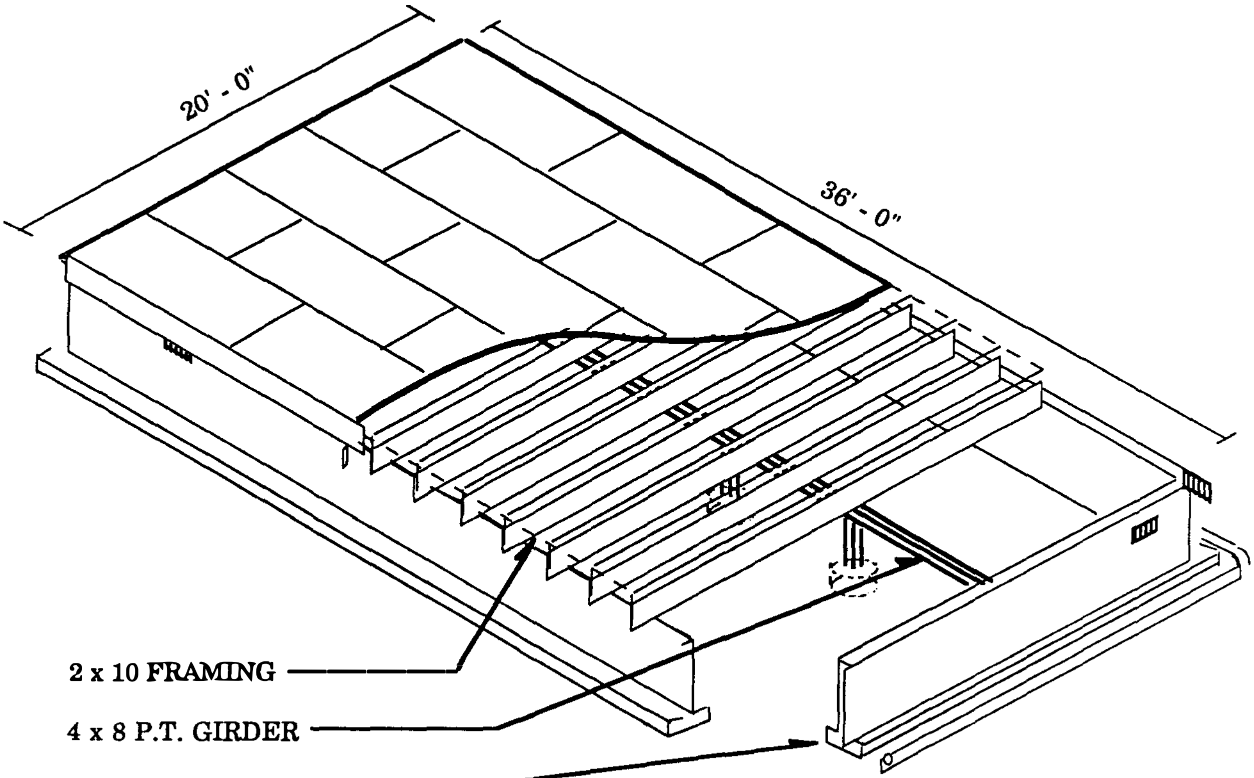


Figure 7.1-8
Reference House Floor and Foundation System

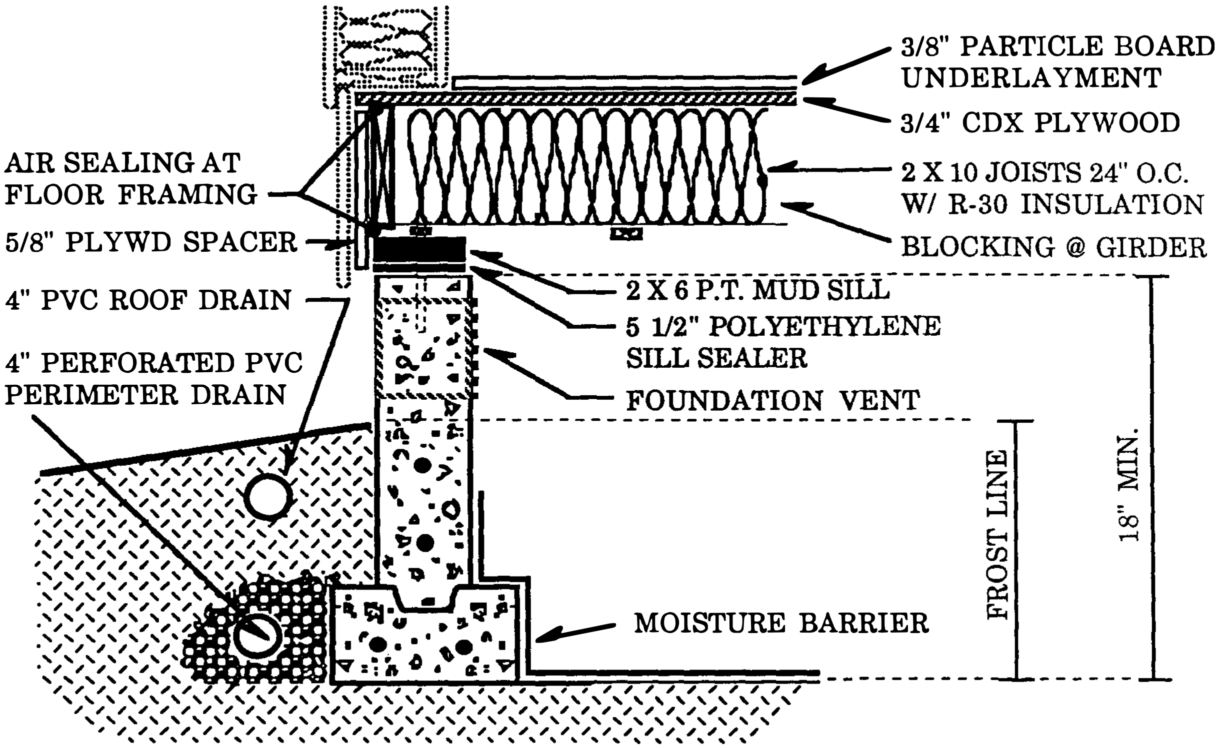


Figure 7.1-9
Reference House Floor and Foundation Section

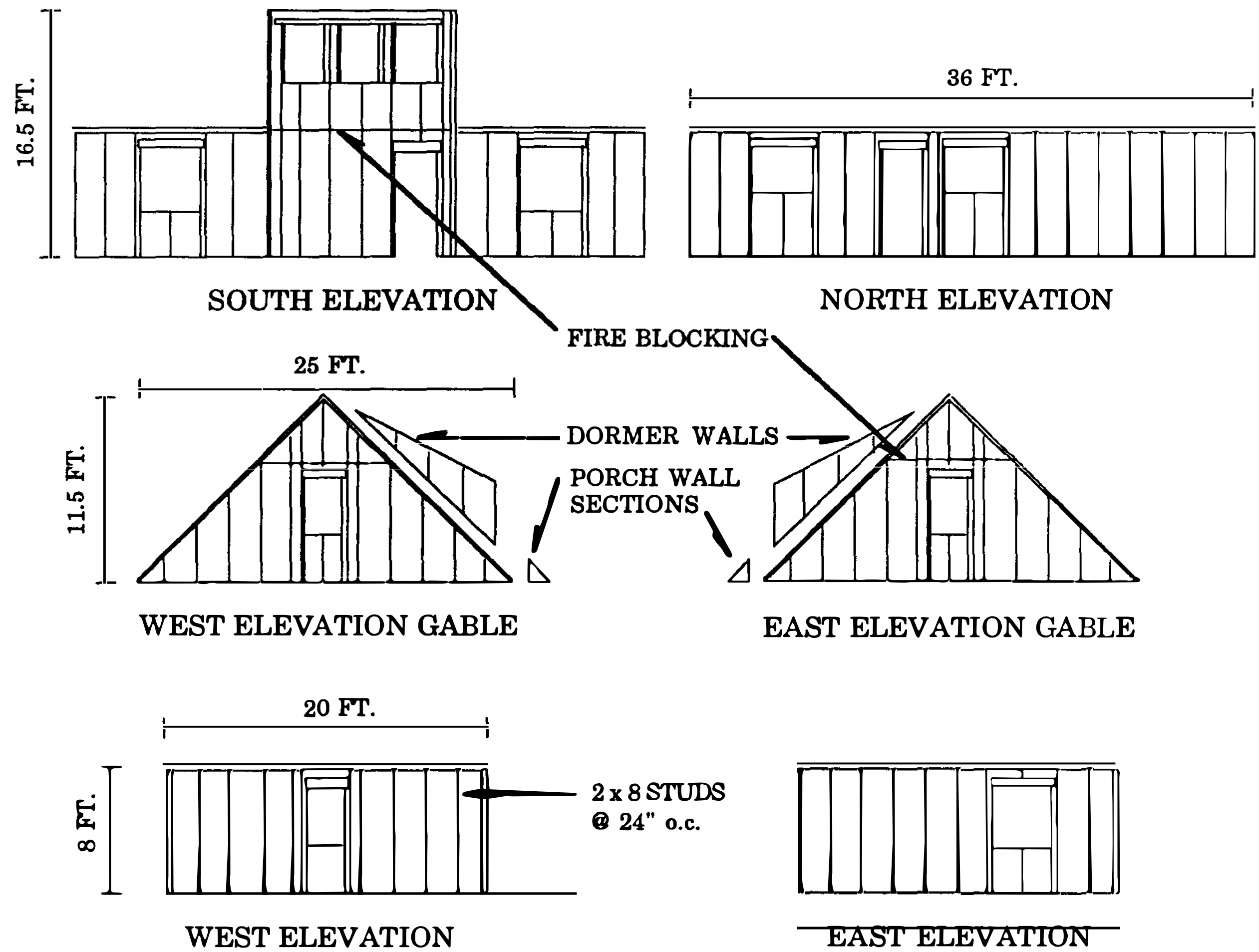


Figure 7.1-10
Reference House Wall Framing

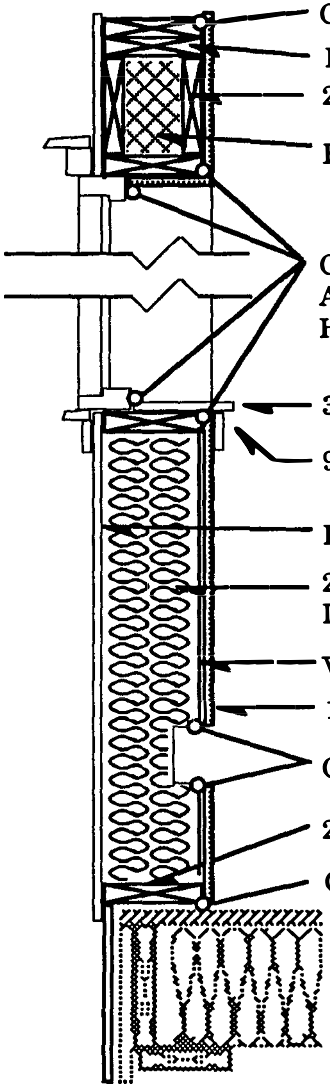


Figure 7.1-11
Reference House Wall Section through Window

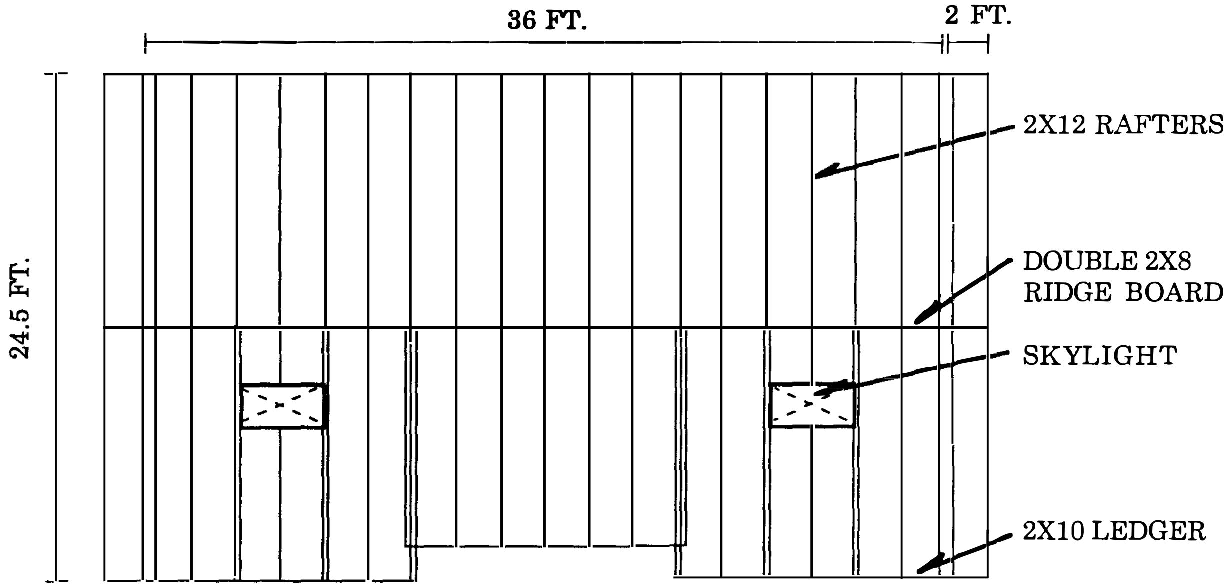


Figure 7.1-12
Reference House Roof Framing Plan

Reference House Sections and Details

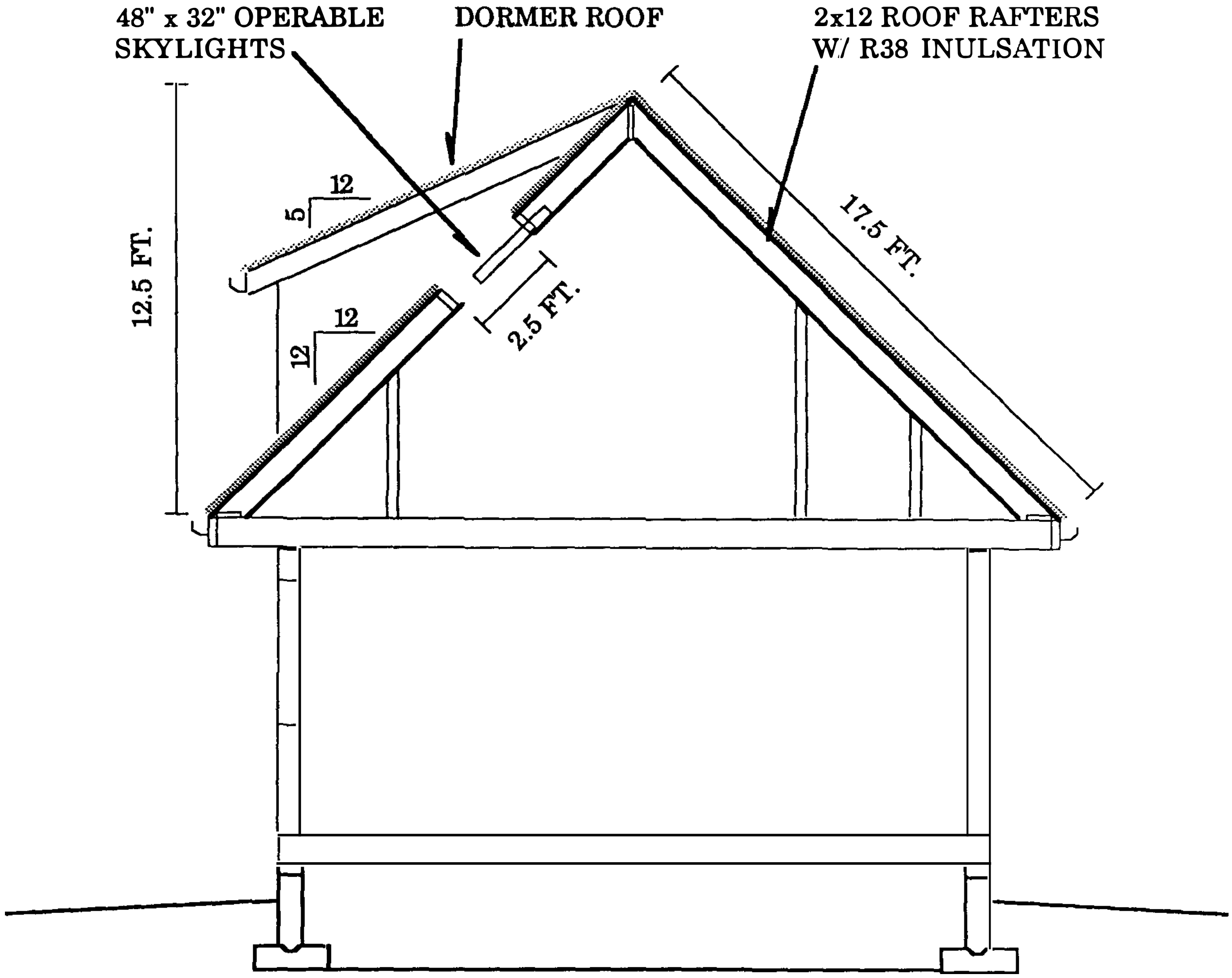


Figure 7.1-13
Reference House Roof Section

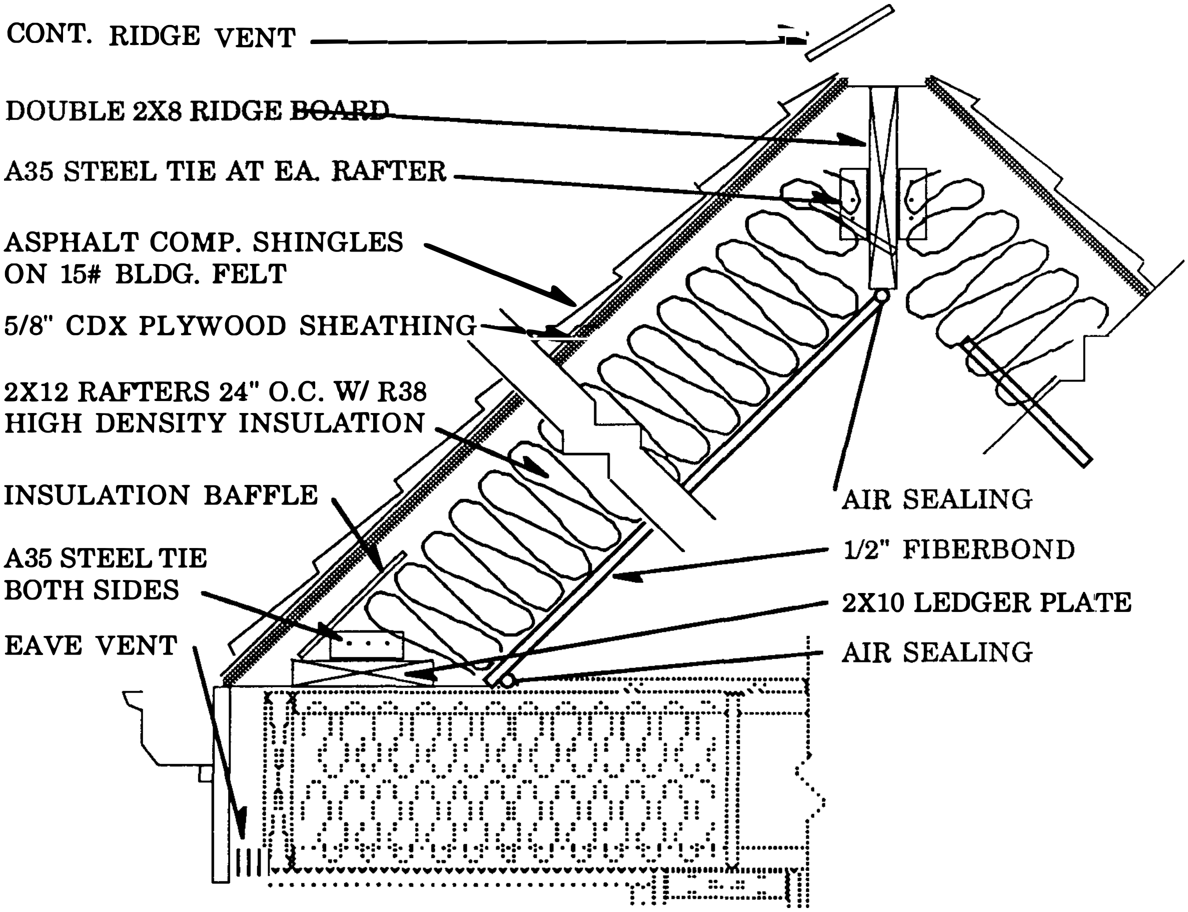
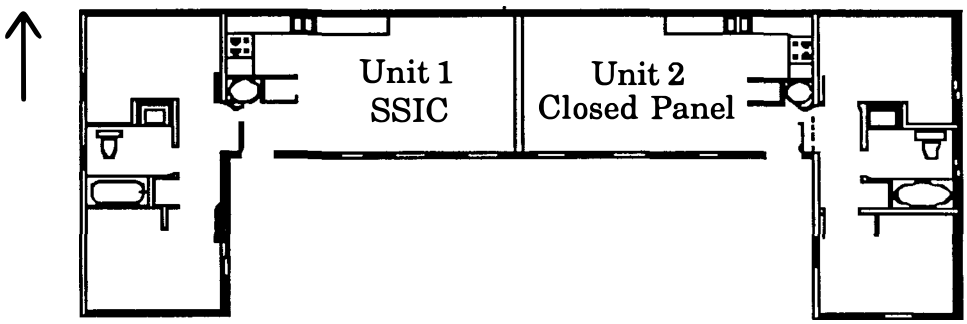
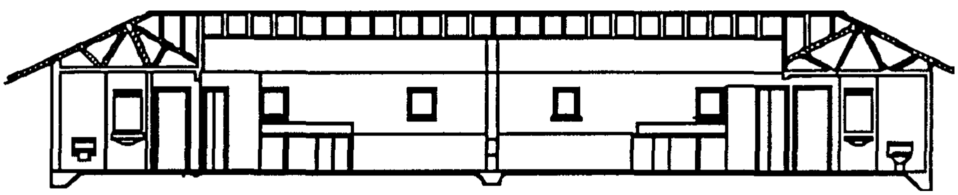


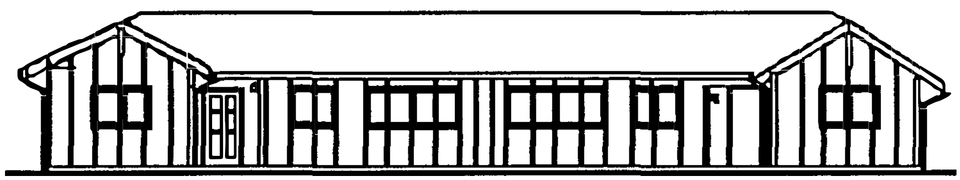
Figure 7.1-14
Reference House Typical Eaves and Ridge Details



Floor Plan



East-West Section of 1 Story Duplex



South Elevation of 1 Story Duplex

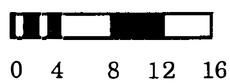
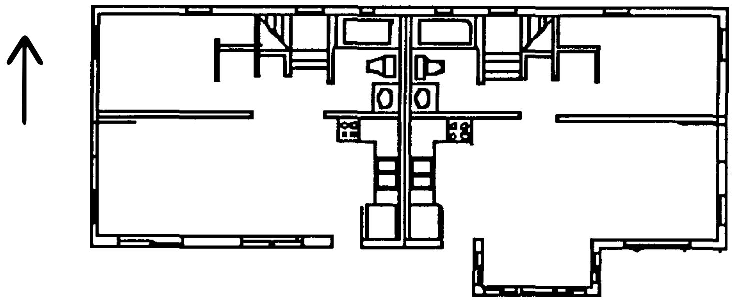
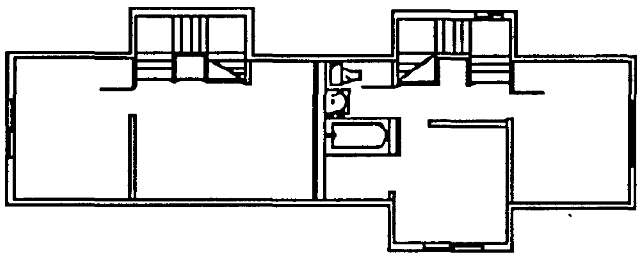


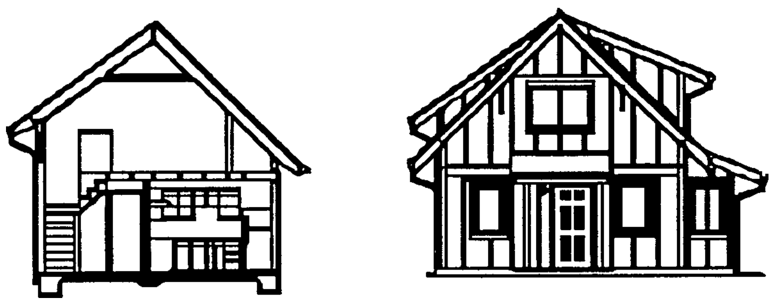
Figure 7.1-15
1 Story SSIC Panel and Closed Panel Duplex



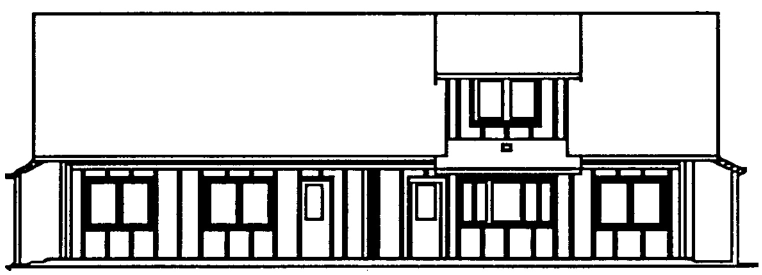
Ground Floor Plan



Second Floor Plan



North-South Section and East Elevation



South Elevation

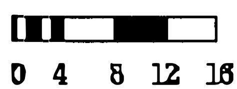


Figure 7.1-16
1 1/2 Story Duplex Plans, Sections and Elevations

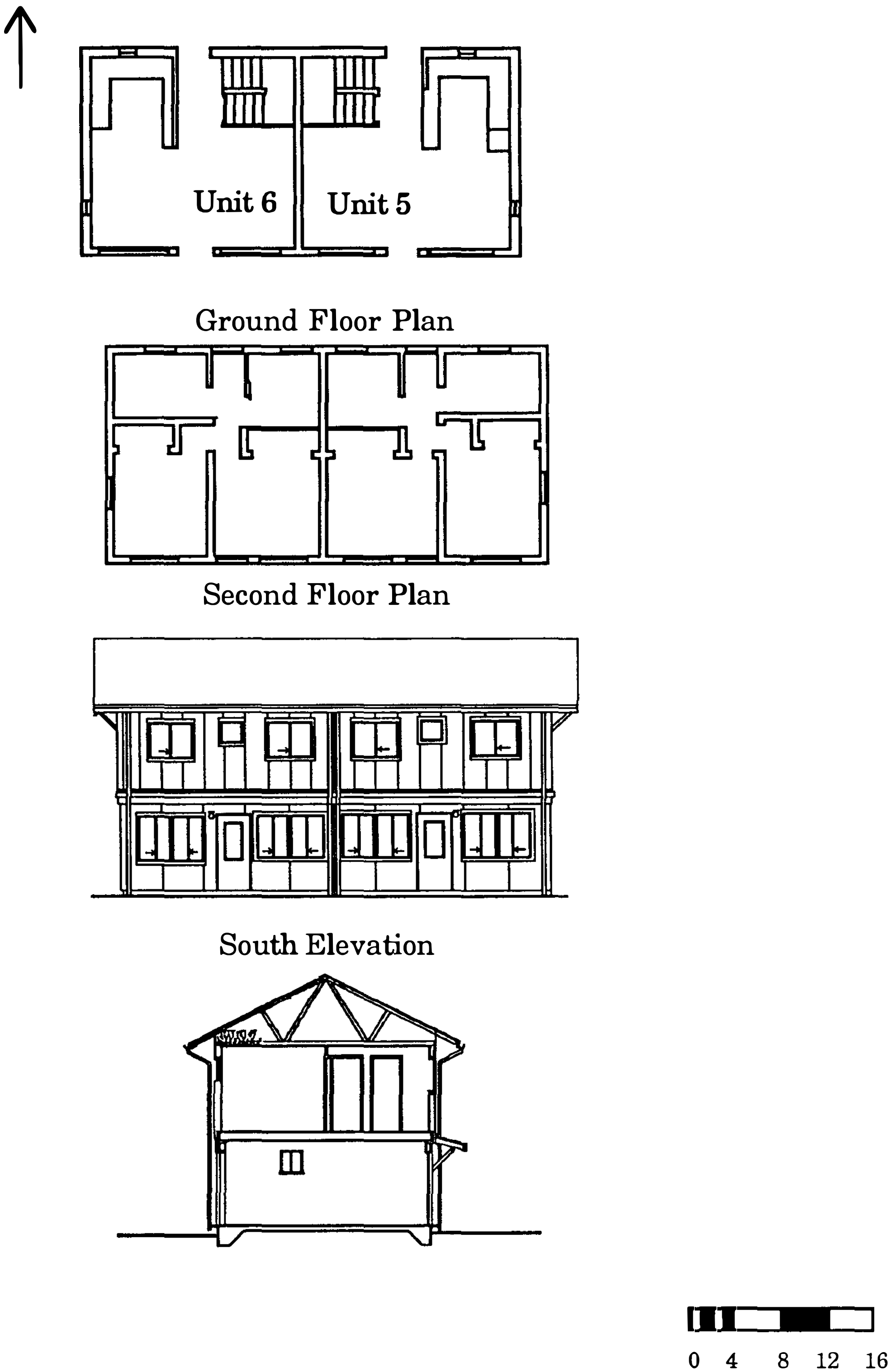


Figure 7.1-17
2 Story Closed Panel Duplex

Unit 1

Unit 1 is the west unit of the 1 story duplex. The construction of Unit 1 features R23 SSIC panel wall. The SSIC panels include an interior and exterior skin of oriented strand board (OSB). Wiring chases were predrilled in the factory. Exterior siding and 15# asphalt felt were installed on site. Gypsum board was also installed on site. In addition, the interior was finished with a layer of vapor barrier paint. The roof, a 6:12 pitch, is primarily formed of manufactured parallel chord trusses with R38 batt insulation. The roof area over the bathroom and hallway, 24% of the total roof area, was constructed as a flat roof with R49 insulation. R49 batt was lapped from the flat roof to the vaulted roof. The slab-on-grade foundation is 4" of concrete, over 2" of sand resting on R5 extruded polystyrene and a 6 mil vapor barrier above a sub grade of 4" of minus 3/4" crushed gravel. At the slab's edge, R15 extruded polystyrene insulates the slab to its depth of 28 inches. At the bottom of the slab edge, the extruded polystyrene is turned outward at a right angle from the slab for 4 inches. In addition, the party wall between Unit 1 and 2 is constructed of an 8" thick, grout filled concrete masonry unit (CMU) to a height of 8 feet. The party wall is traditionally framed above the CMU.

Unit 2

Unit 2 is the east unit of the 1 story duplex and is identical in size and configuration to Unit 1. However,the walls are constructed of manufactured closed panels with an R value of 26 The closed panel walls are composed of an exterior skin of 5/8" T-11 siding with 1"x 2" battens at 24" o.c., 5/8" celotex "blackcore" polyisocyanurate foil face, 15# asphalt felt 2x6 stud framing at 24" o.c., with high density fiberglass batt insulation, 5/8" gypsum board applied in the factory and a vapor barrier paint. The closed panel units also featured a gasket similar to a sill barrier at the panel to panel joints; however, often these "gaskets" were removed to facilitate connection of panels. The wire chases are predrilled in the factory. The roof insulation and foundation construction are identical to Unit 1.

Unit 3

Unit 3 is the west unit of the 1 1/2 story duplex. The walls consist of manufactured open panels. The open panels are identical in construction to the closed panels. However, all the wiring, installation of high density batt insulation and hanging of gypsum board is performed in the field. The foundation is of the same construction of Units 1 and 2. The roof is formed of manufactured trusses with panelized dormer panels framed and sheathed in the factory. Unit 3 also has a combination of vaulted R 38 roof insulation (42%) and Flat R 49 roof insulation (58%). The second floor is formed by the bottom chord of the manufactured trusses and 2 x 8 framing at 24" o.c. under the dormers. The truss system is secured to the top of the open panels as in platform construction. Unit 3 also has 2 doors instead of 1 as in Units 1 and 2.

Unit 4

Unit 4 is the east unit of the 1 1/2 story open panel duplex. Unit 4 is identical in construction to Unit 3. However, unit 3 differs in geometry and size due to the addition of a south facing bay which acts as a breakfast nook. The breakfast nook increases the amount of surface area and window area as compared to Unit 3.

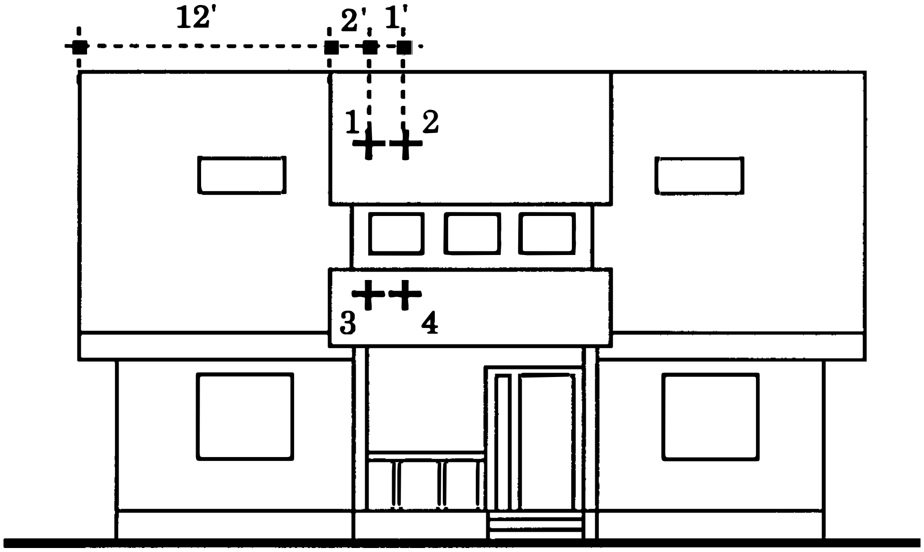
Units 5 and 6

Units 5 and 6 are identical in construction and geometry. Unit 5 is the east side of the duplex, and Unit 6 is the west side of the duplex. The walls are manufactured closed panels identical to the closed panels of Unit 2. The foundations are also identical in construction as all the other units. The roof is constructed of manufactured trusses, and the insulation is entirely of R49 batt insulation in flat roof construction. The 2nd floor is constructed of prefabricated floor cassettes which act as a platform for the second floor walls. Units 5 and 6 share an 8 inch, grout filled CMU party wall on the ground floor for thermal mass. The party wall on the second floor is traditionally framed.

Ventilation Devices

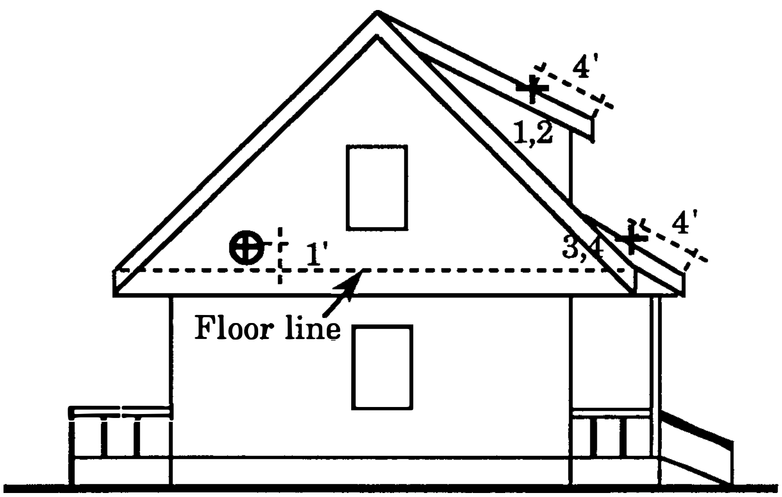
All six units have features to allow ventilation. These features include slotted vents in designated windows, referred to as BPA vents, which are user controlled. In addition, there are ceiling vents operated by bimetallic controls for stack ventilation and bathroom vents operated by timers. All of the ceiling vents, BPA vents, and bathroom vents were closed and taped off for fan de-pressurization and coheating tests.

7.2 INSTRUMENTATION



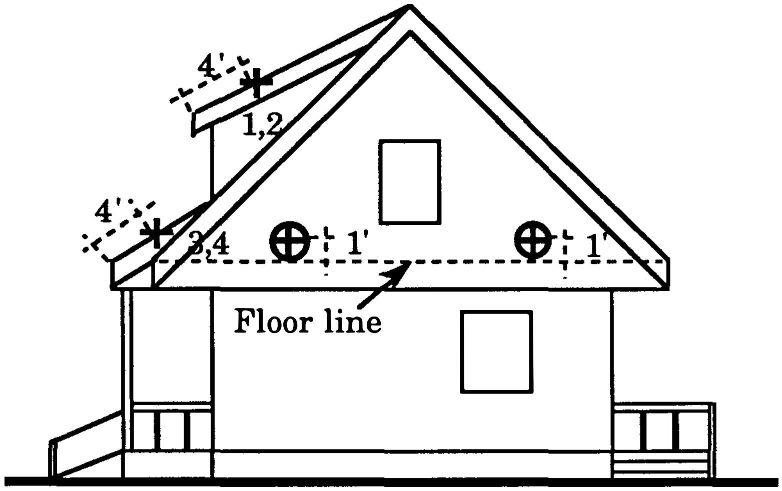
SOUTH ELEVATION

+ THERMOCOUPLE LOCATION



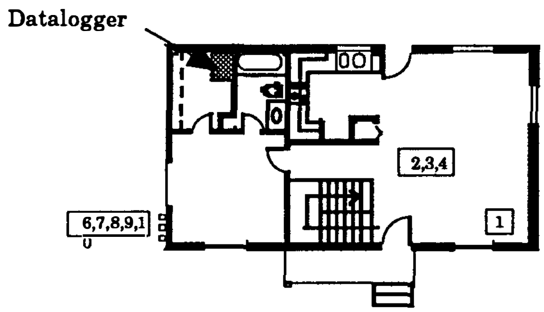
WEST ELEVATION

⊕ WOOD MOISTURE SENSOR LOCATION

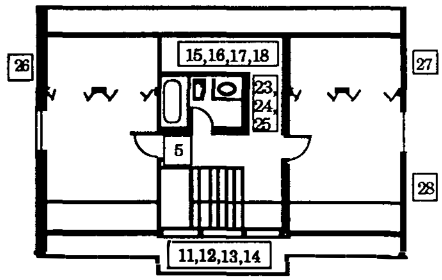


EAST ELEVATION

⊕ WOOD MOISTURE
SENSOR LOCATION



FIRST FLOOR PLAN



SECOND FLOOR PLAN

SENSOR	LOCATION	SENSOR	LOCATION
1	South Wall Temperature	13	Roof Shingle Temperature
2	Ambient Air Temperature	14	Roof Shingle Temperature
3	Mean Radiant Temperature	15	Envirovent, Return Inlet
4	Relative Humidity	16	Envirovent, Supply Outlet
5	Upstairs Ambient Air	17	Envirovent, Exhaust Inlet
6	Meter (main)	18	Envirovent, Exhaust Outlet
7	Meter (downstairs space heaters)	23	Hot Water Inlet Temperature
8	Meter (upstairs space heaters)	24	Hot Water Outlet Temperature
9	Meter (heat pump)	25	Water Flow
10	Meter (water heating)	26	Wood Moisture Sensor (Northwest)
11	Roof Shingle Temperature	27	Wood Moisture Sensor (Northeast)
12	Roof Shingle Temperature	28	Wood Moisture Sensor (Southeast)

7.3 BLOWER DOOR DATA

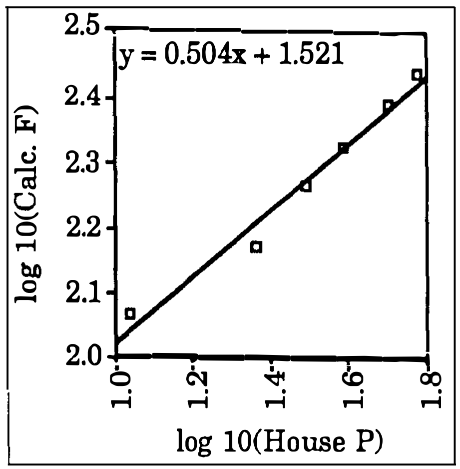
BLOWER DOOR TEST RESULTS: AIR LEAKAGE THROUGH BUILDING ENVELOPE

Home: Demonstration House		Address: Springfield, OR			
Date:	03 May 94				
House Floor Area:	1338 sq. ft	Indoor Air Temp (F):	70	C=	21
House Volume:	10636 cu.ft.	Outdoor Air Temp (F):	63	H=	0.9
House Surface Area:	3107 sq.ft.	Air density factor:	0.993	S=	1
Fresh Air Inlets:	Closed			L=	1.4
Special Note: No Forced Air				N=	26.46

Low Flow Plate # of Holes Plugged	House Pressure (Pa)	log 10	Fan Pressure (Pa)	Calc Flow (cfm)	log 10
4	11.00	1.041	3.00	117.24	2.069
4	23.00	1.362	5.00	147.84	2.17
4	31.00	1.491	8.00	183.01	2.262
4	39.00	1.591	11.00	211.48	2.325
4	51.00	1.708	15.00	243.45	2.386
4	60.00	1.778	19.00	271.03	2.433

Regression Output	
X Coefficient:	0.504
Constant:	1.521
r:	0.987
r squared:	0.975

CFM4 =	66.75 cfm - from curve fit
CFM10 =	105.93 cfm - from curve fit
ELA =	18.92 sq. in @ 4 Pa
EqLA =	31.13 sq. in @ 10 Pa
CFM50 =	238.39 cfm - from curve fit
ACH50 =	1.34 air changes per hour at 50 Pascal
ACH50/20 =	0.07 estimate of natural ACH by Persily
ACH50/N =	0.05 estimate of natural ACH by Sherman
SLA =	0.98 ELA / Floor Area



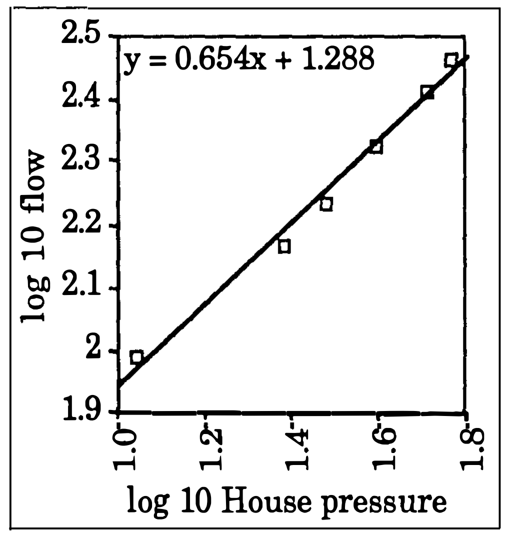
BLOWER DOOR TEST RESULTS: AIR LEAKAGE THROUGH BUILDING ENVELOPE

Home: Demonstration House
Address: Springfield, OR
Date: 03 May 94

House Floor Area:	1338 sq. ft	Indoor Air Temp (F):	70	C=	21
House Volume:	10636 cu.ft.	Outdoor Air Temp (F)	63	H=	0.9
House Surface Area:	3107 sq.ft.	Air density factor:	0.993	S=	1
Fresh Air Vents:	Closed			L=	1.4
Special Note: No Forced Air				N=	26.46

Low Flow Plate # of Holes Plugged	House Pressure (Pa)	log 10	Fan Pressure (Pa)	Calc Flow (cfm)	log 10
4	11.00	1.041	2.00	97.53	1.989
4	24.00	1.380	5.00	147.84	2.17
4	30.00	1.477	7.00	172.24	2.236
4	39.00	1.591	11.00	211.48	2.325
4	51.00	1.708	17.00	257.69	2.411
4	58.00	1.763	22.00	289.69	2.462

Regression Output	
X Coefficient:	0.654
Constant:	1.288
r:	0.955
r squared	0.989



CFM4 = 48.06 cfm - from curve fit
CFM10 = 87.50 cfm - from curve fit
ELA = 13.62 sq. in @ 4 Pa
EqLA = 25.72 sq. in @ 10 Pa
CFM50 = 250.68 cfm - from curve fit
ACH50 = 1.41 air changes per hour at 50 Pascal
ACH50/20 = 0.07 estimate of natural ACH by Persily
ACH50/N = 0.05 estimate of natural ACH by Sherman
SLA = 0.71 ELA / Floor Area

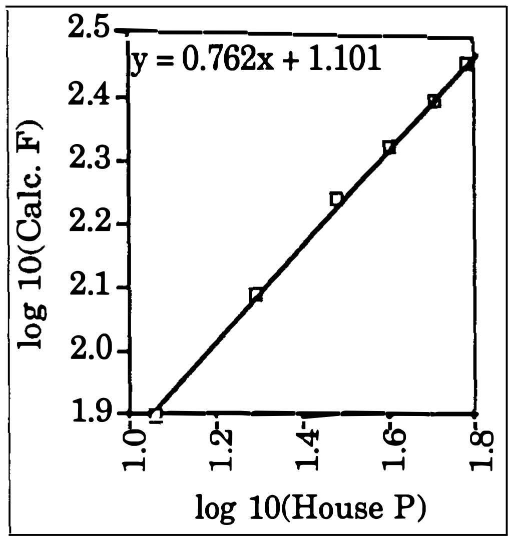
BLOWER DOOR TEST RESULTS: AIR LEAKAGE THROUGH BUILDING ENVELOPE

Home: Demonstration House		Address: Springfield, OR				
Date: 23 May 94						
House Floor Area:	1338 sq. ft	Indoor Air Temp (F):	72		C=	21
House Volume:	10636 cu.ft.	Outdoor Air Temp (F)	75		H=	0.9
House Surface Area:	3107 sq.ft.	Air density factor:	1.003		S=	1
Fresh Air Vents:	Closed				L=	1.4
Special Note: No Forced Air					N=	26.46

Low Flow Plate # of Holes Plugged	House Pressure (Pa)	log 10	Fan Pressure (Pa)	Calc Flow (cfm)	log 10
8	11.50	1.061	37.00	79.62	1.901
8	19.50	1.290	93.00	123.58	2.092
7	30.50	1.484	68.00	174.10	2.241
7	40.00	1.602	101.00	209.27	2.321
6	51.00	1.708	54.00	249.46	2.397
6	60.00	1.778	71.00	283.62	2.453

Regression Output	
X Coefficient:	0.762
Constant:	1.101
r	0.999
r squared	0.999

CFM4 =	36.29 cfm - from curve fit
CFM10 =	72.95 cfm - from curve fit
ELA =	10.29 sq. in @ 4 Pa
EqLA =	21.44 sq. in @ 10 Pa
CFM50 =	248.67 cfm - from curve fit
ACH50 =	1.40 air changes per hour at 50 Pascal
ACH50/20 =	0.07 estimate of natural ACH by Persily
ACH50/N =	0.05 estimate of natural ACH by Sherman
SLA =	0.53 ELA / Floor Area



BLOWER DOOR TEST RESULTS: AIR LEAKAGE THROUGH BUILDING ENVELOPE

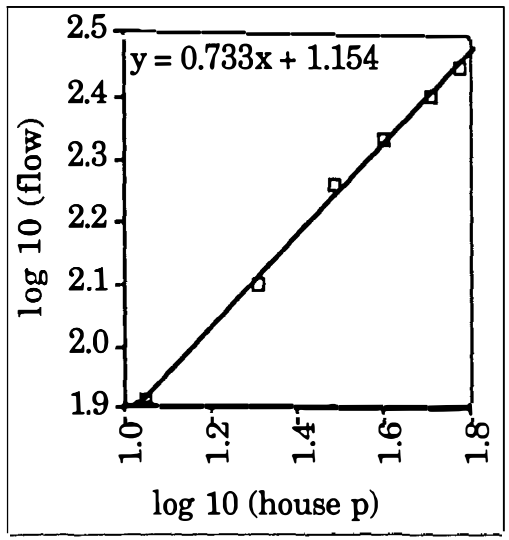
Home: Demonstration House		Address: Springfield, OR					
Date: 23 May 94							
House Floor Area:	1338 sq. ft	Indoor Air Temp (F):	73			C=	21
House Volume:	10636 cu.ft.	Outdoor Air Temp (F)	74			H=	0.9
House Surface Area:	3107 sq.ft.	Air density factor:	1.001			S=	1
Fresh Air Vents:	Closed					L=	1.4
Special Note: No Forced Air						N=	26.46

Low Flow Plate # of Holes Plugged	House Pressure (Pa)	log 10	Fan Pressure (Pa)	Calc Flow (cfm)	log 10
8	11.50	1.061	37.00	79.62	1.901
8	19.50	1.290	93.00	123.58	2.092
7	30.50	1.484	68.00	174.10	2.241
7	40.00	1.602	101.00	209.27	2.321
6	51.00	1.708	54.00	249.46	2.397
6	60.00	1.778	71.00	283.62	2.453

Regression Output

X Coefficient:	0.733
Constant:	1.154
r:	0.999
r squared:	0.998

CFM4 =	39.38 cfm - from curve fit
CFM10 =	77.09 cfm - from curve fit
ELA =	11.17 sq. in @ 4 Pa
EqLA =	22.66 sq. in @ 10 Pa
CFM50 =	250.81 cfm - from curve fit
ACH50 =	1.41 air changes per hour at 50 Pascal
ACH50/20 =	0.07 estimate of natural ACH by Persily
ACH50/N =	0.05 estimate of natural ACH by Sherman
SLA =	0.58 ELA / Floor Area



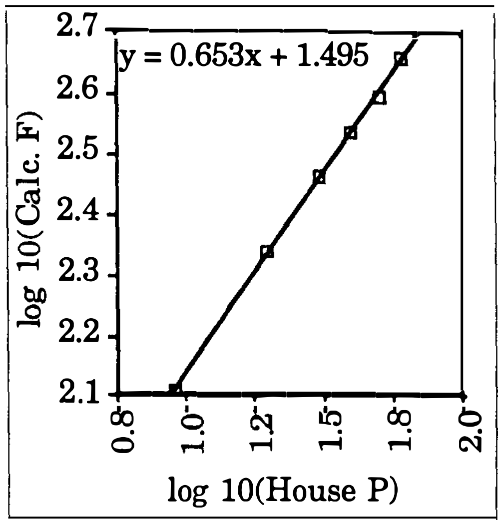
BLOWER DOOR TEST RESULTS: AIR LEAKAGE THROUGH BUILDING ENVELOPE

Home: Demonstration House		Address: Springfield, OR			
Date: 09 Jun 94					
House Floor Area:	1338 sq. ft	Indoor Air Temp (F):	72.14	C=	21
House Volume:	10636 cu.ft.	Outdoor Air Temp (F)	68	H=	0.9
House Surface Area:	3107 sq.ft.	Air density factor:	0.996	S=	1
Fresh Air Vents:	Open			L=	1.4
Special Note: No Forced Air				N=	26.46

Low Flow Plate # of Holes Plugge(	House Pressure (Pa)	log 10	Fan Pressure (Pa)	Calc Flow (cfm)	log 10
8	9.00	0.95	105.00	130.03	2.114
7	19.50	1.29	114.00	219.84	2.342
6	30.00	1.48	76.00	290.78	2.464
6	39.00	1.59	108.00	342.87	2.535
4	50.00	1.70	43.00	393.89	2.595
4	60.00	1.78	59.50	456.47	2.659

Regression Output	
X Coefficient:	0.653
Constant:	1.495
r:	1
r squared:	0.999

CFM4 =	77.29	cfm - from curve fit
CFM10 =	140.60	cfm - from curve fit
ELA =	21.91	sq. in @ 4 Pa
EqLA =	41.32	sq. in @ 10 Pa
CFM50 =	402.19	cfm - from curve fit
ACH50 =	2.27	air changes per hour at 50 Pascal
ACH50/20 =	0.11	estimate of natural ACH by Persily
ACH50/N =	0.09	estimate of natural ACH by Sherman
SLA =	1.14	ELA \ Floor Area



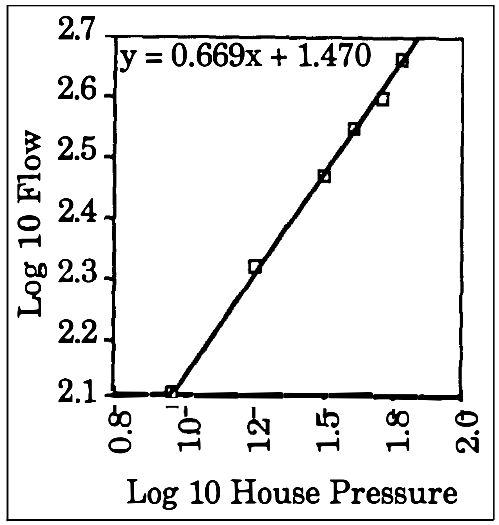
BLOWER DOOR TEST RESULTS: AIR LEAKAGE THROUGH BUILDING ENVELOPE

Home: Demonstration House		Address: Springfield, OR			
Date: 09 Jun 94					
House Floor Area:	1338 sq. ft	Indoor Air Temp (F):	72.5	C=	21
House Volume:	10636 cu.ft.	Outdoor Air Temp (F):	69.8	H=	0.9
House Surface Area:	3107 sq.ft.	Air density factor:	0.997	S=	1
Fresh Air Vents:	Open			L=	1.4
Special Note: No Forced Air				N=	26.46

Low Flow Plate # of Holes Plugged	House Pressure (Pa)	log 10	Fan Pressure (Pa)	Calc Flow (cfm)	log 10
8	9.00	0.954	99.00	126.43	2.102
7	18.00	1.255	103.00	209.71	2.322
6	31.50	1.498	80.00	297.86	2.474
6	41.00	1.613	118.00	357.41	2.553
4	51.50	1.712	44.00	398.02	2.6
4	59.00	1.771	61.00	461.66	2.664

Regression Output	
X Coefficient:	0.669
Constant:	1.47
r:	0.999
r squared:	0.998

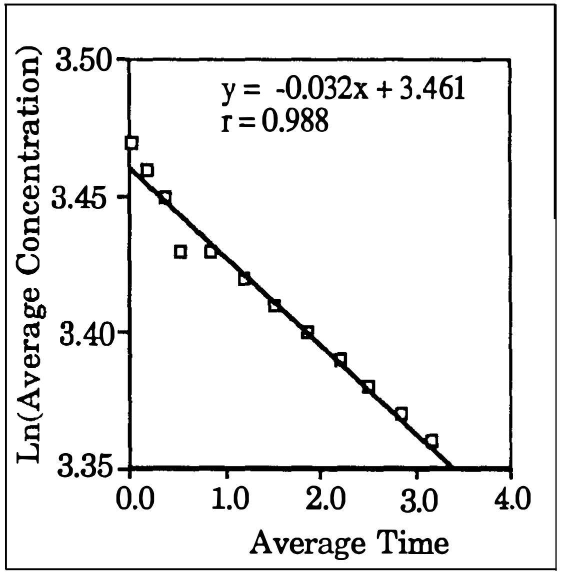
CFM4 =	74.61	cfm - from curve fit
CFM10 =	137.72	cfm - from curve fit
ELA =	21.15	sq. in @ 4 Pa
EqLA =	40.48	sq. in @ 10 Pa
CFM50 =	404.21	cfm - from curve fit
ACH50 =	2.28	air changes per hour at 50 Pascal
ACH50/20 =	0.11	estimate of natural ACH by Persily
ACH50/N =	0.09	estimate of natural ACH by Sherman
SLA =	1.10	ELA / Floor Area



7.4 TRACER GAS DATA

Tracer Gas Test

Date: 23-Jun-94
Unit: Demonstration House, Springfield OR
Vents: Fresh Air 80 vents closed, taped dryer vents, taped envirovent outlet



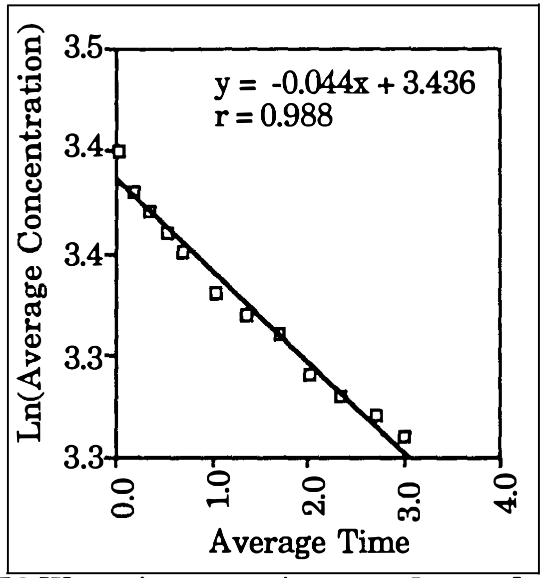
Initial Conditions		**End Conditions**	
Wind:	Mild (0-5 mph)	Wind:	0 - 3 MPH
Indoor Temp:	70 F	Indoor Temp:	73 F
Outdoor Temp:	67.5 F	Outdoor Temp:	57 F
Start Time:	8:11PM	End Time:	11:24PM

Zone Time	**SF6 Living**	**Zone Time**	**SF6 Master BDR**	**Zone Time**	**SF6 E BDR**	**Zone Time**	**SF6 W BDR**	**Avg Time**	**Avg. SF6 Conc.**	**Natural Log Avg Conc.**
(hours)	(ppm)	(hours)	ppm	(hours)	ppm	(hours)	ppm	(hours)	ppm	Ln(ppm)
0.00	32.5	0.02	32.2	0.04	32.2	0.06	32.2	0.03	32.3	3.47
0.18	31.9	0.20	31.7	0.23	32.0	0.25	31.8	0.21	31.9	3.46
0.35	31.7	0.37	31.5	0.40	31.5	0.43	31.4	0.39	31.5	3.45
0.50	31.3	0.55	31.0	0.56	30.9	0.59	30.9	0.55	31.0	3.43
0.83	30.8	0.85	30.8	0.88	31.2	0.91	30.8	0.87	30.9	3.43
1.16	30.4	1.19	30.5	1.21	30.3	1.24	30.6	1.20	30.5	3.42
1.50	30.3	1.52	30.2	1.55	30.1	1.57	30.3	1.53	30.2	3.41
1.83	30.0	1.86	30.0	1.88	29.9	1.91	29.8	1.87	29.9	3.40
2.17	29.7	2.19	29.5	2.24	29.6	2.26	29.7	2.22	29.6	3.39
2.50	29.5	2.52	29.3	2.54	29.3	2.57	29.2	2.53	29.3	3.38
2.84	29.3	2.86	29.1	2.88	29	2.91	28.9	2.87	29.1	3.37
3.16	28.7	3.18	28.4	3.20	28.7	3.23	28.8	3.19	28.7	3.36

ACH: 0.032 **r: 0.988** **r^2: 0.976**

Tracer Gas Test

Date: 27-Jun-94
Unit: Demonstration House, Springfield OR
Vents: Fresh Air 80 vents closed, taped dryer vents, taped envirovent outlet

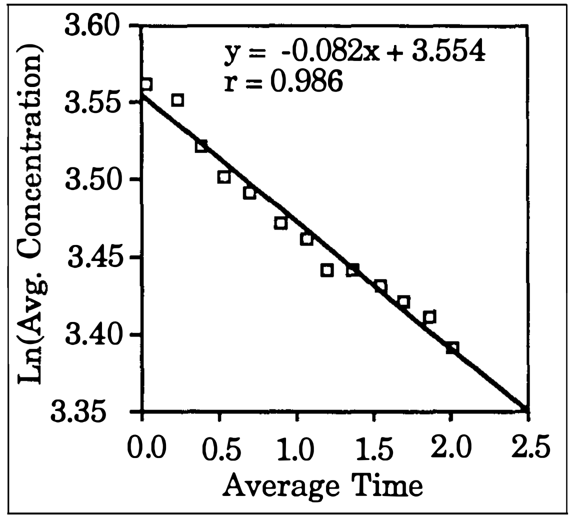


Initial Conditions		**End Conditions**	
Wind:	5-10 mph	Wind:	0-5 mph
Indoor Temp:	77 F	Indoor Temp:	80.0F
Outdoor Temp:	80 F	Outdoor Temp:	77.5F
Start Time:	5:28PM	End Time:	8:31PM

Zone Time	**SF6 Living**	**Zone Time**	**SF6 Master BDR**	**Zone Time**	**SF6 E BDR**	**Zone Time**	**SF6 W BDR**	**Avg Time**	**Avg Conc.**	**Natural Log of Conc.**
(Hours)	(ppm)	(Hours)	(ppm)	(Hours)	(ppm)	(Hours)	(ppm)	(hours)	(ppm)	Ln(ppm)
0.000	31.5	0.024	31.4	0.062	31.3	0.083	31.4	0.042	31.4	3.45
0.167	31.2	0.190	31.0	0.218	31.0	0.234	30.9	0.202	31.0	3.43
0.333	30.8	0.353	30.6	0.385	30.7	0.408	30.5	0.369	30.7	3.42
0.502	30.3	0.523	30.2	0.553	30.2	0.574	30.2	0.538	30.2	3.41
0.669	29.9	0.690	29.9	0.714	29.8	0.737	29.8	0.703	29.9	3.40
1.003	29.3	1.028	29.4	1.049	29.3	1.066	29.3	1.036	29.3	3.38
1.333	29.1	1.352	29.3	1.381	29.0	1.401	28.9	1.367	29.1	3.37
1.668	28.9	1.694	28.7	1.716	28.6	1.740	28.4	1.705	28.7	3.36
2.004	28.2	2.022	28.3	2.062	28.2	2.083	28.2	2.043	28.2	3.34
2.334	27.9	2.357	27.8	2.383	27.8	2.402	27.8	2.369	27.8	3.33
2.671	27.8	2.688	27.8	2.756	27.7	2.777	27.7	2.723	27.8	3.32
2.999	27.3	3.016	27.3	3.033	27.3	3.052	27.4	3.025	27.3	3.31

ACH: 0.044 **r:** 0.988 **r^2:** 0.976

Tracer Gas Test
Date: 16-Jun-94
Unit: Demonstration House, Springfield OR
Vents: Open



Initial Conditions
Wind: Mild (0-5 mph)
Indoor Temp.: 69.5 F
Outdoor Temp.: 72 F
Start Time: 4:15 PM

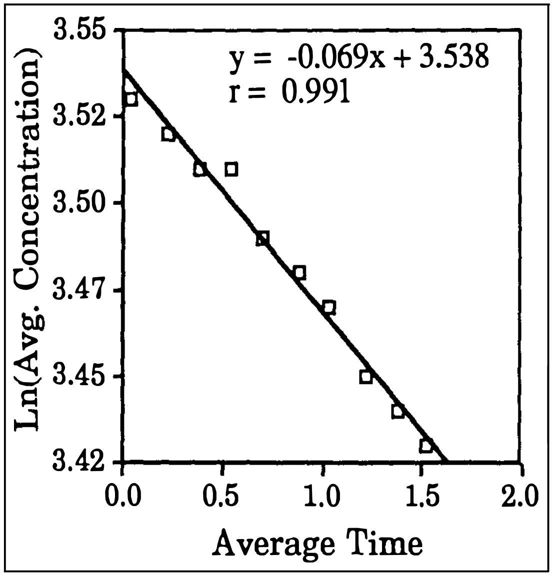
End Conditions
Wind
Indoor Temp.
Outdoor Temp
End Time: 6:15 PM

Zone Time	SF6 Living	Zone Time	SF6 Master BDR	Zone Time	SF6 E BDR	Zone Time	SF6 W BDR	Natural Log Conc.	Avg Time	Average Sf6 Conc.	Natural Log Avg Conc.
(Hours)	(ppm)	(Hours)	(ppm)	(Hours)	(ppm)	(Hours)	(ppm)	Ln(C)	(hours)	(ppm)	Ln(ppm)
0.00	35.2	0.02	35.2	0.05	35.2	0.07	34.9	3.55	0.04	35.1	3.56
0.21	35.2	0.23	35.2	0.26	34.9	0.29	34.2	3.53	0.25	34.9	3.55
0.34	34.1	0.37	34.2	0.40	33.8	0.42	33.5	3.51	0.38	33.9	3.52
0.51	32.9	0.53	32.9	0.56	32.9	0.58	33.2	3.50	0.55	33.0	3.50
0.67	33.1	0.69	33.2	0.72	32.3	0.75	32.3	3.48	0.71	32.7	3.49
0.87	32.4	0.90	32.0	0.93	31.9	0.96	31.9	3.46	0.91	32.1	3.47
1.02	31.8	1.05	31.7	1.09	31.9	1.11	31.6	3.45	1.07	31.8	3.46
1.17	31.3	1.19	31.2	1.22	31.2	1.25	31.1	3.44	1.21	31.2	3.44
1.34	31.2	1.36	31.5	1.39	31.2	1.42	31.2	3.44	1.38	31.3	3.44
1.52	31.0	1.54	31.0	1.58	30.8	1.59	30.7	3.42	1.56	30.9	3.43
1.67	30.7	1.69	30.8	1.72	30.8	1.75	30.5	3.42	1.71	30.7	3.42
1.83	30.5	1.86	30.1	1.89	30.1	1.91	29.9	3.40	1.87	30.2	3.41
1.99	29.8	2.01	29.8	2.03	29.8	2.05	29.3	3.38	2.02	29.7	3.39

ACH: 0.082 **r: 0.986** **r^2: 0.972**

Tracer Gas Test

Date: 21-Jun-94
Unit: Demonstration House
Vents: Fresh Air 80 Vents open, Dryer vents taped



Initial Conditions

Wind: Mild (0-5 mph)
Indoor Temp: 74.5 F
Outdoor Temp: 70 F
Start Time: 3:38 PM

End Conditions

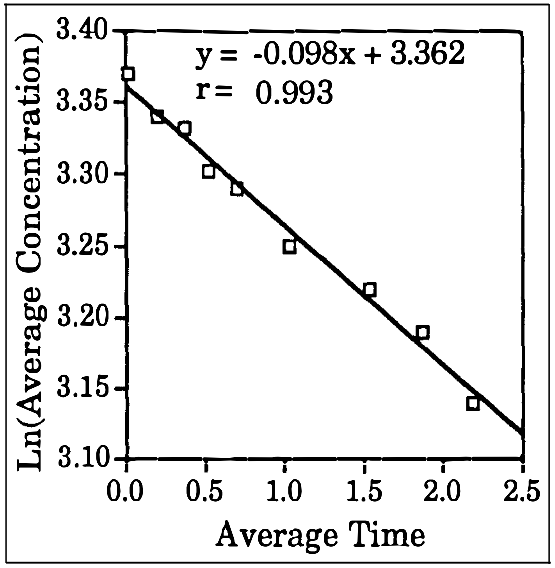
Wind: ***
Indoor Temp: ***
Outdoor Temp: ***
Start Time: 5:12 PM

Zone Time (hours)	SF6 Living (ppm)	Zone Time (hours)	SF6 Master BDR (ppm)	Zone Time (hours)	SF6 E BDR (ppm)	Zone Time (hours)	SF6 W BDR (ppm)	Avg Time (hours)	Avg. SF6 Conc. (ppm)	Natural Log Avg Conc. Ln(ppm)
0.000	34.8	0.027	34.2	0.058	34.2	0.083	33.9	0.04	34.3	3.53
0.171	34.2	0.192	33.8	0.231	33.8	0.268	33.6	0.22	33.9	3.52
0.339	33.5	0.365	33.6	0.394	33.6	0.428	33.5	0.38	33.6	3.51
0.506	33.4	0.534	33.3	0.564	33.3	0.594	33.2	0.55	33.3	3.51
0.672	32.9	0.699	33.0	0.726	33.0	0.753	32.9	0.71	33.0	3.49
0.847	32.6	0.874	32.5	0.900	32.4	0.932	32.4	0.89	32.5	3.48
1.000	32.1	1.028	32.0	1.052	32.0	1.081	32.1	1.04	32.1	3.47
1.175	31.6	1.194	31.8	1.237	31.8	1.265	31.4	1.22	31.7	3.45
1.339	31.2	1.373	31.3	1.400	31.2	1.428	31.2	1.38	31.2	3.44
1.501	30.9	1.522	30.8	1.544	30.8	1.567	30.7	1.53	30.8	3.43

ACH: 0.069 r: 0.991 r^2: 0.982

Tracer Gas Test

Date: 28-Jun-94
Unit: Demonstration House, Springfield OR
Vents: Fresh air 80 vents open, Dryer vents taped



Initial Conditions		**End Conditions**	
Wind:	5-10mph	Wind:	5-10mph
Indoor Temp:	80 F	Indoor Temp:	82 F
Outdoor Temp:	81 F	Outdoor Temp:	82 F
Start Time:	3:56 PM	End Time:	5:59 PM

Normalized Time	SF6 Living	Zone Time	SF6 Master BDR	Zone Time	SF6 E BDR	Zone Time	SF6 W BDR	Avg Time	Avg Conc.	Natural Log of Conc.
(Hours)	(ppm)	(Hours)	(ppm)	(Hours)	(ppm)	(Hours)	(ppm)	(hours)	(ppm)	Ln(ppm)
0.000	29.1	0.021	29	0.042	29	0.063	29	0.031	29.0	3.37
0.167	28.4	0.188	28.3	0.212	28.5	0.232	28.2	0.200	28.4	3.34
0.333	27.9	0.354	27.8	0.379	27.8	0.402	27.7	0.367	27.8	3.33
0.500	27.2	0.521	27.1	0.546	27.2	0.567	27.1	0.533	27.2	3.30
0.671	26.7	0.693	26.7	0.717	26.8	0.733	26.9	0.703	26.8	3.29
1.000	25.8	1.017	25.7	1.033	25.8	1.058	25.4	1.027	25.7	3.25
2.000	24.9	1.350	25.0	1.371	25.1	1.392	25.0	1.528	25.0	3.22
2.333	24.1	1.683	24.2	1.713	24.2	1.733	24.2	1.866	24.2	3.19
2.667	23.2	2.017	23.1	2.033	23.2	2.050	23.1	2.192	23.2	3.14

ACH: 0.098 **r:** 0.993 **r^2:** 0.986

7.5 THEORETICAL EFFECTIVE LEAKAGE AREA OF REFERENCE HOUSE

Description	Dimension and Unit		Minimum Leakage area (ASHRAE 23.15)		ELA (in^2)	Remarks
Windows and Doors						
Living						
Twin Casement, weather stripped	18.67	ft	0.05	in^2/lftc	0.93	Measured in field
Twin Casement, weather stripped	22.67	ft	0.05	in^2/lftc	1.13	Measured in field
Twin Casement, weather stripped	22.67	ft	0.05	in^2/lftc	1.13	Measured in field
Kitchen						
Twin Casement, weather stripped	18.67	ft	0.05	in^2/lftc	0.93	Measured in field
Master Bedroom						
Twin Casement, weather stripped	22.67	ft	0.05	in^2/lftc	1.13	Measured in field
Single Casement, weatherstripped	12.17	ft	0.05	in^2/lftc	0.61	Measured in field
Stairwell						
Half Awning, weatherstripped	14.39	ft	0.006	in^2/ft^2	0.09	Measured in field
East BDR 2nd Floor						
Single Casement, weatherstripped	12.17	ft	0.05	in^2/lftc	0.61	Measured in field
Skylight	10.44	ft	0.006	in^2/ft^2	0.06	Measured in field, assumed same as awning
West Bedroom		ft				
Single Casement, weatherstripped	12.17	ft	0.05	in^2/lftc	0.61	Measured in field
Skylight	10.44	ft	0.006	in^2/ft^2	0.06	Measured in field, assumed same as awning

Description	Dimension and Unit		Minimum Leakage area (ASHRAE 23.15)		ELA (in^2)	Remarks
Single Door Weatherstripped	1	ft	0.6	each	0.60	Measured in field
Single Door Weatherstripped	1	ft	0.6	each	0.60	Measured in field
Total ELA Window and Door Openings					8.50	
Window and Door Frames, Caulked						
Living	feet or lf					
Twin Casement	18.67	ft	0.004	in^2/lftc	0.07	Measured in field
Twin Casement	22.67	ft	0.004	in^2/lftc	0.09	Measured in field
Twin Casement	22.67	ft	0.004	in^2/lftc	0.09	Measured in field
Kitchen						
Twin Casement	18.67	ft	0.004	in^2/lftc	0.07	Measured in field
Master Bedroom						
Twin Casement	22.67	ft	0.004	in^2/lftc	0.09	Measured in field
Single Casement	12.17	ft	0.004	in^2/lftc	0.05	Measured in field
Stairwell						
Half Awning	26.88	ft	0.004	in^2/lftc	0.11	Measured in field
East BDR 2nd Floor						
Single Casement	12.17	ft	0.004	in^2/lftc	0.05	Measured in field
	13.17	ft	0.004	in^2/lftc	0.05	Measured in field, assumed same as awning
West Bedroom						
Single Casement	12.17	ft	0.004	in^2/lftc	0.05	Measured in field
	13.17	ft	0.004	in^2/lftc	0.05	Measured in field, assumed same as awning
Door	19.33	ft	0.001	in^2/lftc	0.02	Measured in field
Door	18.27	ft	0.001	in^2/lftc	0.02	Measured in field
	Total ELA window and door frame				0.82	

Description	Dimension and Unit		Minimum Leakage area (ASHRAE 23.15)		ELA (in^2)	Remarks
Joints						
1st Floor to Wall Joint	108.28	ft	0.04	in^2/lftc	4.33	Measured from plan, assumed similar to sole plate, floor to wall, caulked
1st Floor to Ceiling Joint	96.28	ft	0.081	in^2/lftc	7.80	Measured from plan, assumed similar to ceiling to wall joint
2nd Floor to Roof	106.14	ft	0.04	in^2/lftc	4.25	Measured from plan, assumed similar to sole plate, floor to wall, caulked
Wall to Roof Joint	114.92	ft	0.04	in^2/lftc	4.60	Measured from plan, assumed similar to sole plate, floor to wall, caulked
Ceiling to Ceiling Joint	35.07	ft	0.04	in^2/lftc	1.40	Measured from plan, assumed similar to sole plate, floor to wall, caulked
	Total ELA of Joints				22.38	

Description	Dimension and Unit		Minimum Leakage area (ASHRAE 23.15)		ELA (in^2)	Remarks
Piping/Wiring/Plumping Penetrations through envelope (Caulked)						
Electrical Outlets	11		0.16	in^2/each	1.76	
Switches	6		0.16	in^2/each	0.96	
Datalogger	1		0.16	in^2/each	0.16	
Electrical Meters	5		0.16	in^2/each	0.80	
Water	1		0.16	in^2/each	0.16	
soilstack	1		0.16	in^2/each	0.16	
sewer	1		0.16	in^2/each	0.16	
Envirovent drip	1		0.16	in^2/each	0.16	
Total ELA Piping/Wiring/Plumbing Penetrations					4.32	
Vents						
Kitchen exhaust with gasket	1	each	0.16	in^2/each	0.16	
Dryer with damper	1		0.45	in^2/each	0.45	
Fresh Air 80	4		0.16	in^2/each	0.64	
Envirovent Outlet	1		0.16	in^2/each	0.16	
Envirovent Intake	1		0.45	in^2/each	0.45	
Total ELA Vents					1.86	

Summary of Component Effective Leakage Areas		
Window and Doors	9.32	
Panel Joints	22.38	
Piping/Wiring/Plumbing Penetrations	4.32	
Kitchen, Fresh air 80 and Bathroom Vents	1.86	
Total ELA for Demonstration Reference House	37.88	

7.6 THERMOGRAPHIC IMAGING RESULTS

Tape Time	Location	Thermal Defect	Color Differential	Comment
Tape No. 1	Date: 4/23/94			
0:00:00	East Bedroom, Southeast corner of East wall and roof partition wall joint	Conductive Loss	5 to 7	
4:11:00	East bedroom, ridge joint	Conductive Loss	4 to 5	
4:30:00	East bedroom, roof panel joint	Conductive loss	2 to 3	
4:50:00	East bedroom, roof to wall joint, east gable end	Conductive Loss	4 to 5	
5:03:00	East bedroom, panel joint ≈1 ft south of window	Conductive Loss	5 to 7	
7:50:00	East Bedroom, south roof panel joints on each side of skylights	Conductive loss	2	
8:00:00	East Bedroom, skylight, around frame	Conductive loss	—	No signs of infiltration losses
11:20:00	East Bedroom, East wall electric outlet	Conductive Loss	5 to 6	Possible portion of loss due to infiltration
12:10:00	East bedroom, East wall, panel joint North of window ≈ 1	Conductive Loss	4 to 5	
13:00:00	East bedroom, East wall, panel to panel joint, 5 ft South of window	Conductive Loss	5 to 6	
13:10:00	East Bedroom, East wall, floor to wall	Conductive Loss	5 to 6	

Tape Time	Location	Thermal Defect	Color Differential	Comment
Tape No. 1	**Date: 4/23/94**			
14:30:00	East Bedroom, East wall panel to panel joint 5 ft south of window	Conductive Loss	5 to 6	
17:27	East Bedroom, East wall, Window Frame	Conductive Loss	8	
23:25	East Bedroom, north roof, roof panel joint, 8 ft from east wall	Conductive Loss	1 to 2	
24:10	East Bedroom, north roof, roof panel joint, 8 ft from east wall	Conductive Loss	1 to 2	
27:30	2nd floor, Southeast corner of dormer, wall to wall joint	Conductive Loss	5 to 7	
27:45	2nd floor, Southeast corner of dormer, roof to corner wall joint	Conductive Loss	7 to 10	
28:15	Dormer roof to south Wall joint	Conductive Loss	8 to 9	
28:32	Dormer, South wall	Conductive Loss	3	Color differential more sharp at corners
30:10	Dormer, south wall			No Joints detectable
32:00	South windows, dormer	Conductive Loss/ Infiltration	7 to 10	Windows were not closed tightly prior to scan
35:40	Ceiling ridge, hallway	Conductive Loss	3 to 4	
37:00	Roof dormer to south wall	Conductive Loss	3 to 4	

Tape Time	Location	Thermal Defect	Color Differential	Comment
Tape No. 1	**Date: 4/23/94**			
	Mechanical closet			no significant areas of heat loss identifiable due to obstruction by envirovent
	2nd floor bathroom	Conductive Loss		no significant areas of heat loss identifiable
50:03	West Bedroom, west wall, floor to wall joint	Conductive Loss	3	
50:15	West Bedroom,West wall, panel to panel joint, 1 ft north of window	Conductive Loss	3 to 4	
50:40	West Bedroom, west wall, panel to panel joint	Conductive Loss	3 to 4	
50:40	West Bedroom, west wall, panel to panel joint	Conductive Loss	3 to 4	
51:20	West Bedroom, wall to wall joint	Conductive Loss	2 to 3	
51:40	West Bedroom, east wall, ceiling to wall joint	Conductive Loss	5	
54:40	West Bedroom, east wall window frame	Conductive Loss	2 to 3	
54:40	West Bedroom , east wall, window opening	Conductive Loss/ Infiltration loss	2 to 3	

Tape Time	Location	Thermal Defect	Color Differential	Comment
Tape No. 1	**Date: 4/23/94**			
57:31	West Bedroom, interior partition, east wall, south of door		4	possible heat loss due to infiltraion along conduit or cavity, outlet also visible
59:50	West Bedroom, Skylitht	Conductive Loss		minor conductive losses
1:03:20	West Bedroom, joint of west wall and roof panels	Conductive Loss	5 to 7	
1:05:00	West Bedroom, roof to roof joint, west side of skylight	Conductive Loss	1 to 2	
1:05:20	West Bedroom, roof to roof joint, east side of skylight	Conductive Loss	1 to 2	
1:08:06	West Bedroom, north wall joints	Conductive Loss	1	slightly detectable
Tape No.1	**Date: 4/26/94**			
1:15:36	Livingroom, Southeast corner, panel to panel joint	Conductive Loss / Possible infiltration	12+	Heat loss more severe a bottom joint of walls and floor
1:15:40	Livingroom, Southeast corner, panel to panel joint	Conductive Loss	8+	
1:15:50	Living room, wall to wall and ceiling joint	Conductive Loss	7	
1:16:05	Living room, southwall, panel to panel joint east side of window	Conductive Loss	2	

Tape Time	Location	Thermal Defect	Color Differential	Comment
Tape No.1	**Date: 4/26/94**			
1:16:30	Livingroom, south wall, west joint above window	Conductive Loss	2	
1:16:45	Livingroom, southwall, joint at East corner of door	Conductive Loss	5 to 6	very discernable
1:19:14	Livingroom, South wall, lightswitch	Conduction Loss / Infiltration Loss	10	
1:19:40	Living room, south door	Infiltration Loss / Conductive Loss	5 to 6	
1:19:49	Livingroom, south wall, panel to floor joint	Conductive Loss / Possible Infiltration	8 to10	
1:20:10	Livingroom, Southwall outlet	Conductive Loss	4	
1:20:20	Livingroom, southwall, panel to panel joint, below west corner of	Conductive Loss / Possible Infiltration		
1:21:41	Livingroom, Southwall, panel to panel joint, east side of window	Conductive Loss	7 to 8	
1:23:40	Living room, south wall, window frame	Conductive Loss	8 to 10	
1:25:50	Livingroom, north wall and east wall panel to panel joint and	Conductive Loss	12	

Tape Time	Location	Thermal Defect	Color Differential	Comment
Tape No. 1	Date: 4/26/94			
1:25:50	Living room, north wall and east wall panel to panel joint and ceiling intersection	Conductive Loss	6 to 7	
1:26:10	Living room east wall, Fresh air 80 vent	Conductive Loss	7	Heat loss around perimeter of vent
1:26:30	Living room, east wall, panel to panel joint at north side of window	Conductive Loss	5	more discernable at floor
1:27:30	Living room, east wall, envirovent register	Possible Infiltration	5 to 7	color differential may be due to thermal stratification of air temperature in the house
1:27:47	Living room, east wall,south side of window, panel to panel joint	Conductive Loss	1 to 2	
1:30:17	Living room, east wall, south envirovent register	Conductive Loss	2 to 3	
1:31:23	Living room, east wall	Conductive Loss / Possible Infiltration	6+	
1:31:40	Living room, east wall, outlet	Conductive Loss / Possible Infiltration	6+	

Tape Time	Location	Thermal Defect	Color Differential	Comment
Tape No. 1	**Date: 4/26/94**			
1:33:00	Livingroom, east wall to floor joint	Conductive Loss / Possible Infiltration	6+	heat loss more discernable at corners and joint
1:35:24	Livingroom, east window, frame	Conductive loss	6 to 8	
1:37:35	Livingroom, northwall, wall to floor joint	Conductive Loss / Possible Infiltration Loss	6 to 8	
1:37:37	Livingroom, 4 ft from east wall, floor to floor joint, 1 foot length from North wall	Conductive Loss	5 to 10	Wall to wall joint and floor to floor joint are in line possibly contributing to heat loss
1:37:40	Livingroom, northwall 4 feet from east wall, panel to panel joint	Conductive loss	6 to 7	
1:37:45	Livingroom, north wall, wall to floor joint, conductive losses	Conductive loss	10 +	heat loss more extensive at corners and panel joints
1:38:50	Livingroom, northwall, panel to panel joint	Conductive loss	5 to 6	heat loss more extensive closer to floor
1:38:55	Livingroom, north wall	Conductive loss	10 +	
1:39:00	Livingroom, northwall, door frame	Conductive loss	10 +	

Tape Time	Location	Thermal Defect	Color Differential	Comment
Tape No. 1	**Date: 4/26/94**			
1:39:00	Living room, north wall, door opening	Conductive loss/Infiltration Loss	10 +	Weatherstripping not installed at this phase in construction, consequently infiltration losses more severe
1:39:20	Livingroom north wall, electrical outlet	Conductive loss / possible infiltration loss	12 +	
1:40:20	Livingroom, northwall, panel joint, east side of door	Conductive loss		
1:44:40	Livingroom north wall, panel to panel joint	Conductive loss	6 to 7	
1:44:40	Livingroom, north wall, panel to panel	Conductive loss	6 to 7	Heat loss more severe closer to floor
1:45:40	Livingroom, north wall, window frame	Conductive loss	7 to 10	
1:45:50	Livingroom north wall, window opening	Conductive loss	10+	
Tape No. 1	**Date: 4/28/94**			
1:56:10	Kitchen, joint of north wall and west wall	Conductive Loss / Possible Infiltration	7	Possible conductive and infiltration loss due to kitchen vent and water and waste vent behind west wall of kitchen
1:56:40	Kitchen\Electrical Outlet, 1 ft west of window	Conductive loss	5	

Tape Time	Location	Thermal Defect	Color Differential	Comment
Tape No. 2	**Date: 4/28/95**			
1:59:02	Kitchen \ Window Frame	Conductive Loss	6 to 8	
1:59:02	Kitchen \ Window opening	Conductive Loss \ Infiltration Loss	10 to 12	Conductive loss around window opening mechanism,
0:41:00	1st Floor bathroom, drain	Conductive Loss \ Possible Infiltration Loss	9 to 10	
1:49:00	1st Floor bathroom, north wall and wet wall joint	Conductive Loss\ Possible Infiltration loss	4 to 5	Possible heat loss due to thermal defect or infiltration around pipes and vents in wet wall, Temperature of incoming water may also lower temperature of wall
2:30:00	1st Floor Bathroom, wall to ceiling joint	Conductive Loss	2 to 3	
2:52:00	1st floor bathroom, joint of north wall and east wall interior partition	Conductive Loss	3 to 4	heat loss at the west wall partition is less than that of the east wall reinforcing the theory of incresed heat loss due to wet wall
5:33:00	Master bedroom, joint of south wall and east wall interior partition	Conductive Loss	12 +	corresponds to panel to panel joint, and supports for dormer and stairwell

Tape Time	Location	Thermal Defect	Color Differential	Comment
Tape No. 2	**Date: 4/28/95**			
5:55:00	Master bedroom, South wall, Panel to Panel joint	Conductive Loss	3 to 4	
6:23:00	Master bedroom, window header-panel joint, south wall	Conductive Loss	2 to 3	
6:25:00	South wall window header and panel joint	Conductive Loss	2 to 3	
6:45:00	South wall and west wall panel joint	Conductive Loss	5 to 6	more heat loss at foor joint, ≈8 color differential
7:40:00	South wall panel to panel joint, floor to floor joint	Conductive Loss	5	
7:50:00	Master bedroom, southwall, electric outlet	Conductive Loss	6 to 7	
8:03:00	South wall, panel to panel joint, floor to floor joint	Conductive Loss	6 to 7	
9:32:00	South wall window	Conductive Loss		similar to other windows
11:30:00	West wall, panel to panel joint, window header joint	Conductive Loss	1 to 2	
11:52:00	Master bedroom, west wall, envirovent register	Possible Infiltration Loss	4 to 5	Envirovent register
12:05:00	Master bedroom, West wall, panel to panel joint	Conductive Loss	3 to 4	
12:50:00	Master bedroom, West wall, electrical	Conductive Loss	4 to 5	
15:08:00	Master bedroom, west window, frame	Conductive Loss	6 to 7	

Tape Time	Location	Thermal Defect	Color Differential	Comment
Tape No. 2	**Date: 4/28/95**			
15:08:00	Master bedroom, west window, opening	Conductive Loss	6 to 7	similar to other windows
16:26:00	Master bedroom, closet, wall to floor joint	Conductive Loss	10 +	
17:00:00	Master bedroom closet, north wall to west wall joint	Conductive Loss	6 to 8	
17:43:00	Master bedroom, closet north wall to closet partition joint, Data logger opening	Conductive Loss / Possible Infiltration	6	
18:30:00	Master bedroom closet, electrical outlets and phone jack in partition wall	Conductive Loss / Infiltration Loss	7	
26:16	Stairwell landing, junction of south wall and interior partition correspondes to panel to panel joint	Conductive Loss	12	
27:01	Stairwell, south wall, wall to floor joint	Conductive Loss	5 to 6	
27:05	South wall, floor to panel joint, 1.5 to 2 ft from panel	Conductive Loss	5	
29:10	Southwall, panel to panel joint, intersection of interior partition	Conductive Loss	6 to 8	
32:34	Southwall, panel to panel joint, west of door	Conductive Loss	5 to 6	

Tape Time	Location	Thermal Defect	Color Differential	Comment
Tape No. 2	**Date: 4/30/94**			
	Color Differential: .45 F/color			
39:21	South door frame	Conductive		
40:36	South wall, panel to panel joint 1 ft West of door	Conductive Loss	1 to 2	
40:55	South wall joint of wall to cantilevered 2nd floor	Conductive Loss	3 to 5	
43:20	South wall, panel to panel joint	Conductive Loss		
Tape No. 2	**Date: 5/7/94**			
	Color Differential: 1.8 F/color			
44:45	West Wall, dryer vent	Infiltration Loss	6 to 7	
44:45	West wall, opening for instrumentation conduit	and Infiltration loss	3+	
45:03	West wall, roof panel to west wall	Conductive Loss		More extreme at outlooks, possible infiltration
46:30	West wall, panel to panel joint 8 ft from souht corner	Conductive Loss	3 to 5	
47:20	West wall, panel to panel joint	Conductive Loss	2 to 3	
47:20	West wall , 2nd floor framing area	Conductive Loss	2 to 3	

Tape Time	Location	Thermal Defect	Color Differential	Comment
Tape No. 2	**Date: 5/7/94**			
	Color Differential: 1.8 F/color			
47:38	Westwall, window panel joints	Conductive Loss	3 to 5	
48:30	West wall, 1st floor window header	Conductive Loss	2 to 3	similar losses at window side panels
49:44	Westwall, floor panel to wall joint	Conductive Loss	2 to 3	
52:30	Westwall, floor panel to wall joint	Conductive Loss	2 to 3	
54:07	West wall, crawlspace		4 to 5	space under crawl space appears to be warmer
55:30	West wall, corner panel joint	Conductive Loss	3	
56:04	West wall, dryer outlet	Conductive Loss /	7	
57:50	Corner of North eave	Conductive Loss	4	may be due to shielding of roof
1:01:30	Westwall, panel to panel joint at junction of 2nd floor and South wall	Conductive Loss	2 to 3	
1:01:43	Corner joint of south wall and west wall	Conductive Loss	3 to 4	

7.7 COHEATING DATA

Coheating Test							
SSIC Demonstration House							
Springfield, OR, May, 2 1994							
Time	**Tair1**	**Tair2**	**Tair3**	**Tair4**	**Tair5**	**Tamb**	**Electric**
(hr:min)	(F)	(F)	(F)	(F)	(F)	(F)	(W-hr)
306	75.1	75.3	75.2	75.3	75.2	46.7	100.8
312	75.0	75.3	75.2	75.3	75.2	46.9	108.0
318	75.1	75.3	75.2	75.3	75.3	47.0	115.2
324	75.1	75.4	75.1	75.2	75.2	47.0	93.6
330	75.0	75.4	75.2	75.3	75.2	47.1	108.0
336	75.0	75.3	75.2	75.2	75.3	46.8	122.4
342	75.0	75.2	75.2	75.3	75.3	47.0	100.8
348	75.0	75.3	75.2	75.2	75.3	46.8	108.0
354	75.0	75.3	75.1	75.3	75.2	46.8	108.0
400	75.0	75.2	75.2	75.1	75.3	46.7	115.2
406	75.0	75.3	75.2	75.3	75.2	46.6	108.0
412	75.0	75.3	75.1	75.3	75.2	46.5	115.2
418	75.0	75.2	75.2	75.3	75.2	46.4	100.8
424	75.0	75.3	75.1	75.2	75.3	46.2	115.2
430	75.0	75.2	75.3	75.2	75.2	46.2	115.2
436	75.0	75.3	75.1	75.2	75.2	46.2	108.0
442	75.0	75.3	75.1	75.2	75.3	46.2	122.4
448	75.0	75.2	75.2	75.2	75.2	46.2	108.0
454	75.0	75.4	75.2	75.2	75.2	46.3	129.6
500	75.0	75.2	75.2	75.2	75.2	46.4	100.8
506	75.0	75.3	75.2	75.2	75.2	46.4	122.4
512	75.1	75.4	75.2	75.2	75.2	46.4	115.2
518	75.0	75.2	75.2	75.3	75.3	46.5	115.2
524	75.0	75.3	75.2	75.3	75.2	46.5	115.2
530	75.0	75.3	75.2	75.3	75.2	46.6	122.4
	Average Tair1	Average Tair2	Average Tair3	Aveage Tair4	Average Tair5	Average Outdoor Temp	Total Electrical Consumption
	(F)	(F)	(F)	(F)	(F)	(F)	(W-hr)
	75.0	75.3	75.2	75.2	75.2	46.6	2793.6
					Average Indoor Temp	**Average ΔT**	**Building Conductance**
					(F)	(F)	(Btu/h F)
					75.2	28.6	133.2

7.8 THEORETICAL UA CALCULATIONS

Theoretical UA Vaules @ 75 F, Demonstration House, ASHRAE 93				
Component Calculations				
Component	Material	R value	U value	Source
8 5/16" SSIC Panel		(F ft^2 h/Btu)	(Btu/F ft^2 h)	
(EPS 7.25 ")	outdoor air (7.5 mph)	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	7 -1/4" EPS (1lb/ft^3)	27.9		ASHRAE 93
	7/16" OSB (35 lb/ft^3)	0.61		ASHRAE 93
	.5" gypboard	0.45		ASHRAE 93
	indoor air	0.68		ASHRAE 93
	TOTAL	30.66	0.033	
8 5/16" SSIC Panel at Spline				
	outdoor air (7.5 mph)	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	2X8 DG Stud, (1.5x7.25" nominal)	7.25		ASHRAE 93
	7/16" OSB (35 lb/ft^3)	0.61		ASHRAE 93
	.5" gypboard	0.45		ASHRAE 93
	indoor air	0.68		ASHRAE 93
	TOTAL	10.01	0.10	
2nd floor Framing East and West Walls				
	outdoor air (7.5 mph)	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	1/2" DG Ply	0.62		ASHRAE 93
	R38 Batt	38		Drawings
	1/2" DG Ply	0.62		ASHRAE 93
	indoor air	0.68		ASHRAE 93
	TOTAL	40.94	0.024	

Component	Material	R value	U value	Source
8 5/16" SSIC Panel		(F ft^2 h/Btu)	(Btu/F ft^2 h)	
2nd floor Framing North and South Walls				
	outdoor air (7.5 mph)	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	1" rigid insulation (1.5 lb/ft^3 polyisocyanurate)	5.9		ASHRAE 93
	R38 Batt	38		Drawings
	indoor air	0.68		ASHRAE 93
	TOTAL	45.6	0.022	
2nd floor Framing North and South Walls at TJI				
	outdoor air (7.5 mph)	0.25		ASHRAE 93
	1" DG plywood	1.03		ASHRAE 93
	1.5" stud	1.545		ASHRAE 93
	2.0' , TJI	24.72		Drawings
	TOTAL	27.545	0.036	
Eave Overhang				
	outdoor air	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	R38 Batt	38		Drawings
	3/4" Sheathing	0.94		ASHRAE 93
	Indoor air (downward)	0.92		ASHRAE 93
	TOTAL	40.88	0.024	

Component	Material	R value	U value	Source
8 5/16" SSIC Panel		(F ft^2 h/Btu)	(Btu/F ft^2 h)	
Eave Overhang				
at TJI	outdoor air	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	11 7/8 TJI	12.23		Drawings
	3/4" Sheathing	0.94		ASHRAE 93
	Indoor air (downward)	0.92		ASHRAE 93
	TOTAL	15.11	0.066	
Window Headers				
	outdoor air (7.5 mph)	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	1.5" DG (1.03 1/k)	1.55		ASHRAE 93
	4.25" EPS	16.4		ASHRAE 93
	1.5" DG (1.03 1/k)	1.55		ASHRAE 93
	7/16" OSB (35 lb/ft^3)	0.61		ASHRAE 93
	.5" gypboard	0.45		ASHRAE 93
	indoor air	0.68		ASHRAE 93
	TOTAL	22.26	0.045	
Roof Panels	outdoor air (7.5 mph)	0.25		ASHRAE 93
10 1/8" panels	asphalt shingles	0.44		ASHRAE 93
(9.25" foam)	30 lb felt	0.06		ASHRAE 93
	7/16" OSB (35 lb/ft^3)	0.61		ASHRAE 93
	9 -1/4" EPS (1lb/ft^3)	35.6		ASHRAE 93
	7/16" OSB (35 lb/ft^3)	0.61		ASHRAE 93
	.5" gypboard	0.45		ASHRAE 93
	indoor air (sloping 45)	0.68		ASHRAE 93
	TOTAL	38.7	0.026	

Component	Material	R value	U value	Source
8 5/16" SSIC Panel		(F ft^2 h/Btu)	(Btu/F ft^2 h)	
Roof Panel at Spline	outdoor air (7.5 mph)	0.25		ASHRAE 93
	asphalt shingles	0.44		ASHRAE 93
	30 lb felt	0.06		ASHRAE 93
	7/16" OSB (35 lb/ft^3)	0.61		ASHRAE 93
	9.25" d.g. stud (1.03 1/k)	9.5278		ASHRAE 93
	7/16" OSB (35 lb/ft^3)	0.61		ASHRAE 93
	.5" gypboard	0.45		ASHRAE 93
	indoor air (sloping 45)	0.68		ASHRAE 93
	TOTAL	12.63	0.079	
Floor Panel	outdoor air (7.5 mph)	0.25		ASHRAE 93
6 3/8" SSIC	7/16" OSB (35 lb/ft^3)	0.61		ASHRAE 93
(5.5" foam)	5.5" EPS (1lb/ft^3)	21.18		ASHRAE 93
	7/16" OSB (35 lb/ft^3)	0.61		ASHRAE 93
	Carpet and fibrous pad	2.08		ASHRAE 93
	indoor air (horizontal down)	0.92		ASHRAE 93
	TOTAL	25.65	0.039	
Windows				
	window	3.33		product data
	TOTAL	3.33	0.300	
Skylights				
	skylight	3.66		ASHRAE 93
	TOTAL	3.66	0.273	

Component	Material	R value	U value	Source
8 5/16" SSIC Panel		(F ft^2 h/Btu)	(Btu/F ft^2 h)	
Door				
	outdoor air (7.5 mph)	0.25		ASHRAE 93
	Door	5		DEMO house specs 92
	indoor air	0.68		ASHRAE 93
	TOTAL	5.93	0.169	
Notes:	EPS foam 1.0 lb/ft^3; 1/k - 3.85			
UA calculation				
East Elevation		Area	U Value	UA
		ft^2	Btu/F ft^2 h	Btu/F h
	SSIC Wall Panel	252.59	0.033	8.24
	Splines	25.00	0.100	2.50
	Headers	3.08	0.045	0.14
	Windows	26.00	0.300	7.81
	Doors	0.00	0.169	0.00
	2nd Floor Framing East West	19.07	0.024	0.47
	Total East Elevation	325.74		19.15
West Elevation		Area	U Value	UA
		ft^2	Btu/F ft^2 h	Btu/F h
	SSIC WallPanel	258.59	0.03	8.43
	Splines	25.00	0.100	2.50
	Headers	3.08	0.045	0.14
	Windows	20.00	0.300	6.01
	Doors	0.00	0.169	0.00
	2nd Floor Framing East-West	19.07	0.024	0.47

	Total West Elevation	325.74		17.54
South Elevation		Area	U Value	UA
		ft^2	Btu/F ft^2 h	Btu/F h
	SSIC Wall Panel	253.86	0.03	8.28
	Splines	26.00	0.100	2.60
	Headers	15.00	0.045	0.67
	Windows	68.00	0.300	20.42
	Doors	14.70	0.169	2.48
	2nd Floor Framing South North	34.07	0.022	0.75
	2nd Floor Framing South North at TJI	1.00	0.036	0.04
	Total South Elevation	411.63		35.23
North Elevation		Area	U Value	UA
		ft^2	Btu/F ft^2 h	Btu/F h
	SSIC Wall Panel	208.50	0.03	6.80
	Splines	25.40	0.100	2.54
	Headers	9.25	0.045	0.42
	Windows	24.00	0.300	7.21
	Doors	14.70	0.169	2.48
	2nd floor framing South-North	33.78	0.022	0.74
	2nd floor framing South-North at TJI	1.29	0.036	0.05
	Total North Elevation	315.63		20.23
North Roof		Area	U Value	UA
		ft^2	Btu/F ft^2 h	Btu/F h
	SSIC Roof Panel	609.40	0.026	15.75
	Splines	4.38	0.079	0.35
	Total North Roof	613.78		16.09

South Roof		Area	U Value	UA
		ft^2	Btu/F ft^2 h	Btu/F h
	SSIC Roof Panel	552.76	0.026	14.28
	Splines	2.89	0.079	0.23
	Skylights	19.75	0.273	5.40
	Total South Roof	535.90		19.91
1st floor		Area	U Value	UA
		ft^2	Btu/F ft^2 h	Btu/F h
	SSIC Floor Panel	668.80	0.039	26.07
Eave	Eave overhang	26.79	0.024	0.655
	Eave overhang at TJI	2.29	0.066	0.152
	Total Eave	29.08		0.807
	Total Area	3224		
				UA
	East Elevation			19.15
	West Elevation			17.54
	South Elevation			35.23
	North Elevation			20.23
	North Roof			16.09
	South Roof			19.91
	1st Floor			26.07
	Eave Overhang			0.81
	TOTAL UA			155.03

Theoretical UA Vaules @ 75 F, Reference House, ASHRAE 93				
Component Calculations				
Component	Material	R value	U value	Source
Wall		(F ft^2 h/Btu)	(Btu/F ft^2 h)	
	outdoor air (7.5 mph)	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	R26 insul	26		Drawings
	.5" gypboard	0.45		ASHRAE 93
	indoor air	0.68		ASHRAE 93
	TOTAL	28.15	0.036	
Wall at Stud				
	outdoor air (7.5 mph)	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	2X8 DG Stud, (1.5x7.25" nominal)	7.25		ASHRAE 93
	.5" gypboard	0.45		ASHRAE 93
	indoor air	0.68		ASHRAE 93
	TOTAL	9.4	0.106	
Window Headers				
	outdoor air (7.5 mph)	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	1.5" DG (1.03 1/k)	1.55		ASHRAE 93
	4.25" EPS	16.4		
	1.5" DG (1.03 1/k)	1.55		
	1.5" DG (1.03 1/k)	1.55		ASHRAE 93
	.5" gypboard	0.45		ASHRAE 93
	indoor air	0.68		ASHRAE 93
	TOTAL	23.2	0.043	

Component	Material	R value (F ft^2 h/Btu)	U value (Btu/F ft^2 h)	Source
Window Headers				
at Stud	outdoor air (7.5 mph)	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	3.5" DG (1.03 1/k)	3.605		ASHRAE 93
	1" DG (1.03 1/k)	1.03		ASHRAE 93
	1.5" DG (1.03 1/k)	1.55		ASHRAE 93
	1.5" DG (1.03 1/k)	1.55		ASHRAE 93
	.5" gypboard	0.45		ASHRAE 93
	indoor air	0.68		ASHRAE 93
	TOTAL	9.885	0.101	
Roof	outdoor air (7.5 mph)	0.25		ASHRAE 93
	asphalt shingles	0.44		ASHRAE 93
	30 lb felt	0.06		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	R38	38		Drawings
	.5" gypboard	0.45		ASHRAE 93
	indoor air (sloping 45)	0.68		ASHRAE 93
	TOTAL	40.65	0.025	
Roof at Stud	outdoor air (7.5 mph)	0.25		ASHRAE 93
	asphalt shingles	0.44		ASHRAE 93
	30 lb felt	0.06		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	11.25" d.g. stud (1.03 1/k)	11.59		ASHRAE 93
	.5" gypboard	0.45		ASHRAE 93
	indoor air (sloping 45)	0.68		ASHRAE 93
	TOTAL	14.24	0.070	

Component	Material	R value	U value	Source
		(F ft^2 h/Btu)	(Btu/F ft^2 h)	
1st Floor	outdoor air (7.5 mph)	0.25		ASHRAE 93
	R30	30		Drawings
	3/4" DG (1.03 1/k)	0.93		ASHRAE 93
	Carpet and fibrous pad	2.08		ASHRAE 93
	indoor air (horizontal down)	0.92		ASHRAE 93
	TOTAL	34.18	0.029	
1st Floor at stud	outdoor air (7.5 mph)	0.25		ASHRAE 93
	9 1/4" DG	9.53		ASHRAE 93
	3/4" DG (1.03 1/k)	0.93		ASHRAE 93
	Carpet and fibrous pad	2.08		ASHRAE 93
	indoor air (horizontal down)	0.92		ASHRAE 93
	TOTAL	13.71	0.073	
2nd floor framing @ East-West Walls	outdoor air (7.5 mph)	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	1/2" DG Ply	0.62		ASHRAE 93
	R38 Batt	38		Drawings
	indoor air	0.68		ASHRAE 93
	TOTAL	40.32	0.025	

Component	Material	R value	U value	Source
		(F ft^2 h/Btu)	(Btu/F ft^2 h)	
2nd floor Framing North and South Walls				
	outdoor air (7.5 mph)	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	1" rigid insulation (1.5 lb/ft^3 polyisocyanurate)	5.9		ASHRAE 93
	R38 Batt	38		Drawings
	indoor air	0.68		ASHRAE 93
	TOTAL	45.6	0.022	
2nd floor Framing North and South Walls at TJI				
	outdoor air (7.5 mph)	0.25		ASHRAE 93
	1" DG plywood	1.03		ASHRAE 93
	1.5" stud	1.545		ASHRAE 93
	2.0' , TJI	24.72		Drawings
	TOTAL	27.545	0.036	
Eave Overhang				
	outdoor air	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	R38 Batt	38		Drawings
	3/4" Sheathing	0.94		ASHRAE 93
	Indoor air (downward)	0.92		ASHRAE 93
	TOTAL	40.88	0.024	

Component	Material	R value	U value	Source
		(F ft^2 h/Btu)	(Btu/F ft^2 h)	
Eave Overhang				
at TJI	outdoor air	0.25		ASHRAE 93
	5/8" DG plywood	0.77		ASHRAE 93
	11 7/8 TJI	12.23		Drawings
	3/4" Sheathing	0.94		ASHRAE 93
	Indoor air (downward)	0.92		ASHRAE 93
	TOTAL	14.09	0.071	
Windows				
	window	3.33		product data
	TOTAL	3.33	0.300	
Skylights				
	skylight	3.66		
	TOTAL	3.66	0.273	
Door				
	outdoor air (7.5 mph)	0.25		
	Door	5		DEMO house specs 92
	indoor air	0.68		
	TOTAL	5.93	0.169	
Notes:	EPS foam 1.0 lb/ft^3; 1/k - 3.85			

UA calculation				
East Elevation		Area	U Value	UA
		ft^2	Btu/F ft^2 h	Btu/F h
	Wall	231.93	0.036	8.24
	Studs	43.91	0.106	4.67
	Headers	3.83	0.043	0.17
	Headers at studs	1.000	0.101	0.10
	Windows	26.00	0.300	7.81
	2nd Floor Framing East West	19.07	0.024	0.46
	Total East Elevation	325.74		21.44
West Elevation		Area	U Value	UA
		ft^2	Btu/F ft^2 h	Btu/F h
	Wall	236.93	0.036	8.42
	Studs	44.91	0.106	4.78
	Headers	3.83	0.043	0.17
	Headers at studs	1.000	0.101	0.10
	Windows	20.00	0.300	6.01
	2nd floor Framing East West	19.07	0.024	0.46
	Total West Elevation	325.74		19.92
South Elevation		Area	U Value	UA
		ft^2	Btu/F ft^2 h	Btu/F h
	Wall	228.40	0.036	8.11
	Studs	50.86	0.106	5.41
	Headers	11.496	0.043	0.50
	Headers at studs	3.000	0.101	0.30
	Windows	68.00	0.300	20.42
	Doors	14.70	0.169	2.48
	2nd Floor Framing North-South	34.17	0.022	0.75
	2nd Floor Framing North South at TJI	1.00	0.036	0.04
	Total South Elevation	411.63		38.01

North Elevation		Area	U Value	UA
		ft^2	Btu/F ft^2 h	Btu/F h
	Wall	199.89	0.036	7.10
	Studs	34.33	0.106	3.65
	headers	5.748	0.043	0.25
	headers at studs	1.5	0.101	0.15
	Windows	24.00	0.300	7.21
	Doors	14.70	0.169	2.48
	2nd Floor Framing North-South	34.17	0.022	0.75
	2nd Floor Framing North South at TJI	1.29	0.036	0.05
	Total North Elevation	315.63		21.63
North Roof		Area	U Value	UA
		ft^2	Btu/F ft^2 h	Btu/F h
	Roof	558.90	0.025	13.75
	Studs	54.88	0.070	3.85
	Total North Roof	613.78		17.60
South Roof		Area	U Value	UA
		ft^2	Btu/F ft^2 h	Btu/F h
	Roof	452.68	0.025	11.14
	Studs	54.38	0.070	3.82
	Skylights	19.75	0.273	5.40
	Total South Roof	526.80		20.35
1st floor		Area	U Value	UA
		ft^2	Btu/F ft^2 h	Btu/F h
	Floor	621.30	0.029	18.18
	Studs	47.50	0.073	3.46
	Total 1st Floor	668.80		21.64

Eave Overhang	Eave	26.79	0.024	0.66
	Eave overhang at TJI	2.29	0.071	0.16
	Total Eave Overhang			0.818
	Total Area	3217		
				UA
	East Elevation			21.44
	West Elevation			19.92
	South Elevation			38.01
	North Elevation			21.63
	North Roof			17.60
	South Roof			20.35
	1st Floor			21.64
	Eave Overhang			0.82
	TOTAL UA			161.42

Framing Areas Reference House				
North Wall Framing				
Component	**Number**	**Total Linear Feet**	**Unit Area**	**Total Area**
sole plate	1	35.07	0.125	4.384
top plate	2	70.14	0.125	8.768
studs	15	114.375	0.125	14.297
cripple studs	2	6.5	0.125	0.813
header studs	6	38.25	0.125	4.781
sill plates	2	7.5	0.125	0.938
			Total	33.979
Mid header		12	0.479	5.748
Header at stud		12	0.125	1.500
			Total	7.248
South Wall Framing				
sole plate	1	35.07	0.125	4.384
top plate	2	47.31	0.125	5.914
studs @ 7.625'	15	91.5	0.125	11.438
studs @ 15.875'	4	63.5	0.125	7.938
studs @ 11.75'	6	70.5	0.125	8.813
dormer window studs@3.75	4	15	0.125	1.875
cripple studs	2	38.25	0.125	4.781
header studs	6	38.25	0.125	4.781
sill plates	2	7.5	0.125	0.938
			Total	50.860
Window and door header		12	0.479	5.748
headers at studs		12	0.125	1.500
Dormer header		12	0.479	5.748
Dormer header @ stud		12	0.125	1.500
			Total	14.496

Component	Number	Total Linear Feet	Unit Area	Total Area
East Elevation				
1st Floor				
sole plate	1	19.07	0.125	2.384
top plate	2	38.14	0.125	4.768
studs	10	76.25	0.125	9.531
cripple studs	1	12.75	0.125	1.594
header studs	2	12.75	0.125	1.594
sill plates	1	4	0.125	0.500
			Total	20.370
Mid header		4	0.479	1.916
Header at stud		4	0.125	0.500
2nd floor				
sole plates	1	22.46	0.125	2.808
top plates	2	35	0.125	4.375
studs @ 1.875	2	3.75	0.125	0.469
studs @ 3.625	2	7.25	0.125	1.906
studs @ 5.625	2	11.25	0.125	1.406
studs @7.625	2	15.25	0.125	1.906
studs @ 9.625	2	19.25	0.125	2.406
studs @ 7.375	2	14.75	0.125	1.844
			Total	17.120
Window header		4	0.479	1.916
Window header @ stud		4	0.125	0.500
Dormer Panel				
sole plate	1	14	0.125	1.750
top plate	2	22	0.125	2.750
stud @ .635	1	0.625	0.125	0.078
stud @2.125'	1	2.125	0.125	0.266
stud @3.125'	1	3.125	0.125	0.391
stud @4.125'	1	4.125	0.125	0.516
stud @5.375'	1	5.375	0.125	0.672
			Total	6.422

		Total stud framing		43.912
		Total header framing		3.832
		Total header at stud		1.000
Component	**Number**	**Total Linear Feet**	**Unit Area**	**Total Area**
West Elevation				
1st Floor				
sole plate	1	19.07	0.125	2.384
top plate	2	38.14	0.125	4.768
studs	10	76.25	0.125	9.531
cripple studs	1	12.75	0.125	1.594
header studs	2	12.75	0.125	1.594
sill plates	1	4	0.125	0.500
window filler studs	2	8	0.125	1.000
			Total	21.370
Mid header		4	0.479	1.916
Header at stud		4	0.125	0.500
2nd floor				
sole plates	1	22.46	0.125	2.808
top plates	2	35	0.125	4.375
studs @ 1.875	2	3.75	0.125	0.469
studs @ 3.625	2	7.25	0.125	1.906
studs @ 5.625	2	11.25	0.125	1.406
studs @7.625	2	15.25	0.125	1.906
studs @ 9.625	2	19.25	0.125	2.406
studs @ 7.375	2	14.75	0.125	1.844
			Total	17.120
Window header		4	0.479	1.916
Window header @ stud		4	0.125	0.500

Component	Number	Total Linear Feet	Unit Area	Total Area
Dormer Panel				
sole plate	1	14	0.125	1.750
top plate	2	22	0.125	2.750
stud @ .635	1	0.625	0.125	0.078
stud @2.125'	1	2.125	0.125	0.266
stud @3.125'	1	3.125	0.125	0.391
stud @4.125'	1	4.125	0.125	0.516
stud @5.375'	1	5.375	0.125	0.672
			Total	6.422
			Total framing	44.912
			Total header area	3.832
			Total header at stud	1.000
framing,				
rimjoist		70.14	0.125	8.768
floor joists	19	362.33	0.125	45.291
2nd floor framing				
rim joist		115	1	115.000
joist overhang	60	20	0.125	2.500
Roof Framing				
South side				
2x12 rafters @a7.5'	17.00	297.50	0.125	37.188
2x12 rafters at dormer	9.00	99.00	0.125	12.375
2x12 rafters to skylight	2.00	18.00	0.125	2.250
skylight framing	4.00	15.50	0.125	1.938
2x12 rafters above skylight	2.00	5.00	0.125	0.625
			Total	54.375

Component	Number	Total Linear Feet	Unit Area	Total Area
North side				
2x12 rafters	23.00	402.50	0.125	50.313
ridge beam	1.00	36.50	0.125	4.563
			Total	54.875