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Solar Energy Research Institute Validation Test House Site Handbook

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This work is a cooperative effort between
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SOLAR ENERGY RESEARCH INSTITUTE
VALIDATION TEST HOUSE
SITE HANDBOOK

by

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ABSTRACT

The Validation Test House at the Solar Energy Research Institute in Golden, Colorado, is being used to collect performance data for analysis/design tool validation as part of the DOE Passive Solar Class A Performance Evaluation Program. This site handbook describes in detail the construction, instrumentation, and test configuration of the building for use by passive solar analysis/design tool developers and researchers.

I. OVERVIEW

A. History and Purpose

The Solar Energy Research Institute (SERI) Validation Test House is located in Golden, Colorado, in Jefferson County. This test building has been established for Class A performance monitoring activities under the U.S. Department of Energy (DOE) Passive and Hybrid Solar Energy Program. The objective of the Class A project is to obtain system and energy-transfer mechanism level data from which public-domain building energy analysis programs can be validated and their accuracy assessed.

In 1980 this single-family detached residence, originally built in the early 1950s, was purchased by SERI for use in detailed monitoring of energy flows in buildings. It was moved to the site at the SERI outdoor test area and installed on footings poured to accommodate the building. The thermal integrity of the building envelope was then upgraded by insulating the attic, adding foam insulation to the wall cavities, extensive caulking, and adding storm doors and windows. Although not designed as a passive solar heated building, its large south-facing glazing makes it representative of many low-mass, direct-gain (sun tempered) residences. A photograph of the building is shown in Fig. 1.

B. The Building

The test site on which the building is located is at 39.7°N latitude, 105.20°W longitude, at an elevation of 1740 m (5710 ft) above sea level. Figure 2 shows the location of the building on the site and the topography of the immediate area.

A floor plan of the building in Fig. 3 shows this 93.6 m^2 (1007 ft^2) single-story, unoccupied residence to be of well-insulated frame construction. Its substantial south-facing glazing, coupled with a layer of brick pavers placed on the floor in the living/dining room and south bedroom to provide thermal-storage mass, creates a low-mass, direct-gain passive solar heating system.

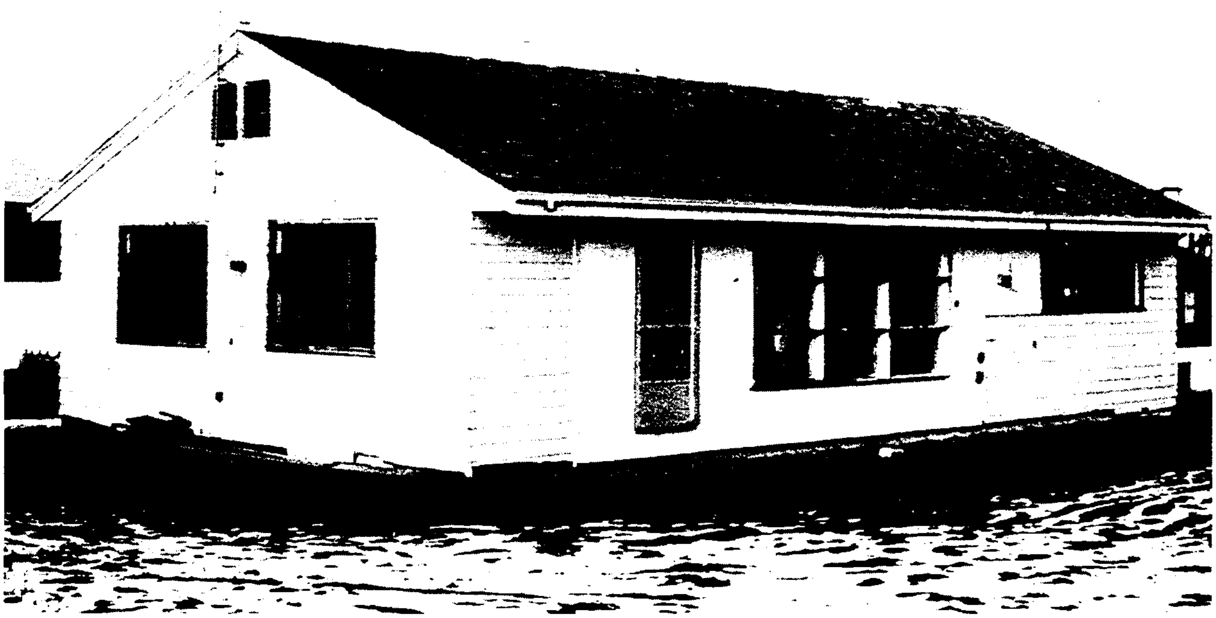

Fig. 1. SERI Validation Test House.

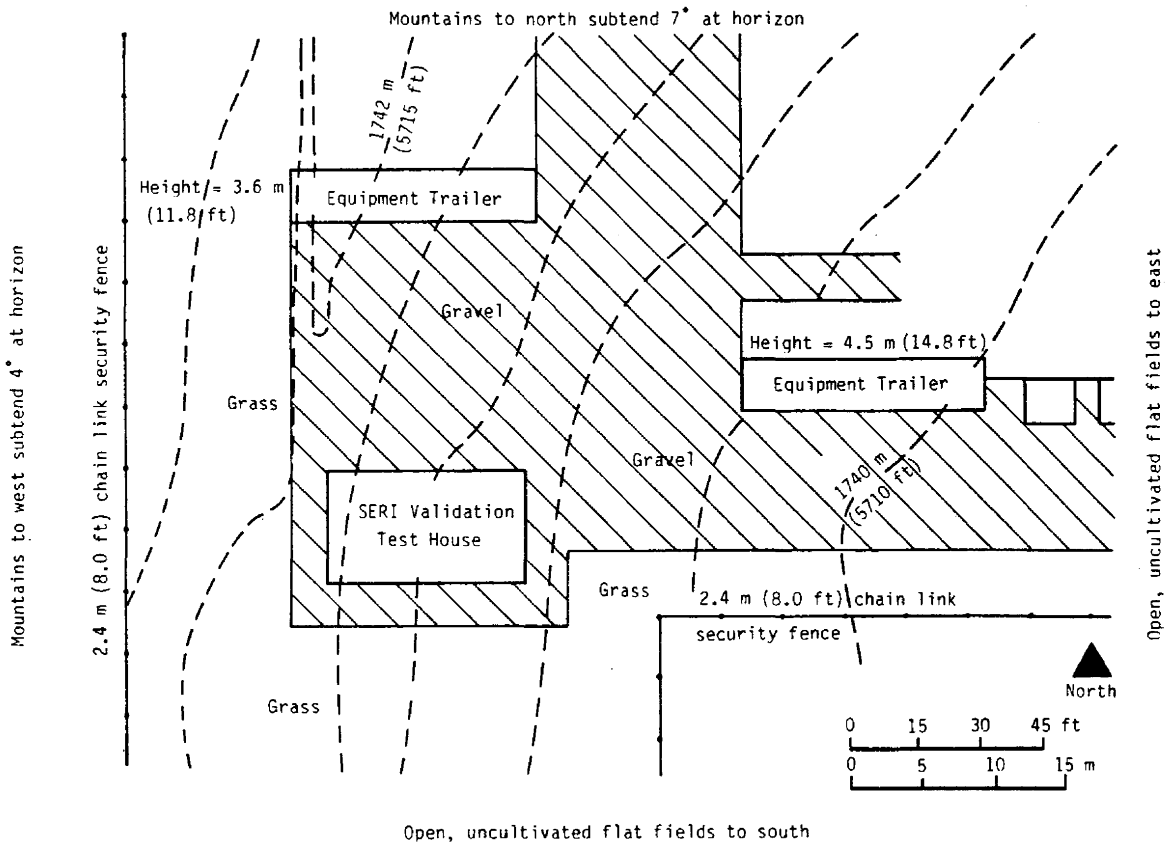

Fig. 2. Site plan of the SERI Validation Test House.

C. Scope of this Handbook

This handbook gives a complete physical description of the validation test house, and the results of one-time thermal/physical property and operating parameter measurements. These data are intended to provide sufficient information to prepare measurement-based inputs of building properties for any level of building energy simulation. Hourly experimental data (state points and energy flows) taken in the building will be available on magnetic tape. Sensor placements and a list of data taken during normal operation are provided in the Appendices. Additional information concerning the SERI test house may be obtained from:

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1617 Cole Boulevard
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(303) 231-1453 or 231-1095
(FTS) 327-1453 or 327-1095

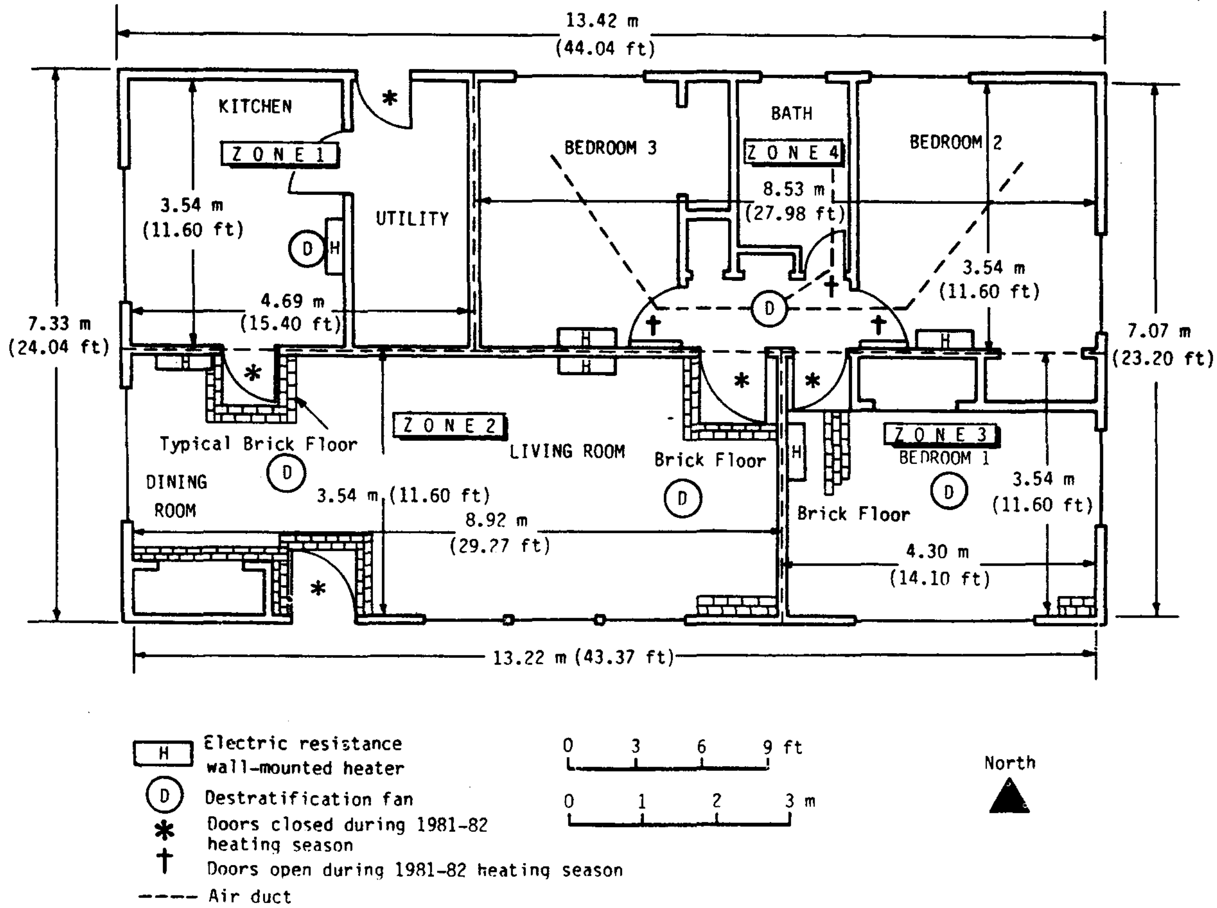


Fig. 3. Floor plan of SERI Validation Test House.

II. DESCRIPTION OF THE ENVIRONMENT

A site plan for the SERI Validation Test House is given in Fig. 2. The contour is generally level, with gravel (reflectance ≈ 0.2) immediately surrounding the entire building; during the winter, this area is sometimes covered with snow (reflectance ≈ 0.7). There is no significant shading effect from trees or other external objects. Mountains to the west and to the north subtend angles from the horizon of 4° and 7° on average, respectively.

The American Institute of Architects/Research Corporations (AIA/RC) regional climatic classification for Golden, Colorado, is type 3 (Great Plains, intermountain basin and plateaus).[1] Local weather data are summarized in Table I; the nearest Typical Meteorological Year weather station is in Denver, Colorado.

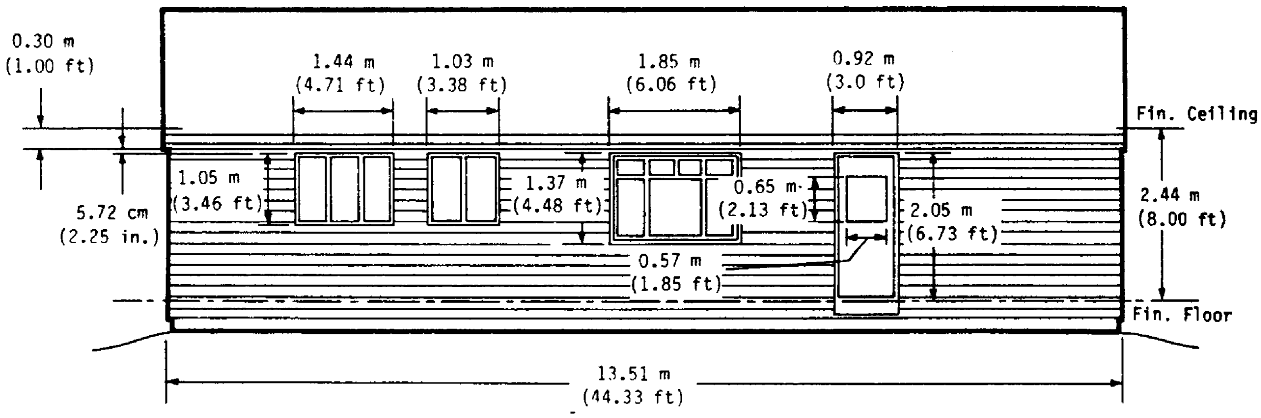


Fig. 4. North elevation.

TABLE I

LOCAL WEATHER DATA

Heating degree days	3634°C-days (6542°F-days)
Average winter temperature (December - March)	0.2°C (32.3°F)
Design dry-bulb temperature for heating (97.5% point)	-17.2°C (1°F)[2]
Cooling degree days [base temperature = 21.1°C (70°F)]	286°C-days (515°F-days)
Design dry-bulb and mean coincident wet-bulb temperatures (2.5% point)	32.8°C (92°F)/15°C (59°F)[2]
Average annual wind speed	14.5 km/h (9.0 mph) - medium
Prevailing wind direction	West*
Cloud cover	
December - March	51-58%
April - November	41-58%

*Data from Rocky Flats, Colorado, 24 km (15 m) north of the site.

TABLE I (cont.)

Monthly Rain and Snowfall

	Rain cm	Rain in.	Snow cm	Snow in.
January	1.2	0.5	20.3	8.0
February	1.5	0.6	19.6	7.7
March	2.8	1.1	33.0	13.0
April	5.1	2.0	23.6	9.3
May	6.1	2.4	4.6	1.8
June	3.8	1.5	trace	---
July	4.3	1.7	0	0
August	3.6	1.4	0	0
September	2.8	1.1	4.1	1.6
October	2.5	1.0	9.4	3.7
November	1.7	0.7	20.1	7.9
December	1.6	0.6	16.5	6.5
Annual	37.0	14.6	151.2	59.5

III. DESCRIPTION OF THE TEST HOUSE

The SERI Validation Test House is of light frame construction [2x6s and 2x4s on 0.41 m (16 in.) centers], with hardwood floors over a crawl space. After the building was moved to the site, it was heavily retrofitted with insulation and caulking, and storm windows were installed. To obtain greater storage mass for the direct-gain system, brick pavers were placed on the hardwood floors throughout virtually the entire south zones (Zones 2 and 3). North, south, east, and west elevations of the house are shown in Figs. 4-7.

For purposes of computer modeling, the building is divided into four zones separated by closed, sealed doors (Fig. 3); dimensioned floor plans for the zones are shown in Figs. 8-11, and areas and volumes are summarized in Table II. The kitchen and the utility room are Zone 1 (Fig. 8), the dining room-living room is Zone 2 (Fig. 9); Zone 3 is bedroom 1 (Fig. 10); and Zone 4 is comprised of the bathroom and bedrooms 2 and 3 (Fig. 11). Destratifiers were used in each zone, as shown in Fig. 3.

A description of the construction details and materials is given in Table III for each wall, floor, ceiling, and roof construction. A typical north/south building section is shown in Fig. 12 and a typical east/west section is shown in Fig. 13. Thermal and physical properties of construction materials are given in Appendix A. Four louvers, each with 0.093 m^2 (1.00

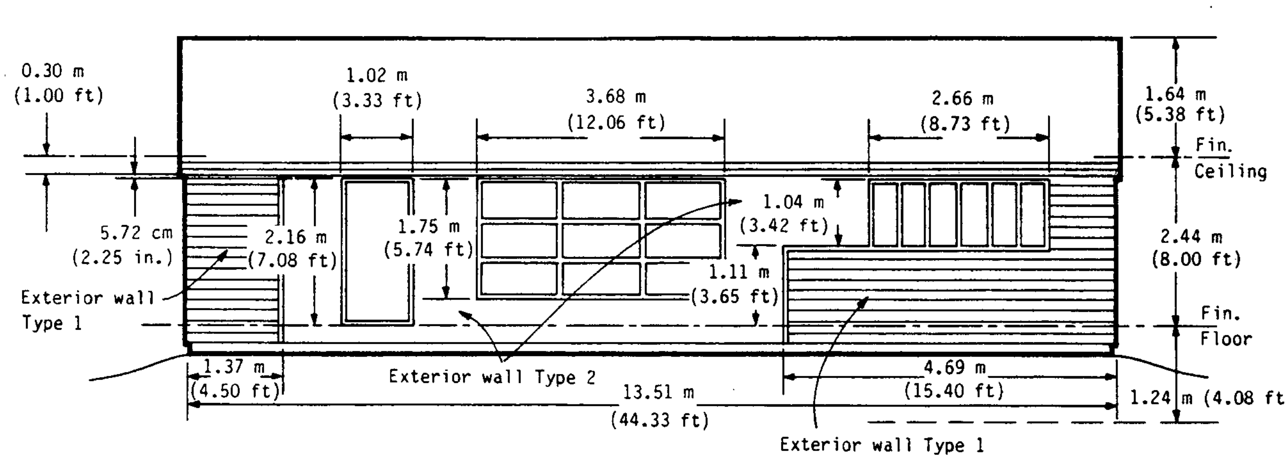


Fig. 5. South elevation.

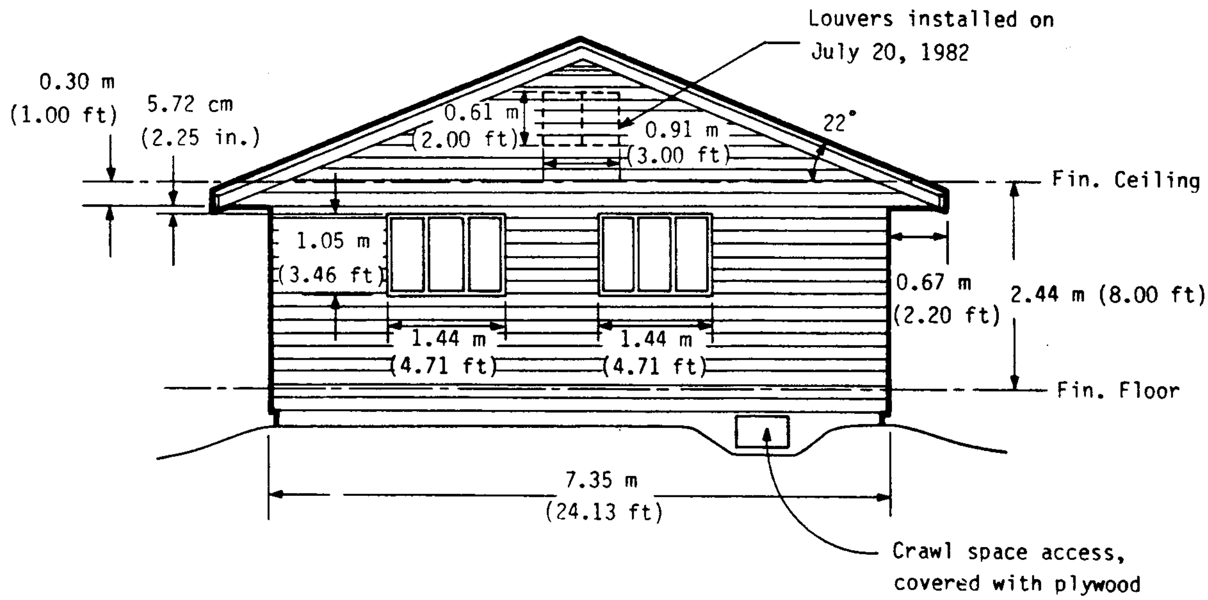


Fig. 6. East elevation.

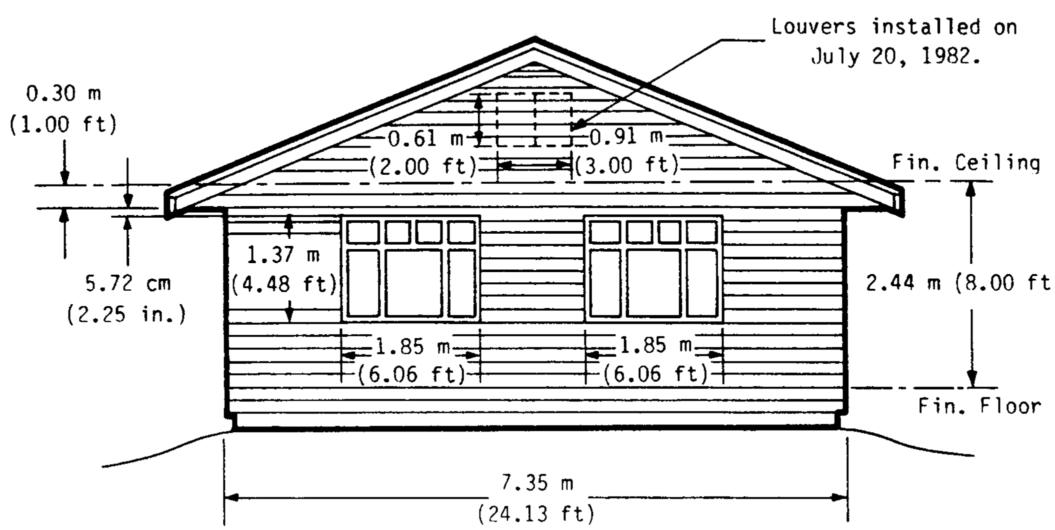


Fig. 7. West elevation.

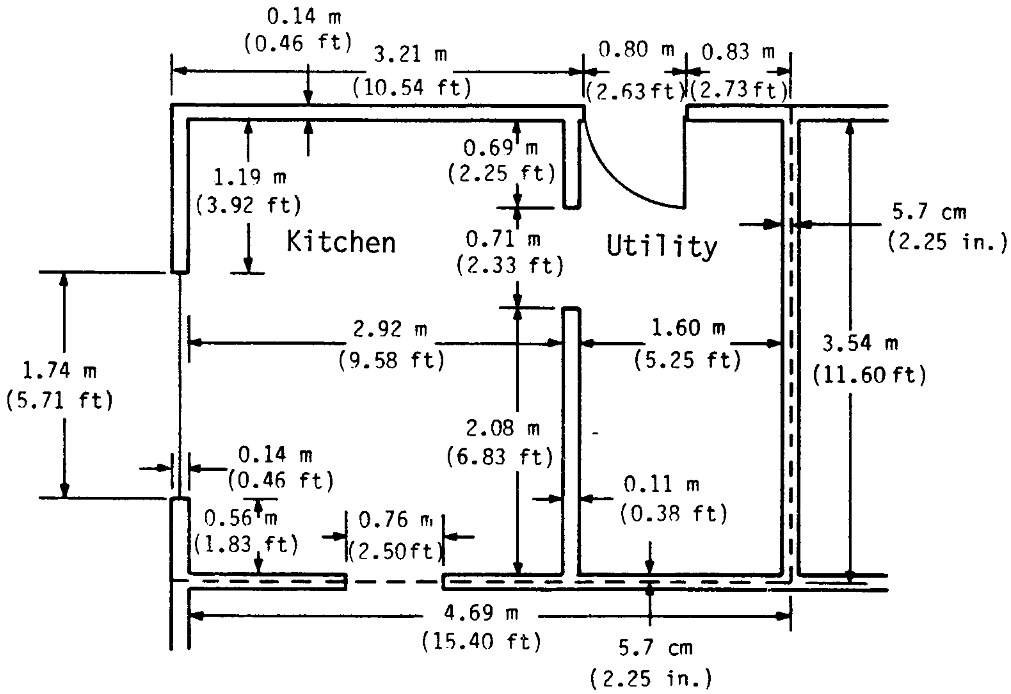


Fig. 8. Zone 1 floor-plan dimensions.

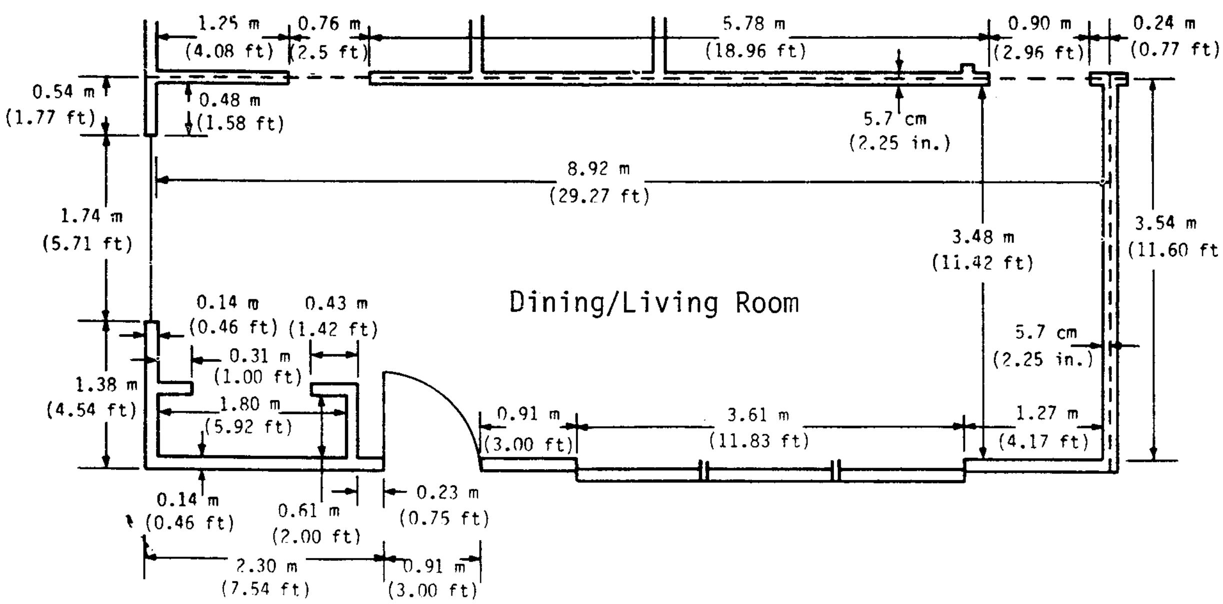


Fig. 9. Zone 2 floor-plan dimensions.

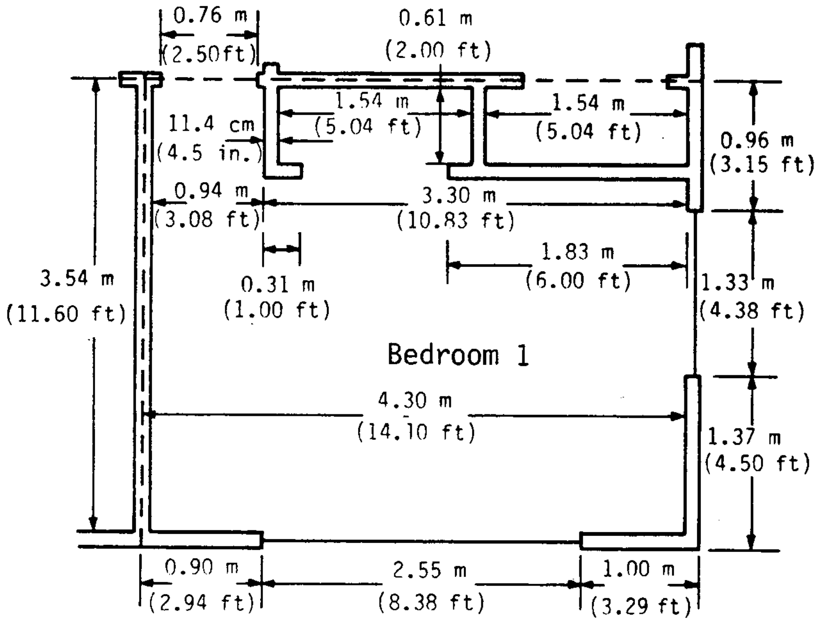


Fig. 10. Zone 3 floor-plan dimensions.

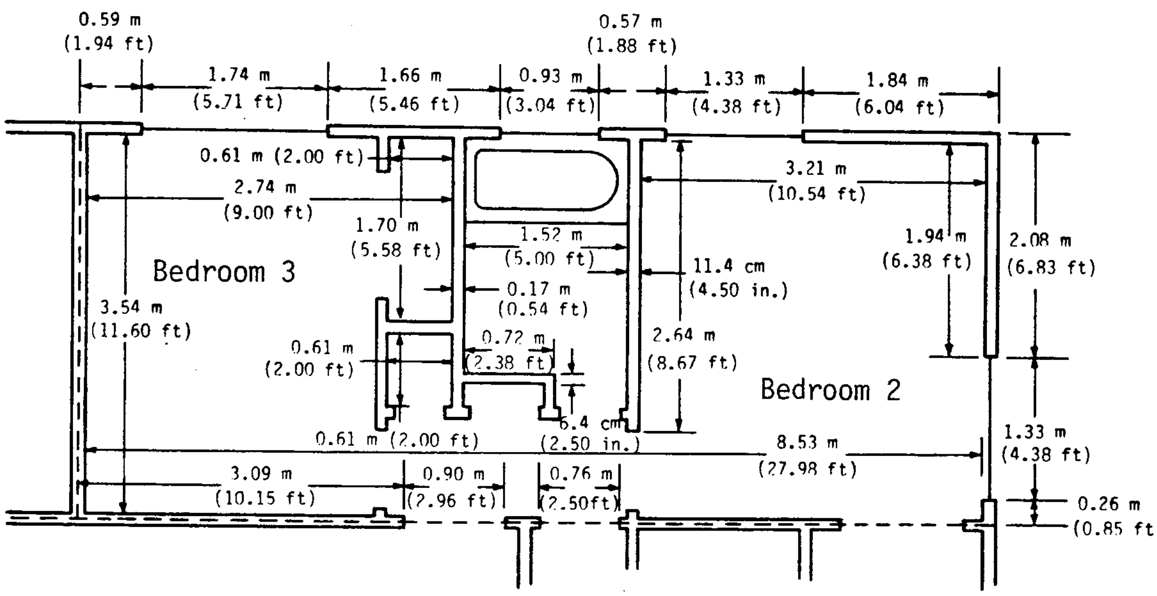


Fig. 11. Zone 4 floor-plan dimensions.

TABLE II

ZONAL AREA AND VOLUME SUMMARY

Zone		Floor Area $[m^2(ft^2)]$	Volume $[m^3(ft^3)]$
1	Kitchen/utility	16.6 (179)	40.5 (1429)
2	Dining/living room	31.6 (340)	76.9 (2717)
3	Bedroom 1	15.2 (163)	37.0 (1308)
4	Bedrooms 2 and 3, bath	30.2 (325)	73.5 (2596)
Building		93.6 (1007)	228.0 (8050)

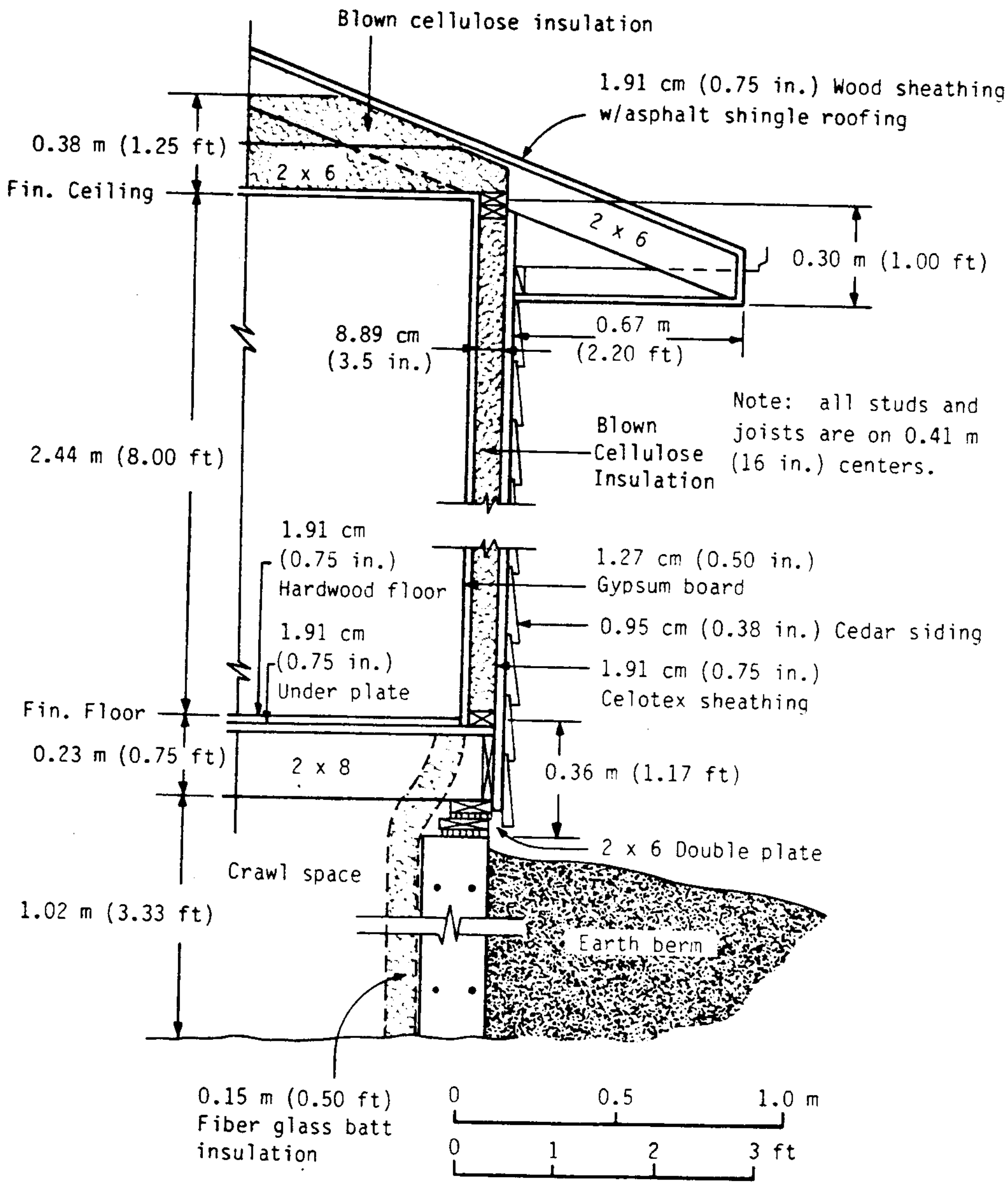


Fig. 12. Typical (north or south) wall section.

TABLE III

ENVELOPE CONSTRUCTION DESCRIPTIONS

Interior Walls
1.27 cm (0.50 in.) gypsum board
6.35 cm (2.50 in.) air space
1.27 cm (0.50 in.) gypsum board

Exterior Wall Type 1 (North, East, West, and 53.3% of South Wall Siding) (See Fig. 6)
1.27 cm (0.50 in.) gypsum board
8.89 cm (3.50 in.) blown cellulose insulation
1.91 cm (0.75 in.) Celotex
0.95 cm (0.375 in.) cedar siding

Exterior Wall Type 2 (46.7% of South Wall Siding)
1.27 cm (0.50 in.) gypsum board
8.89 cm (3.50 in.) blown cellulose insulation
1.91 cm (0.75 in.) Celotex
0.79 cm (0.31 in.) plywood

Tile Flooring (Kitchen, Bathroom)
0.32 cm (0.125 in.) linoleum
0.16 cm (0.063 in.) tar paper sheet
1.91 cm (0.75 in.) hardwood (oak)
2 sheets paper
1.91 cm (0.75 in.) subfloor

Wooden Flooring (Bedrooms 2 and 3)
1.91 cm (0.75 in.) hardwood (oak)
2 sheets paper
1.91 cm (0.75 in.) subfloor

Brick Flooring (Living Room, Dining Room, and Bedroom 1)
5.72 cm (2.25 in.) common red brick
Plastic sheeting
1.91 cm (0.75 in.) hardwood (oak)
2 sheets paper
1.91 cm (0.75 in.) subfloor, softwood (pine)

Ceiling
1.27 cm (0.50 in.) gypsum board
0.38 m (15.00 in.) blown cellulose insulation

Gable Walls (East, West Attic End Walls)
1.91 cm (0.75 in.) Celotex
0.79 cm (0.375 in.) cedar siding

Roof
1.91 cm (0.75 in.) subfloor underplate, softwood
0.16 cm (0.063 in.) tar paper sheet
0.48 cm (0.188 in.) asphalt shingle
0.48 cm (0.188 in.) asphalt shingle

All joists and framing are 0.41 m (16 in.) on center. All walls have a single plate (2x4) at bottom and a double plate (2x4) at top.

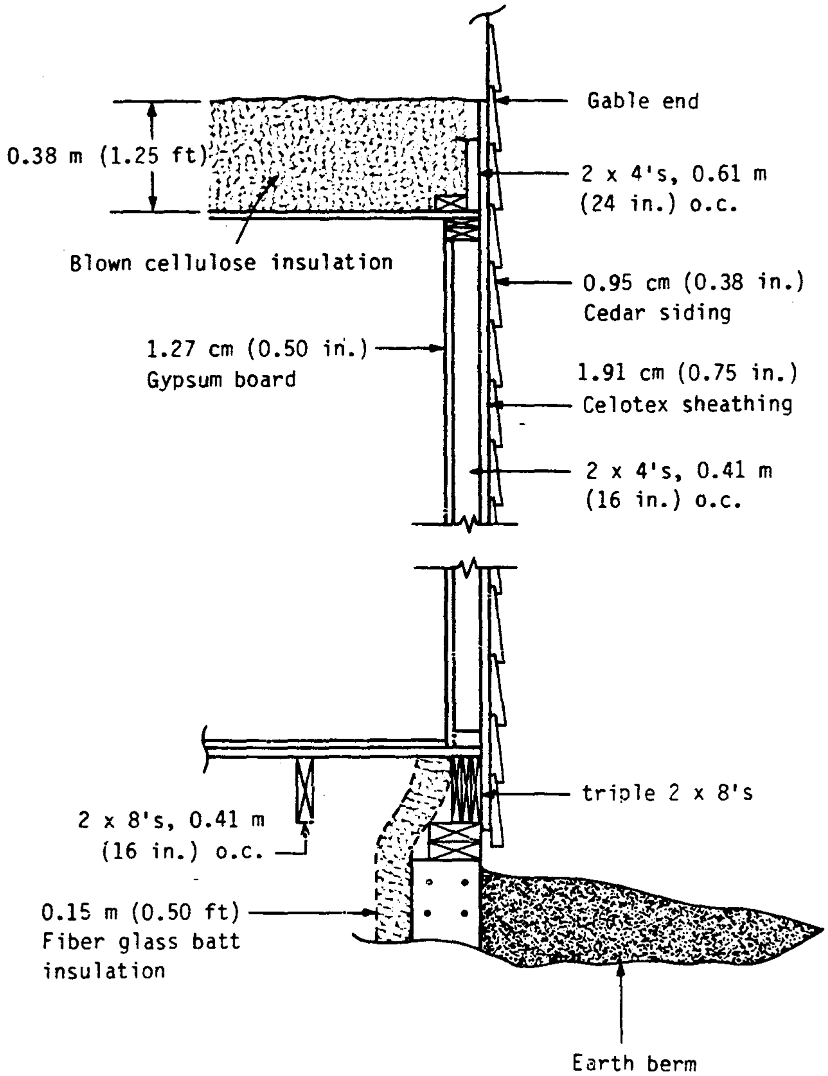


Fig. 13. Typical (east or west) section.

ft^2) of open air flow, were installed on July 20, 1982, in the attic, with two louvers at the apex of both the east and west gables (see Figs. 6 and 7). The louvers were required for a whole-house fan that was installed in mid-July 1982. Outside walls are painted a pastel green, and inside walls and ceilings are all flat white.

A. Windows

The locations of the windows are shown in the building elevations (Figs. 4-7). The top of all window frames is located 5.72 cm (2.25 in.) below the bottom of the roof overhang.

The windows, except on the south side, of the living room were originally of the single-glazed, steel casement type. All windows (except that in the north door) have been retrofitted with an interior, aluminum-frame storm sash that holds the inner glazing. Except for the living room south window, all windows have the outer glazing held in a steel frame; the living room south window has a wooden frame holding the outer glazing (see Fig. 14). The typical sash configuration for all but the living room south window is shown in Fig. 15; the number of lites differs from window to window, but the relative dimensions are identical. The exterior of the window frames is painted dark green (solar absorptance ≃ 0.89).

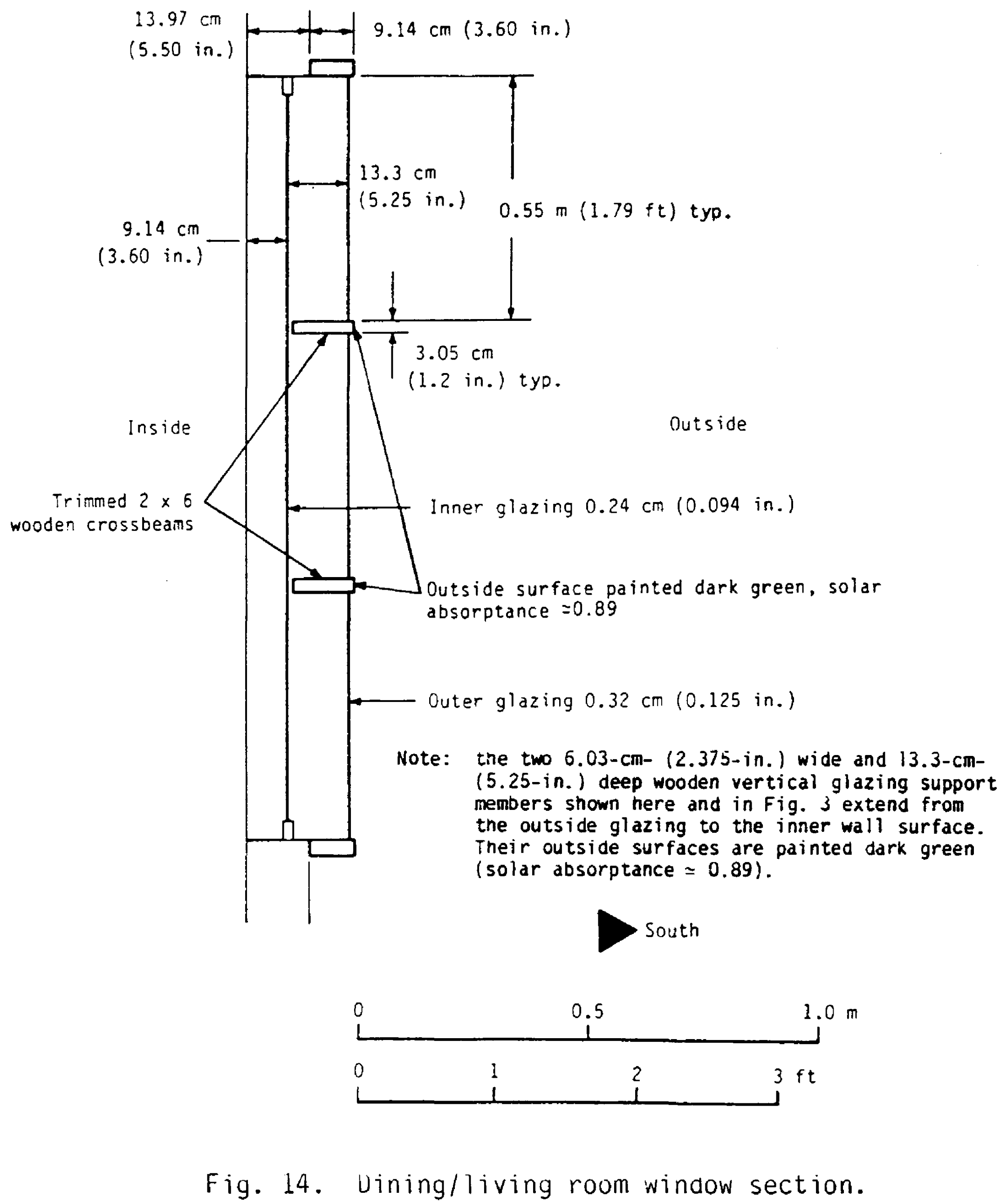


Fig. 14. Dining/living room window section.

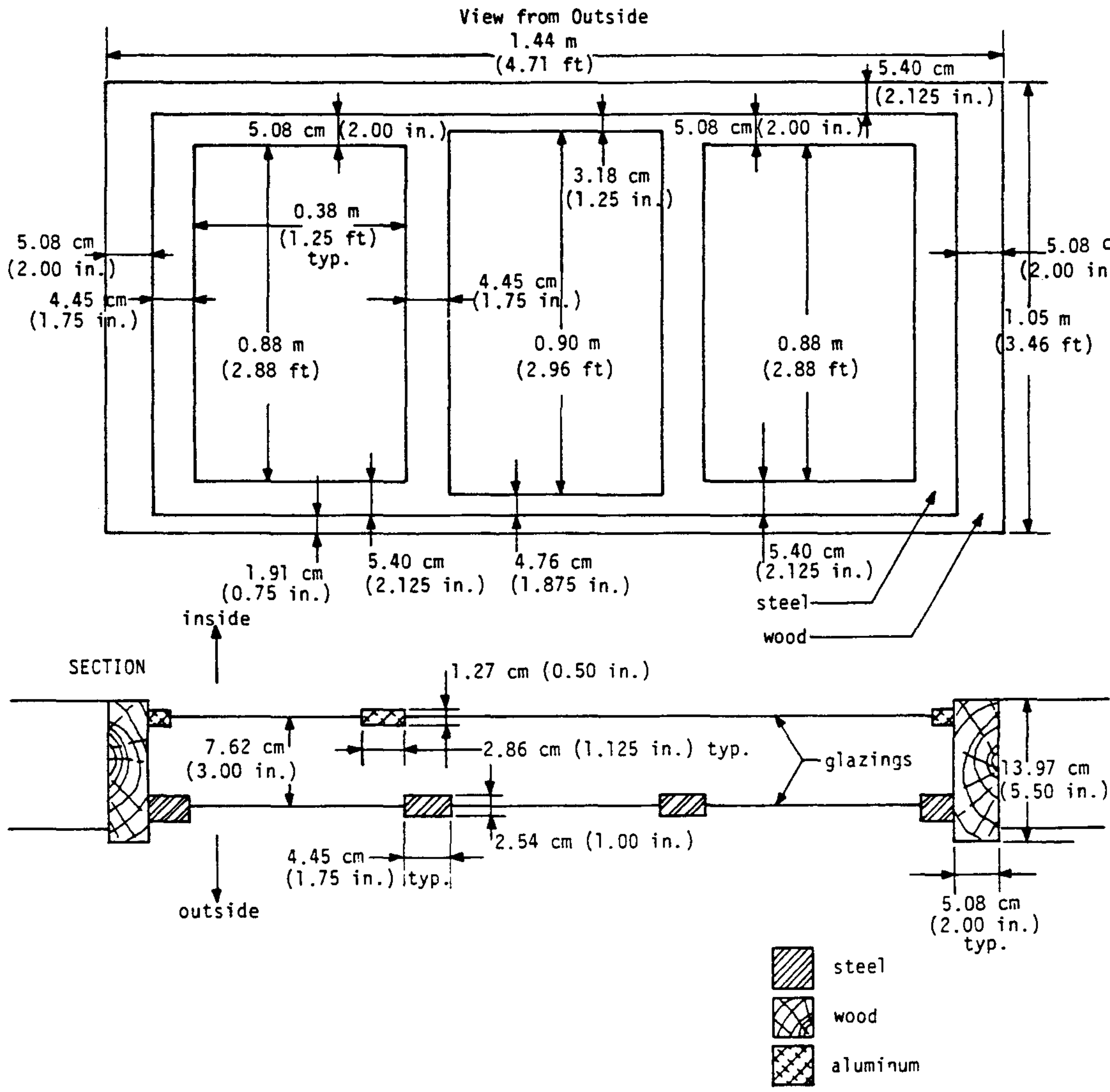


Fig. 15. Typical window section (except dining/living room window).

On all windows the outer pane is 0.32-cm (0.125-in.)-thick glass and the inner pane is 0.24-cm (0.094-in.)-thick glass. All windows except the living room south window have a 7.62-cm (3.00-in.) air gap between panes, the living room south window has a 13.3-cm (5.25-in.) air gap; a vertical section of this window is shown in Fig. 14. Glazing constitutes 11.9% of the north-wall exterior surface, 21.3% of the south-wall exterior surface, 7.7% of the east, and 13.8% of the west. Table IV shows the percentage of glazing to the gross area of the frame for each window. All window frames have been carefully caulked to reduce air leakage.

TABLE IV

WINDOW DESCRIPTIONS

	Fraction of Window Assembly that is Unobstructed Glass	Total Area (including jambs)	Net Glazed Area
North-Facing Wall			
Bedroom 2 Window	66.8%	1.51 m^2 (16.3 ft^2)	1.01 m^2 (10.9 ft^2)
Bathroom Window	64.9%	1.08 m^2 (11.7 ft^2)	0.70 m^2 (7.6 ft^2)
Bedroom 3 Window	72.3%	2.52 m^2 (27.2 ft^2)	1.83 m^2 (19.6 ft^2)
Door	22.3%	1.64 m^2 (17.6 ft^2)	0.37 m^2 (3.9 ft^2)
West-Facing Wall			
Kitchen Window	72.3%	2.52 m^2 (27.2 ft^2)	1.83 m^2 (19.6 ft^2)
Dining Room Window	72.3%	2.52 m^2 (27.2 ft^2)	1.83 m^2 (19.6 ft^2)
South-Facing Wall			
Living Room Window	77.2%	6.43 m^2 (69.2 ft^2)	4.97 m^2 (53.5 ft^2)
Bedroom 1 Window	73.5%	2.77 m^2 (29.8 ft^2)	2.04 m^2 (21.9 ft^2)
East-Facing Wall			
Bedroom 1 Window	66.8%	1.51 m^2 (16.3 ft^2)	1.01 m^2 (10.9 ft^2)
Bedroom 2 Window	66.8%	1.51 m^2 (16.3 ft^2)	1.01 m^2 (10.9 ft^2)

Glazing - Number of panes = 2

Glazing thickness: inside glass = 0.24 cm (0.094 in.)
outside glass = 0.32 cm (0.125 in.)

Distance between panes = 13.3 cm (5.25 in.) living room south window
= 7.6 cm (3.00 in.) all other windows

Normal reflectance = 0.074 (same for both thicknesses)

Normal transmittance = *

Hemispherical transmittance (clear day) = 0.88 (same for both thicknesses)

Index of refraction = *1.526

Extinction coefficient = *0.5/in.

*Measured values not available at present; listed value is taken from Ref. 2, if available.

Note that the south window in the living room will experience significant blockage of solar radiation because of the glazing support structure (see Fig. 14). The horizontal bottom ledge and the four vertical support members (one on each side and two in the middle) each extend back 22.7 cm (8.94 in.) from the outer glazing. Also, the two horizontal members located between the inner and outer glazings will intercept considerable beam radiation during solar equinox periods. The radiation transmitted to the living room should be adjusted to account for this situation.

B. Doors

The two exterior doors are both wooden hollow-core flush doors with aluminum and glass storm doors; the south door is 4.45-cm (1.75 in.) thick and the north door is 3.49-cm (1.375-in.) thick. An 8.89-cm (3.50-in.) air space separates the exterior doors from the storm doors. The north door has a single-glazed panel, as shown in Fig. 4, that covers 22% of the total door area.

C. Description of Passive Solar and Conservation Features

The test house is a direct-gain system, with 7.0 m^2 (75 ft^2) of south-facing glazing, and 5.7 m^2 (61 ft^2) of east- and west-facing glazing. This corresponds to a south glazing-area-to-floor-area ratio of 7.5%. A small amount of diffuse solar radiation enters the house through north-facing windows. The sloping roof overhang projects out 0.67 m (2.20 ft) from the south wall just above the windows and provides shading during the summer months. No movable insulation or drapes are used on any of the windows.

Thermal storage is provided by 5.72-cm (2.25-in.) thick, common red brick covering virtually the entire floor in the dining room/living room and in the south bedroom, and by 1.27-cm (0.50-in.) gypsum board on all walls and ceilings. The solar absorptance of the brick floor is 0.82 and that of the gypsum board is 0.36. The kitchen and utility rooms (Zone 1) contain significant thermal capacitance in excess of that contained in the building structure. This excess capacitance is contained primarily in the form of metal cabinets and monitoring equipment. Table V lists the major categories of mass, their weight, and estimated values for specific heat. This mass, which approximately doubles the effective thermal storage mass of the interior walls and floors in Zone 1, is well coupled to the room air. Additional thermal and physical properties of these elements are given in Appendix A.

TABLE V

ADDITIONAL THERMAL MASS IN KITCHEN AND UTILITY ROOM

Room and Description of Mass	Weight	Estimated C_p
1. Utility room monitoring equipment: metal	302 kg (666 lb)	502 J/kg°C (0.12 Btu/lb°F)[a]
2. Sink in utility room: high-density concrete, some metal	68 kg (150 lb)	879 J/kg°C (0.21 Btu/lb°F)[b]
3. Kitchen cabinets: mostly metal and formica	250 kg (552 lb)	586 J/kg°C (0.14 Btu/lb°F)[c]
4. Other kitchen equipment: mostly metal	52 kg (114 lb)	502 J/kg°C (0.12 Btu/lb°F)[a]

[a]Assuming 90% steel and iron, 10% aluminum.

[b]Concrete.

[c]Assuming 80% steel and iron, 20% formica.

Cellulose insulation was blown into the 8.89-cm (3.5-in.) exterior wall cavities, and 0.38-m (15.0-in.) was blown onto the attic floor. Extensive caulking was done on all windows and door frames, and on any other cracks and possible air leaks. R-19 fiber glass batts were installed on the inside of the foundation wall and outer joist box, as shown in Fig. 12. This insulation extends up to the bottom of the floor and down to the bottom of the foundation stem wall.

D. Heating, Ventilating, and Air Conditioning (HVAC) System and Plant Description

Auxiliary heating is provided by Dayton Model 441-E 3.5-kW (11940 Btu/h), 208-V electric-resistance heaters with fans, there are two heaters in Zones 2 and 4, and one heater in each of the other two zones. After March 1982, only one of the two heaters has been used in Zones 2 and 4. The heater thermostats are located inside the shield of the nearest zonal temperature-sensing unit, and therefore should see the same temperature as the zone air.

These Dayton Model 2E173 thermostats had a deadband of about 1°C (1.8°F), and controlled the temperature of each zone to about ±0.6°C (±1°F). (Pneumatic thermostats provided with the units proved unreliable.) To provide cooling, a Sears Model 42K64077N248.7W [0.25 kW (1/3 hp)], 0.762-m (30-in.)-diameter whole-house fan [approximately 10,000 m^3/h (1350 cfm)] was installed during June 1982, and therefore was not present during the previous heating season. Details of control strategies used are given in individual experiment descriptions.

IV. DATA ACQUISITION AND TEST CONDITIONS

A. Description of Sensors

With sensor symbols defined in Fig. B-1, the building instrumentation plans are shown in Figs. B-2 through B-6 of Appendix B. A list of data recorded hourly (channel directory) is given in Appendix C. Unless noted otherwise, vertical placement is at the midpoint of the monitored space or surface. The instrumentation was developed to satisfy the following measurement requirements:

1. measure air temperature of each zone with a triply shielded thermocouple placed near the zone center point (for the living room, temperature is monitored at midpoints of two equal volumes);
2. define heater, fan, and other electrical power into each zone with Hall-effect wattmeters that account for all voltage, current, and phase conditions, measuring total power with a zone-by-zone breakdown;
3. install rakes at two or more locations for each principal wall type, consisting of a heat-flux meter, a surface thermocouple, and differential thermocouples across all homogeneous wall layers (see Ref. 3);
4. monitor inside-outside surface temperatures of each wall type at each orientation, from which flux can be inferred, using correlations derived from the rakes with flux meters (see Ref. 3);
5. measure infiltration continuously zone-by-zone, using tracer-gas decay (see Ref. 4);
6. measure transmitted global vertical solar radiation through each window orientation;

7. instrument all living room walls as described in either 3 or 4 above, to allow a complete zonal energy balance in the living room, including the wall conduction losses, infiltration (as in 5 above), and transmitted solar radiation (as in 6 above);
8. monitor foundation-wall-surface heat fluxes at the midpoint of each principal orientation;
9. monitor ground temperatures down to 2 m (6.6 ft) depth and surface fluxes and 6 evenly spaced locations, and determine north/south variation of ground surface flux across the crawl space;
10. monitor globe temperature in several zones at 0.6 m (5.35 ft) height.

The site weather data are taken at 4-second intervals and recorded in one-minute averages (see Ref. 3). Total horizontal radiation is measured at the site [approximately 90 m (300 ft) east of the test house] with an Eppley pyranometer, Model PSP (±3% accuracy), south-facing vertical radiation outside the south aperture is measured with an Eppley pyranometer, Model PSP (±8% accuracy). Another Eppley Model PSP pyranometer (±5% accuracy), mounted in an inverted position 1 m (3.28 ft) above the ground at the location of the total horizontal radiation pyranometer, is used to measure ground reflected radiation. Direct-normal (beam) radiation is measured using an Eppley normal incidence pyrheliometer, Model NIP (±1% accuracy). No diffuse radiation is measured, it is deduced from the total horizontal and direct-normal measurements. Kipp and Zonen Model CM6 pyranometers (±8% accuracy when tilted, ±3% accuracy horizontal) are used to measure transmitted solar radiation inside the apertures.

The site weather station takes wind speed and direction measurements at 2 and 10 m (6.6 and 32.8 ft) using a Teledyne Geotech instrument (±3% accuracy). Ambient temperatures (±1°F accuracy) are measured using a shielded and shaded thermocouple (type J), whereas the relative humidity is measured using a Texas Instruments Model TH-2013-2 sensor (accuracy is ±5% for RH = 5-15% and ±2% for RH = 20-90%). Barometric pressure is measured with a Setra Systems, Inc. Model 270 pressure transducer. Finally, night-sky infrared radiation is measured with a Teledyne Geotech Model 188 sensor (±5% accuracy).

All temperatures (±0.8°F accuracy in situ) and differential temperatures (±0.6% accuracy in situ) in and beneath the house are measured with type J thermocouples. Heat fluxes are measured using Valley Laboratories Research and Development Company transducers; Model T335 (approximately $\pm 10\%$ accuracy in situ) is used for all ground locations and Model T225 (approximately $\pm 10\%$ accuracy in situ) is used for all other locations. Finally, electrical power is measured using Ohio Semetronics Model PC5 wattmeters ($\pm 0.5\%$ accuracy). A complete listing of monitored channels is given in Appendix C.

B. Description of Data-Acquisition System

Pyranometers, wattmeters, and some differential thermocouples are sampled every 15 seconds; the remaining sensors are sampled every five minutes. These are converted to hourly averages and recorded at the site. Data reduction and editing are done on the SERI mainframe computer.

A Fluke Model 2240B data-acquisition system, with Model 2201 and 2202 remote scanners and a high-performance digital voltmeter ($\pm 0.02\%$ of reading accuracy), is used for collecting 190 channels of building data. The remaining 37 channels of building data are collected with a Kinetic Systems Model 3553C A/D data-acquisition system that includes a digital voltmeter with $\pm 0.01\%$ accuracy. The digital voltmeter used for the weather data has $\pm 0.002\%$ accuracy.

C. One-Time and Special Measurements

A coheating test to measure the overall conduction loss coefficient for the building was conducted for three nights during May 1982 at a constant inside ambient temperature. During the day the windows were covered to prevent solar gain. The results are not fully analyzed, but preliminary analysis indicates a load coefficient of about 106 W/°C (200 Btu/h-°F).

An infrared thermographic scan was taken to determine major energy-leakage paths, any obvious leakage paths were sealed to prevent further major energy losses. A blower door was also used to find leaks, which were then caulked. Major leak areas were located at plumbing penetrations, water heater vents, and hallway baseboards. Effective leakage crack area was determined before and after each of a series of conservation measures was taken, results are shown in Fig. 16. The final blower door test results indicate an air-change rate of 0.73 ac/h at 4 Pa pressurization and 4.41 ac/h at 50 Pa.

D. Hourly Data Tape

Hourly measured data are available on an unlabeled 9-Track, 1600 BPI magnetic tape, written in ASCII code, the blocking and format are indicated on

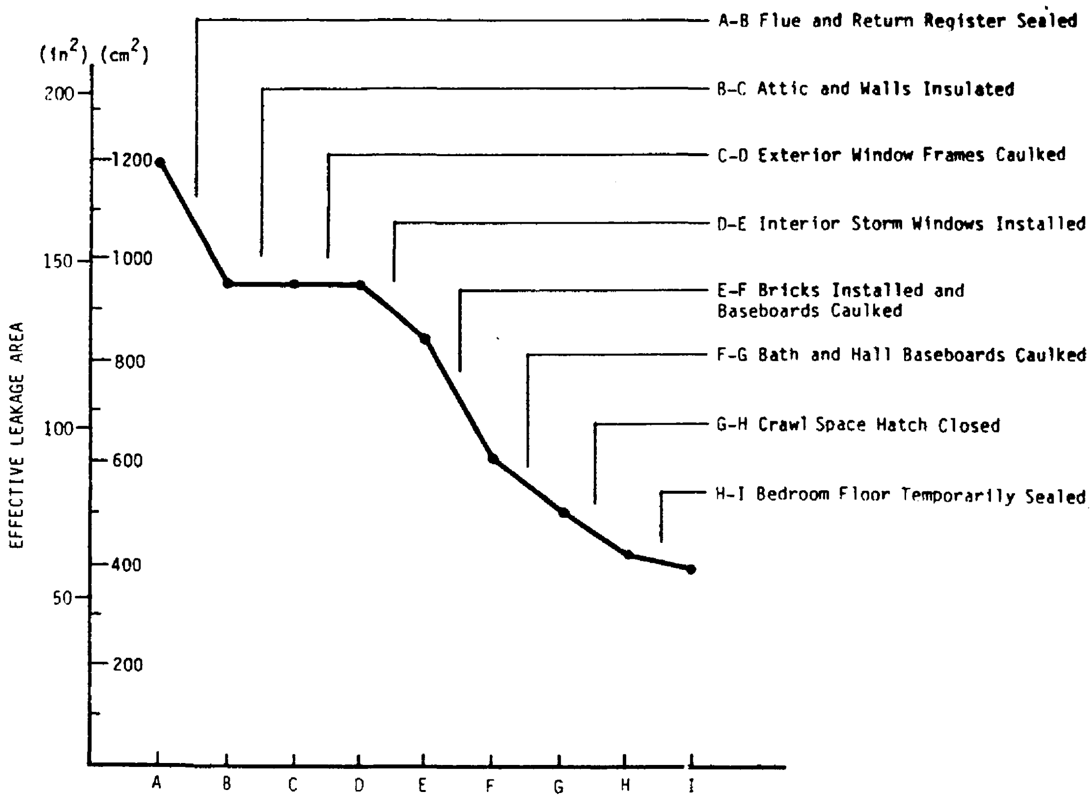


Fig. 16. Reduction in infiltration resulting from envelope integrity improvements.

the header file and in the tape documentation. The channel directory for this tape is presented in Appendix C.

E. Test Conditions

Detailed test conditions are described in documentation accompanying the hourly data tapes. In general, while data were taken the house was closed and unoccupied, no lights were on, but the destratifiers were in continuous operation. Destratifiers (Stratojet 25-W) were used in all zones except Zone 4 where a 225-W (184-W measured) Dayton 4C445 blower and air duct assembly was used.

V. SUMMARY

This site handbook gives a detailed description of the construction, instrumentation, and test configuration of the SERI Validation Test House in Golden, Colorado. This facility is being used to collect performance data for analysis/design tool validation as part of the DOE Passive Solar Class A Performance Evaluation Program.

REFERENCES

1. "Regional Guidelines for Building Passive Energy Conserving Homes," prepared by the AIA/RC for the U.S. Department of Housing and Urban Development, HUD-PDR-355 (November 1978), p. 65.

2. ASHRAE Handbook of Fundamentals, 1981 (American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Atlanta, Georgia, 1981).

3. R. Judkoff, D. Wortman, J. Burch, and B. O'Doherty, Validation of Building Energy Simulations, SERI report to be published.

4. D. N. Wortman, J. Burch, and R. Judkoff, "A Multizone Infiltration Monitoring System," Proc. of the 7th National Passive Solar Conference, August 30-September 1, 1982, Knoxville, Tennessee (American Solar Energy Society, Newark, Delaware, 1982), pp. 767-771.

APPENDIX A

MATERIAL PROPERTIES

TABLE A-I

MATERIAL PROPERTIES[a]
(English Units)

Materials	α_S	ϵ	k (Btu/h-ft-°F)	ρ (lb/ft^3)	C_p (Btu/lb-°F)
Gypsum board - 127 cm (0.50 in.)	0.36[b]	0.90	0.093	50.	0.26
Cedar siding - 0.95 cm (0.375 in.)	0.52[b]	d	0.067	32.	0.33
Cellulose insulation, walls - 8.89 cm (3.50 in.)	-	-	0.0167[c]	2.7[c]	0.33[c]
Cellulose insulation, ceiling 0.38 m (15.00 in.)	-	-	0.0167[c]	2.7[c]	0.33[c]
Studs (2x4s), walls - 8.89 cm (3.50 in.)			0.067	32.	0.33
Soil, under crawlspace	d	d	0.5	125.	0.20
Soil, berm	d	d	0.75	131.	0.23
Plywood - 0.79 cm (0.313 in.)	0.52[b]	d	0.067	34.	0.29
Asphalt shingles - 0.48 cm (0.188 in.)	0.90[b]	d	d	70.	0.30
Hardwood (oak) - 1.91 cm (0.75 in.)	0.49[b]	0.90	0.102	47.	0.57
Subfloor - 1.91 cm (0.75 in.)	-	d	0.067	32.	0.33
Common red brick - 5.72 cm (2.25 in.)	0.82[b]	d	0.20	123.	0.20
Linoleum tile - 0.32 cm (0.125 in.)	0.71[b]	d	d	d	d
Celotex (sheathing)	-	-	0.0316	18.	0.31
Concrete	-	d	0.54	144.	0.156
Fiber glass insulation	-	-	0.024	1.3	0.17
Tar paper	-	-	d	d	d

Ground albedo: Unimproved fields = 0.23[b]
Gravel areas = d

[a]Listed value is taken from Ref. 2, except as otherwise noted.

[b]Measured property.

[c]Studs are not included in these properties; thermal conductivity is a measured value.

[d]Unavailable.

TABLE A-II

MATERIAL PROPERTIES
(SI Units)

Materials	α_S	ϵ	k w/m-°C	ρ kg/m^3	C_p J/kg-°C
Gypsum board - 127 cm (0.50 in.)	0.36[b]	0.9C	0.161	801.	1089.
Cedar siding - 0.95 cm (0.375 in.)	0.52[b]	d	0.115	513.	1382.
Cellulose insulation, walls - 8.89 cm (3.50 in.)	-	-	0.029[c]	43.	1382.
Cellulose insulation, ceiling 0.38 m (15.00 in.)	-	-	0.029[c]	43.	1382.
Studs (2x4s), walls - 8.89 cm (3.50 in.)			0.115	513.	1382.
Soil, under crawlspace	d	d	0.87	2003.	837.
Soil, berm	d	d	1.30	2099.	963.
Plywood - 0.79 cm (0.313 in.)	0.52[b]	d	0.115	545.	a
Asphalt shingles - 0.48 cm (0.188 in.)	0.90[b]	d	d	1121.	a
Hardwood (oak) - 1.91 cm (0.75 in.)	0.49[b]	0.90	0.177	753.	2387.
Subfloor - 1.91 cm (0.75 in.)	-	d	0.115	513.	1382.
Common red brick - 5.72 cm (2.25 in.)	0.82[b]	d	0.35	1970.	837.
Linoleum tile - 0.32 cm (0.125 in.)	0.71[b]	d	d	d	d
Celotex (sheathing)	-	-	0.055	288.	1298.
Concrete	-	d	0.935	2307.	653.
Fiber glass insulation	-	-	0.042	21.	712.
Tar paper	-	-	d	d	d

Ground albedo: Unimproved fields = 0.23[b]
Gravel areas = d

[a]Listed value is taken from Ref. 2, except as otherwise noted.

[b]Measured property.

[c]Studs are not included in these properties; thermal conductivity is a measured value.

[d]Unavailable.

APPENDIX B

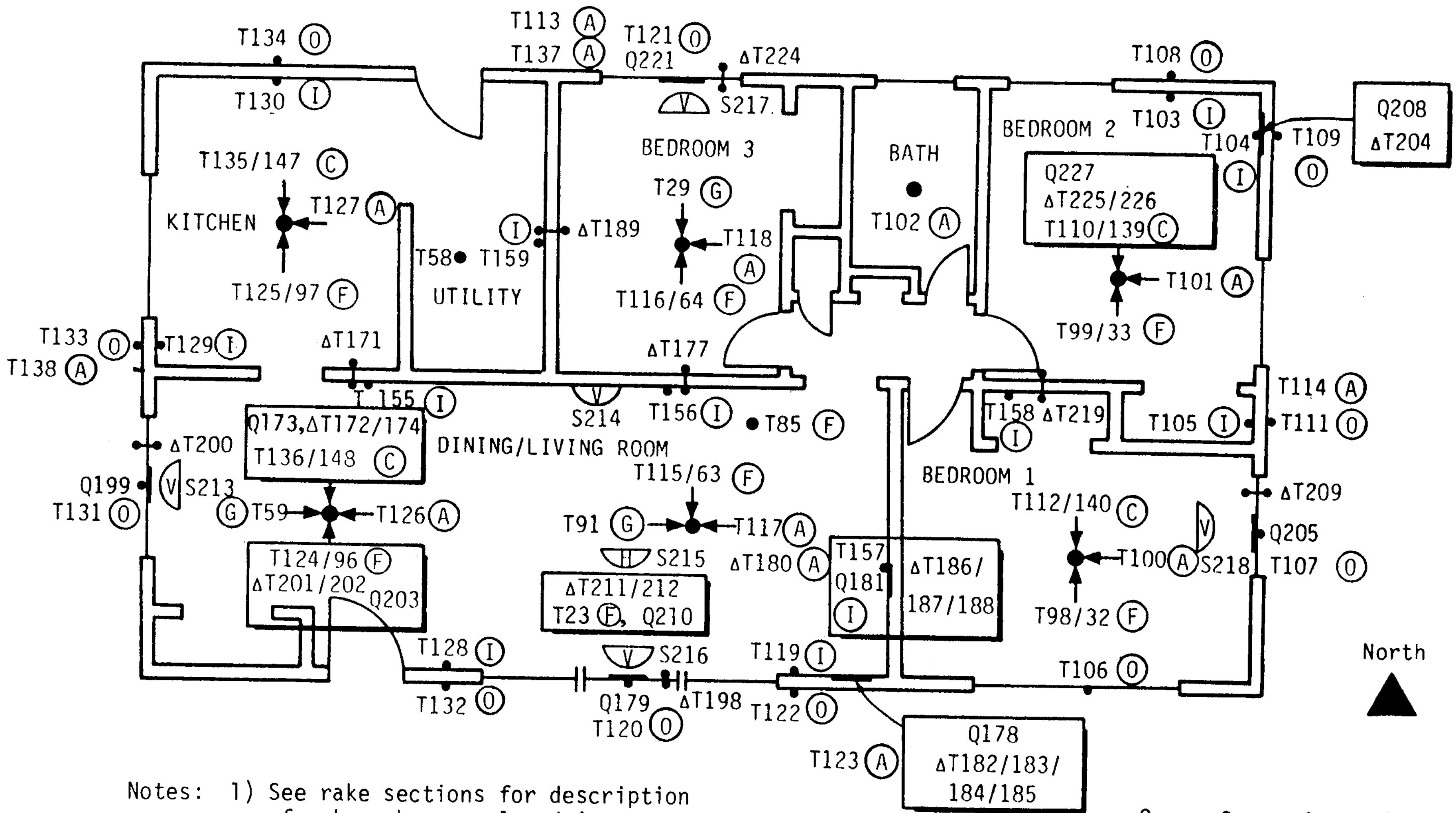
SENSOR LOCATION DIAGRAMS

Figures B-2 to B-6 show the location of all house-specific sensors, symbols used in these figures are presented in Fig. B-1. Figure B-2 shows the location of interior and exterior thermocouples; heat flux meters, and pyranometers; Fig. B-3 gives the location of the ceiling, attic, and roof sensors. Figure B-4 diagrams the crawl space sensors, Fig. B-5 details the section rakes shown in Figs. B-2, and B-3, and Fig. B-6 illustrates the ground temperature rakes shown in Fig. B-4.

FIGURE SYMBOLS

Major Symbol	Descriptor (Inside Symbol)	Subscript (Outside Symbol)
●	THERMOCOUPLE	
	A = Shielded air temperature shown	I/O = both sides (inside and outside) of surface
	I = Inside surface	
	O = Outside surface	
	G = Globe temperature	
	F = Floor surface	
	R = Roof surface	
	C = Ceiling surface	
	U = Under foundation wall (earth temperature)	
	E = Earth temperature	
ΔT	DIFFERENTIAL THERMOCOUPLE	
	A = Shielded air temperature wall	
	W = Across wall surfaces	
▬	HEAT FLUX METER	
	PYRANOMETER	
	V = Vertical, oriented as shown	
	H = Horizontal	
▭	SECTION RAKE (SEE SECTION DETAILS, FIG. B-5)	
	Roof	
	Ceiling	
	Floor	
	External (wall)	
	Internal (wall)	
	Ground, N	

Fig. B-1. Figure symbols for Figs. B-2 through B-5.



0 3 6 9 ft

0 1 2 3 m

Notes:
1) See rake sections for description of rakes shown enclosed in square boxes.
2) For symbol descriptions see Fig. B-1.
3) Vertical placement is at midpoint of surface or space being monitored.

Fig. B-2. Sensor locations--floor, walls, and ceiling.

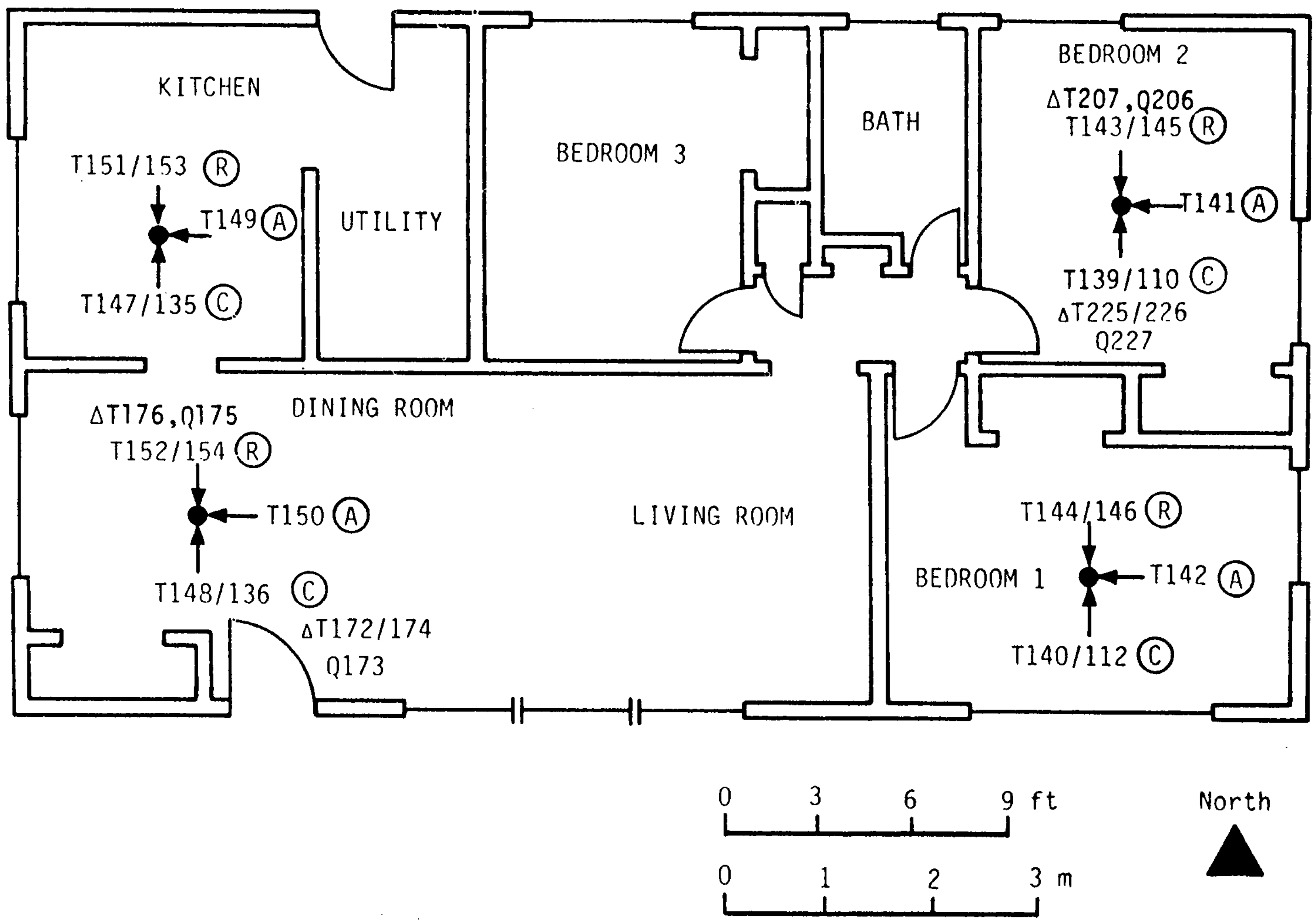


Fig. B-3. Sensor locations--ceiling, attic, and roof.

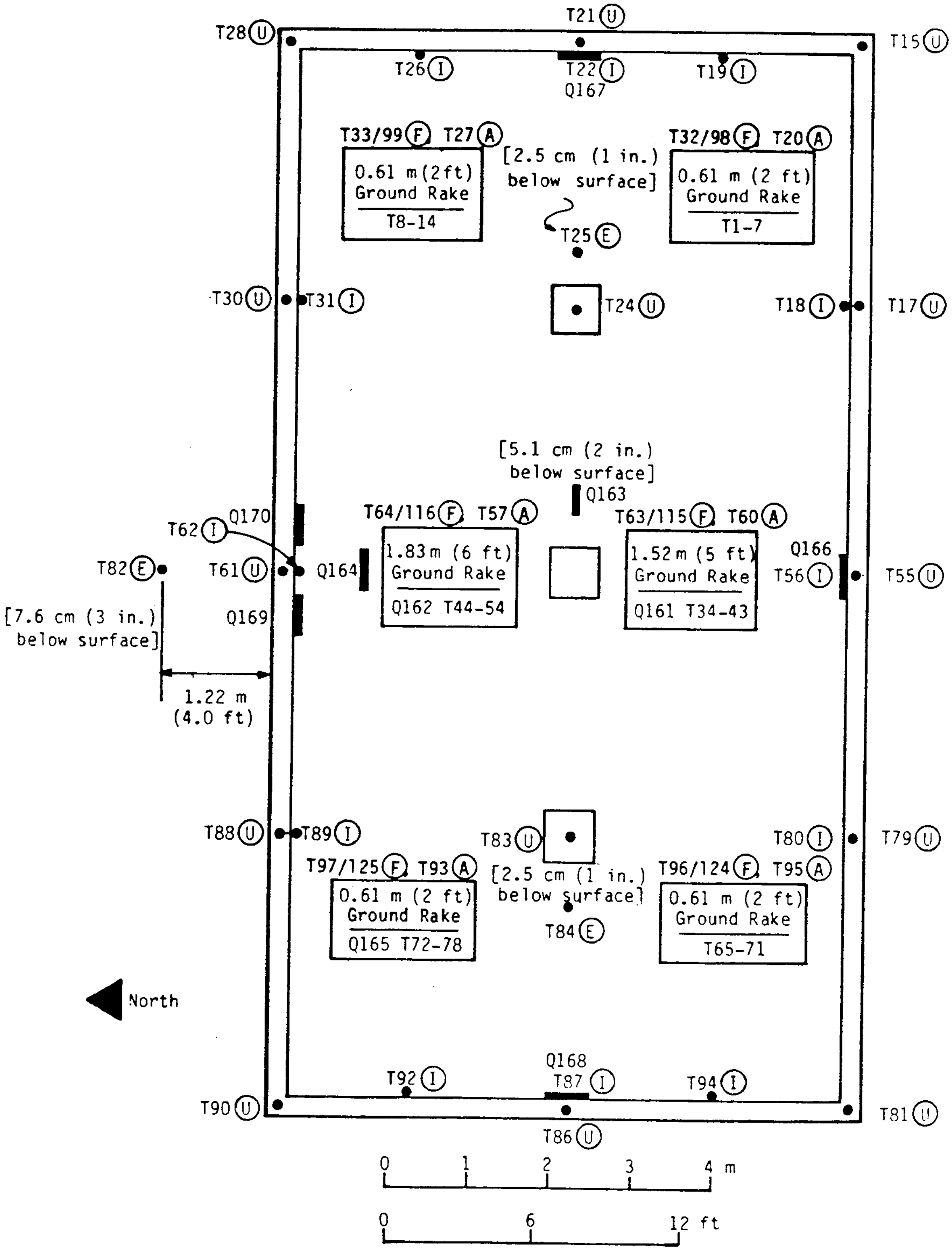


Fig. B-4. Sensor locations--crawl space.

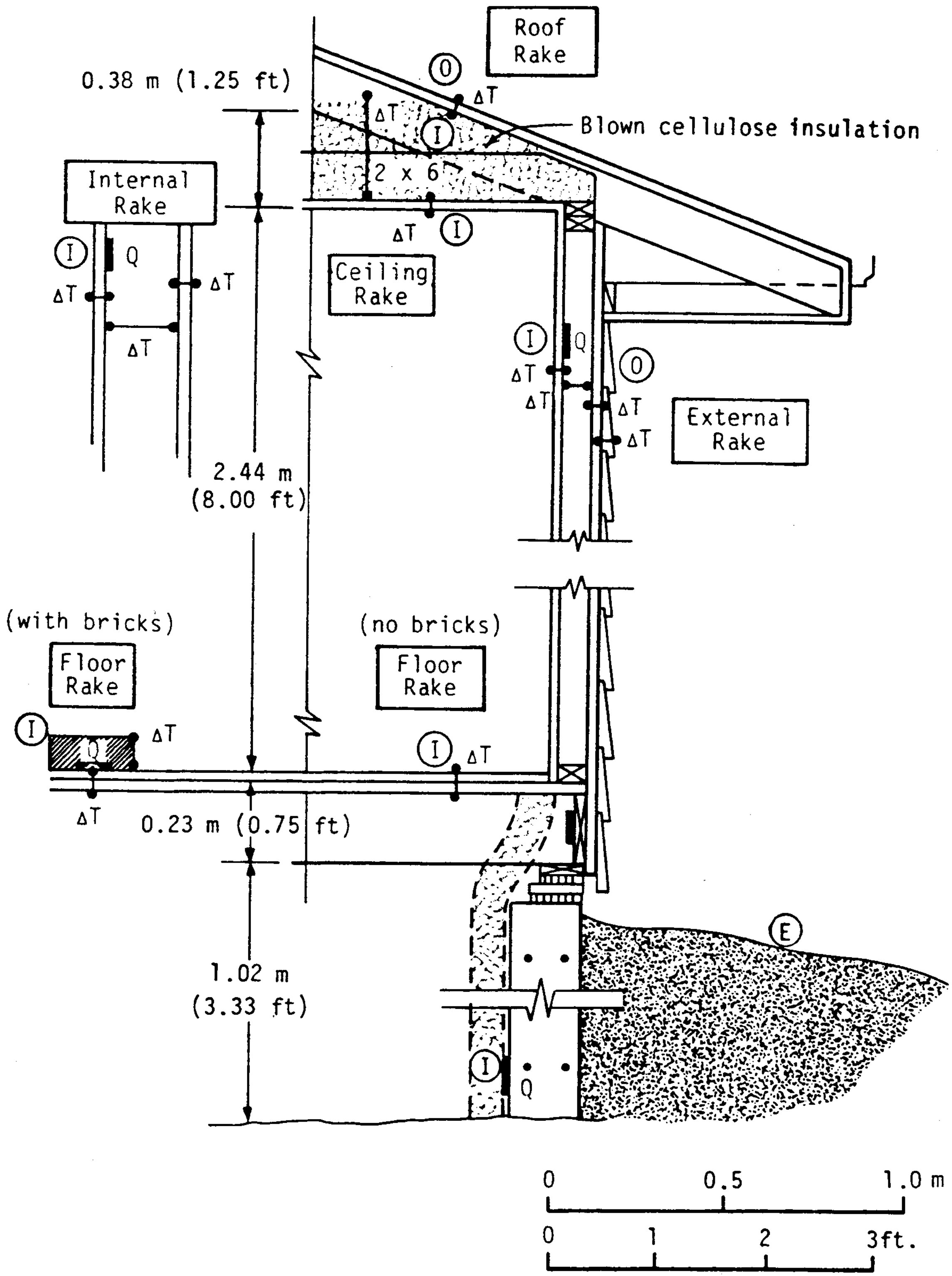


Fig. B-5. Sensor locations--thermocouple rakes.

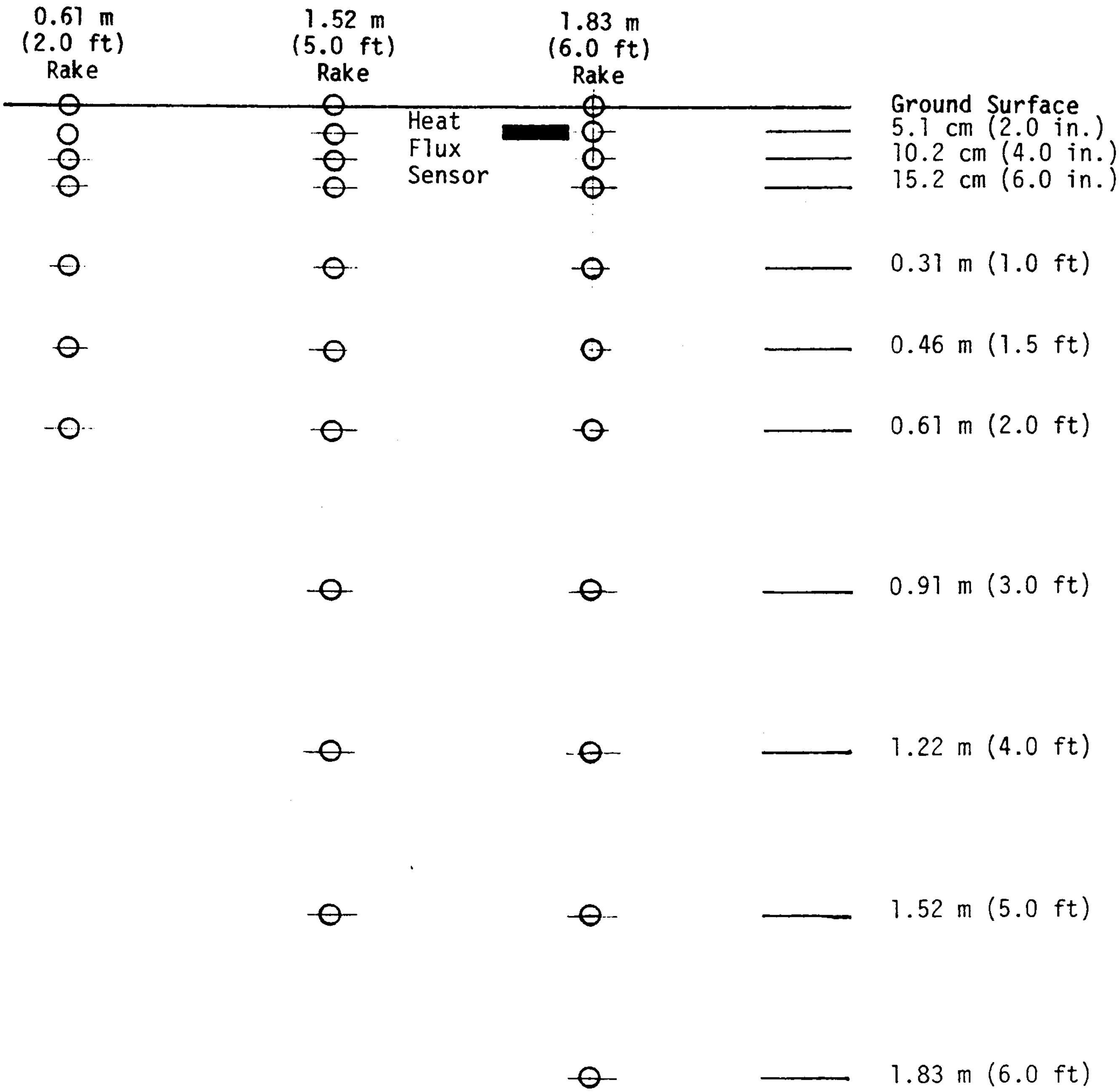


Fig. B-6. Ground thermocouple placement.

APPENDIX C

LIST OF DATA RECORDED HOURLY
(CHANNEL DIRECTORY)

T1 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-EAST RAKE, AT 2' DEPTH (F) *BAD*/
T2 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-EAST RAKE, AT 1.5' DEPTH (F)/
T3 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-EAST RAKE, AT 1.0' DEPTH (F)/
T4 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-EAST RAKE, AT .5' DEPTH (F)/
T5 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-EAST RAKE, AT 4" DEPTH (F)/
T6 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-EAST RAKE, AT 2" DEPTH (F)/
T7 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-EAST RAKE, AT INSIDE SURFACE (F)/
T8 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-EAST RAKE, AT 2' DEPTH (F)/
T9 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-EAST RAKE, AT 1.5' DEPTH (F)/
T10 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-EAST RAKE, AT 1.0' DEPTH (F)/
T11 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-EAST RAKE, AT .5' DEPTH (F)/
T12 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-EAST RAKE, AT 4" DEPTH (F)/
T13 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-EAST RAKE, AT 2" DEPTH (F)/
T14 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-EAST RAKE, AT INSIDE SURFACE (F)/
T15 TEMPERATURE OF FOUNDATION WALL SOUTH-EAST CORNER BOTTOM (F)/
T16 TEMPERATURE OF TEMPERATURE OF STANDARD S1 (F) > JULIAN DAY 50/
T17 TEMPERATURE OF FOUNDATION WALL SOUTH-EAST BOTTOM (F)/
T18 TEMPERATURE OF FOUNDATION WALL SOUTH-EAST MID-HEIGHT INSIDE SURFACE OF CONCRETE (F)/
T19 TEMPERATURE OF FOUNDATION WALL EAST-SOUTH MID-HEIGHT INSIDE SURFACE OF CONCRETE (F)/
T20 TEMPERATURE OF AIR IN THE CRAWLSPACE SOUTH-EAST MID-HEIGHT (F)/
T21 TEMPERATURE OF FOUNDATION WALL EAST-MIDDLE BOTTOM (F)/
T22 TEMPERATURE OF FOUNDATION WALL EAST-MIDDLE MID-HEIGHT INSIDE SURFACE OF CONCRETE (F)/
T23 TEMPERATURE OF FLOOR IN THE LIVINGROOM EAST-SOUTH ON INSIDE SURFACE (F) > JULIAN DAY 89/
T24 TEMPERATURE UNDERNEATH PILLAR EAST-MIDDLE (F)/
T25 TEMPERATURE OF GROUND IN CRAWLSPACE EAST OF EAST-MIDDLE PILLAR,AT 1" DEPTH (F)/
T26 TEMPERATURE OF FOUNDATION WALL EAST-NORTH MID-HEIGHT INSIDE SURFACE OF CONCRETE (F)/
T27 TEMPERATURE OF AIR IN THE CRAWLSPACE NORTH-EAST MID-HEIGHT (F)/
T28 TEMPERATURE OF FOUNDATION WALL NORTH-EAST BOTTOM (F)/
T29 TEMPERATURE OF GLOBE IN THE NORTHMIDDLE BEDROOM MID-HEIGHT (F) > JULIAN DAY 75/
T30 TEMPERATURE OF FOUNDATION WALL NORTH-EAST BOTTOM (F)/
T31 TEMPERATURE OF FOUNDATION WALL NORTH-EAST MID-HEIGHT INSIDE SURFACE OF CONCRETE (F)/
T32 TEMPERATURE OF FLOOR IN THE SOUTHEAST BEDROOM MID-POINT ON OUTSIDE SURFACE (F)/
T33 TEMPERATURE OF FLOOR IN THE NORTHEAST BEDROOM MID-POINT ON OUTSIDE SURFACE (F)/
T34 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-MIDDLE RAKE, AT 5' DEPTH (F)/
T35 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-MIDDLE RAKE, AT 4' DEPTH (F)/
T36 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-MIDDLE RAKE, AT 3' DEPTH (F)/
T37 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-MIDDLE RAKE, AT 2' DEPTH (F)/
T38 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-MIDDLE RAKE, AT 1.5' DEPTH (F)/
T39 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-MIDDLE RAKE, AT 1' DEPTH (F)/
T40 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-MIDDLE RAKE, AT 6" DEPTH (F)/
T41 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-MIDDLE RAKE, AT 4" DEPTH (F)/
T42 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-MIDDLE RAKE, AT 2" DEPTH (F)/
T43 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-MIDDLE RAKE, AT INSIDE SURFACE (F)/
T44 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-MIDDLE RAKE, AT 6' DEPTH (F)/
T45 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-MIDDLE RAKE, AT 5' DEPTH (F)/
T46 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-MIDDLE RAKE, AT 4' DEPTH (F)/
T47 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-MIDDLE RAKE, AT 3' DEPTH (F)/
T48 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-MIDDLE RAKE, AT 2' DEPTH (F)/
T49 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-MIDDLE RAKE, AT 1.5' DEPTH (F)/
T50 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-MIDDLE RAKE, AT 1' DEPTH (F)/
T51 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-MIDDLE RAKE, AT 6" DEPTH (F)/
T52 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-MIDDLE RAKE, AT 4" DEPTH (F)/
T53 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-MIDDLE RAKE, AT 2" DEPTH (F)/
T54 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-MIDDLE RAKE, AT INSIDE SURFACE (F)/
T55 TEMPERATURE OF FOUNDATION WALL SOUTH-MIDDLE BOTTOM (F)/
T56 TEMPERATURE OF FOUNDATION WALL SOUTH-MIDDLE MID-HEIGHT INSIDE SURFACE OF CONCRETE (F)/
T57 TEMPERATURE OF AIR IN THE CRAWLSPACE NORTH-MIDDLE MID-HEIGHT (F)/
T58 TEMPERATURE OF S2 STANDARD,>50;AIR IN THE UTILITY ROOM >120 (FS)/
T59 TEMPERATURE OF GLOBE IN THE LIVINGROOM WEST-MIDDLE MID-HEIGHT (F)/
T60 TEMPERATURE OF AIR IN THE CRAWLSPACE SOUTH-MIDDLE MID-HEIGHT (F)/
T61 TEMPERATURE OF FOUNDATION WALL NORTH-MIDDLE BOTTOM (F)/
T62 TEMPERATURE OF FOUNDATION WALL NORTH-MIDDLE MID-HEIGHT INSIDE SURFACE OF CONCRETE (F)/
T63 TEMPERATURE OF FLOOR IN THE LIVINGROOM EAST-MIDDLE ON OUTSIDE SURFACE (F)/
T64 TEMPERATURE OF FLOOR IN THE NORTHMIDDLE BEDROOM MID-POINT ON OUTSIDE SURFACE (F)/

T65 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-WEST RAKE, AT 2' DEPTH (F)/
T66 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-WEST RAKE, AT 1.5' DEPTH (F)/
T67 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-WEST RAKE, AT 1' DEPTH (F)/
T68 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-WEST RAKE, AT 6" DEPTH (F)/
T69 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-WEST RAKE, AT 4" DEPTH (F)/
T70 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-WEST RAKE, AT 2" DEPTH (F)/
T71 TEMPERATURE OF GROUND IN CRAWLSPACE SOUTH-WEST RAKE, AT INSIDE SURFACE (F)/
T72 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-WEST RAKE, AT 2' DEPTH (F)/
T73 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-WEST RAKE, AT 1.5' DEPTH (F)/
T74 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-WEST RAKE, AT 1' DEPTH (F)/
T75 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-WEST RAKE, AT 6" DEPTH (F)/
T76 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-WEST RAKE, AT 4" DEPTH (F)/
T77 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-WEST RAKE, AT 2" DEPTH (F)/
T78 TEMPERATURE OF GROUND IN CRAWLSPACE NORTH-WEST RAKE, AT INSIDE SURFACE (F)/
T79 TEMPERATURE OF FOUNDATION WALL SOUTH-WEST BOTTOM (F)/
T80 TEMPERATURE OF FOUNDATION WALL SOUTH-WEST MID-HEIGHT INSIDE SURFACE OF CONCRETE (F)/
T81 TEMPERATURE OF FOUNDATION WALL SOUTH-WEST-CORNER BOTTOM (F)/
T82 TEMPERATURE OF GROUND OUTSIDE 4' FROM NORTHMIDDLE BEDROOM ,AT 3" DEPTH >JULIAN DAY 75 (F)/
T83 TEMPERATURE UNDERNEATH PILLAR WEST-MIDDLE (F)/
T84 TEMPERATURE OF GROUND IN CRAWLSPACE WEST OF WEST-MIDDLE PILLAR AT DEPTH OF 1" (F)/
T85 TEMPERATURE OF FLOOR IN THE LIVINGROOM NORTH-EAST ON INSIDE SURFACE (F) > JULIAN DAY 89/
T86 TEMPERATURE OF FOUNDATION WALL WEST-MIDDLE BOTTOM (F)/
T87 TEMPERATURE OF FOUNDATION WALL WEST-MIDDLE MID-HEIGHT INSIDE SURFACE OF CONCRETE (F)/
T88 TEMPERATURE OF FOUNDATION WALL NORTH-WEST BOTTOM (F)/
T89 TEMPERATURE OF FOUNDATION WALL NORTH-WEST MID-HEIGHT INSIDE SURFACE OF CONCRETE (F)/
T90 TEMPERATURE OF FOUNDATION WALL NORTH-WEST-CORNER BOTTOM (F)/
T91 TEMPERATURE OF GLOBE IN THE LIVINGROOM EAST-MIDDLE MID-HEIGHT (F)/
T92 TEMPERATURE OF FOUNDATION WALL WEST-NORTH MID-HEIGHT INSIDE SURFACE OF CONCRETE (F)/
T93 TEMPERATURE OF AIR IN THE CRAWLSPACE NORTH-WEST MID-HEIGHT (F)/
T94 TEMPERATURE OF FOUNDATION WALL WEST-SOUTH MID-HEIGHT INSIDE SURFACE OF CONCRETE (F)/
T95 TEMPERATURE OF AIR IN THE CRAWLSPACE SOUTH-WEST MID-HEIGHT (F)/
T96 TEMPERATURE OF FLOOR IN THE LIVINGROOM WEST-MIDDLE ON OUTSIDE SURFACE OF WOOD (F)/
T97 TEMPERATURE OF FLOOR IN THE KITCHEN MID-POINT ON OUTSIDE SURFACE (F)/
T98 TEMPERATURE OF FLOOR IN THE SOUTHEAST BEDROOM MID-POINT ON INSIDE SURFACE (F)/
T99 TEMPERATURE OF FLOOR IN THE NORTHEAST BEDROOM MID-POINT ON INSIDE SURFACE (F)/
T100 TEMPERATURE OF AIR IN THE SOUTHEAST BEDROOM MID-POINT MID-HEIGHT (F)/
T101 TEMPERATURE OF AIR IN THE NORTHEAST BEDROOM MID-POINT MID-HEIGHT (F)/
T102 TEMPERATURE OF AIR IN THE BATH MID-POINT MID-HEIGHT (F)/
T103 TEMPERATURE OF NORTH WALL IN THE NORTHEAST BEDROOM MIDDLE-EAST ON INSIDE SURFACE (F)/
T104 TEMPERATURE OF EAST WALL IN THE NORTHEAST BEDROOM MIDDLE-NORTH ON INSIDE SURFACE (F)/
T105 TEMPERATURE OF EAST WALL IN THE NORTHEAST BEDROOM MIDDLE-SOUTH ON INSIDE SURFACE (F)/
T106 TEMPERATURE OF SOUTH GLAZING IN THE SOUTHEAST BEDROOM MID-POINT ON OUTSIDE SURFACE (F)/
T107 TEMPERATURE OF EAST GLAZING IN THE SOUTHEAST BEDROOM MID-POINT ON OUTSIDE SURFACE (F)/
T108 TEMPERATURE OF NORTH WALL IN THE NORTHEAST BEDROOM MIDDLE-EAST ON OUTSIDE SURFACE (F)/
T109 TEMPERATURE OF EAST WALL IN THE NORTHEAST BEDROOM MIDDLE-NORTH ON OUTSIDE SURFACE (F)/
T110 TEMPERATURE OF CEILING IN THE NORTHEAST BEDROOM MID-POINT ON INSIDE SURFACE (F)/
T111 TEMPERATURE OF EAST WALL IN THE NORTHEAST BEDROOM MIDDLE-SOUTH ON OUTSIDE SURFACE (F)/
T112 TEMPERATURE OF CEILING IN THE SOUTHEAST BEDROOM MID-POINT ON INSIDE SURFACE (F)/
T113 TEMPERATURE OF AIR IN THE OUTSIDE NORTH-MIDDLE BOTTOM (F)/
T114 TEMPERATURE OF AIR IN THE OUTSIDE EAST-MIDDLE MID-HEIGHT (F) *BAD*/
T115 TEMPERATURE OF FLOOR IN THE LIVINGROOM EAST-MIDDLE ON INSIDE SURFACE (F)/
T116 TEMPERATURE OF FLOOR IN THE NORTHMIDDLE BEDROOM MID-POINT ON INSIDE SURFACE (F)/
T117 TEMPERATURE OF AIR IN THE LIVINGROOM EAST-MIDDLE MID-HEIGHT (F)/
T118 TEMPERATURE OF AIR IN THE NORTHMIDDLE BEDROOM MID-POINT MID-HEIGHT (F)/
T119 TEMPERATURE OF SOUTH WALL IN THE LIVINGROOM EAST-MIDDLE ON INSIDE SURFACE (F)/
T120 TEMPERATURE OF SOUTH GLAZING IN THE LIVINGROOM MID-POINT ON OUTSIDE SURFACE (F)/
T121 TEMPERATURE OF NORTH GLAZING IN THE NORTHMIDDLE BEDROOM MID-POINT ON OUTSIDE SURFACE (F
T122 TEMPERATURE OF SOUTH WALL IN THE LIVINGROOM EAST-MIDDLE ON OUTSIDE SURFACE (F)/
T123 TEMPERATURE OF AIR IN THE OUTSIDE SOUTH-MIDDLE TOP NEAR OVERHANG (F)/
T124 TEMPERATURE OF FLOOR IN THE LIVINGROOM WEST-MIDDLE ON INSIDE SURFACE OF BRICK (F)/
T125 TEMPERATURE OF FLOOR IN THE KITCHEN MID-POINT ON INSIDE SURFACE (F)/
T126 TEMPERATURE OF AIR IN THE LIVINGROOM WEST-MIDDLE (F)/
T127 TEMPERATURE OF AIR IN THE KITCHEN MID-POINT (F)/
T128 TEMPERATURE OF SOUTH WALL IN THE LIVINGROOM WEST-MIDDLE ON INSIDE SURFACE (F)/

T129 TEMPERATURE OF WEST WALL IN THE KITCHEN SOUTH-MIDDLE ON INSIDE SURFACE (F)/
T130 TEMPERATURE OF NORTH WALL IN THE KITCHEN MID-POINT ON INSIDE SURFACE (F)/
T131 TEMPERATURE OF WEST GLAZING IN THE LIVINGROOM MID-POINT ON OUTSIDE SURFACE (F)/
T132 TEMPERATURE OF SOUTH WALL IN THE LIVINGROOM WEST-MIDDLE ON OUTSIDE SURFACE (F)/
T133 TEMPERATURE OF WEST WALL IN THE KITCHEN SOUTH-MIDDLE ON OUTSIDE SURFACE (F)/
T134 TEMPERATURE OF NORTH WALL IN THE KITCHEN MID-POINT ON OUTSIDE SURFACE (F)/
T135 TEMPERATURE OF CEILING IN THE KITCHEN MID-POINT ON INSIDE SURFACE (F)/
T136 TEMPERATURE OF CEILING IN THE LIVINGROOM WEST-MIDDLE ON INSIDE SURFACE (F)/
T137 TEMPERATURE OF AIR IN THE OUTSIDE NORTH-MIDDLE TOP NEAR OVERHANG (F)/
T138 TEMPERATURE OF AIR IN THE OUTSIDE EAST-MIDDLE MIDDLE OF WEST WALL (F)/
T139 TEMPERATURE OF CEILING IN THE NORTHEAST BEDROOM MID-POINT ON OUTSIDE SURFACE (F)/
T140 TEMPERATURE OF CEILING IN THE SOUTHEAST BEDROOM MID-POINT ON OUTSIDE SURFACE (F)/
T141 TEMPERATURE OF AIR IN THE ATTIC NORTH-EAST MIDDLE-HEIGHT (F)/
T142 TEMPERATURE OF AIR IN THE ATTIC SOUTH-EAST MIDDLE-HEIGHT (F)/
T143 TEMPERATURE OF NORTH ROOF IN THE ATTIC NORTH-EAST ON INSIDE SURFACE (F)/
T144 TEMPERATURE OF SOUTH ROOF IN THE ATTIC SOUTH-EAST ON INSIDE SURFACE (F)/
T145 TEMPERATURE OF NORTH ROOF IN THE ATTIC NORTH-EAST ON OUTSIDE SURFACE (F)/
T146 TEMPERATURE OF SOUTH ROOF IN THE ATTIC SOUTH-EAST ON OUTSIDE SURFACE (F)/
T147 TEMPERATURE OF CEILING IN THE KITCHEN MID-POINT ON OUTSIDE SURFACE (F)/
T148 TEMPERATURE OF CEILING IN THE LIVINGROOM WEST-MIDDLE ON OUTSIDE SURFACE (F)/
T149 TEMPERATURE OF AIR IN THE ATTIC NORTH-WEST MIDDLE-HEIGHT (F)/
T150 TEMPERATURE OF AIR IN THE ATTIC SOUTH-WEST MIDDLE-HEIGHT (F)/
T151 TEMPERATURE OF NORTH ROOF IN THE ATTIC NORTH-WEST ON INSIDE SURFACE (F)/
T152 TEMPERATURE OF SOUTH ROOF IN THE ATTIC SOUTH-WEST ON INSIDE SURFACE (F)/
T153 TEMPERATURE OF NORTH ROOF IN THE ATTIC NORTH-WEST ON OUTSIDE SURFACE (F)/
T154 TEMPERATURE OF SOUTH ROOF IN THE ATTIC SOUTH-WEST ON OUTSIDE SURFACE (F)/
T155 TEMPERATURE OF NORTH WALL IN THE LIVINGROOM WEST-MIDDLE ON INSIDE SURFACE (F)/
T156 TEMPERATURE OF NORTH WALL IN THE LIVINGROOM EAST-MIDDLE ON INSIDE SURFACE (F)/
T157 TEMPERATURE OF EAST WALL IN THE LIVINGROOM MID-POINT ON INSIDE SURFACE (F)/
T158 TEMPERATURE OF NORTH WALL IN THE SOUTHEAST BEDROOM WEST-MIDDLE ON INSIDE SURFACE (F)/
T159 TEMPERATURE OF EAST WALL IN THE UTILITYROOM MID-POINT ON INSIDE SURFACE (F)/
T160 TEMPERATURE OF ICE BATH REFERENCE (F)/
Q161 THERMAL FLUX INTO THE GROUND IN CRAWLSPACE SOUTH-MIDDLE AT DEPTH OF 2" (BTU\FT2-HR)/
Q162 THERMAL FLUX INTO THE GROUND IN CRAWLSPACE NORTH-MIDDLE AT DEPTH OF 2" (BTU\FT2-HR)/
Q163 THERMAL FLUX INTO THE GROUND IN CRAWLSPACE MID-POINT AT DEPTH OF 2" (BTU\FT2-H)/
Q164 THERMAL FLUX INTO THE GROUND IN CRAWLSPACE NORTH-MIDDLE-NORTH AT DEPTH OF 2" (BTU\FT2-H)/
Q165 THERMAL FLUX INTO THE GROUND IN CRAWLSPACE WEST-NORTH AT DEPTH OF 2" (BTU\FT2-H)/
Q166 THERMAL FLUX INTO THE FOUNDATION WALL IN THE CRAWLSPACE SOUTH-MIDDLE MID-HEIGHT INSIDE SURFACE OF CONCRETE (BTU\FT2-HR)/
Q167 THERMAL FLUX INTO THE FOUNDATION WALL IN THE CRAWLSPACE EAST-MIDDLE MID-HEIGHT INSIDE SURFACE OF CONCRETE (BTU\FT2-HR)/
Q168 THERMAL FLUX INTO THE FOUNDATION WALL IN THE CRAWLSPACE WEST-MIDDLE MID-HEIGHT INSIDE SURFACE OF CONCRETE (BTU\FT2-HR)/
Q169 THERMAL FLUX INTO THE FOUNDATION WALL IN THE CRAWLSPACE NORTH-MIDDLE MID-HEIGHT INSIDE SURFACE OF CONCRETE (BTU\FT2-HR)/
Q170 THERMAL FLUX INTO THE JOISTBOX-CRAWLSPACE NORTH-MIDDLE-TOP INSIDE SURFACE OF WOOD (BTU\FT2-HR)/
DT171 DIFFERENTIAL TEMPERATURE AT NORTH WALL IN THE LIVINGROOM WEST-MIDDLE INSIDE SURFACE TO OUTSIDE SURFACE (F)/
DT172 DIFFERENTIAL TEMPERATURE AT CEILING IN THE LIVINGROOM WEST-MIDDLE INSIDE TO OUTSIDE OF GYPSUM (F)/
Q173 THERMAL FLUX INTO THE CEILING IN THE LIVINGROOM WEST-MIDDLE BURIED BETWEEN GYPSUM AND CELLULOSE (BTU\FT2-HR)/
DT174 DIFFERENTIAL TEMPERATURE AT CEILING IN THE LIVINGROOM WEST-MIDDLE INSIDE TO OUTSIDE OF CELLULOSE (F)/
Q175 THERMAL FLUX INTO THE ROOF IN THE ATTIC SOUTH-WEST ON INSIDE SURFACE (BTU\FT2-H)/
DT176 DIFFERENTIAL TEMPERATURE AT ROOF IN THE ATTIC SOUTH-WEST INSIDE SURFACE TO OUTSIDE SURFACE (F)/
DT177 DIFFERENTIAL TEMPERATURE AT NORTH WALL IN THE LIVINGROOM EAST-MIDDLE INSIDE SURFACE TO OUTSIDE SURFACE (F)/
Q178 THERMAL FLUX INTO THE SOUTH WALL IN THE LIVINGROOM EAST-MIDDLE BURIED BETWEEN GYPSUM AND CELLULOSE (BTU\FT2-H)/
Q179 THERMAL FLUX INTO THE SOUTH GLAZING IN THE LIVINGROOM MID-POINT ON INSIDE SURFACE (BTU\FT2-HR)/
DT180 DIFFERENTIAL TEMPERATURE AT AIR IN THE LIVINGROOM EAST-MIDDLE CEILING IN THE FLOOR (F)/
Q181 THERMAL FLUX INTO THE EAST WALL IN THE LIVINGROOM MID-POINT BURIED BETWEEN GYPSUM AND CELLULOSE (BTU\F2-H)/
DT182 DIFFERENTIAL TEMPERATURE AT SOUTH WALL IN THE LIVINGROOM EAST-MIDDLE INSIDE TO OUTSIDE OF GYPSUM (F)/
DT183 DIFFERENTIAL TEMPERATURE AT SOUTH WALL IN THE LIVINGROOM EAST-MIDDLE INSIDE TO OUTSIDE OF CELLULOSE (F)/
DT184 DIFFERENTIAL TEMPERATURE AT SOUTH WALL IN THE LIVINGROOM EAST-MIDDLE INSIDE TO OUTSIDE OF CELOTEX (F)/
DT185 DIFFERENTIAL TEMPERATURE AT SOUTH WALL IN THE LIVINGROOM EAST-MIDDLE INSIDE TO OUTSIDE OF SIDING (F)/
DT186 DIFFERENTIAL TEMPERATURE AT EAST WALL IN THE LIVINGROOM MID-POINT INSIDE TO OUTSIDE OF GYPSUM (F)/
DT187 DIFFERENTIAL TEMPERATURE AT EAST WALL IN THE LIVINGROOM MID-POINT INSIDE TO OUTSIDE OF AIRGAP (F)/
DT188 DIFFERENTIAL TEMPERATURE AT EAST WALL IN THE LIVINGROOM MID-POINT INSIDE TO OUTSIDE OF GYPSUMINSOUTHEAST BEDROOM (F)/
DT189 DIFFERENTIAL TEMPERATURE AT EAST WALL IN THE UTILITYROOM MID-POINT INSIDE SURFACE TO OUTSIDE SURFACE (F)/
V190 REFERENCE VOLTAGE, AG-AGOX BATTERY+DIVIDER=6 MV [MV]/
W191 WATTMETER FOR HOUSE TOTAL POWER (WATTS)/
W192 WATTMETER FOR HOUSE TOTAL 110V POWER (WATTS)/

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W193  WATTMETER FOR KITCHEN HEATER POWER (WATTS)/
W194  WATTMETER FOR LIVING ROOM HEATER POWER (WATTS)/
W195  WATTMETER FOR NORTH  BEDROOMS HEATER POWER (WATTS)/
W196  WATTMETER FOR SOUTH-EAST  BEDROOM HEATER POWER (WATTS)/
W197  WATTMETER FOR UTILITY ROOM DEVICES AFTER DAY 120 [WATTS]/
DT198  DIFFERENTIAL TEMPERATURE AT SOUTH GLAZING IN THE LIVINGROOM MID-POINT INSIDE SURFACE TO OUTSIDE SURFACE (F)/
Q199  THERMAL FLUX INTO THE WEST GLAZING IN THE LIVINGROOM MID-POINT ON INSIDE SURFACE (BTU\FT2-HR)/
DT200  DIFFERENTIAL TEMPERATURE AT WEST GLAZING IN THE LIVINGROOM MID-POINT INSIDE SURFACE TO OUTSIDE SURFACE (F)/
DT201  DIFFERENTIAL TEMPERATURE AT FLOOR IN THE LIVINGROOM WEST-MIDDLE INSIDE TO OUTSIDE OF WOOD (F)/
DT202  DIFFERENTIAL TEMPERATURE AT FLOOR IN THE LIVINGROOM WEST-MIDDLE INSIDE TO OUTSIDE OF BRICK (F)/
Q203  THERMAL FLUX INTO THE FLOOR IN THE LIVINGROOM WEST-MIDDLE BURIED BETWEEN BRICK AND WOOD (F)/
DT204  DIFFERENTIAL TEMPERATURE AT EAST WALL IN THE NORTHEAST BEDROOM NORTH-MIDDLE INSIDE TO OUTSIDE OF CELLULOSE (F)/
Q205  THERMAL FLUX INTO THE EAST GLAZING IN THE SOUTHEAST BEDROOM MID-POINT ON INSIDE SURFACE (BTU\FT2-HR)/
Q206  THERMAL FLUX INTO THE ROOF IN THE ATTIC NORTH-EAST ON INSIDE SURFACE (BTU\FT2-HR)/
DT207  DIFFERENTIAL TEMPERATURE AT ROOF IN THE ATTIC NORTH-EAST INSIDE TO OUTSIDE SURFACE (F)/
Q208  THERMAL FLUX INTO THE EAST WALL IN THE NORTHEAST BEDROOM NORTH-MIDDLE BURIED BETWEEN GYPSUM AND CELLULOSE (BTU\FT2-HR
DT209  DIFFERENTIAL TEMPERATURE AT EAST GLAZING IN THE SOUTHEAST BEDROOM MID-POINT ON OUTSIDE SURFACE (BTU\FT2-HR)/
Q210  THERMAL FLUX INTO THE FLOOR IN THE LIVINGROOM SOUTH-EAST BURIED BETWEEN WOOD AND BRICK (BTU\FT2-HR)/
DT211  DIFFERENTIAL TEMPERATURE AT FLOOR IN THE LIVINGROOM SOUTH-EAST INSIDE TO OUTSIDE OF WOOD (BTU\FT2-HR)/
DT212  DIFFERENTIAL TEMPERATURE AT FLOOR IN THE LIVINGROOM SOUTH-EAST INSIDE TO OUTSIDE OF BRICK (BTU\FT2-HR)/
S213  GLOBAL SOLAR IRRADIANCE AT WEST GLAZING IN THE LIVINGROOM MID-POINT VERTICAL TRANSMITTED (W\M2)/
S214  GLOBAL SOLAR IRRADIANCE AT NORTH WALL IN THE LIVINGROOM EAST-MIDDLE VERTICAL INCIDENT (W\M2)/
S215  GLOBAL SOLAR IRRADIANCE AT FLOOR IN THE LIVINGROOM SOUTH-MIDDLE HORIZONTAL INCIDENT (W\M2)/
S216  GLOBAL SOLAR IRRADIANCE AT SOUTH GLAZING IN THE LIVINGROOM SOUTH-BOTTOM VERTICAL TRANSMITTED (W\M/
S217  GLOBAL SOLAR IRRADIANCE AT NORTH GLAZING IN THE NORTHMIDDLE BEDROOM MID-POINT VERTICAL TRANSMITTED (W\M2)/
S218  GLOBAL SOLAR IRRADIANCE AT EAST GLAZING IN THE SOUTHEAST BEDROOM MID-POINT VERTICAL TRANSMITTED (W\M2)/
DT219  DIFFERENTIAL TEMPERATURE AT NORTH WALL IN THE SOUTHEAST BEDROOM WEST-MIDDLE INSIDE SURFACE TO OUTSIDE SURFACE (F)/
V220  VOLTAGE REFERENCE- AG-AGOX BATTERY= 1.6V [V]/
Q221  THERMAL FLUX INTO THE NORTH GLAZING IN THE NORTHMIDDLE BEDROOM MID-POINT ON INSIDE SURFACE (BTU\FT2-HR)/
V222  VOLTAGE REFERENCE- SHORTED CHANNEL ZERO OHMS [V]/
V223  VOLTAGE REFERENCE- SHORTED CHANNEL 1K OHMS [V]/
DT224  DIFFERENTIAL TEMPERATURE AT NORTH GLAZING IN THE NORTHMIDDLE BEDROOM MID-POINT INSIDE TO OUTSIDE SURFACE (F)/
DT225  DIFFERENTIAL TEMPERATURE AT CEILING IN THE NORTHEAST BEDROOM MID-POINT INSIDE TO OUTSIDE OF CELLULOSE (F)/
DT226  DIFFERENTIAL TEMPERATURE AT CEILING IN THE NORTHEAST BEDROOM MID-POINT INSIDE TO OUTSIDE OF GYPSUM (F)/
Q227  THERMAL FLUX INTO THE CEILING IN THE NORTHEAST BEDROOM MID-POINT BURIED BETWEEN GYPSUM AND CELLULOSE (BTU\FT2-HR)/

*****************METEOROLOGICAL DATA FROM SERI TEST SITE**********************
GLOBAL SOLAR IRRADIANCE HORIZONTAL  (W\M2)/
GLOBAL SOLAR IRRADIANCE  AT 40DEG TILT (W\M2)/
GLOBAL SOLAR IRRADIANCE  VERTICAL SOUTH AT IRL STATION (W\M2)/
GLOBAL SOLAR IRRADIANCE  VERTICAL SOUTH AT VALIDATION TEST CELL (W\M2)/
NORMAL BEAM NIP (W\M2)/
GLOBAL SOLAR IRRADIANCE HORIZONTAL DIFFUSE ONLY (W\M2) (DERIVED FROM GLOBAL SOLAR IRRADIANCE HORIZ AND BEAM)/
GLOBAL SOLAR IRRADIANCE VERTICAL SOUTH DIFFUSE ONLY (W\M2) (DERIVED FROM GLOBAL SOLAR IRRADIANCE VERTICAL SOUTH
                        AND BEAM DATA)/
GLOBAL SOLAR IRRADIANCE VERTICAL SOUTH SKY DIFFUSE ONLY (W\M2) (DERIVED FROM GLOBAL SOLAR IRRADIANCE VERTICAL
               SOUTH,BEAM, AND ALBEDO DATA)/
GLOBAL SOLAR IRRADIANCE 40 DEG. TILT DIFFUSE ONLY (W\M2) (DERIVED FROM GLOBAL SOLAR IRRADIANCE 40DEG AND BEAM
               DATA)/
GLOBAL SOLAR IRRADIANCE 40 DEG TILT DIFFUSE SKY ONLY (W\M2) (DERIVED FROM GLOBAL SOLAR IRRADIANCE 40DEG TILT,
               BEAM, AND ALBEDO DATA)/
GLOBAL SOLAR IRRADIANCE  AT 180DEG TILT (W\M2)/
ALBEDO OF GRASS FIELDS (DERIVED FROM GLOBAL HORIZ AND GLOBAL 180DEG TILT)
WIND SPEED AT 10M HEIGHT (M\S)/
WIND NORTHERN COMPONENT 10M (M\S)/
WIND EASTERN COMPONENT 10M (M\S)/
WIND SPEED AT 2M HEIGHT (M\S)/
WIND NORTHERN COMPONENT 2M (M\S)/
WIND EASTERN COMPONENT 2M (M\S)/
ATMOSPHERIC PRESSURE (MILLIBARS)/
SEA LEVEL ATMOSPHERIC PRESSURE (MB) (DERIVED FROM STATION PRESSUREO/
AMBIENT TEMPERATURE (SHIELDED) (F)/
RELATIVE HUMIDITY (%)/
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SKY INFRARED FLUX (BTU/FT2-HR)/
DEWPOINT TEMPERATURE (F) (DERIVED AS IN ASHRAE77,CHAP5,FROM RELATIVE HUMIDITY
                          AND PRESSURE)
SKY TEMPERATURE (F) (DERIVED FROM SKY INFRARED FLUX AND AMBIENT TEMPERATURE)/
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