#506

INFILTRATION IN TWO MOBILE HOMES

A Thesis

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Dedication

Commit your works unto the Lord, . . .

Proverbs 16:3

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TABLE OF SYMBOLS

a	Mean face clearance (crack width) cm
A_W	Total exterior wall area m^2
$\frac{a}{b}$	Length of front wall/length of side wall
C	Concentration of tracer gas ppm
C_o	Initial concentration of tracer gas ppm
Cd	Discharge coefficient $= \frac{\rho V^2}{2\Delta P}$
C_{in}	Concentration of tracer gas in home ppm
C_m	Measured concentration ppm
C_{out}	Concentration of tracer gas in outside air ppm
Cp	Coeficient of pressure loss
C_W	Exterior wall flow coefficient $m^3/s\text{-}m^2\ Pa^n$
Dh	Hydraulic diameter = 4×Area/Wetted perimeter cm
E_c	Error in concentration measurement ppm
E_i	Error in infiltration measurement cph
ELA	Equivalent Leakage Area m^2
F	Pressure difference coefficient, local to measured
h	Height above neutral pressure level m
H	Solar radiation Watts/m^2
h_o	Neutral level m
h_{ai}	Enthalpy of inflowing air kJ/kg
h_{ao}	Enthalpy of outflowing air kJ/kg
h_w	Enthalpy of condensate kJ/kg

h_t	Building height m
I	Total infiltration rate cph (changes per hour)
I_c	Calculated infiltration rate cph
I_ℓ	Larger of I_T or I_W
I_m	Measured infiltration rate cph
I_N	Infiltration in north home cph
I_S	Infiltration in south home cph
I_s	Smaller of I_T or I_W
I_T	Infiltration with only stack forces considered cph
I_W	Infiltration with only wind forces considered cph
K_H	Meter coefficient watts/revolution
$\dot{m}$	Mass flow rate kg/s
n	Flow exponent
P	Pressure Pa
ΔP_T	Pressure difference due to stack effect Pa
ΔP_W	Pressure difference due to wind Pa
q	Heat removed per unit time kJ/s
Q	Flow rate m^3/s
Q_c	Volume flow rate per meter of crack m^3/s-m
Q_{co}	Volume flow per meter of crack with $\Delta T = 0$ m^3/s-m
R	Ideal gas constant 287 N-m/kg-°K
Re	Renolds number
t	time (decimal hour)
t_o	initial time (decimal hour)
T_i	Temperature inside home °K
T_o	Temperature outside the home °K

ΔT	Temperature difference $T_i - T_o$ °K
V	Velocity of air through the crack m/s
$\forall$	Volume of the home m^3
$d\forall_{in}$	Differential volume of air entering the home m^3
$d\forall_{out}$	Differential volume of air leaving the home m^3
W	Wind velocity m/s
Z	Distance through the crack cm
β	Ratio of the height of neutral pressure level to height of the building
β_o	Best fit coefficient
ε_A	Error in the coefficient A
ε_C	Error in the coefficient C
θ	Wind direction °
μ	Viscosity kg/m-s
ρ	Density kg/m^3
ρ_i	Density of the inside air kg/m^3
ρ_o	Density of the outside air kg/m^3
Φ	Function of ΔT
Ψ	Difference function, Equation 4.30
Ω	Function of W
ω	Humidity ratio kg/kg of dry air

ABSTRACT

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Research was undertaken to find the effect of a continuous sheathing board and skirting on the infiltration rate in a mobile home. To do this, two mobile homes were tested, one was equipped with sheathing board, and one was caulked at structural joints. The homes were alternately tested with and without skirting. The third goal was to find the effect of wind, wind direction, temperature difference between inside and outside the home, humidity, and solar radiation on infiltration.

Infiltration was found to vary linearly with temperature difference and the square of wind velocity. The effects of wind and temperature difference on infiltration were found to be approximately additive. Wind direction had a very small effect, humidity and solar radiation were insignificant.

Sheathing board was found to reduce infiltration by an average of 42%. The effect on the wind coefficient was slightly greater than on the temperature difference coefficient. Sheathing board reduced energy usage to heat (or cool) the homes by 10% in the winter and 3% in the summer.

The effect of skirting was insignificant.

1 INTRODUCTION

At a time when energy costs are soaring, many ways of reducing energy usage are being implemented. Among these are retrofits to homes to reduce the amount of fuel used for home heating and cooling. This has proven to be a long overlooked area of energy conservation. Mobile homes are especially notorious for their high heating cost to living area ratio. In 1978 approximately 275,000 units were sold.[1] This represents almost one in six new housing starts.[2] Thus, the need for higher energy usage efficiencies in mobile homes can be seen. Energy loss from mobile homes occurs by three mechanisms: heat transmission through the envelope, radiation from or to the envelope, and air infiltration. The first two of these have been investigated to some degree. Very little research has been done on air infiltration in mobile homes, although it can be as high as 48% of the heat load for site built houses.[3] With this in mind, the investigation was undertaken.

Infiltration is defined as air leakage through cracks and interstices around windows and doors, and through floors, walls and ceilings into the home.[4] This air represents a heating (or cooling) load in that the air must be heated (or cooled) to the conditions of the home interior.

The objective of the research was to measure the amount of air infiltrating into a mobile home, quantify this amount with respect to weather conditions, and look at two possible methods of reducing the amount of air infiltration and the associated energy savings.

To accomplish this objective, two 1975, top of the line mobile homes were used. One was equipped with a continuous sheathing board and the other was caulked at all structural joints. The caulked home was equipped with two roof vents to vent moisture from the home. The home manufacturer claimed such vents were not necessary for the sheathed home and they were not used. Other than this, the homes were identical. These homes were compared to find the effect of sheathing. The homes were alternately tested with and without skirting to find its effect on infiltration and energy consumption. Throughout the tests the amount of electricity needed to heat the homes was recorded to determine the effects on energy usage. In a final test the sheathing board was removed from the home so equipped, and further comparisons were made with the caulked home as a reference.

The homes were unoccupied during all of the tests.

2 REVIEW OF RESEARCH DONE BY OTHERS

2.1 Mobile Homes

Air infiltration measurements on mobile homes (or manufactured housing) are sparce at the present time. Prado[5,6] found that for his limited range of tests the infiltration rate, I, in changes per hour (cph) was a linear function of the temperature difference between the inside and the outside. Data was taken in the spring and fall with the blower in the furnace chamber on. He found that $I = 1.1 + .0198\Delta T$. With the furnace blower off, infiltration was on the order of .8 cph less, with no wind and a negligible temperature difference. Only one measurement was taken with high wind. That measurement was not discernably different from the others.

Hunt, Treado, and Peavy[7] found infiltration rates to be $I = .362 + .00560\Delta T$, for a home in an environmental chamber with no wind. In an attempt to simulate wind, eight large fans were directed against the home from a distance of 1.5m. New infiltration rates were between .55 and .71 cph, or about .1 to .3 cph higher than with no fans operating. They also found that: a) storm windows had little effect on infiltration, b) opening one or both doors increased infiltration to 2 to 4 cph, and c) the furnace blower increased infiltration .2 to .3 cph. Hunt, Treado, and Peavy also did pressurization and depressurization tests on their home. Given a simulated pressure difference equal to a theoretically stack induced pressure difference, the infiltration was much higher than would be produced by that stack induced pressure difference.

Tietsma and Peavy[8] did further depressurization work on the same home. They attempted to identify the leakage paths for air and then seal them. They were able to reduce flow by 1/2. Unfortunately, they did no further natural infiltration tests to compare the sealed home with the unsealed home.

2.2 Site Built Homes

2.2.1 Tracer Measurements of Infiltration

A number of researchers have done infiltration measurements on site built homes. Results of their work are presented in table 2.1. Other comments, where necessary, will be made here.

Dick and Thomas[9] did their research on two groups of homes rather than on individual homes; one group at Abbots Langley, and the other at Bucknells Close, England. The homes were occupied. The stack effect could not be determined at Abbots Langley because of the lack of low wind speed data.

Bhanfleth, Moseley and Harris[10] did air infiltration measurements on two research homes at the University of

Table 2.1 Sample of research done and some models

Authors	Home (type heat)	Results*	Comments
Dick Thomas[9]	Abbots Langley	$I = .87 + .168W + .23n + .060nW$	n--number of open vents
	Bucknells Close	$I = (.36 + .16n)W$	$W^2/\Delta T > .70$
		$I = (.30 + .07n)\ \Delta T^{1/2}$	$W^2/\Delta T < .70$
			one open window = 1.4 open vents
Bahnfleth Moseley Harris[10]	IBR Research Home (gas)	$I = .12 + .00585\Delta T + .029W$	
	Warm Air Research Residence #2 (gas)	$I = .19 + .0119\Delta T + .027W$	
Tamura Wilson[25,13]	Home #1 (oil)	$I_W = .04 + .038W$	Due to wind only
		$I_T = .04 + .032\sqrt{\Delta T}$	Due to stack only
		$I = I_\ell(1. + .24(I_s/I_\ell)^{3.3}$	
	Home #2 (oil)	$I_W = .06 + .045W$	Data was not sufficient to determine temperature effect
Lachober Healy[14]	IBR Research Home (electric)	$I = .11 + .029\Delta T + .188W_L$	W_L--wind on the long side of home
	Warm Air Research Residence #4 (gas and electric)	$I = -.27 + .083EG + .0189\Delta T + .150W_L$	EG= +1 gas heat -1 electric heat

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*All results are presented in metric units

Table 2.1, cont.

Authors	Home (type heat)	Results	Comments
Hunt[15] Burch	Townhouse	$I = .117 + .0194\Delta T$	Home in an environmental chamber
Prado[5] Goldschmidt Leonard	Mobile home (gas)	$I = 1.1 + .0198\Delta T$	Limited data
Hunt[7] Treado	Mobile home	$I = .362 + .00560\Delta T$	Home in an environmental chamber
Luck[16] Nelson	2 bedroom home	$I = I_o(1 + .177W^2 + (\frac{1}{T_o} - \frac{1}{T_i}))$ $I_o = .072 - .0080Pe$	Pe--lumber equilibrium vapor pressure
Burch[17] Hunt	Pre-retrofit	$I = .11 + .0180\Delta T + .0438W$ $I = .051 + .0875\sqrt{\Delta T} + .0345W$	$\delta = .062$ $\delta = .061$
	Post-retrofit (heat pump)	$I = .221 + .0165\Delta T + .0512W$ $I = .059 + .135\sqrt{\Delta T} + .0527W$	$\delta = .064$ $\delta = .064$ δ--standard dev.
Reeves[18] McBride Sepsy		$Q = \beta_o C_T (4\Delta P_T + \sqrt{2}\Delta P_W)^{1/2}$ $\beta_o x10^4$ C_T	Q--volume fow rate m^3/min
	ETCS (gas)	1.33 101.4	
	(electric)	1.19 "	
	KTSC (gas)	1.39 "	
	(electric)	1.24 "	
	CTSE (electric)	1.27 "	
	HTSG (gas)	2.72 "	

Table 2.1, cont.

Authors	Home (type heat)	Results	Comments
Reeves cont.		$\beta_o \times 10^4$ C_T	
	HSLG (gas)	.94 115.7	
	SRSG (gas)	1.02 129.6	
	KAWG (gas)	1.12 45.3	
	OAMG (gas)	1.54 "	
	PAEG (gas)	2.60 "	
Malik[3]	Townhouse #1 (gas)	$I = .186 + .0148\Delta T$	with only ΔT
		$I = .193 + .0095\Delta T + .107G + .0016B + .0088F + .0021\lvert W\cos(\theta-280)\rvert$	G--gas consumed kw B--basement door opening min/hr F--front door opening min/hr W < 2.6 m/s
		$I = .00031\Delta T\cdot W\lvert\cos(\theta-300)\rvert + .023G + .00014B\cdot\Delta T + .30$	High wind
	Townhouse #2 (gas)	$I = .26 + .0128\Delta T$	with only ΔT
		$I = .22 + .0128\Delta T + .00308\lvert W\cos(\theta-15)\rvert$	low wind

Illinois. Of interest, in the IBR Research Home, a change of 5°C ΔT or 1.m/s wind velocity produced the same change in infiltration while a change of 1.6°C ΔT or 1 m/s wind velocity caused the same change in inside, outside pressure difference measured at the first story floor level. Also of interest was the fact that wind reduced the pressure inside the home. The opposite effect was observed for the Warm Air Heating Research Residence. Bahnfleth, et al, found that the wind induced a large amount of flow out the chimney on the IBR Research Home but not on the Warm Air Home, thus, the different reaction to wind.

Other conclusions reached were that a) the IBR home was tighter than the Warm Air Home, b) the temperature difference caused much more infiltration than expected, c) air change rates were less during the summer for the same wind and absolute value of the temperature difference, and d) the crack and air change method gave good results at design conditions by over predicting infiltration due to wind and neglecting temperature difference.

Coblentz and Achenback[11] took a few measurements on each of ten electrically heated homes. Using a model based on the average values of Bahnfleth, Moseley and Harris' work, the points were corrected to 22°C ΔT and 4.5m/s wind. They claimed they could then compare the different homes. They concluded that new buildings had lower infiltration rates than old, wood frame construction had higher values than masonry, and that two story buildings had higher values than one story buildings.

Jordan, Erickson and Leonard[12] measured infiltration in two houses as part of a larger study. They performed only a limited number of measurements to determine a range of infiltration and made broad comparisons. They then used these values as part of the heat loss study.

Tamura and Wilson[13] did infiltration measurements on two test homes. They also measured pressure differences across the outside walls of the homes at 1.2 m above the floor level. They found infiltration varied linearly with wind and with the square root of the temperature difference. When the two effects were added, the sum was less than the total of each acting alone. When the infiltration due to wind equalled the infiltration due to stack, the combined effect was 65% of the sum of the individual effects. See table 2.1. They also found the pressure difference across the windward wall was 86% and 85% of the pressure drop across the entire house for homes #1 and #2, respectively. In addition, they found the largest negative pressure differences were across the chimney.

Laschober and Healy[14] measured infiltration in two split-level residences. The IBR Research Home was heated with a gas fired boiler. Conbustion air was drawn directly from the outside. The Warm Air Research Residence #4 with a forced air, full perimeter system, used, alternately, gas and electric heat. Lachober and Healy tried finding equations of infiltration as a function of temperature difference, temperature difference squared, the wind component incident on each of the walls, and the square of the wind component incident on each of the walls. For the IBR home they found only the temperature difference and the wind on the long side of the home significant. Similar results were obtained for the warm air home with the addition of one variable, EG. EG equalled 1 when the home was heated with gas and -1 when the home was heated with electricity. Gas heat was found to produce an additional .17 cph infiltration rate. Justification for a model with wind incident on the long side came from the large ratio of crack on the long side to the short side. Values predicted by the air change and crack method were consistently less than those given by their model at design conditions.

Hunt and Burch[15] found that in a four bedroom townhouse located in an environmental chamber, infiltration was a linear function of temperature difference. They then tried sealing suspected leakage areas: a) kitchen, bathroom, and dryer vents, b) doors, and c) air ports under the furnace. Little reduction in infiltration was achieved.

Luck and Nelson[16] discovered that in addition to wind and temperature difference, the humidity of the home affected infiltration. They found that increasing the humidity of the home reduced infiltration rates. They theorized this was due to the expansion of the lumber as it gained moisture, the cracks would become smaller and thus, less infiltration.

Burch and Hunt[17] performed retrofits on a frame house in several stages. Their first retrofit was an attempt to reduce air leakage. They measured the infiltration characteristic of the home and then applied the following retrofits: a) caulking around warm air ducts where they penetrated the inside walls, b) installation of improved weather stripping under the outside doors, c) sealing the large crack between the foundation and the siding, and d) the installation of storm windows. They then remeasured infiltration and compared with the equation fit to the previous data. The results were not significant. Note that two models are given in table 2.1. This was because both models fit the data equally well.

Reeves, McBride and Sepsy[18] performed air infiltration studies on nine homes in Columbus, Ohio. They first attempted to fit all of the data to linear models, but concluded that the linear model was not acceptable (Reference 19). They then developed a physical model,

$$I = \beta_o C_T (A\Delta P_T + B\Delta P_W)^{1/2} \qquad (2.1)$$

where the symbols are defined in the table of symbols, and

$$\Delta P_T = 34 \cdot P \cdot h \cdot (1/T_o - 1/T_i) \qquad (2.2)$$

$$\Delta P_W = \frac{176.5}{T_o} \cdot W^2 \qquad (2.3)$$

are the pressure due to stack and wind, respectively. A and B were determined semiempirically and were given values of 4 and $\sqrt{2}$, respectively. The advantage of the above model is its simplicity, and a single correlation coefficient. This allows direct comparison of different residences, and modifications of the same residence. The disadvantage of the above model is a slight loss of accuracy.

As part of the energy consumption study at Twin Rivers (see references 20 and 21) Malik[3] measured infiltration in two townhouse apartments. Variables considered included temperature difference, wind velocity, wind direction, rate of furnace gas consumption, G, front door opening (minutes per hour), F, and basement door opening, B. Results are presented in table 2.1. Apartment #2 was sheltered from the dominant westerly winds, while #1 was not.

2.2.2 Pressurization and Depressurization Tests

Tracer techniques, while measuring infiltration to a high degree of accuracy are time consuming and do not provide any simple method of identifying leakage areas in the home. In an attempt to provide a quick method for finding infiltration rates or to identify leakage areas many researchers are using fans to pressurize or depressurize their test homes. Flow rates through the fan can then be measured and the flow characteristic of the home determined, or the contribution of individual cracks to infiltration can be measured by sealing them and measuring the reduction of flow.

Tamura[22] and Caffey[23] have used depressurization to measure the sources of leakage in site built homes. Tamura measured the amount of leakage through the ceiling, outside wall, and through windows and doors, at 75 Pa pressure difference. Caffey vacuum tested 50 homes. He found that on the average, 25% of the leakage occurred around the baseboard (soleplate) of the homes, and that 20% occurred around electrical outlets. Windows and doors provided for 19% of the leakage. Up to 50% of this leakage was through the facing or framing area of the window or door. After identifying leakage areas he sealed the leakage areas and found that with only minimal outlay for material costs the leakage opening could be reduced by half. Harrje, et al,[20] also used depressurization to find large leakage areas which they then sealed as part of their retrofit work at Twin Rivers.

Other researchers have tried to predict infiltration using pressurization or depressurization tests. Kronvall[24] performed vacuum and pressure tests on 29 Swedish homes. He also measured one natural infiltration point on each home. He found that

$$I = 0.003\ (Q/A)^{1.1}$$

where Q/A is the air leakage at 50 Pa divided by the area of the building envelope.

Tamura[25] using his earlier work (reference 13 and 22) and his model for tall buildings developed the following model:

$$I_T = 10,800 \; \frac{C_W A_W \beta^{1.65}}{\forall} \; h_t^{.65} \left|\frac{\Delta T}{T_o}\right|^{.65} , \qquad (2.4)$$

$$I_W = 850 \; \frac{a}{b} \; \frac{A_W C_W}{\forall} \; F^{.65} \; (W)^{1.3} \qquad (2.5)$$

$$\frac{I}{I_\ell} = 1 + .24 \; (\frac{I_s}{I_\ell})^{3.3} \qquad (2.6)$$

Tamura's model assumes a uniform crack distribution in the walls, uniform cross sectional area with building height, $n = .65$, $Ti = 294\ ^{o}K$ and that the side walls are shielded from the wind. Using his depressurization work (reference 22) he was able to determine the flow coefficient for the crack from

$$Q = C_W A_W \Delta P^n, \; n = .65 \; . \qquad (2.7)$$

In this equation C_W is referred to as the flow coefficient, and n as the flow exponent. He then used his experimental data (reference 13) to compare his model with actual infiltration rates. His model predicted I_T reasonably well, but underpredicted I_W. I was predicted fairly well. (Note that all of Tamura's work was done on the same homes.)

Grimsrud, Sherman, Diamond, Condon and Rosenfeld[26] and Blomsterberg and Harrje[27] followed a similar procedure to relate pressurization tests to infiltration. Both groups determined the flow coefficient and exponent for their home using equation 2.7. Grimsrud, et al, then measured pressure differences across the surface of the home simultaneously with infiltration. Using the pressure differences they calculated infiltration. Their results were quite good. Blomsterberg and Harrje used pressure differences obtained from a wind tunnel test to calculate infiltration and compared their results against earlier infiltration measurements by Harrje's research group. Their predicted values were over twice as high as the measured values of infiltration. Both groups assumed uniform crack distribution for their calculations. Blomsterberg and Harrje pointed out this may not be a very good assumption, and showed theoretically that a different distribution of the same amount of crack could change infiltration by a factor of 2.

In another study Stricker[28] correlated the equivalent leakage area measured using depressurization to humidity. He found that

$$\omega = .003 + (.0004/ELA) \text{ where } ELA = 1.29(Q/\sqrt{P}). \quad (2.8)$$

ELA is the area of an orifice giving the same flow rate as the home.

2.2.3 Other Studies

Of interest are two studies done by Mattingly and Peters[29] and Mattingly, Harrje, and Heisler[30]. In the first study, wind tunnel tests were used to find the pressure on the surface of a model of a townhouse. Using equation 2.7 inside pressures could be predicted and pressure differences across the walls and nondimensional infiltration rates estimated. Of interest was that simulated trees could reduce infiltration by up to 40%. To check this the second group wired up full size evergreen trees outside one of the townhouses at Twin Rivers. They found that for winds perpendicular to the home, infiltration due to wind was reduced 42%.

2.3 Tall Buildings

Research done on tall buildings can be divided into three groups: a) the measurement of pressure difference across the exterior of a building, b) computer models of air infiltration, and c) actual air infiltration measurements.

Most of the research in the first group has been done by Tamura, Shaw, Wilson, and Sanders at the Division of Building Research, National Research Council of Canada, in Ottawa, Canada. They have measured the pressure difference across the wall due to stack and forced ventilation[31,32] the pressure differences across the walls due to wind[33,34,35] and the flow coefficients which resulted from the pressurization of the building.[36,37] The pressure difference due to wind was measured on actual buildings[33] and on wind tunnel models.[34,35] One wind tunnel model was for wind with a simulated suburban boundary layer,[34] and one model was for wind with a simulated urban boundary layer.[35] Using the computer and results from the previous studies they could calculate the infiltration in a building.[34,35] With this information they were able to develop a simplified model for predicting infiltration in tall buildings.[34,35,36] In this simplified model they found that when both stack and wind pressure were acting, the total was no more than 40% of the largest component. The actual amount was dependent on the ratio of the wind to stack forces, and wind direction.

The second group of research consisted of the development of computer models to predict air infiltration. Tamura and Wilson first developed a model to calculate pressure differences caused by stack action.[38] Using his earlier work to measure the actual flow coefficients in buildings Tamura extended this computer model to calculate air flow within the building.[39]

Jackman and Teck[40] also developed a computer model for air infiltration very similar to Tamura's. They also set up an electrical analogue model using current to represent air flow, resistors to represent pressure drop, and voltage to represent pressure. The computer model and the electrical model gave similar results for air flow.

All of the computer models used an iterative process to balance the inflow and outflow air by adjusting to pressure in the various rooms and floors.

Only two references were found where actual tracer gas techniques were used to measure infiltration in tall buildings.[41,42] Both of these studies looked at the air exchange rate caused by ventilation rather than at the infiltration due to stack and wind. Both cases gave fairly good results.

2.4 Component Studies

In addition to infiltration studies on entire buildings, research has been done on air flow through wall components placed under a pressure difference in the laboratory. The typical test consisted of fastening the component to be tested to a chamber which could either be pressurized or depressurized. Flow and pressure difference were then measured and a pressure flow curve was plotted. The flow coefficient and exponent were determined from this curve.

Larson, Nelson, and Braatz[43] measured airflow through various types of wood frame construction. They made no attempts at correlating the data mathematically, but did present all data graphically. These graphs were all of the form $Q = C(\Delta p)^n$ with $n<1$.

Thomas and Dick[44] measured airflow through cracks around windows. They found that

$$\Delta P = \frac{18.5}{a^2} (Q_c + 775 Q_c^2) \tag{2.9}$$

for a series of 13 metal and wood frame windows.

Sasaki and Wilson[45] pressure and/or vacuum tested 39 windows of varying types. Data could be fitted with an equation of the type $Q = C\ (\Delta P)^n$, where C was dependent on the window tested and $n \cong 2/3$. They also concluded that the values given by the ASHRAE Guide and Data Book[46] were within the range of the windows tested.

Bursey and Green[47] measured infiltration through a window as part of a study for determining the effect of infiltration on the U value of the window. The infiltration versus pressure difference curve was of the form $Q = C(\Delta P)^n$ with $.6 < n < .75$. (Similar results, but with a smaller exponent were found by Sabine et al.[48]) They also found that $Q_c = Q_{co}(1. + 0.009\Delta T)$ for infiltrating air (where ΔT is in °C). The dependence of exfiltrating air was less than that of infiltrating air and was not determined. The U value for infiltration and conduction acting together was found to be less than the sum of the U values for each acting alone.

Hopkins and Hansford[49] and Ethenridge[50] studied air flow through simple cracks. Hopkins and Hansford theorized this flow should take the form:

$$\frac{1}{Cd^2} = \frac{C_a Z}{R_e D_h} + K. \qquad (2.10)$$

From theory, $C_a = 96$. They measured flow for three different types of cracks: a) straight through, b) one bend, and

c) two bends. The values of C_a and K were found to be 95.7 and 1.5; 91.36 and 2.2; and 43.2 and 3.4 for each of the above cracks, respectively. This model can be compared with equation 2.9. Using $Z/D_h = 10.3$ (which was typical for a window tested by Thomas and Dick), standard values of ρ and μ, and equation 2.10 for a single bend crack, one obtains

$$\Delta P = (20.9/a^2)\cdot(Q_c + 643Q_c^2).$$

This is in reasonable agreement with equation 2.9.

2.5 Summary

Most of the work done on air infiltration in buildings has been empirical. Models to predict relationship to wind and temperature have been inconclusive with only moderate success in correlating actual data.

Measurements in different types of buildings have also been limited. Most of the reported data used the tracer gas technique for determining infiltration rates. Relating pressurization or laboratory data to field measurements has not always been successful. (See, for instance, Ross and Grimsrud[51]).

The literature reveals the need for further data and correlations giving models for the dependence of infiltration rates on weather and structural characteristics. This need became the defining factor for part of this study.

3 FIELD SET UP

3.1 Mobile Home Set Up

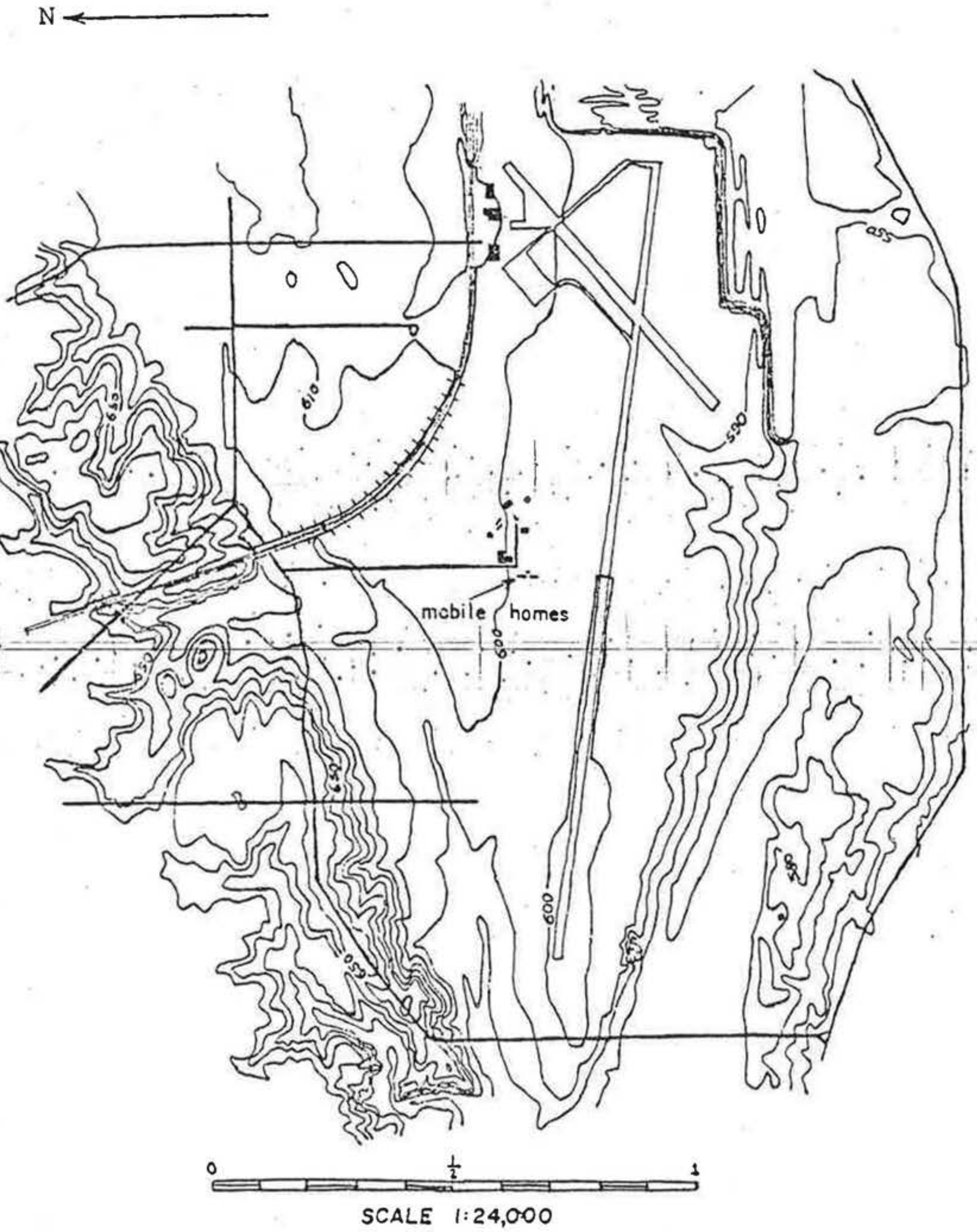
As stated in the introduction, two homes were used to measure infiltration and to gather information about sheathing and skirting.

3.1.1 Description of Site

The mobile homes were located at a site on the north edge of the Purdue University Airport about 1 km west of the city of West Lafayette, Indiana. The site was a grassy flatland 1 km west and 1/2 km to the north and south of the homes. Several large buildings were located 100-150m east of the homes (see figure 3.1). The homes were placed with the long dimension north to south to take advantage of the dominant westerly winds. The front of the homes faced east. The sheathed home was placed on the south and the caulked home was placed on the north. Between the homes, and to the east was the instrument shed which housed all of the instrumentation used for measuring infiltration. (See figures 3.2 and 3.3.)

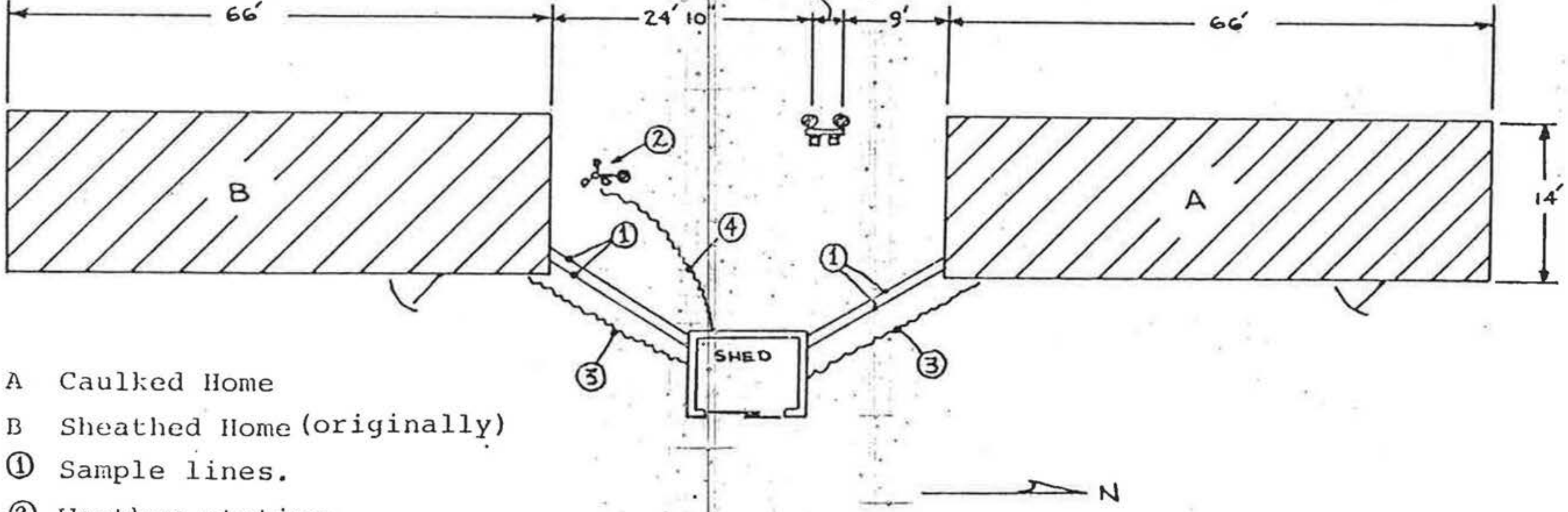
3.1.2 Description of the Homes

Both homes were single wide, two bedroom homes 20.13m long by 4.27m wide (66'×44') with 2.29m (7.5') ceilings.



1 mile = 1.61 Km

Figure 3.1 Topographical map of site area



A Caulked Home
B Sheathed Home (originally)
① Sample lines.
② Weather station
③ Thermocouples.
④ Weather station leads.

Figure 3.2 Site arrangement

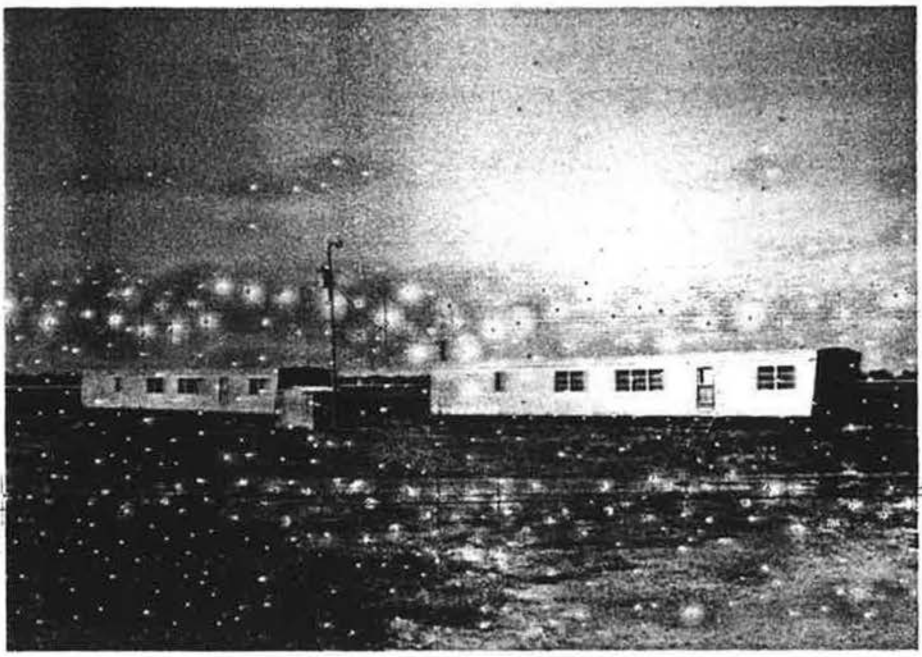


Figure 3.3 The homes

The floorplans are given in figure 3.4. Heating was done with a 19.6 kW electric furnace (at 240V). The unit efficiency was approximately 98%.* Homes were cooled with 9.4 kW units, with a COP rating of 2.3.* The home contained a single floor duct 10 by 38.0cm along the length of the home. There were 8 registers 10 by 19.5cm, 2 in the kitchen, living room and master bedroom and 1 in the bath and central bedroom. See figure 3.4 for the location of each register. Rated flow through the duct system was .364 m^3/s.* All return air was through a large vent in the door of the furnace room.

Homes were insulated with R14 fiberglas bats in the ceiling, R11 in the walls, and a combination of R11 and R7 in the floor. Typical wall sections are given in figure 3.5. For the caulked home the sheathing indicated in the figure is not present.

Each home contained 17 windows of 4 types and sizes. Window dimensions are given in figure 3.6. The location of the windows in the homes is given in figure 3.4 and can be seen in figure 3.7. All windows have inside storm sashes. Figure 3.6 also gives the dimensions of the doors. Each home contains two doors as shown in figure 3.4. The front door (on the east wall) is equipped with a storm door. The rear door is not.

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*From manufacturers specifications.
See also appendix D for measurements of flow rates and COP of air conditioners.

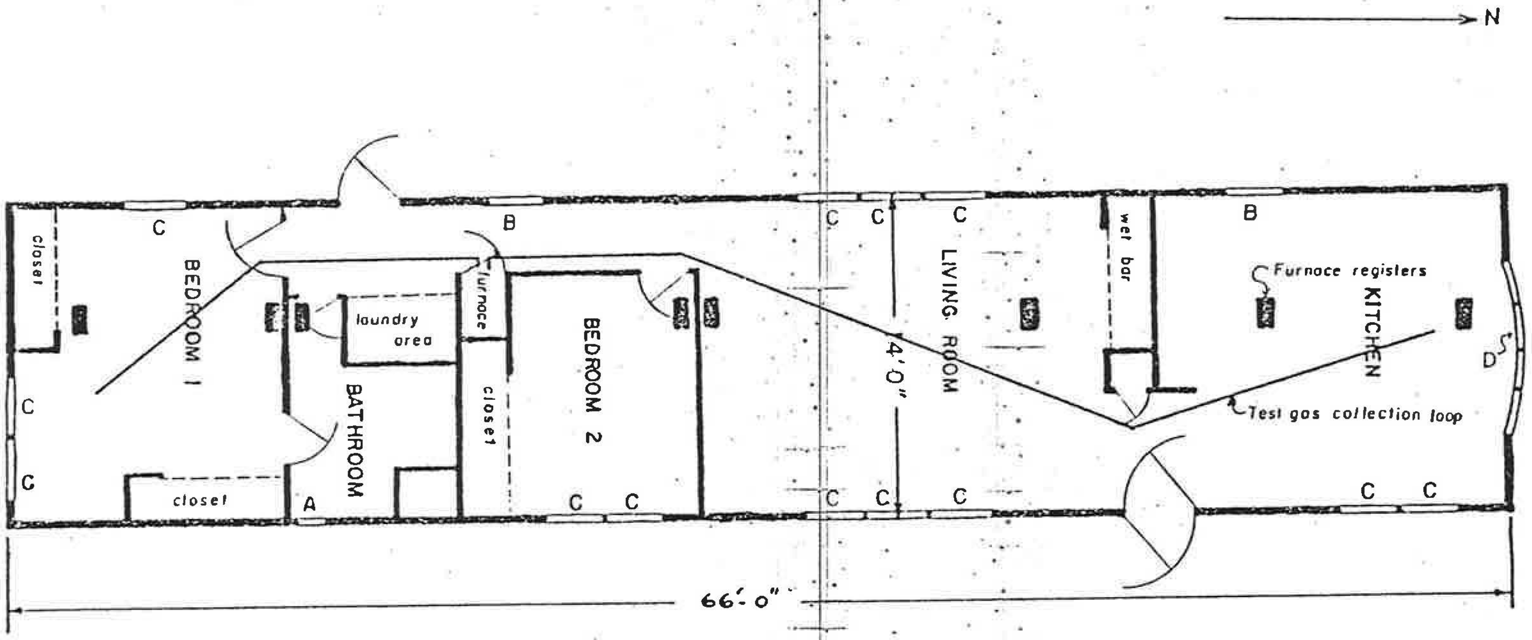
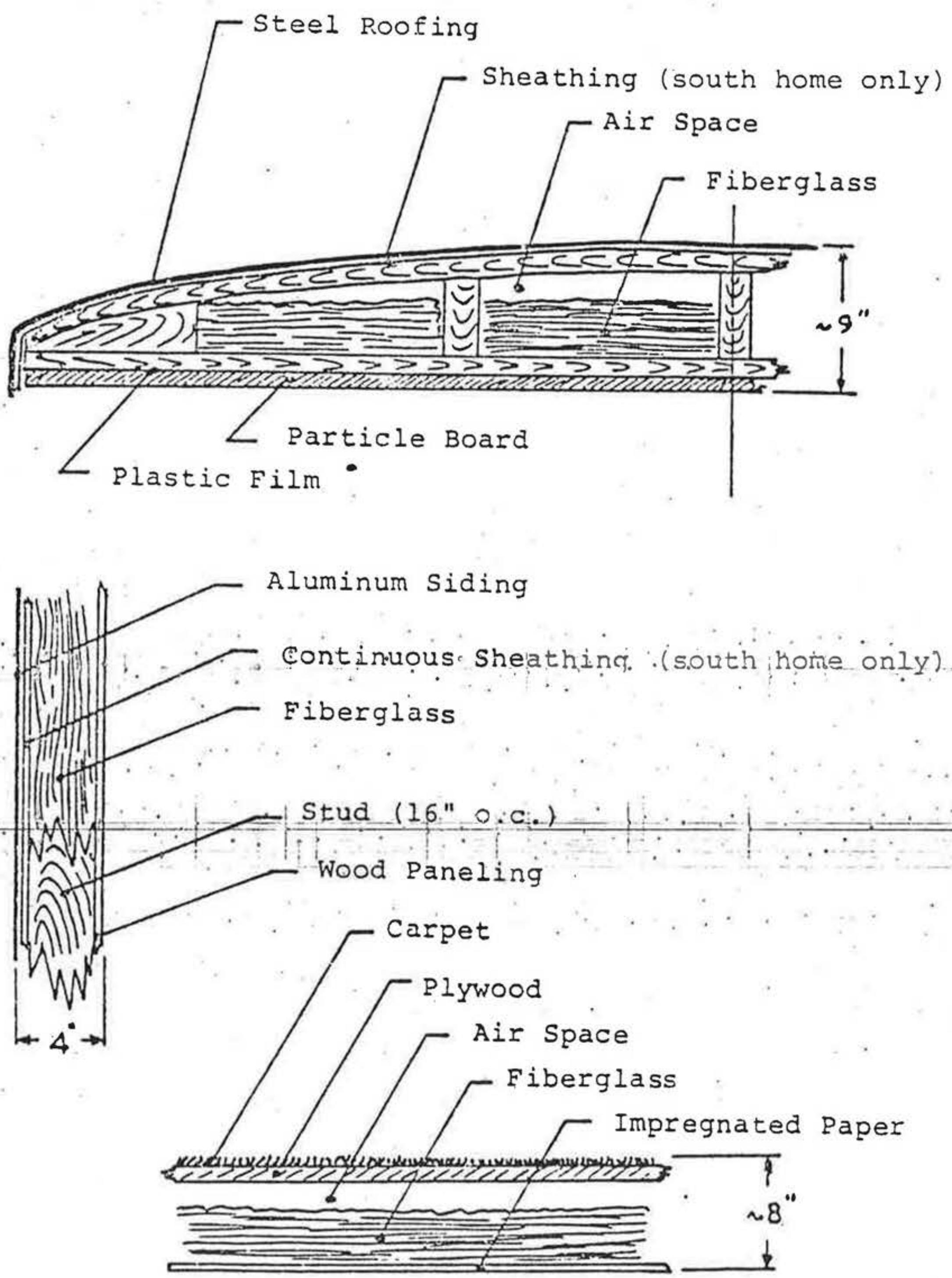


Figure 3.4 Floor plan of the mobile homes



1" = 2.54 cm

Figure 3.5 Typical sections

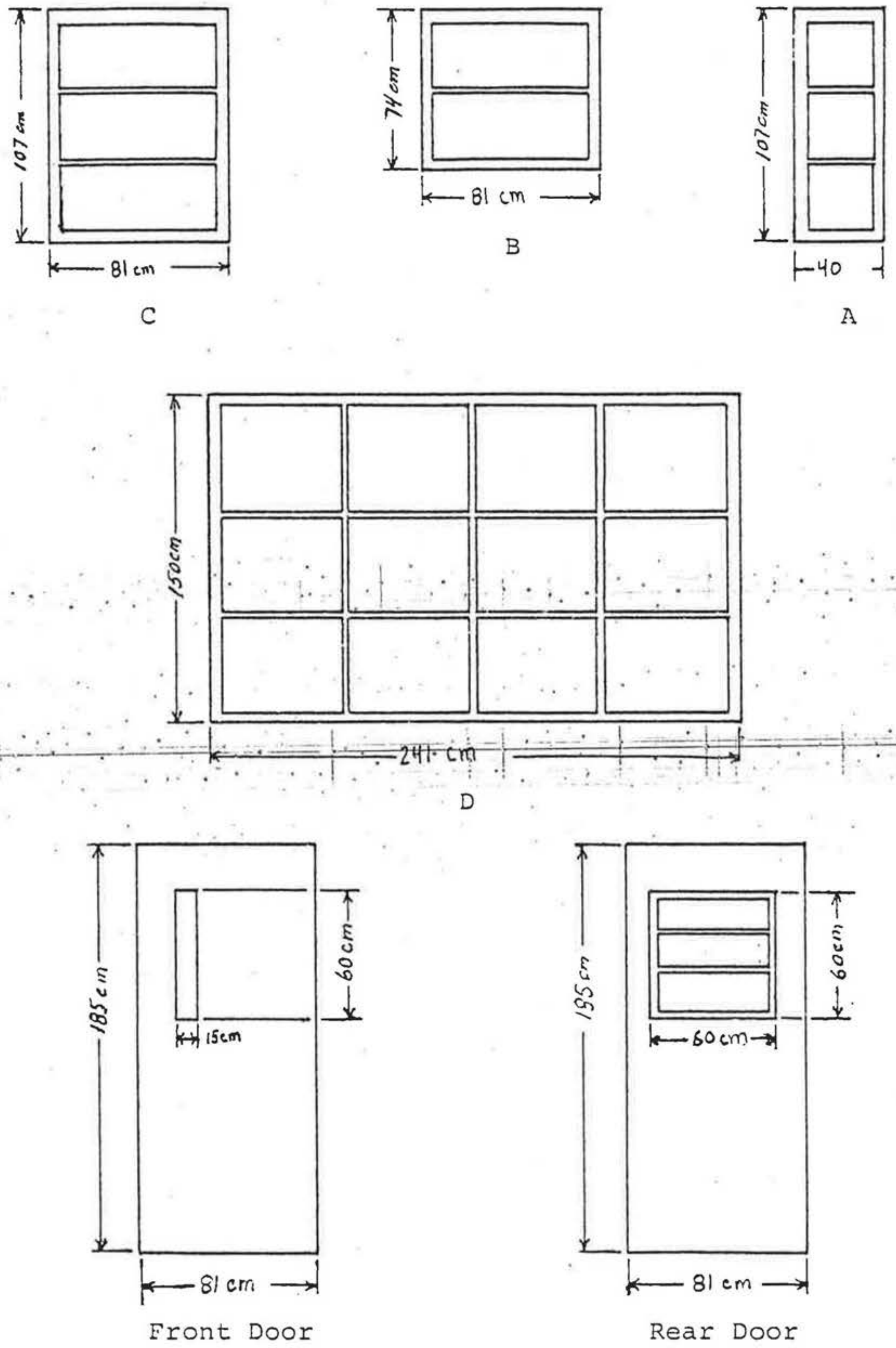


Figure 3.6 Window and door dimensions

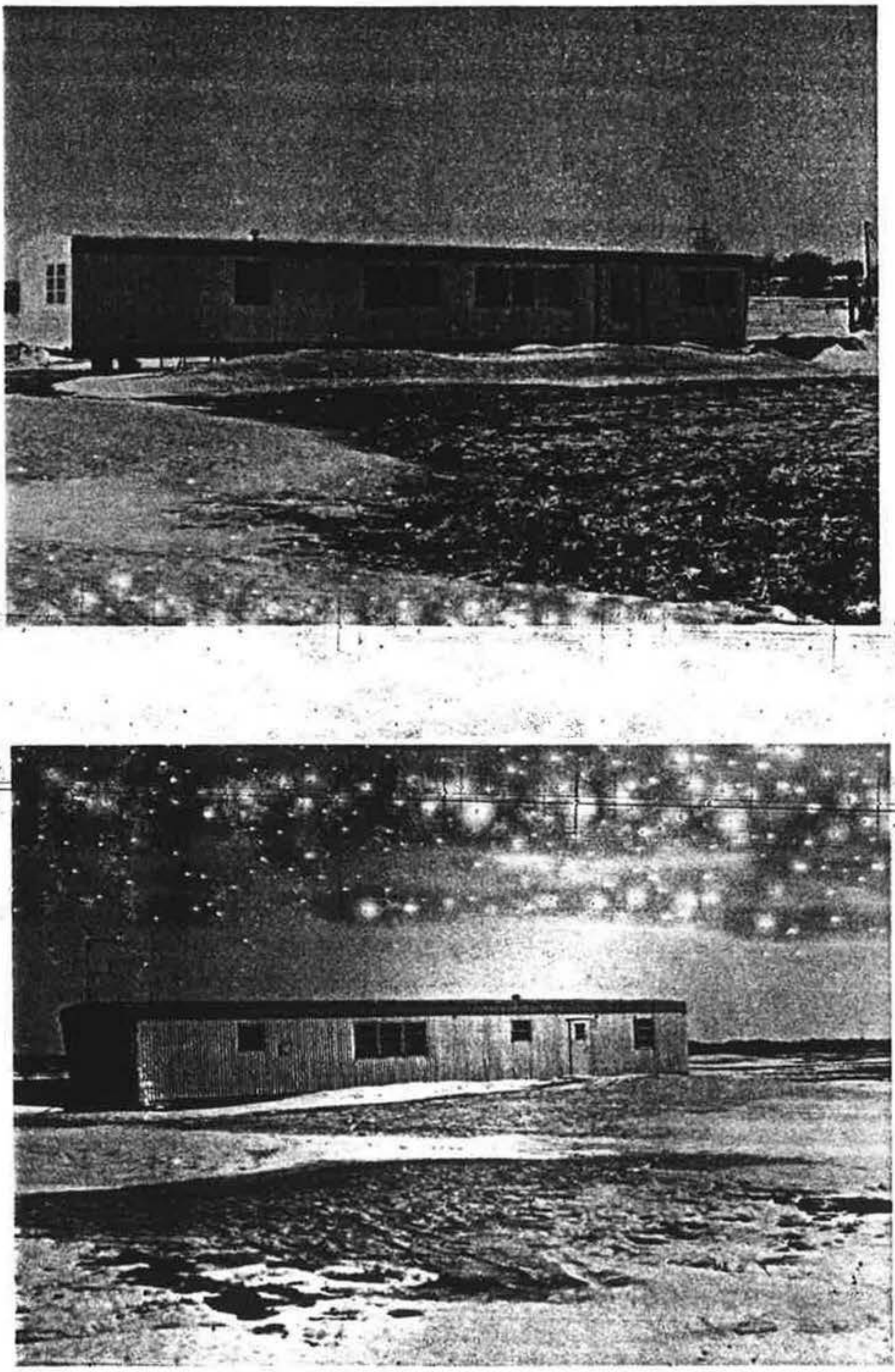


Figure 3.7 View of south home from southeast and northwest

Cracks on the outside wall are those around windows and doors, joints between sections of metal siding, at the bottom joint of the home siding and at the top joint of the siding. Cracks on the inside wall are those around windows and doors, between sections of paneling, between the paneling and the floor, between paneling and ceiling, between ceiling sections, and around electrical outlets and fixtures. Table 3.1 gives the length of cracks for each outside wall. The large front window was caulked around each pane so crack length was taken as that around the outside frame. Cracks in the siding on the south home were taken as zero since the sheathing would cover them.

Both homes contained two vent fans. One was in the kitchen near the electric range in the rear wall of the home. This vent had a cover which was pulled closed when the vent was not in operation. The second vent was in the bathroom ceiling. This vent was equipped with a barometric damper which opened when pressure was placed against it.

3.2 The Measurement of Infiltration

Infiltration was measured using the decay, tracer gas technique. (For a complete discussion of different methods of measuring infiltration see reference 52.) Using this method, a gas, the tracer, whose concentration can be easily measured is injected into the home. The gas is allowed to mix with the air in the home. As fresh air enters the home, and air mixed with tracer leaves, the concentration of

Table 3.1 Estimated crack lengths

Wall	Type of crack	North home (m)	South home (m)
East	Window&door	53.7	53.7
	Siding	35.0	----
	Joints	40.3	40.3
	Subtotal	129.0	93.0
South	Window&door	12.7	12.7
	Siding	8.4	----
	Joints	8.5	8.5
	Subtotal	29.6	11.2
West	Window&door	43.8	43.8
	Siding	28.6	----
	Joints	40.3	40.3
	Subtotal	112.7	84.1
North	Window&door	7.8	7.8
	Siding	3.9	---
	Joints	8.5	8.5
	Subtotal	20.2	16.3
Grand Total		291.5	204.6

tracer in the home will decrease. The change of concentration of tracer at any instant in time is given by

$$dC = \frac{-C_{in}d\forall_{out} + C_{out}d\forall_{in}}{\forall} . \qquad (3.1)$$

But

$$\rho_o d\forall_{in} = \rho_i d\forall_{out} \qquad (3.2)$$

by conservation of mass. Assuming: a) perfect mixing so that $C_{in} = C$, and b) negligivle concentration of the tracer in the outside air, so that $C_{out} = 0$, then

$$dC = \frac{-Cd\forall_{out}}{\forall} . \qquad (3.3)$$

Infiltration, for this work, is defined as the amount of air leaving the home per unit time, divided by the volume of the home,

$$I = \frac{d\forall}{dt} / \forall . \qquad (3.4)$$

Since by definition $d\forall = d\forall_{out}$, Equations 3.4 and 3.3 can be combined to give,

$$\frac{dC}{C} = -Idt. \qquad (3.5)$$

Integrating with $C = C_o$ at $t = t_o$,

$$\ell n \frac{C}{C_o} = -I(t - t_o) \qquad (3.6)$$

or

$$I = \frac{1}{t-t_o} \ell n \left(\frac{C_o}{C}\right). \qquad (3.7)$$

Thus, by measuring the change in concentration over a fixed period of time, infiltration can be determined.

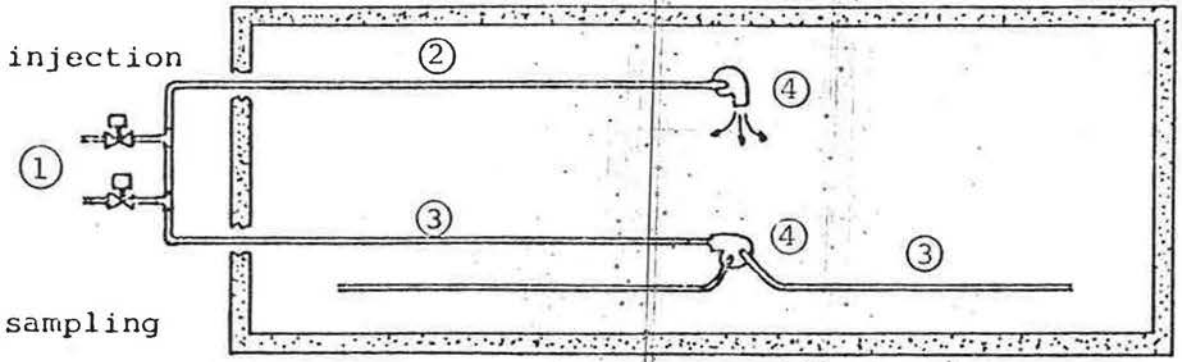
3.2.1 The Tracer Gas

The gas used as a tracer must meet certain requirements:[52] a) it should have similar density to air, if it is not, the gas can produce buoyancy forces in magnitudes similar to those produced by stack effect, and the tracer will tend to stratify within the home; b) it should not condense or be absorbed by components of the home, or react chemically with anything in the home; c) it should not be explosive; d) it should not be produced in the home; e) the background concentration must remain constant throughout a test; f) if the home is occupied, it must be odorless, non-irritating and non-toxic; g) it must be introduced in small enough quantities that it does not disturb natural airflow in the home; and h) instrumentation must be available to measure the concentration accurately. Carbon monoxide was chosen as a tracer because a) the homes were unoccupied throughout all tests, b) its properties were very similar to air, c) it has very low natural concentration, d) it was readily available, and e) accurate detection equipment was available. (In initial phases of the research, SF_6 was used but was found to be difficult to use. See reference 2.)

3.2.2 The Sample Loop

Since the tracer used was a gas, a sample loop was necessary to bring a sample of the air in the homes to a central instrument shed without requiring entry of the test homes. The requirements for the sample loop were: a) the loop had to collect a uniform distribution of sample air from the homes, b) the loop had to provide the sample to the detector in a reasonable amount of time so that infiltration measurement was not out of phase with weather variables, and c) the loop could not remove samples so large that the infiltration would be significantly altered.

The sample loop consisted of four basic parts. A simple schematic is given in figure 3.8. Carbon monoxide was injected at the sample station (1) in the instrument shed. See Figure 3.9. The injection was accomplished by opening an electrically operated solenoid in a supply line between the carbon monoxide bottle and the sample loop. The carbon monoxide bottle was located outside the shed for safety reasons. The carbon monoxide then entered the sampling loop (2) where air from the home was continuously circulated. This sampling loop then dumped the carbon monoxide into the return air side of the furnace blower, see figure 3.10. The furnace blower, which was operated continuously throughout the tests, distributed the carbon monoxide to all rooms in the home. Air from the home was then collected from the home by the sampling loop (3) and was



① Sampling station.

② Injection loop.

③ Collection loop.

④ Circulation fans.

Figure 3.8 Sampling loop schematic

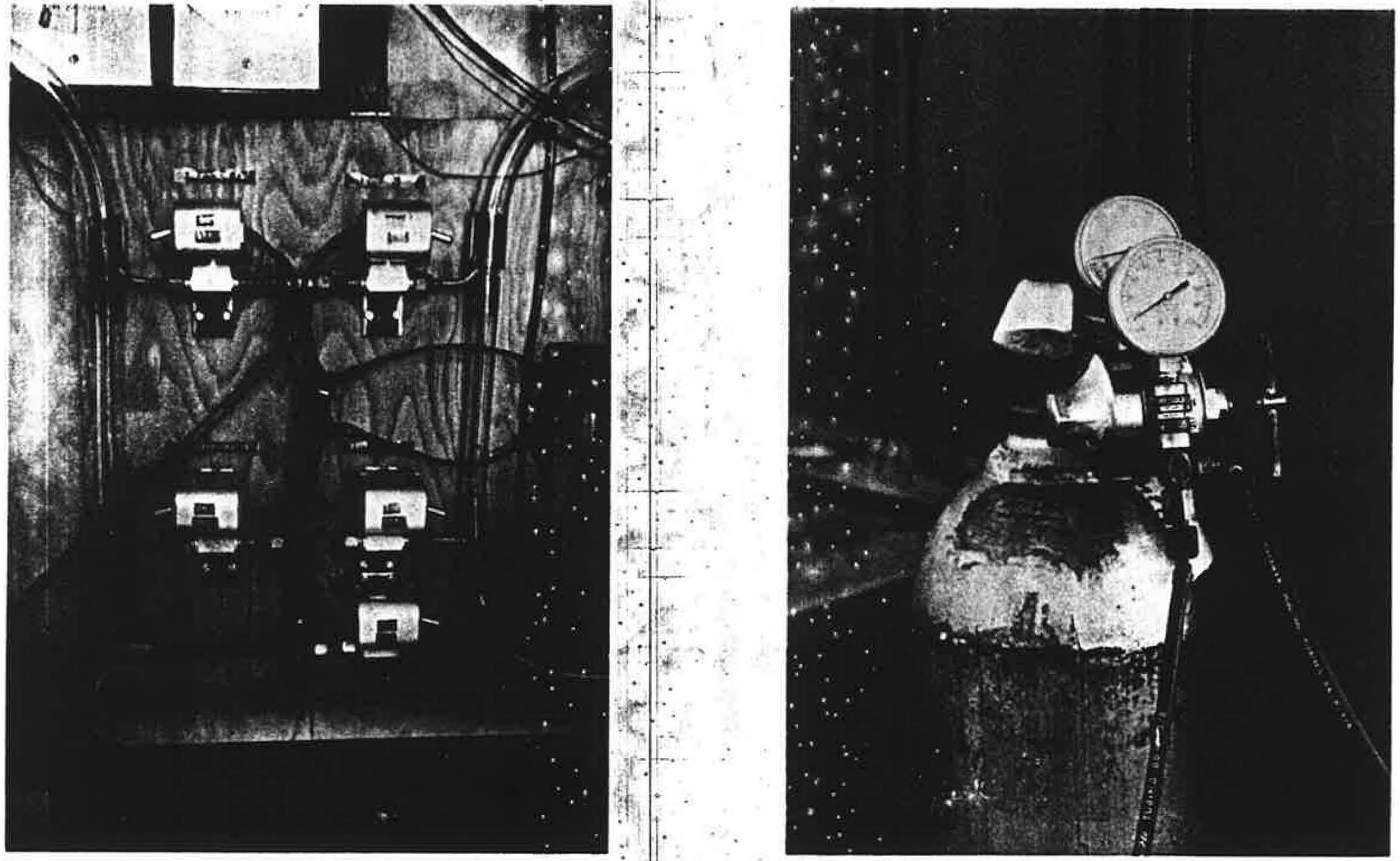


Figure 3.9 Sample station and carbon monoxide source

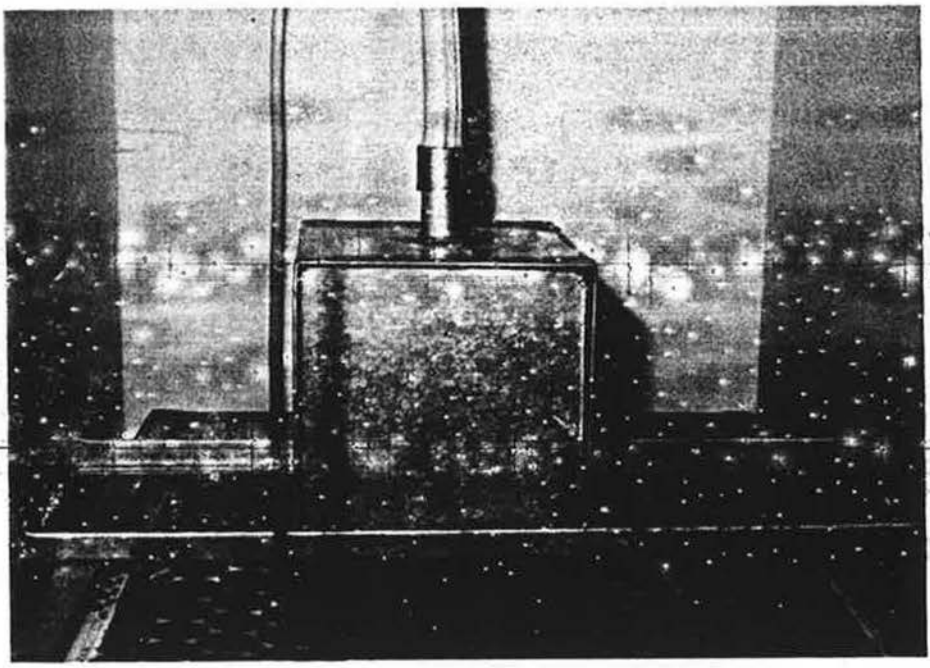


Figure 3.10 CO injection into furnace blower

circulated to the instrument shed where the necessary samples could be drawn off at the sample station (1). The location of the sampling part of the loop in the home is shown in figure 3.4. This loop was a 1.9cm diameter pipe with tygon tube connections. The loop was hung 30cm from the ceiling. See figures 3.11 & 3.12. 0.6cm holes were drilled in the tube every 60cm throughout the kitchen, living room and rear bedroom. The ends of the pipe were closed with a rubber stopper, thus, the entire sample was drawn through the small holes. There were 7 holes in the living room, 6 in the kitchen, 5 in the rear bedroom, and one in the hall outside the central bedroom. The sample collected was weighted slightly more heavily toward the rear bedroom with only a small protion from the central bedroom. It should be pointed out that the furnace blowers would circulate one house volume approximately once every 8 minutes, so only small errors were made in not collecting the sample in a perfectly homogeneous manner. Air was circulated in the loops by two small blowers, (4) on figure 3.8. See also figure 3.10 and 3.13. The time for one complete circulation of the air in the sample loop was 60 seconds for the north home and 120 seconds for the south. The sample loop was 30m long for the north home and 60m long for the south. Thus, the flow rate within the loop was about 140 ml/sec. The carbon monoxide samplers drew off 20 ml/sec. The remaining 120 ml/sec were returned to

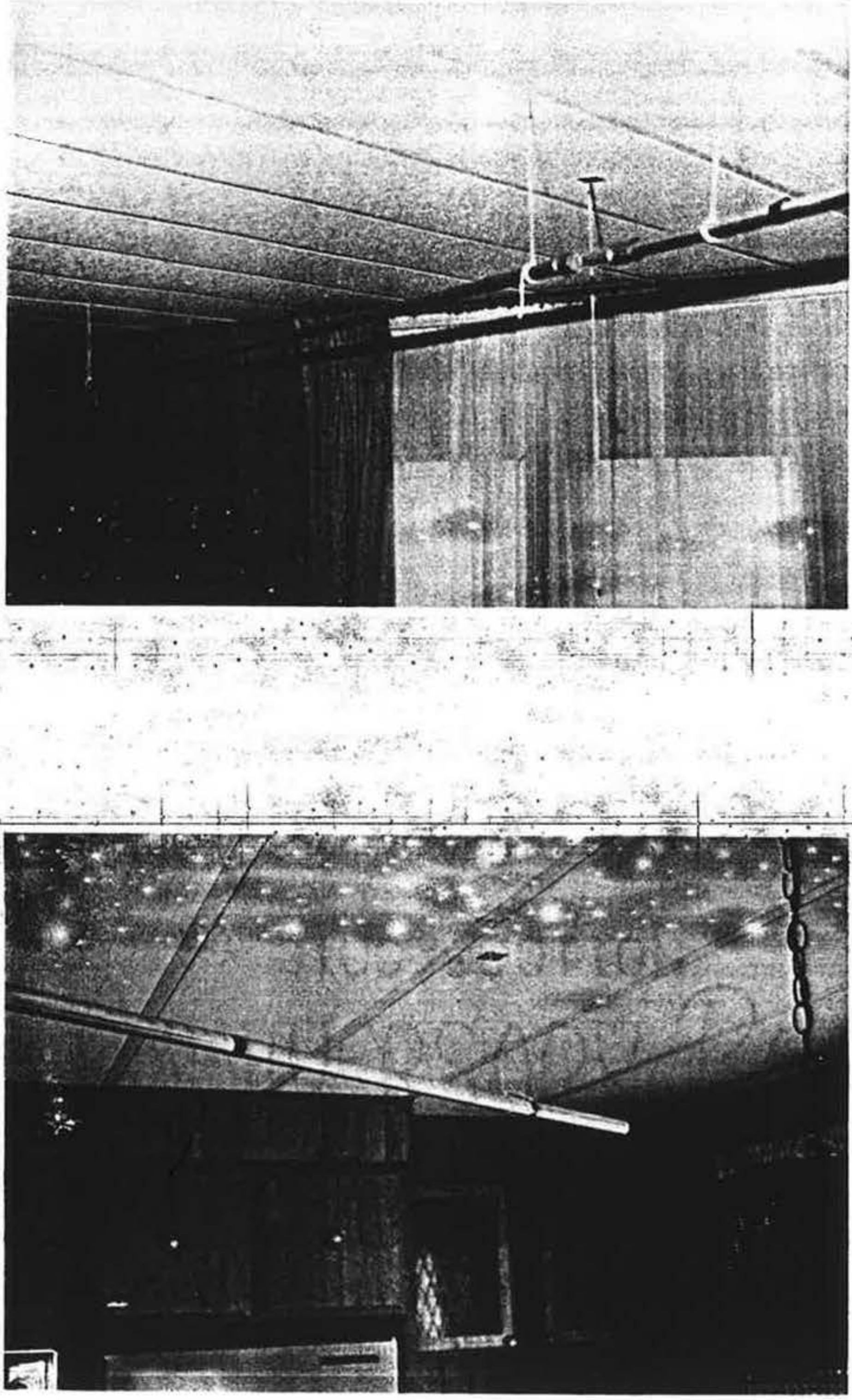


Figure 3.11 Sample collection loop living room, kitchen

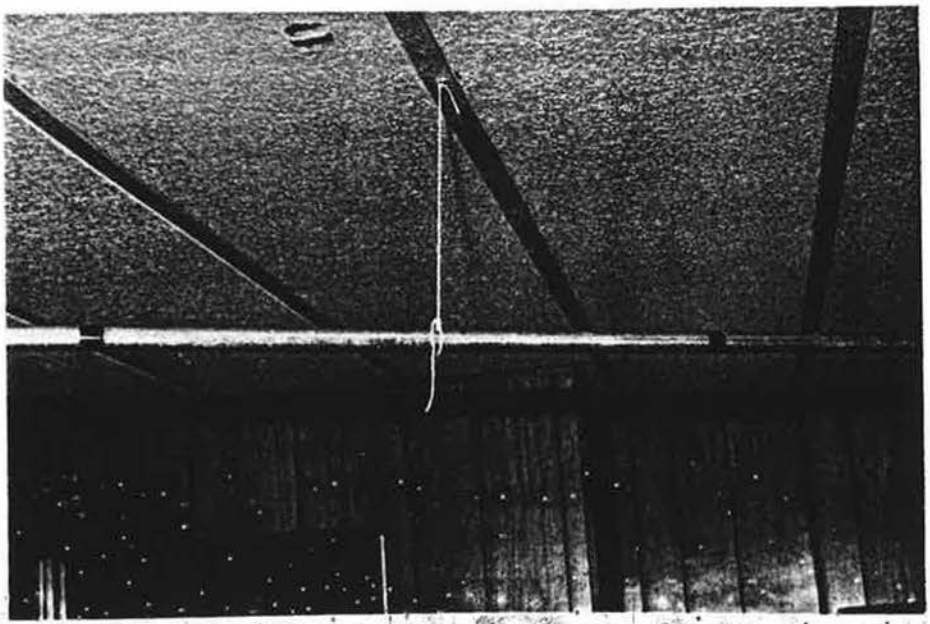


Figure 3.12 Sample collection loop, bedroom

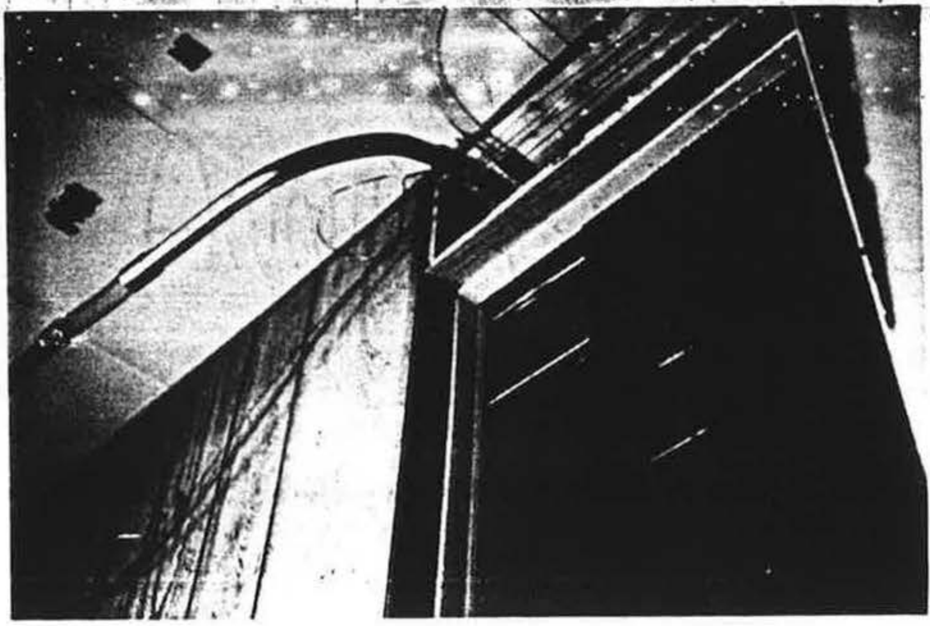


Figure 3.13 Circulation fan

the home. The concentration measured in the shed would be the same as the concentration of the homes 30 sec and 60 seconds earlier for the north and south home, respectively.

Shortly after the start of the test an automatic injector was added to the sample loop system. This automatic injector allowed the injection of CO for a predetermined (and adjustable) amount of time, approximately once every ninety minutes. (The system was later modified to allow injection once every 2 1/2 hours.) This facilitated the taking of infiltration measurements over long periods of time with no one present to monitor the concentration in the homes.

3.2.3 Tracer Measurement

To measure the concentration of the carbon monoxide, two Interscan 1142 CO detectors were used, one for each home. (See figure 3.14) The output of these instruments was linear to within ±1 ppm (part per million) on the 100 ppm scale. Zero drift was 1 ppm per °C. Span drift was .1% per °C. The repeatability of the instruments was ±2 ppm. Rise and fall time was 20 sec to 90% of full scale.[53]

The Interscan 1142 detector used an electrochemical cell with gas diffusion through the cell at a controlled rate. The carbon monoxide was then electrochemically oxidized at a sensing electrode. This electrode was maintained at a fixed potential with respect to a second electrode, so that the current produced was proportional to the

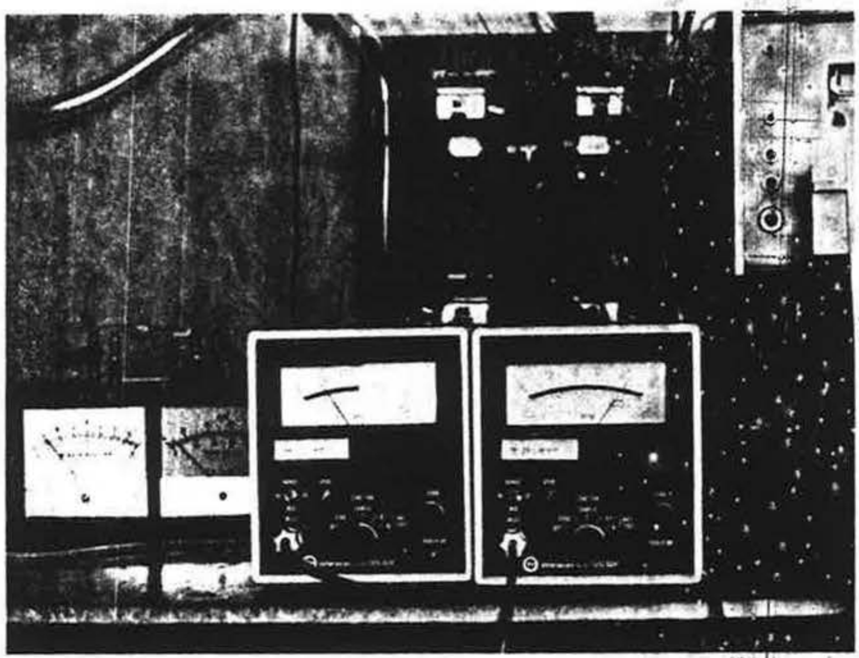


Figure 3.14 CO detectors

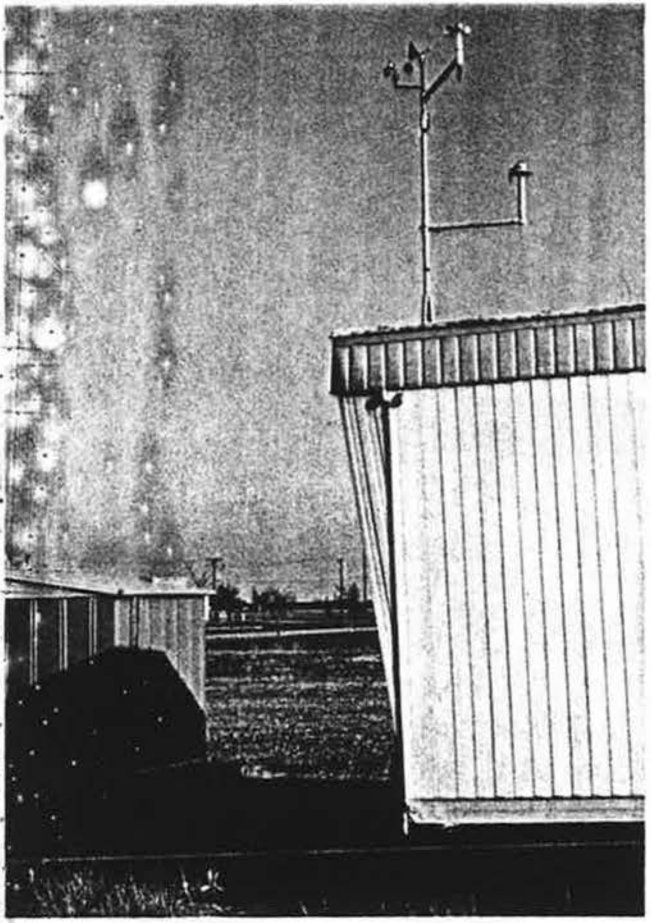


Figure 3.15 Location of weather tower

concentration of the carbon monoxide. Electrical output was 100mV. This made necessary a voltage divider so that the output could be read on a 10mV recorder. This voltage divider was set so that 1 ppm produced a .1mV input to the recorder.

Two checks were made on the interscan CO detectors. Approximately once a month, the meters were set using a standard sample of 50 ppm CO mixture in air. A second test was performed by hooking both meters to the same home during an infiltration run. When the meters were operating properly both meters gave the same values of infiltration and concentration. If not, appropriate action was taken by either readjusting the meters or repairing them as needed.

3.3 Measurement of Weather Parameters

To correlate infiltration against weather parameters, the weather parameters had to be measured. Measured were: a) wind speed, b) wind direction, c) inside wet and dry bulb temperatures, d) outside wet and dry bulb temperatures and e) solar radiation.

3.3.1 Wind Speed

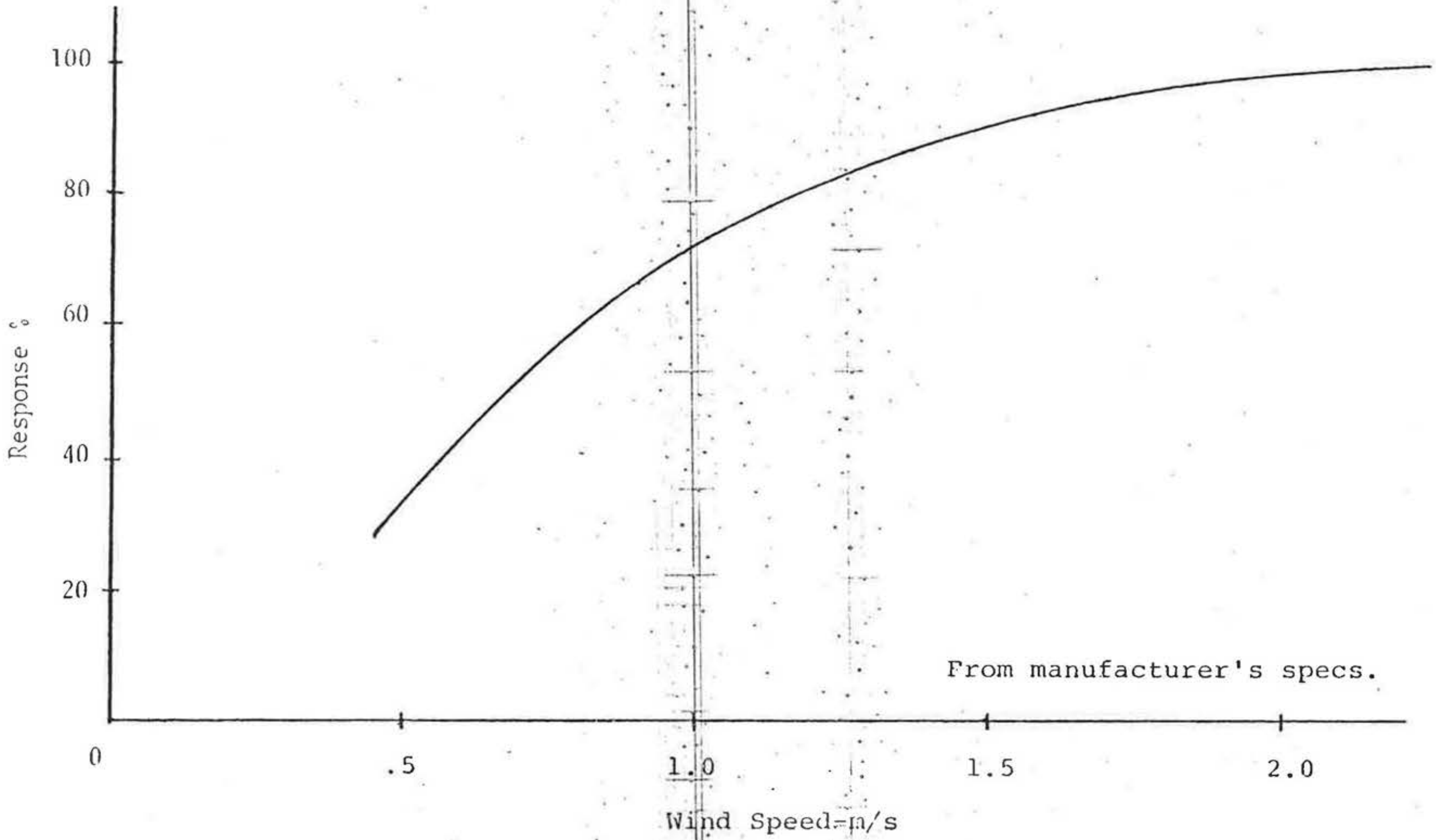
Wind speed was measured with a Gill 3 cup anemometer, model 12102. The Gill anemometer used a small d.c. generator whose output voltage was directly proportional to the rotation rate. The cup response was 1 revolution per meter of wind passage. The distance constant was 2.4 meters;

below this level the cup responded to only a percentage of the passing air. See figures 3.16 and 3.17. Threshold was .4 m/sec. This threshold was considered the friction of the system, and its effect was considered constant at all wind speeds. Thus, the wind speed measured would be the actual wind speed minus the wind speed needed to overcome friction (.4 m/sec).[54]

The anemometer was mounted on a tower located on the north end of the south home. See figure 3.15. The anemometer was 5m above the ground, and was mounted on an arm extending 1.m west of the tower. See figure 3.18. The voltage output from the generator was greater than permitted by the recorder. For example at 1800 rpm (=30m/s) the voltage output was 2400mV. A voltage divider was used so that with 60 mph winds the voltage input to the recorder was 30mV instead of 2145mV. This particular anemometer was not calibrated (since it would not fit in the wind tunnel available) but comparisons were made against an older meter which was calibrated in the wind tunnel.

3.3.2 Wind Direction

Wind direction was measured with a Princeton model 414 wind vane. The wind vane was a variable helipot across which a constant voltage was maintained. The output, in volts, was proportional to wind direction, 0 to 2.6mV with 0 = south, increasing clockwise. The curve was linear to within 1.5% (approximately 5°). The wind vane was also



From manufacturer's specs.

Figure 3.16 Response of the anemometer to low wind speeds

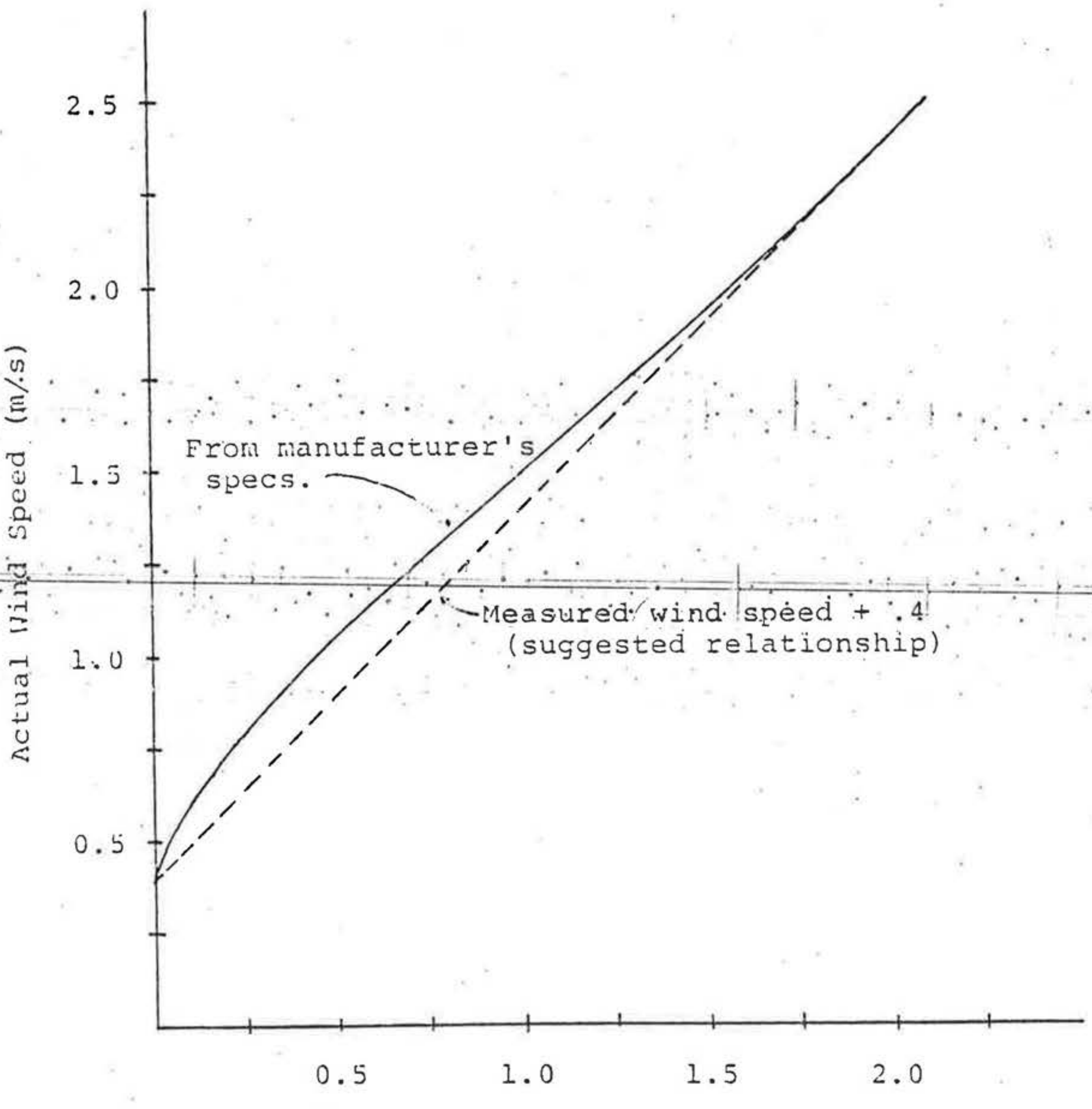


Figure 3.17 Actual vs. wind speed measured by the anemometer

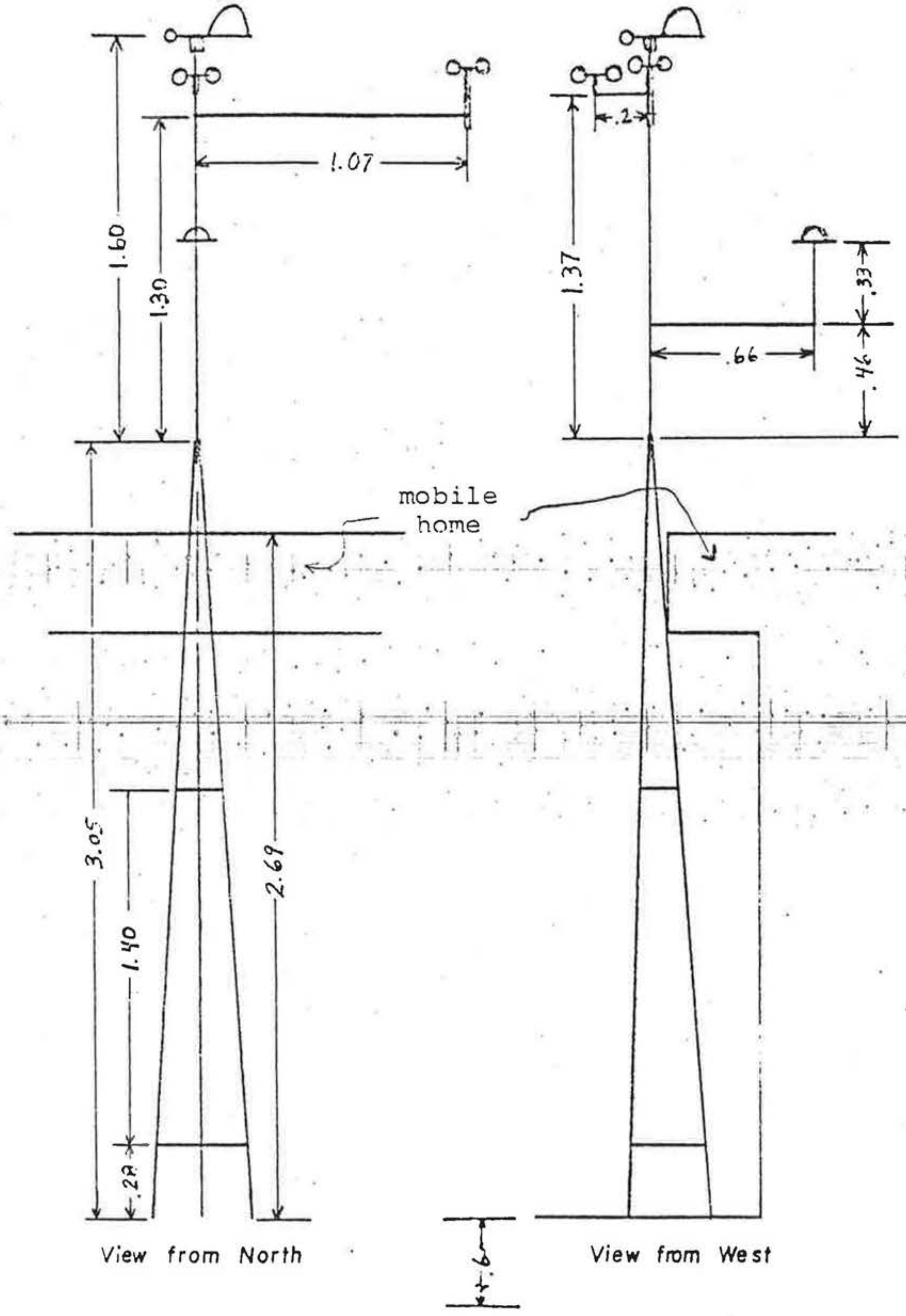


Figure 3.18 Weather tower

mounted at the top of the weather tower. See figure 3.18. The fact that the wind vane had two different voltage values at zero degrees proved a problem during the tests. With southern winds the meter was reduced to rapid fluctuations between 0 and 2.6 making it difficult to measure wind direction accurately. The wind vane was calibrated with a small hand held compass.

3.3.3 Solar Radiation

Solar radiation was measured with an Epply Black and White Pyranometer, which measured global radiation. Sensitivity was 11.73 microvolts per watt per square meter as calibrated by the factory. Impedance was approximately 350 ohms. Temperature dependence was ±1.5% constancy between -20 and 40°C. Linearity was ±1% from 0 to 1400 watts per square meter. Cosine response was ±2% between 0° and 70° zenith angle, and ±5 percent from 70° to 80° zenith angle.[55] The pyranometer was mounted on the weather tower as shown in figure 3.18.

3.3.4 Temperatures

Wet and dry bulb temperatures were measured for both homes and for outdoor air when the temperature was high enough so that the water didn't freeze in the psychometer. All temperatures were measured with 20 gauge copper - constantan thermocouples, and psychrometers made by our own shop. (See figure 3.19) The temperatures were read on an

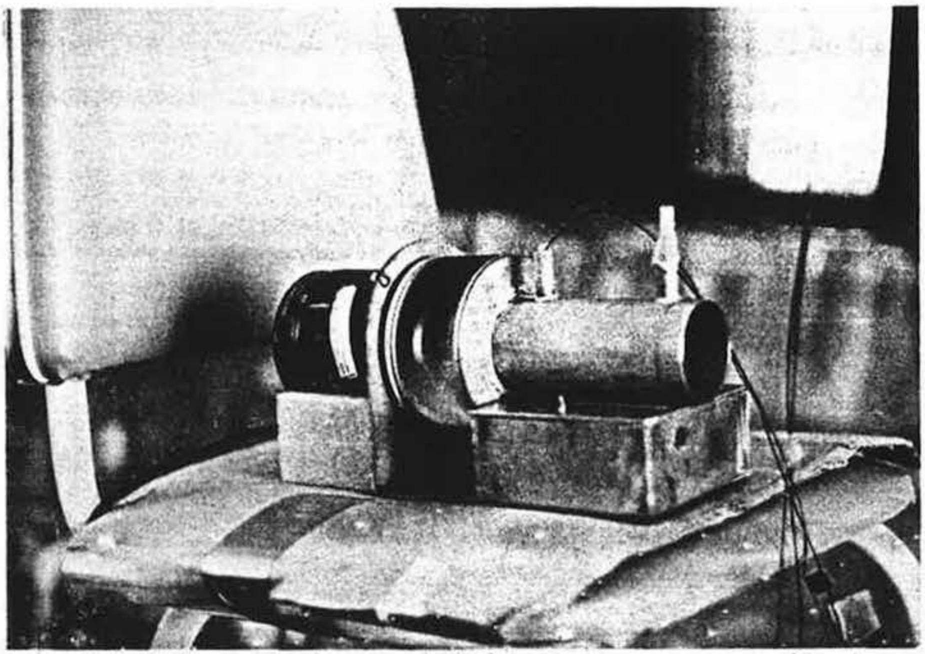


Figure 3.19 Psychrometer

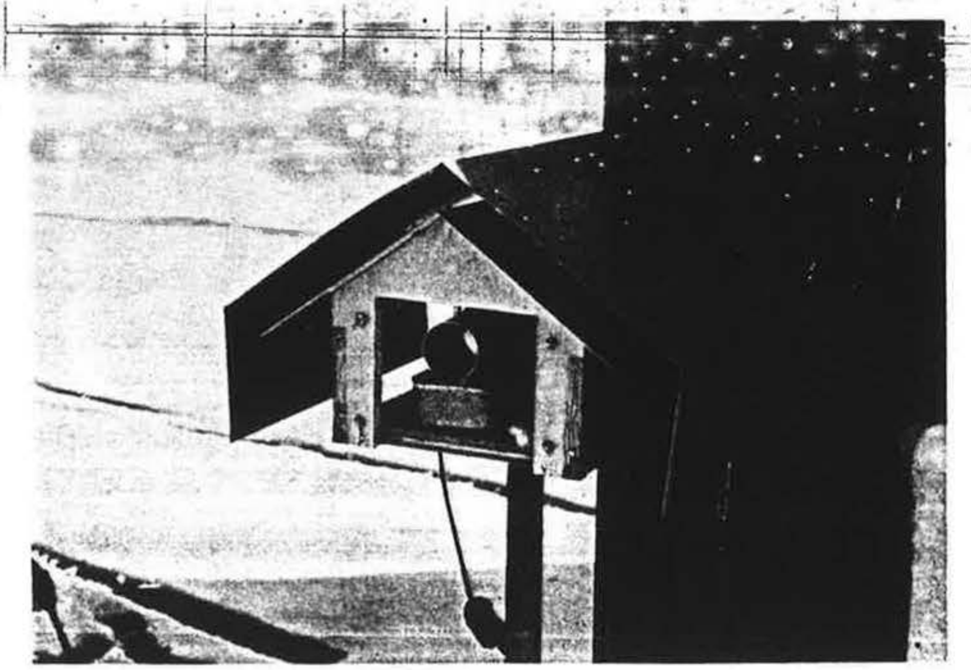


Figure 3.20 Psychrometer shed

Esterline Angus Data Logger with direct voltage to temperature conversion. Each thermocouple had a one microfarad capacitor attached to filter the noise picked up by the thermocouples. The thermocouples were tested in an ice bath and warm water bath (30°C) once a month. Thermocouples off by more than 1°C were repaired or replaced as needed. Most were within 1/2°C. To provide a quick check of dry bulb thermocouples a mercury thermometer was placed in each home which could be read before a test was begun.

The temperatures were measured at the center of each home, about .9m from the floor. Outside temperatures were measured in a small shed near the northeast corner of the instrument shed, 1.2m above the ground. The shed was open on all sides to allow the free flow of air through the shed. See figure 3.20 and 3.21.

In addition to temperatures at the center of the home, temperature profiles could be measured across each wall as part of additional research in energy consumption.[56]

All thermocouples were placed inside a plastic garden hose between the instrument shed and the homes to protect them from the elements.

3.4 Data Recording

All of the data was recorded on an Esterline Angus Data Acquisition System. The system was capable of measuring and recording up to 100 channels, in 5 groups, 20 channels each, from continuously up to once every hour.

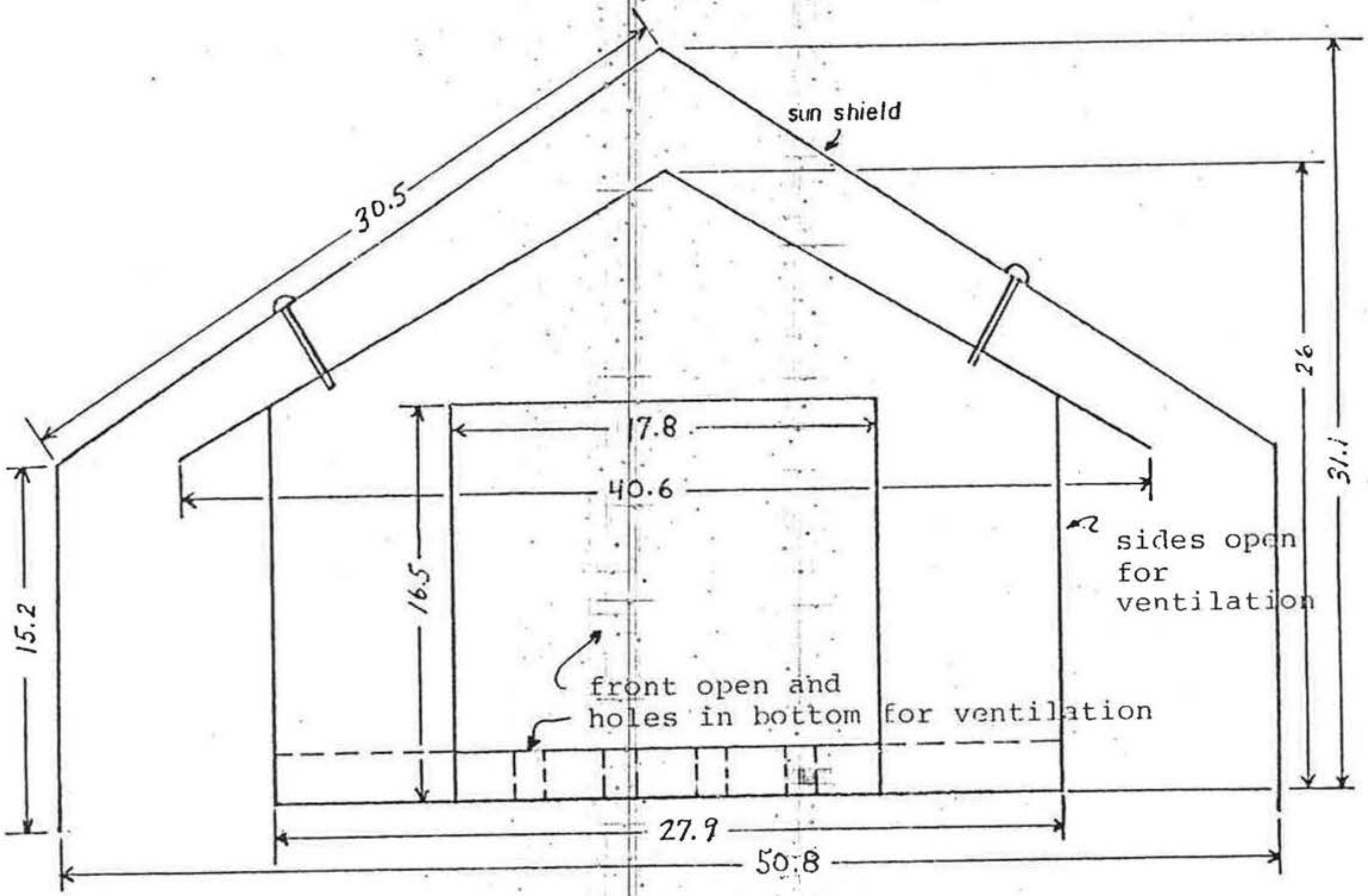


Figure 3.21 Dimensions of the psychrometer shed

Channels were scanned at a rate of 2.4 channels per second. The Esterline Angus had three ranges, 1.0mV, 10.mV, and °C. The millivolt ranges were accurate to .1% full scale or 5μV, whichever was greater. Each range was capable of 200% over range. The temperatures were measured directly without a reference water bath. All the thermocouples were attached to the Esterline Angus under an insulated cover. A thermistor measured the temperature of these junctions and the Esterline Angus produced a compensating voltage. The temperature range was -118°C to 192°C. Accuracy was .2% of scale or .5°C. Output from the Esterline Angus was on both paper tape and 8 channel punched tape. The paper tape could be read directly, the punched tape was read by the computer.[57] See figure 3.22.

Information was recorded on the following channels: 00, blank; 01, wind speed; 02, outside dry bulb temperature; 03, outside wet bulb temperature; 20, CO concentration south home; 21, wind direction; 22, south home dry bulb temperature; 23, south home wet bulb temperature; 40, CO concentration north home; 41, solar radiation; 42, north home dry bulb; and 43, north home wet bulb.

3.5 Electric Consumption

Electric consumption was measured by keeping a daily log of the energy used for each home. Each home had a kilowatt-hour meter with a K_H value of 7.2. K_H = Watt/ Revolution of meter disc. Using the above information, the electric use at any instant could be measured by timing the revolution rate of the meter disc. See figure 3.23.

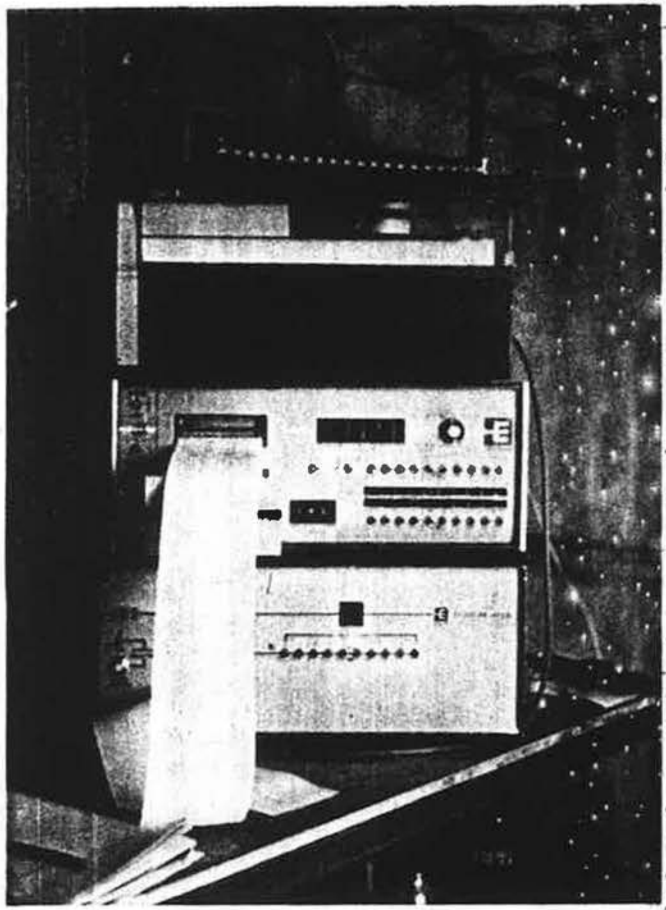


Figure 3.22 Esterline Angus Data Acquisition System

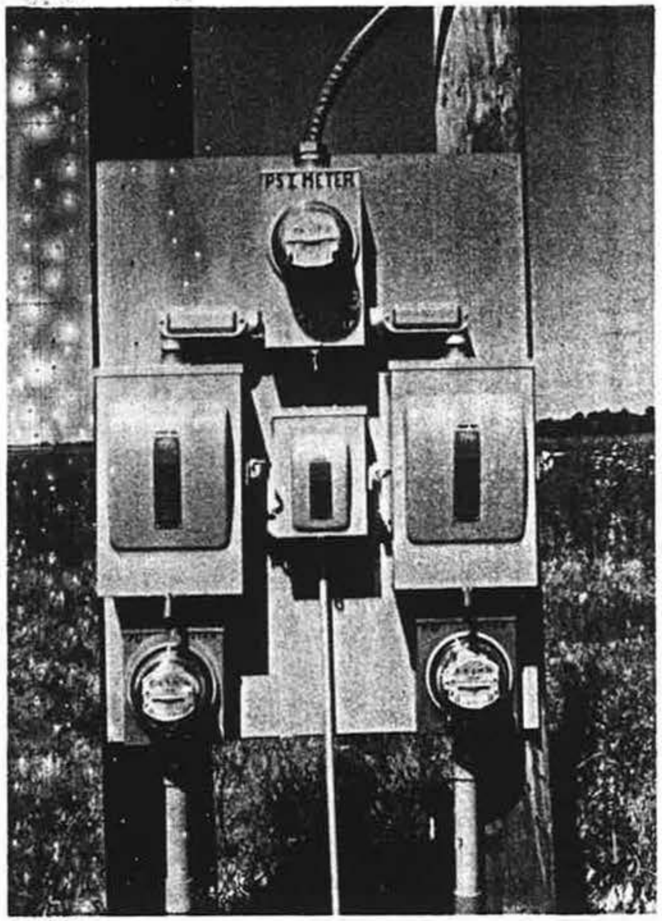


Figure 3.23 Kwatt-hr meters

4 EXPERIMENTAL PROCEDURE AND RESULTS

4.1 Infiltration Measurements

Infiltration measurements were taken for a period of 11 months, from December 7, 1976 to October 29, 1977. Data collection was done over 5 distinct periods: a) winter, homes were unskirted and heated; b) spring, the north home was skirted and the south was not, both homes were heated; c) summer I, homes were skirted and air conditioned; d) summer II, homes were unskirted and air conditioned d) fall, sheathing was removed from the south home. During the fall the homes were alternately skirted and unskirted, air conditioned and heated. See Table 4.1 for significant dates in the project.

4.1.1 Data Collection Procedure

Data collection could start at any time of day. The first step was to prepare the instruments and home for the test, including several safety steps. First the homes were checked to make sure they were unoccupied. The homes were then secured and danger signs were posted.

The carbon monoxide meters were zeroed, connected to the sample taps and the sample solenoids were opened. The valve on the CO bottle was opened, and the regulator was set

Table 4.1 Schedule of setup changes

Event	Day number	Date
SF6 sampler set up		June 1976
CO sampling set up		September 21, 1976
New sampler set up (North home)	316	November 12, 1976
New wind meter installed	324	November 24, 1976
Replaced detector cell for south sampler	341	December 7, 1976
Skirting on north home	71	March 12, 1977
South sampler sent back for repairs	76	March 17, 1977
Skirting on south home	118	April 28, 1977
Air conditioner started	118	April 28, 1977
South sampler reset	130	May 10, 1977
Skirting off both homes	193	July 12, 1977
Detector cell bad north sampler	206	July 25, 1977
Replaced detector cell in north sampler	220	August 8, 1977
Detector cell bad south sampler	237	August 25, 1977
Replaced detector cell for south sampler	238	August 26, 1977
Sheathing off south home	247	September 4, 1977
Skirting on north home	281	October 8, 1977
Skirting on south home	289	October 16, 1977
End of data collection	302	October 29, 1977

to 10 psig. Carbon monoxide was then injected for approximately 90 seconds. This would give CO levels from 120 to 130 ppm. Next the wind direction indicator was turned on and zeroed. The Esterline Angus data logger was set to read the correct channels for concentration and weather parameters, and the automatic reinjector system was set. Time settings chosen for reinjection were from 30 to 50 seconds depending mostly on wind speed. During the summer, it was found that reinjection could take place at much longer intervals, 4 to 6 hours, and the automatic reinjection system was no longer used. With the reinjector set, the time period for data collection was chosen, 5 minutes for winds under 7 m/s, 2 minutes for higher wind speeds. After the first frame of data had been printed, it was read and checked for correctness. The paper punch was started, and the Esterline Angus was set to send the data to the paper punch. At this point, the operator was free to leave for as long as paper quantities in the Esterline Angus and paper punch would allow; up to 24 hours or more, if the automatic reinjection system was used. If not, the operator would have to return every 4-6 hours to reinject manually.

Carbon monoxide levels were usually kept in the 50-100 ppm range. Should the automatic injection system over inject, it was equipped with a level switch, which would close a safety solenoid in the injection line when even one of the homes reached a level of 200 ppm.

Before the operator left, two other small chores were performed: he read the kilowatt-hour meters, and emptied the condensate collecting cans. Condensate was collected as part of a test discussed in appendix A.

Upon returning after each test, several jobs were required of the operator. First, the CO meters were disconnected from the sample taps and fresh air was run through them for several minutes. The valve on the CO bottle was closed and the automatic injection system was shut off. The Esterline Angus was set so that no further data would be taken. The paper tape punch was turned off. The wind direction meter was switched off. The CO meters were set to zero position and the drift of the zero reading was read and recorded. The tapes were removed from the Esterline Angus and the paper punch and labeled. The label consisted of the number of the day in the year and time in hours when the run was started. Also recorded on each tape were peculiarities such as rain, or snow during a run. Later on in the tests, it was realized that south winds could not be measured correctly so this was recorded also.

At this point, the operator was free to leave, or to start another run. If a second run was started only the steps taken above to rezero and reset the instruments would be required. Danger signs were removed from the homes only if the final concentration of CO was less than 50 ppm.

4.1.2 Data Reduction

At this point in time, the punched tape was rewound, then taken to the computer center and submitted at the operations desk. After the tape was taken to the tape readers, it was read onto cards which were used later for further data reduction. All computer programs used for data reduction are shown in appendix B. The computer printout of the data was then checked against the printed output from the Esterline Angus for correctness. This was required because of errors in reading the tape and in the tape itself.

With this done, all concentration data points above 10 ppm were plotted, the natural log of concentration against time. Below 10 ppm errors became extremely large and the data meaningless. A typical graph of the data is shown in figure 4.1. Almost immediately it was seen that certain sections of the data fell on straight lines. Since both homes had similar responses at the same time, it was concluded these changes were the result of a change in controlling mechanisms rather than equipment error. These sections were then chosen by hand (see figure 4.2.) and the starting and stopping points were punched on data cards which were used with the data reduction program (Appendix B). Also note from figure 4.2 that data reduction did not start with the first concentration data points. A positive amount

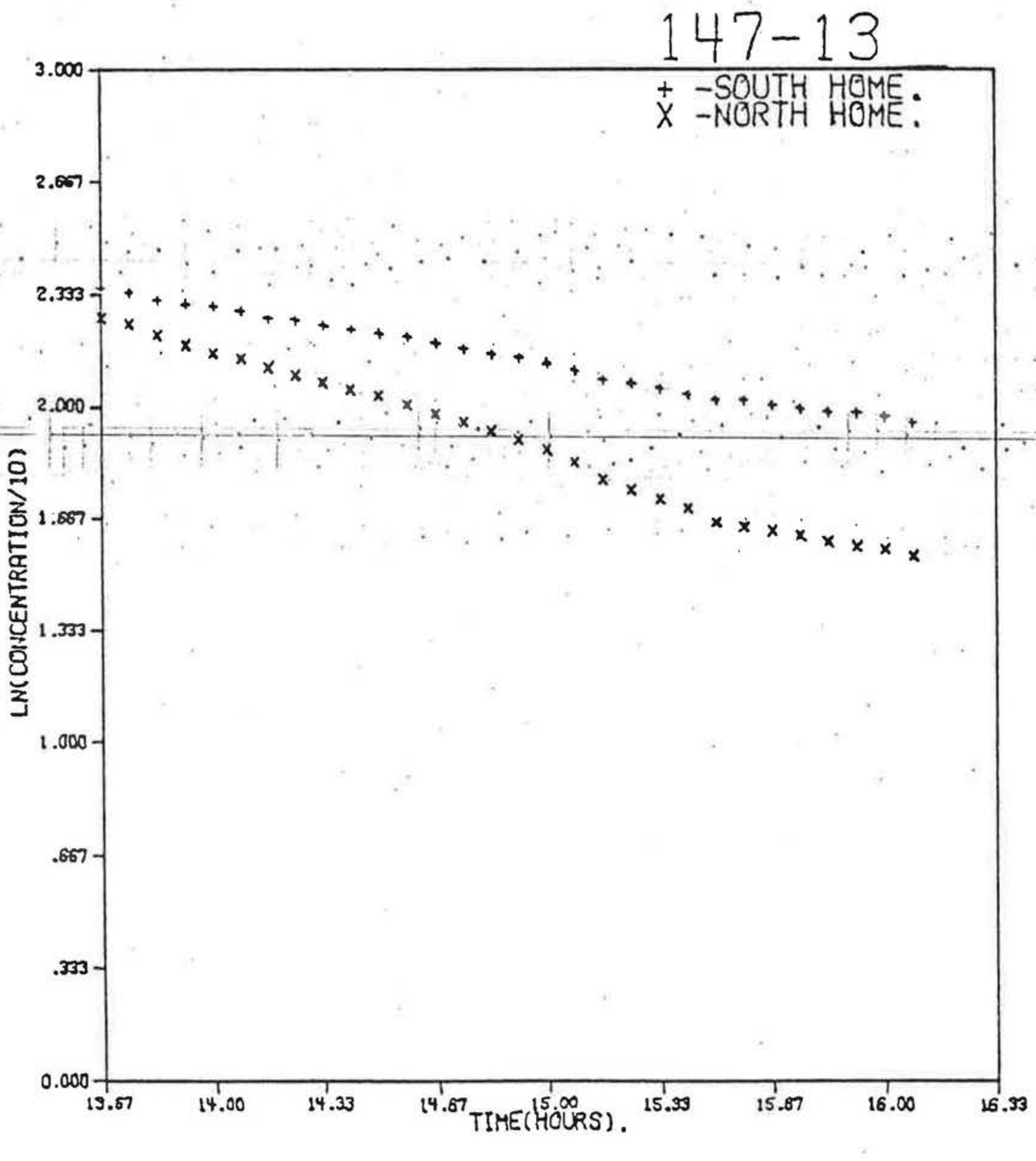


Figure 4.1 Typical plot of concentration data

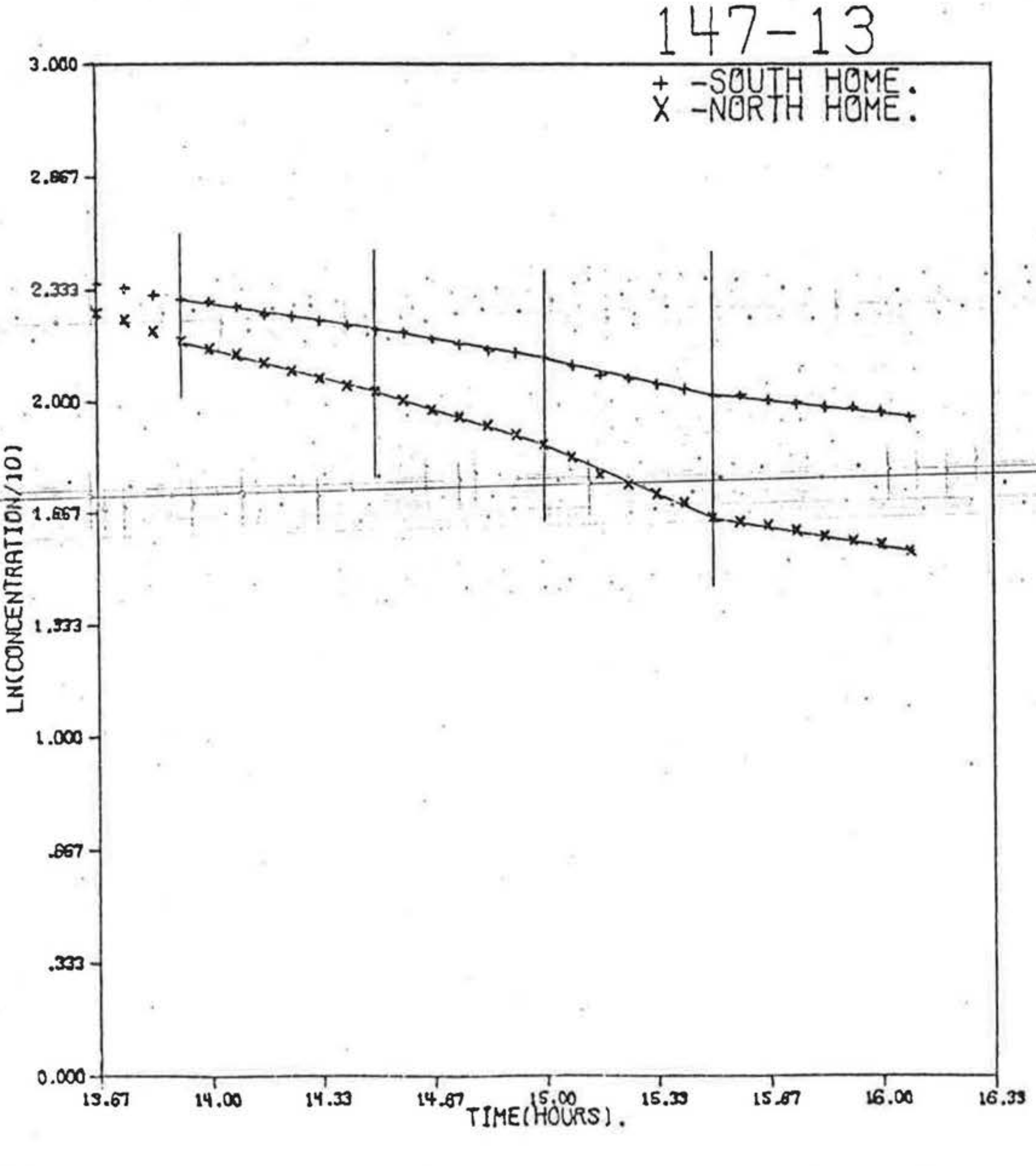


Figure 4.2 Division of concentration data into time periods

of time was needed for the mixing of the CO in the homes and for the stabilization of the CO meters. Mixing took about 10-15 minutes. Stabilization of meters could take as long as 30 minutes when the CO meters were first started. The meter on the south home, which was older, usually took longer to stabilize than the meter on the north home.

The data reduction program (appendix B) fitted the best straight line, $\ell nC = \ell nC_o - It$, to each of the concentration curves for the preselected time intervals, to find I. The program then averaged the weather data for the same time period, and found the errors in the values of I and the standard deviation for each of the weather parameters. If different time intervals were used to calculate I, as was required sometimes by errors in the measurements, the longest time period was used to calculate the average of the weather parameters. Wind direction created a special problem in the averaging routine. Wind direction could take on values of both 0 or 360° for south. This was handled by comparing each new point with the average value of the previous points. If the value changed by more than 180°, 360° was added to the new point if it was low, or subtracted if it was high. The values calculated by the program were printed and punched. The printed values provided for direct evaluation. The punched output was used for further statistical studies. The complete set of infiltration data is given in appendix C.

4.1.3 Error in Measurements

Errors in the measurement of infiltration could be due to a) incomplete mixing of the tracer or b) errors in measurement of tracer concentration and time.

The assumption of perfect mixing could result in values being too high or too low. The two extremes might be a) the fresh air enters the home and drives out the air-tracer mixture in the home without mixing with it or b) the fresh air passes through the home without mixing with the air-tracer mixture in the home. In the first case all of the tracer would be gone in one air change, instead of being reduced by 63% as otherwise predicted. In the second case, no infiltration would be measured. See reference 27 for a complete discussion. While both of the above extreme cases were unlikely, similar types of errors at small magnitudes were possible. Examples would be areas of high air flow due to infiltration and dead spots due to air trapped in closets and drawers in cabinets. Hitchin (in reference 52) and Prado found that assuming complete mixing was generally acceptable. Any large errors in incomplete mixing would have been seen in that the natural log of the concentration would no longer produce a straight line when plotted against time.

Little error exists in the measurement of time, whereas considerable error in the measured concentration could result due to zero drift and nonlinearities of the equipment.

Finding the possible errors due to nonlinearities and zero drift was a problem in that they could not be identified directly. Zero drift was measured after each run, but that drift occurred nonuniformly at any time over the run; the maximum rate of zero drift was not determined. During one particularly long run, when the homes ran out of CO, it was noted that zero drift usually occurred in one direction over a period of about 2 hours, and that zero drift could occur in both directions during one test. In order to determine the maximum error in I attributed to zero drift, the assumption was made that the error in measuring an individual concentration level after injection was given by E_c equal to the zero drift.

Defining the error in infiltration, E_i, as the difference between the true value of infiltration, I, and the measured infiltration, I_m, divided by measured infiltration

$$E_i = \frac{I - I_m}{I_m} = \frac{\frac{1}{t}\ell n\frac{C_o}{C_m - E_c} - \frac{1}{t}\ell n\frac{C_o}{C_m}}{I_m}, \qquad (4.1)$$

which reduces to:

$$E_i = \frac{1}{tI_m}\ \ell n\frac{C_m}{C_m - E_c}. \qquad (4.2)$$

Errors calculated this way generally overpredict the true errors involved.

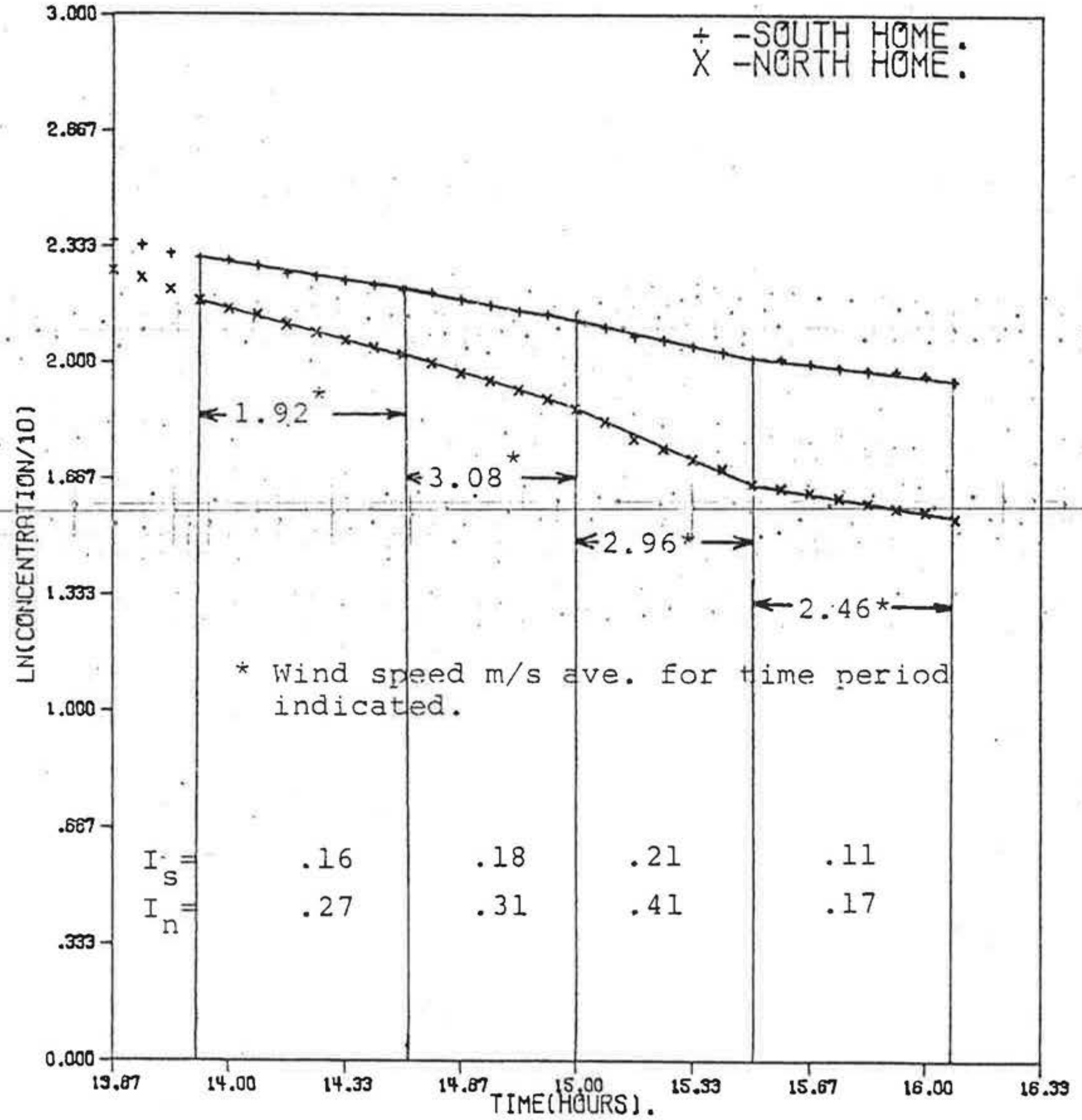
The zero drift was measured after each run. Based on it, and using equation 4.2, the expected errors could be determined. Selected ones are given in Table C6. Given also, are the standard deviations of the weather parameters. (Comparison of the expected error to data scatter is shown in section 4.2.4.)

4.2 Results of Infiltration Study

Overall 885 infiltration points were obtained for the winter, spring, and summer. Another 162 were obtained for fall. Of these points, 360 were for a skirted north home, 202 for a skirted south home.

4.2.1 Wind Effects

Almost immediately, the effects of wind upon infiltration became apparent. In figure 4.3 infiltration and wind speed are shown for one run. The infiltration follows the wind speed fairly well. This plot is typical of the data taken. Figure 4.4 shows the effect of changes in wind speed (increasing from 2.4 m/sec to over 8 m/sec) as well as temperature difference (decreasing from 20°C to 10°C). During this time, infiltration increased from .13 to .83 and from .33 to 1.50 for the south and north homes, respectively. This larger dependence on wind speed than on temperature difference can be seen. But, as data collection proceeded from the cold winter months to the warmer spring months infiltration rates at comparable levels of wind speed steadily decreased, indicating a dependence on



* Wind speed m/s ave. for time period indicated.

Figure 4.3 Data taken on day no.147, May 27,1977

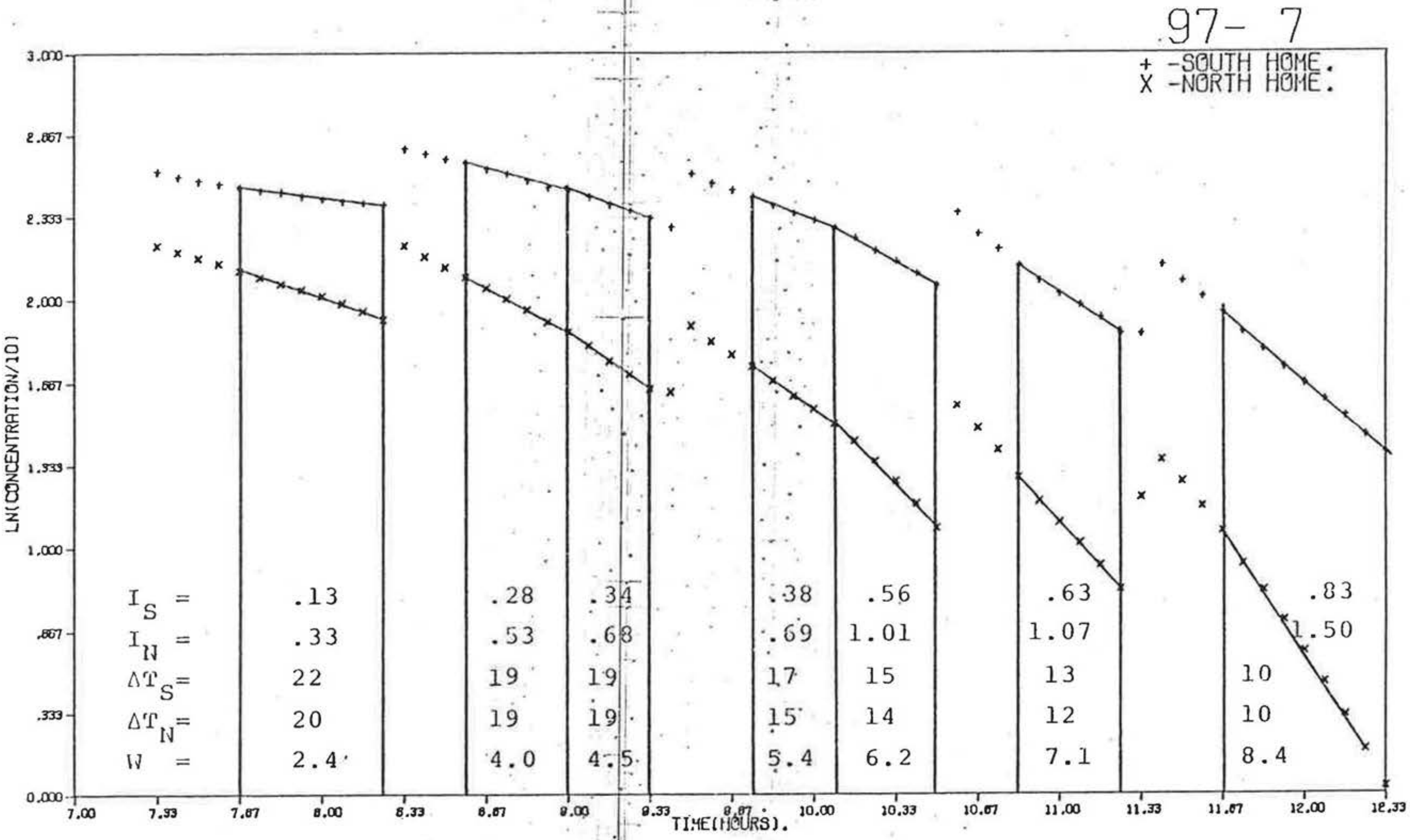


Figure 4.4 Data taken on day no. 97, April 7, 1977

temperature as well. Since the effect of wind on infiltration was much larger than temperature difference effects the effect of wind speed on infiltration was examined for different ranges of temperature difference. Ranges of temperature difference chosen were always less than 10°C and usually 7°C or smaller. Ranges were chosen so that sufficient data would be available in each range to produce a good plot. As will be discussed in the next chapter, the effects of skirting were small so all the data (except fall) was included in the graphs of I vs. W for given ranges of ΔT. Graphs are presented in figures 4.5 - 4.15. From the graphs, it can be seen that a) the infiltration rates are much higher in the north home, b) the dependence is not linear, but can be represented by a squared term in W, and c) the skirted and non-skirted data fall on the same general curve. Each of the curves was fitted with the equation

$$I = A + CW^2. \qquad (4.3)$$

The coefficients are given in table 4.2 along with the 95% confidence interval. (The 95% confidence interval is the interval that has a 95% probability of containing the true value of the coefficient.)

4.2.2 Temperature Effects

With the wind effects determined, the next step was to find the dependence of infiltration on the temperature difference. Since the effects of wind were much greater

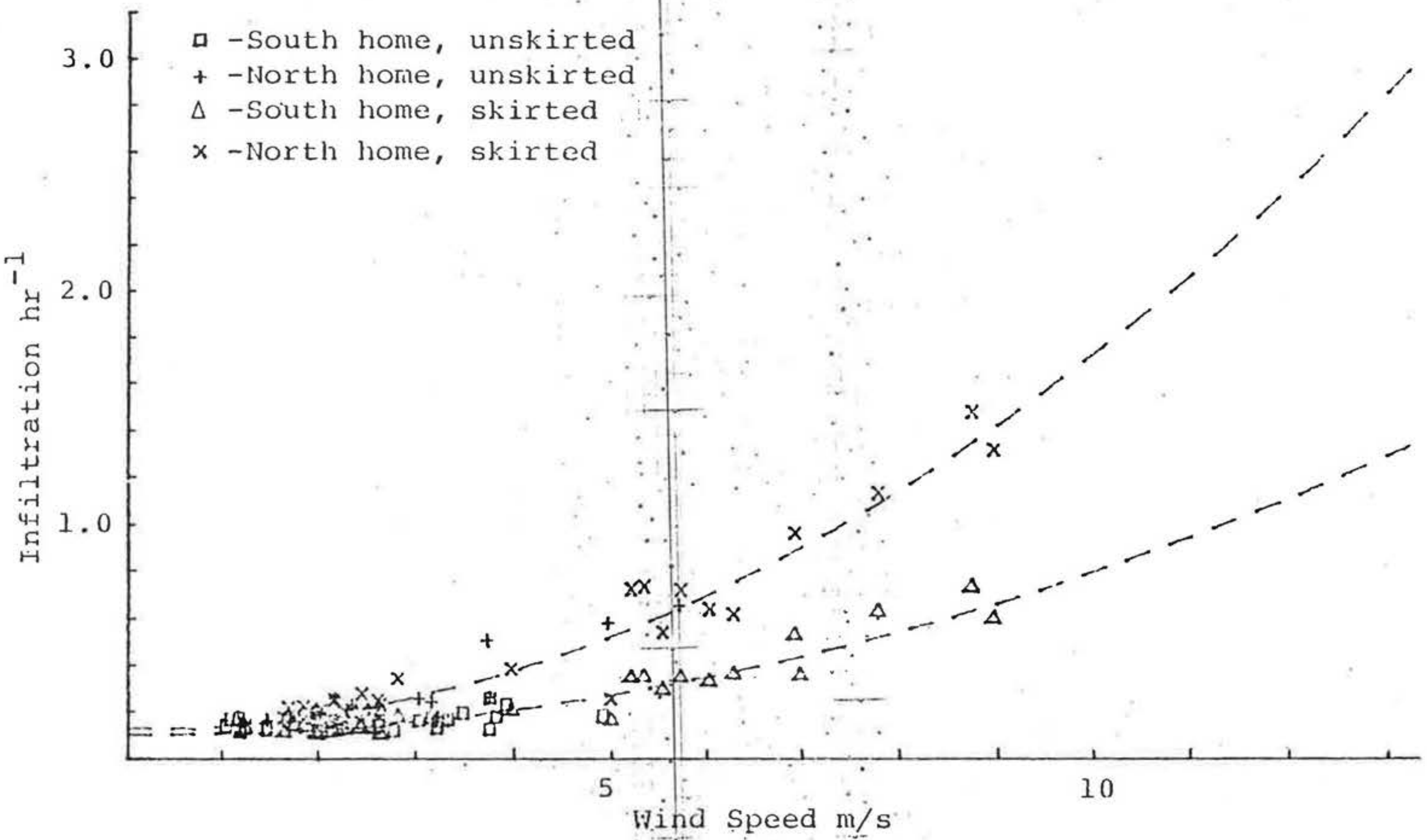


Figure 4.5 Infiltration vs. wind speed, -18<ΔT<-9 °C

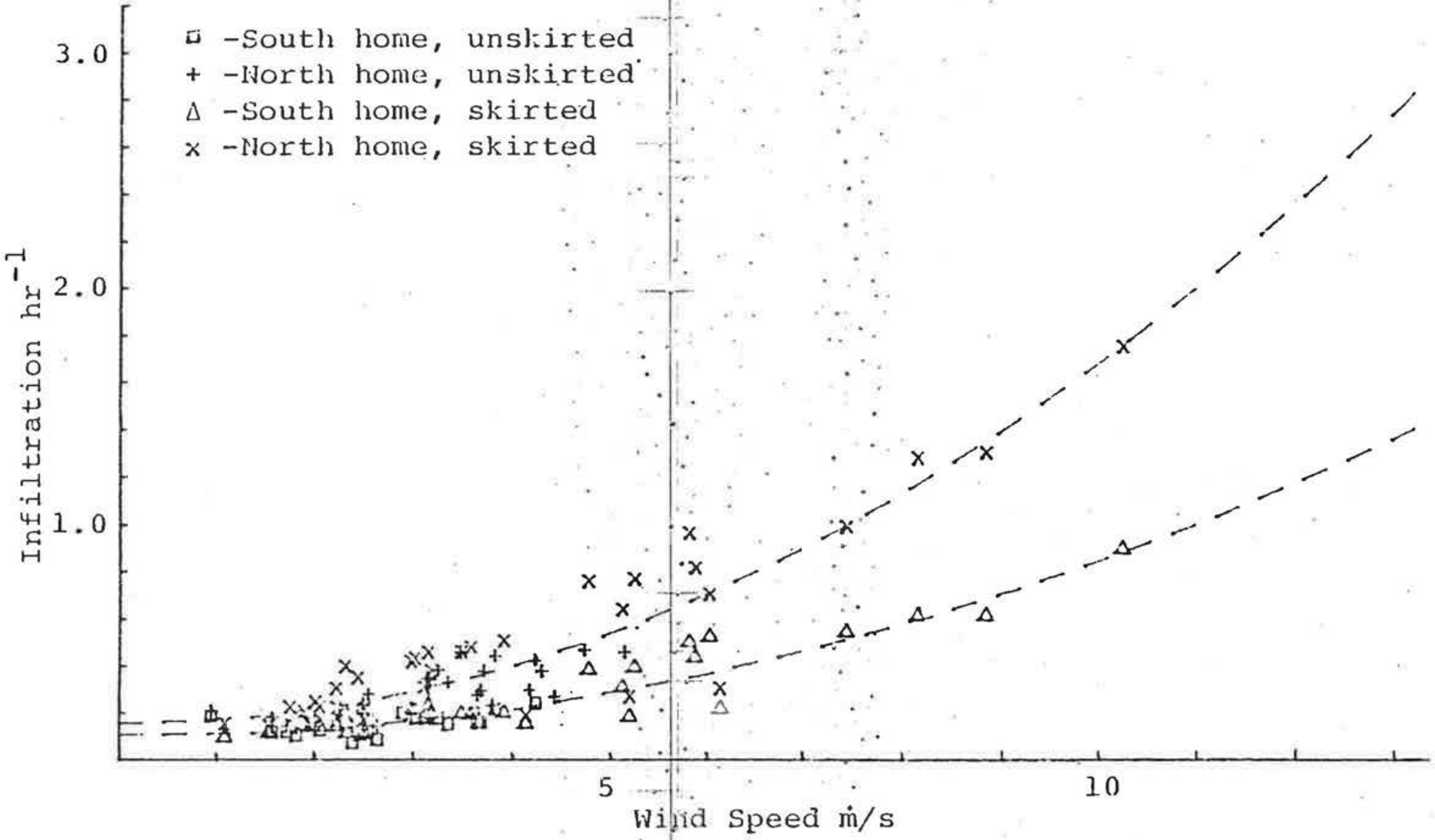


Figure 4.6 Infiltration vs. wind speed, $-9<\Delta T<-7$ °C

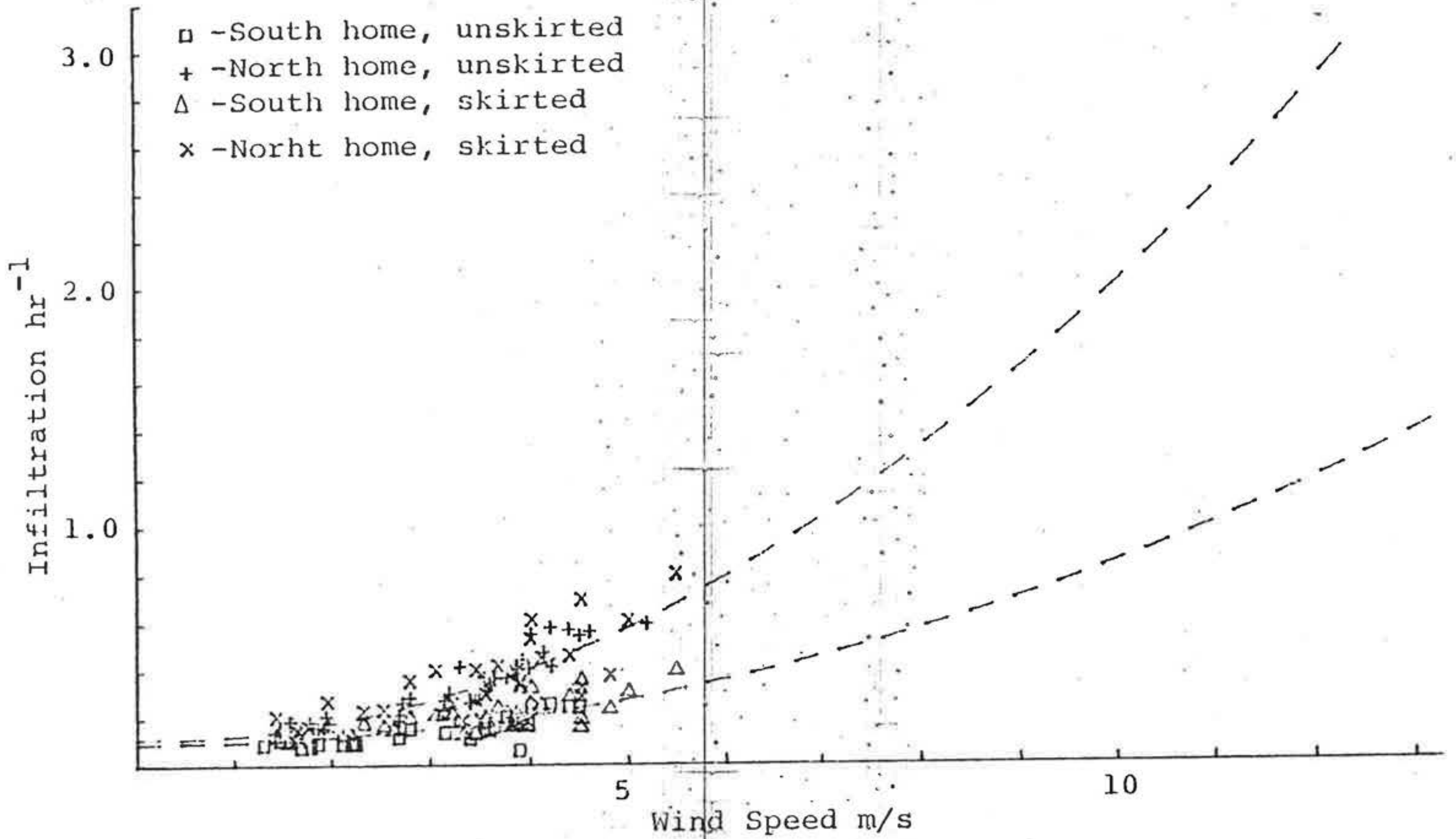


Figure 4.7 Infiltration vs. wind speed, -7<ΔT<-5 °C

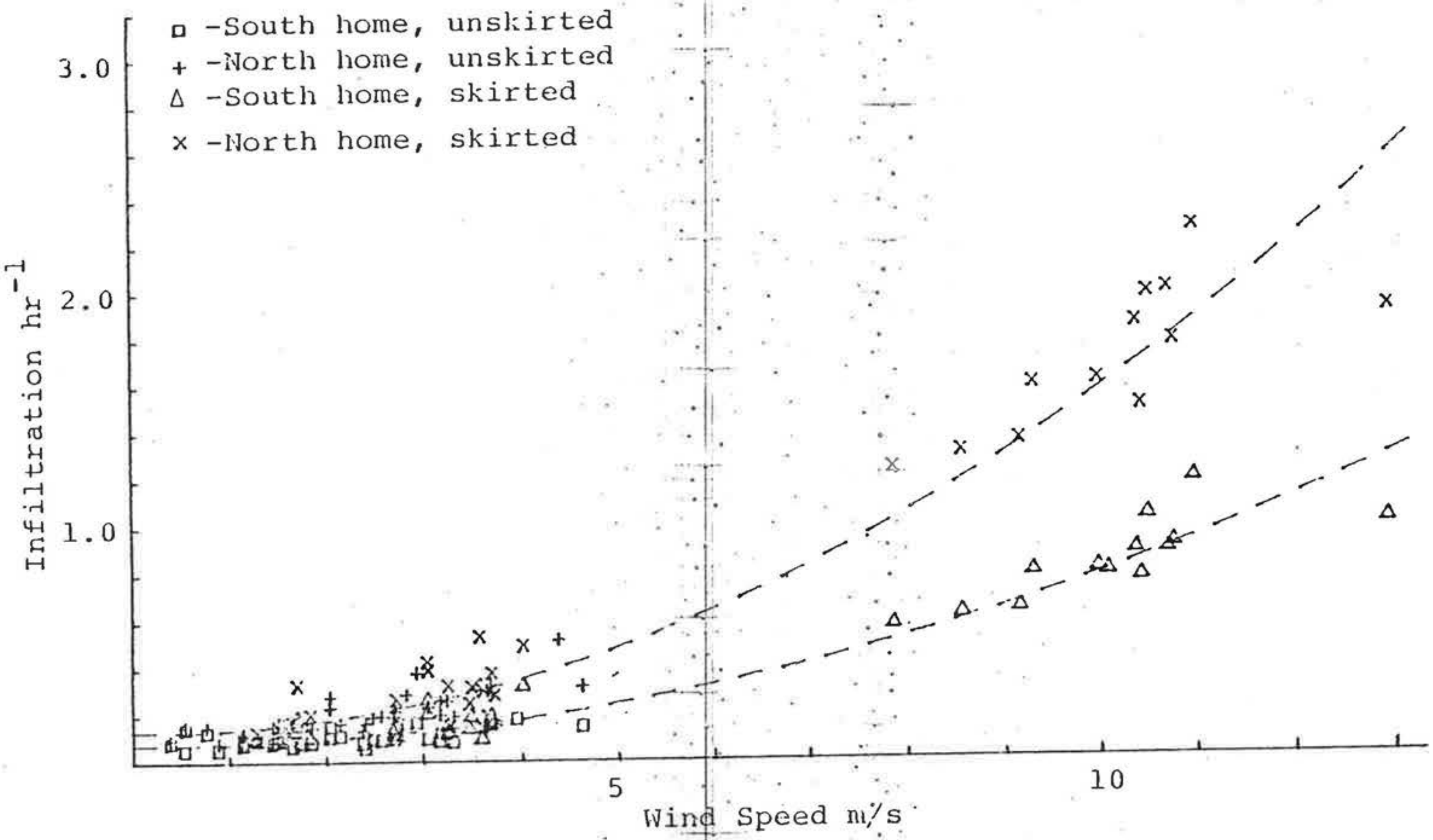


Figure 4.8 Infiltration vs. wind speed, -5<ΔT<-2.5 °C

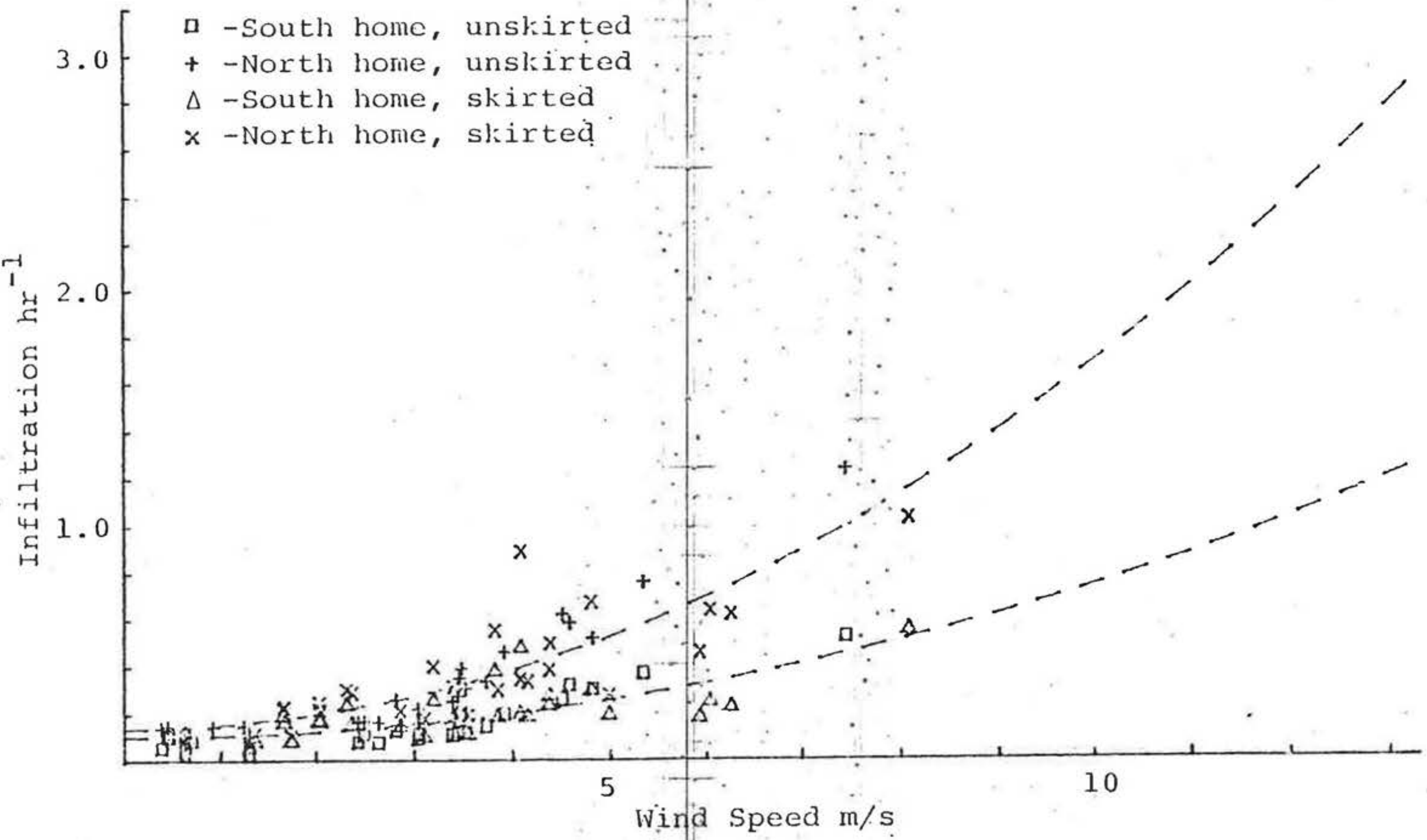


Figure 4.9 Infiltration vs. wind speed, -2.5<ΔT<2 °C

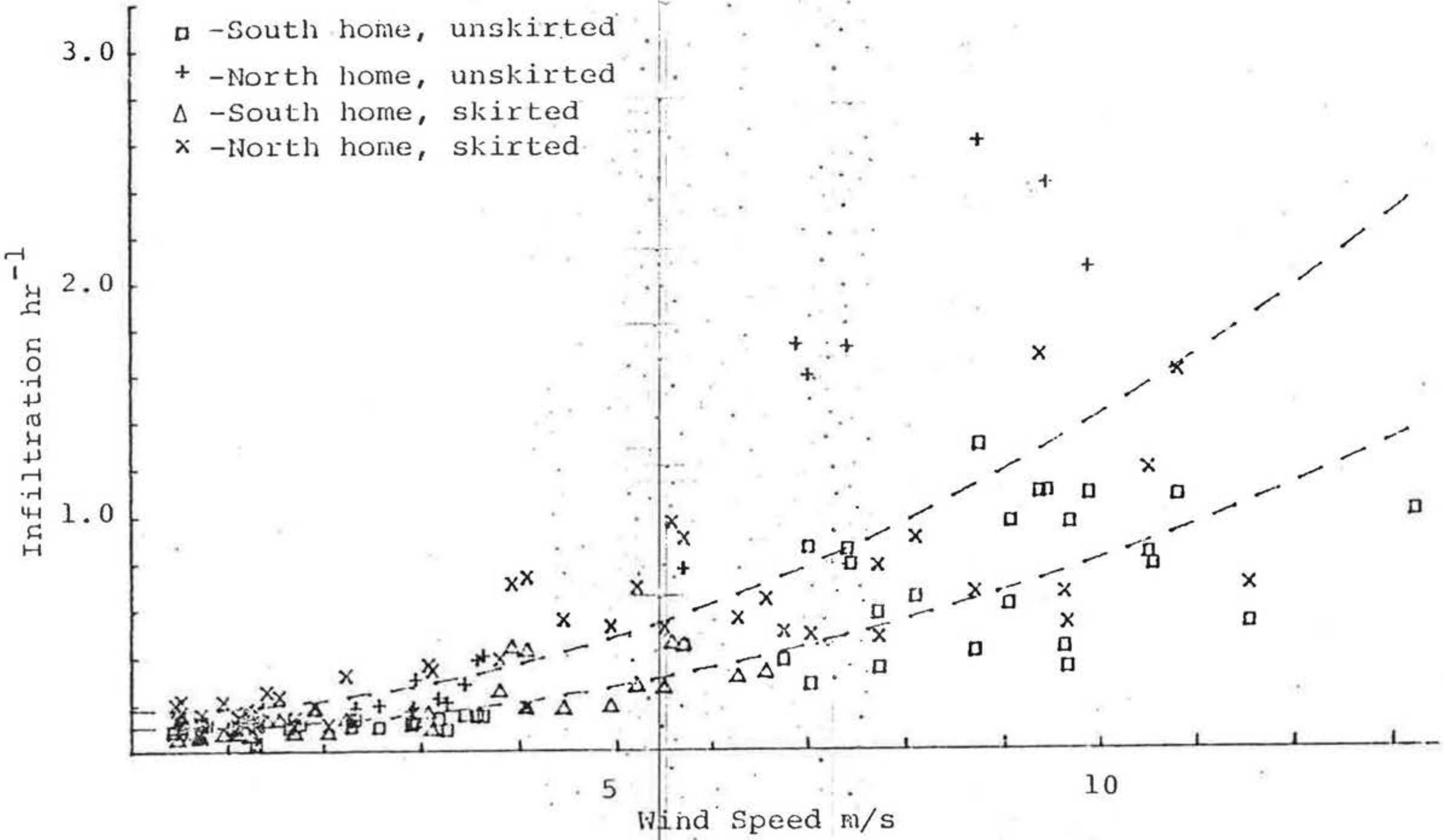


Figure 4.10 Infiltration vs. wind speed, 2<ΔT<9 °C

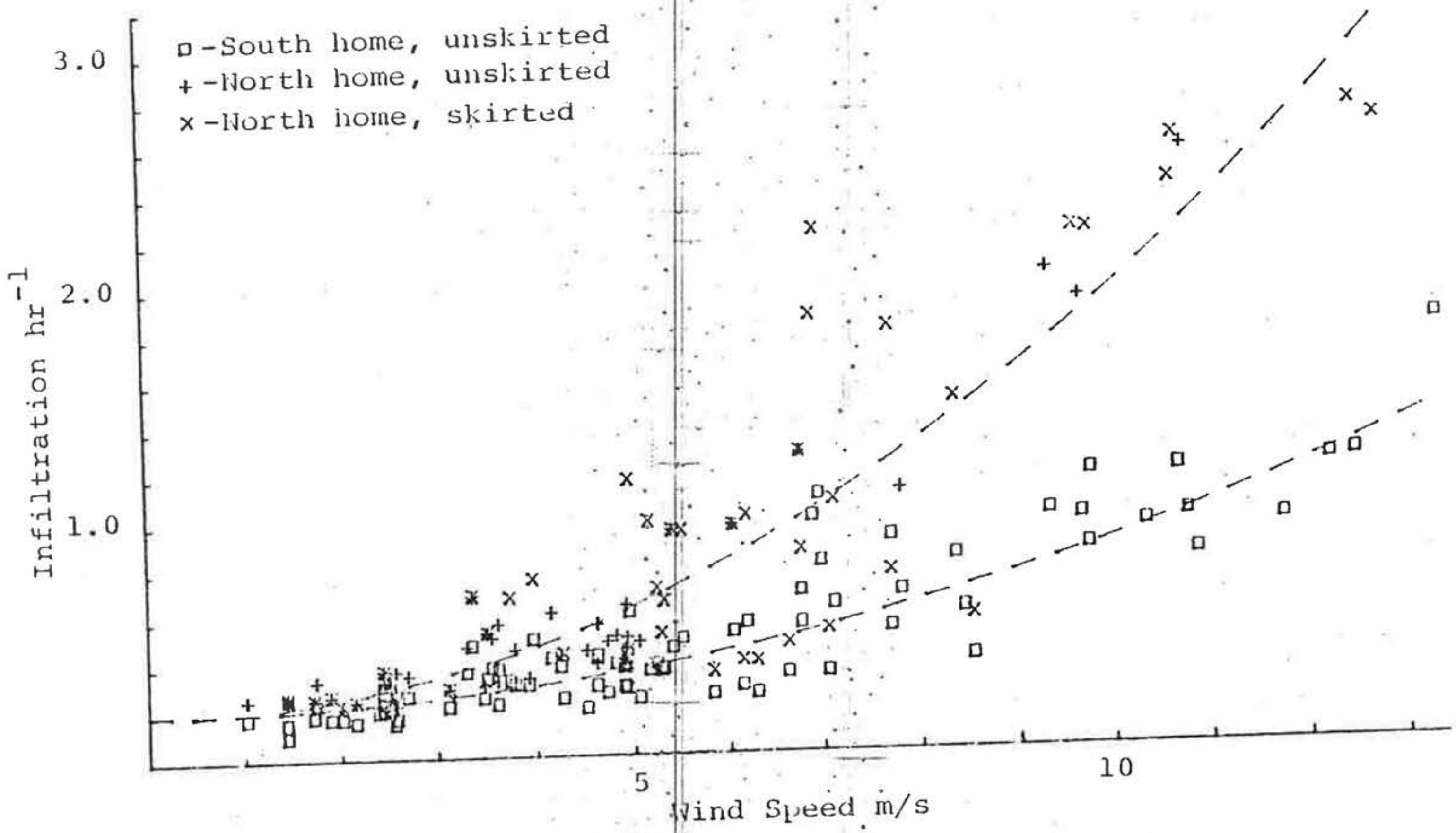


Figure 4.11 Infiltration vs. wind speed, 9<ΔT<16 °C

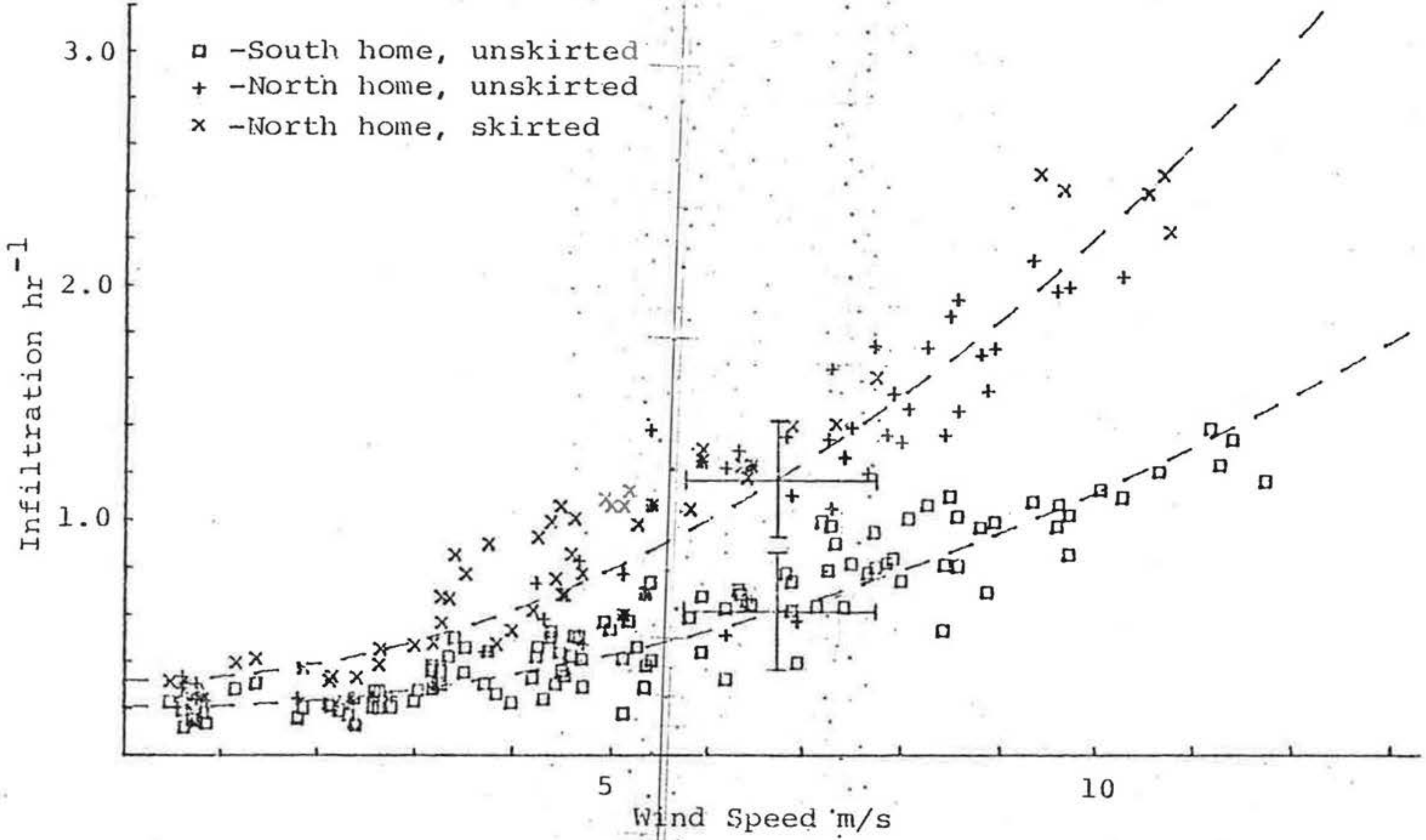


Figure 4.12 Infiltration vs. wind speed, 16<ΔT<23 °C

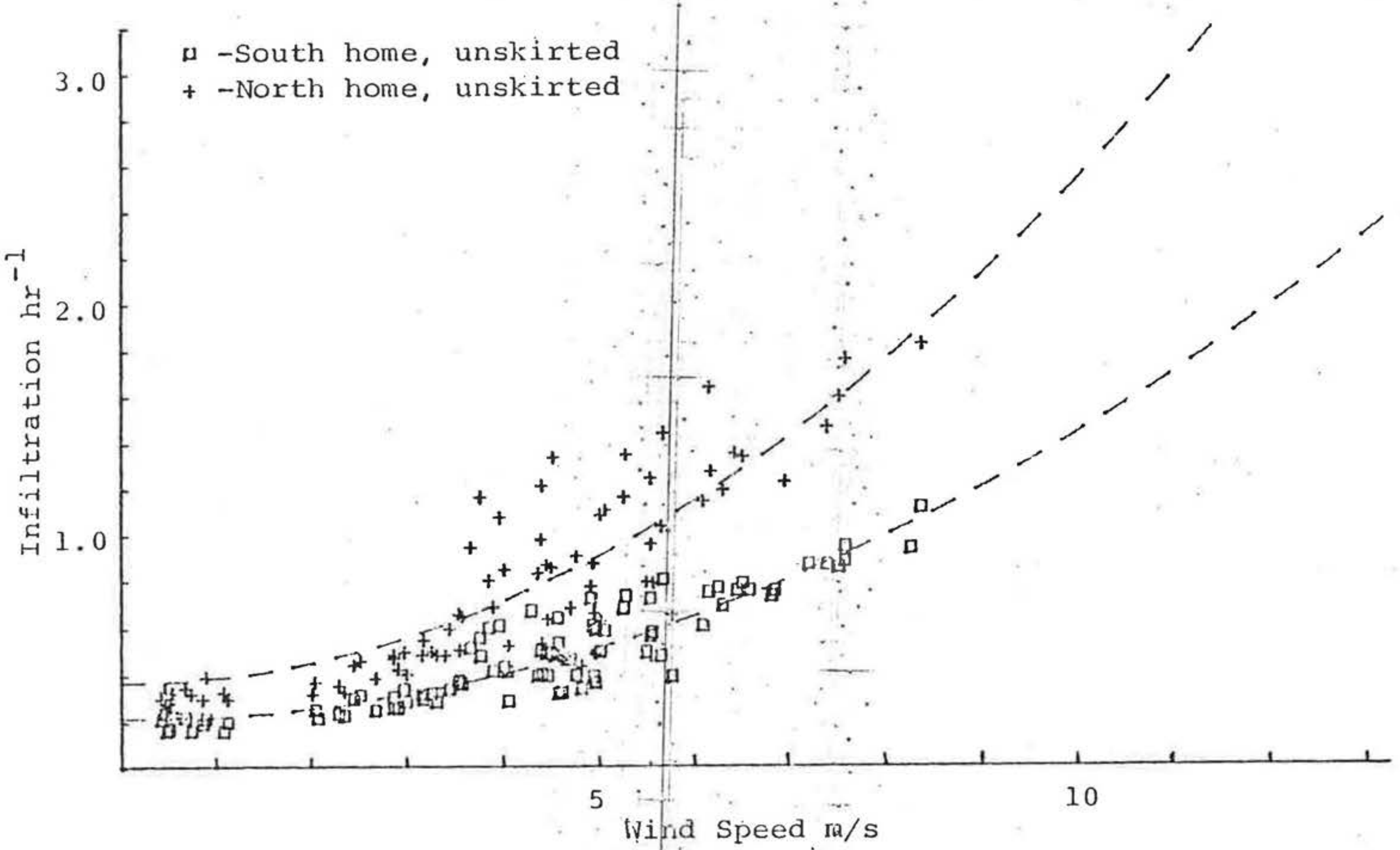


Figure 4.13 Infiltration vs. wind speed, 23<ΔT<30 °C

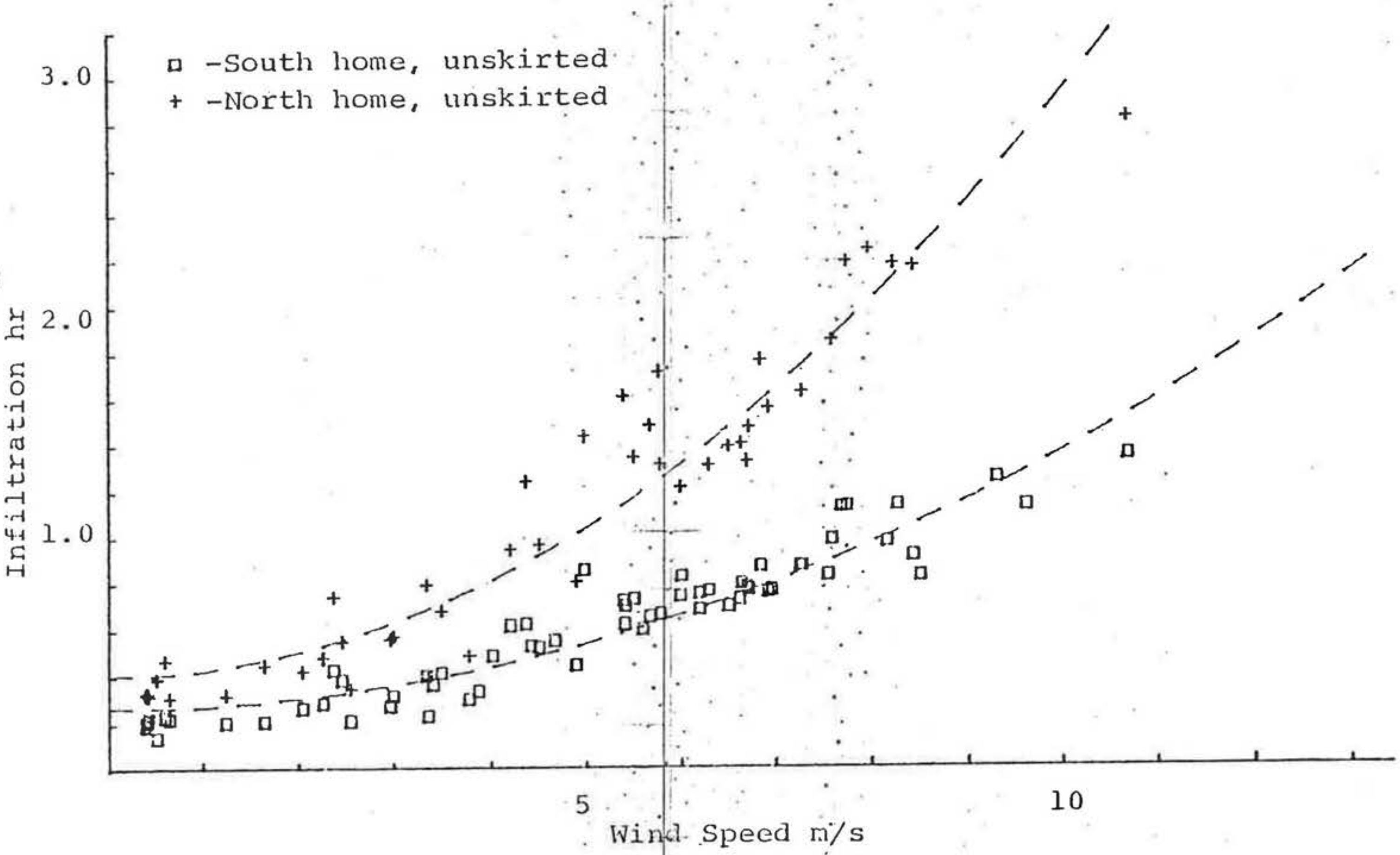


Figure 4.14 Infiltration vs wind speed, 30<ΔT<37 °C

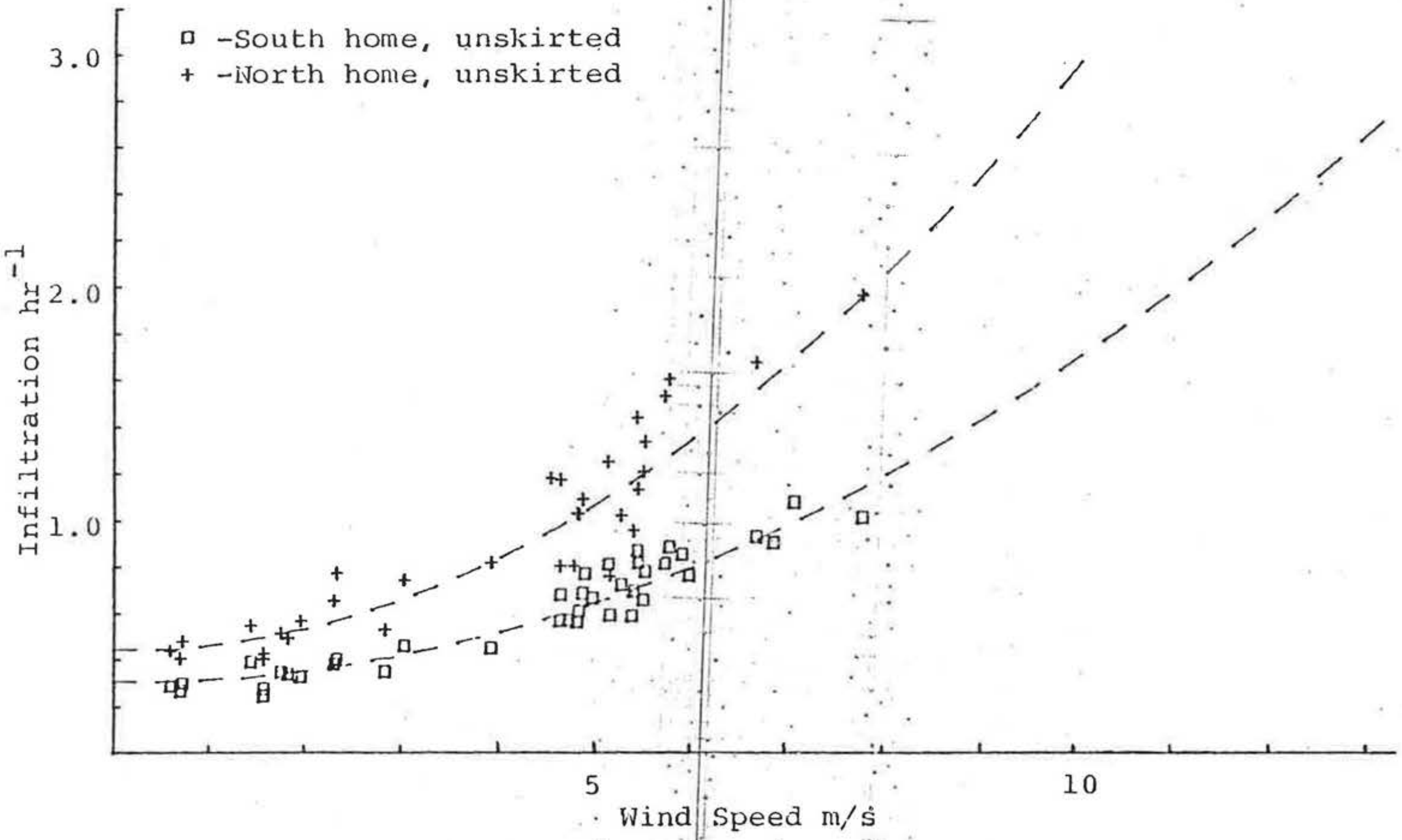


Figure 4.15 Infiltration vs. wind speed, 37<ΔT<44 °C

Table 4.2 Coefficients for $I = A + CW^2$

Temperature range		North home				South home			
T_h	T_ℓ	A	ε_A	C	ε_C	A	ε_A	C	ε_C
-18	-9	.126	.0224	.0162	.00104	.101	.0117	.00711	.000520
-9	-7	.163	.0355	.0153	.00132	.107	.0183	.00746	.000691
-7	-5	.109	.0347	.0191	.00262	.090	.0103	.00761	.000576
-5	-2.5	.126	.0328	.0145	.00073	.072	.0152	.00711	.000337
-2.5	2.0	.143	.0448	.0156	.00199	.102	.0234	.00651	.001381
2.0	9.0	.177	.0893	.0124	.00179	.102	.0362	.00711	.000716
9	16	.195	.0679	.0177	.00137	.202	.0378	.00686	.000641
16	23	.324	.0436	.0188	.00188	.207	.0249	.00916	.000526
23	30	.347	.0444	.0226	.00207	.216	.0186	.01231	.000811
30	37	.403	.0697	.0253	.00193	.268	.0328	.01101	.000811
37	44	.446	.0676	.0251	.00290	.303	.0352	.01386	.001321

Units

Temperatures--°C

A --cph

C --cph s^2/m^2

than the effects of temperature difference the effects of wind had to be eliminated. This was first done by looking at only conditions with low wind speed and later at specific values of wind. Originally, attempts at finding temperature dependence by turning off the heating elements of the furnace and allowing the temperature of the home to drop, changing the temperature difference were conducted. This was done by attaching switches to the furnace thermostats. The switches were turned off, effectively disconnecting the thermostat from the furnace. Such runs were made on days 350 and 351, 18 and 39. The plot of the concentration values for day 350 is shown in figure 4.16. Infiltration values of day 350 and 39 with winds less than 1.8 m/sec are plotted against ΔT in figure 4.17. An increase of I with ΔT is noted. Days 19 and 351 were not plotted; the higher winds effected the data sufficiently that the temperature dependence could not be seen (table C1).

To determine the effect of temperature difference infiltration data with wind speed less than 1.4 m/s was plotted against temperature difference. The plots are given in figures 4.18 and 4.19. From these figures it can be seen that: a) the dependence of I on ΔT is approximately linear, b) for low values of W, I depends on |ΔT| not ΔT, c) the infiltration values do not go to zero as ΔT goes to zero even for low wind speed, and d) the infiltration rates are higher for the north home. In figures 4.20 and 4.21, infiltration is plotted against the absolute

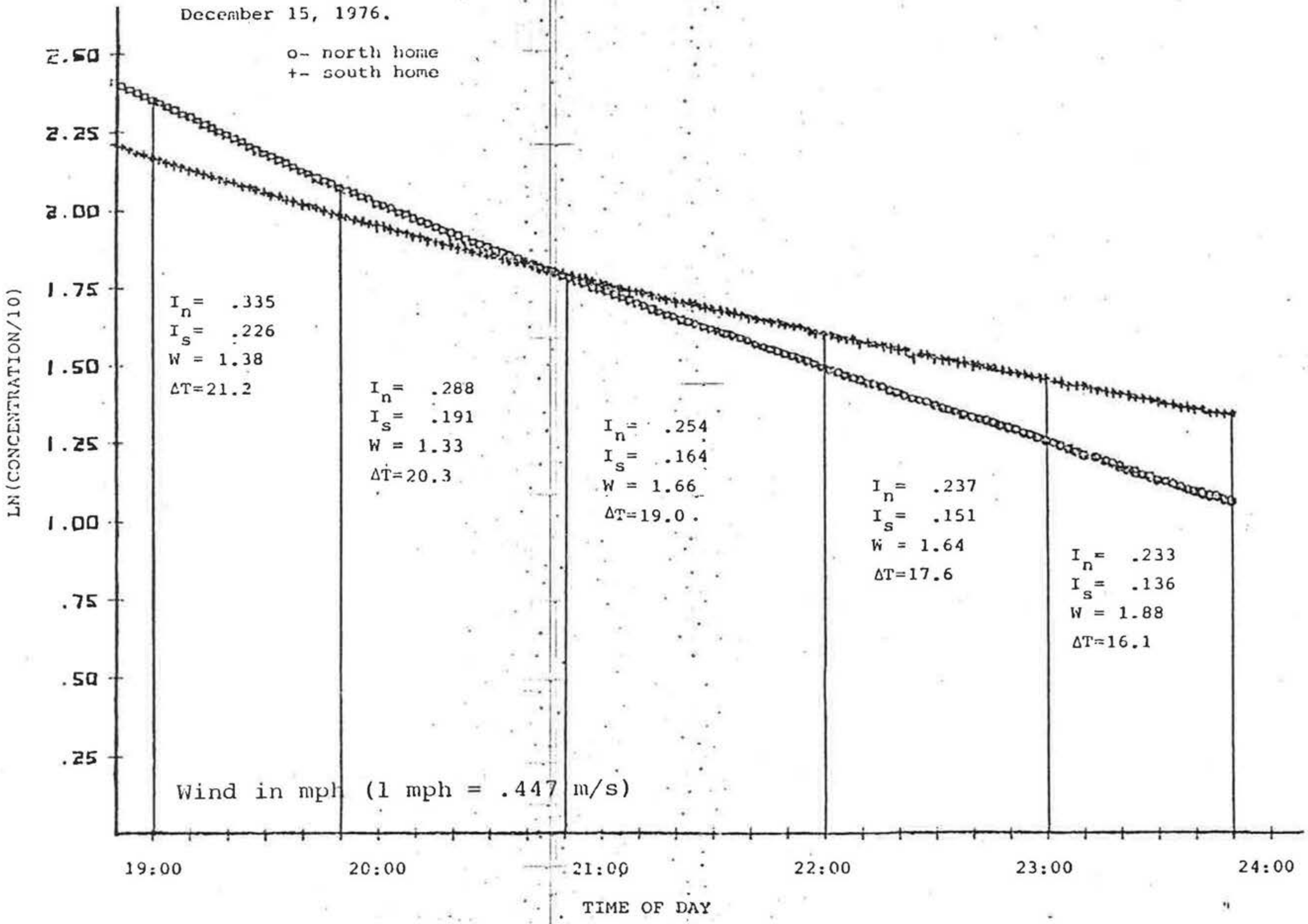


Figure 4.16 Data taken on day 350, Dec. 15, 1976

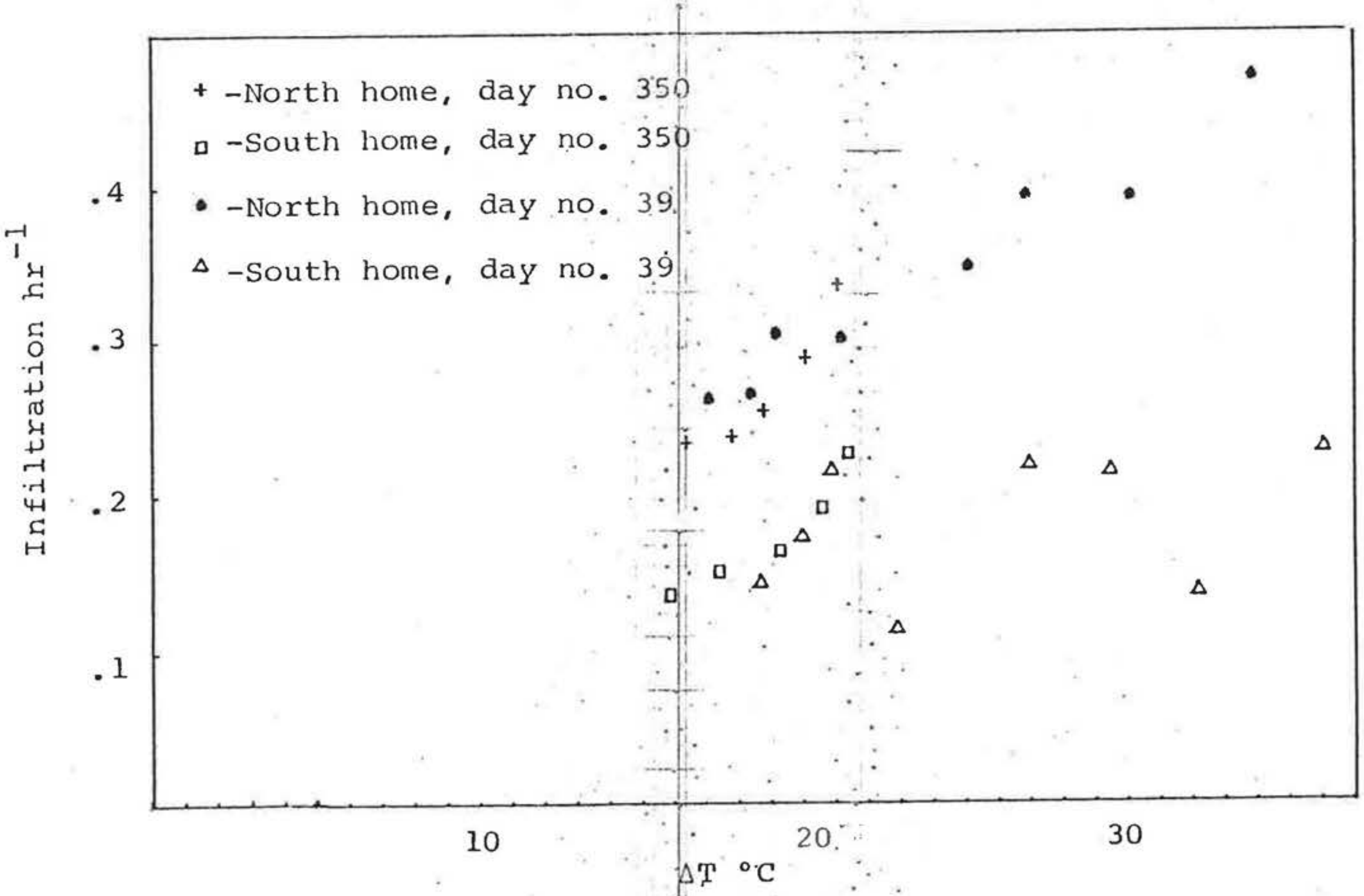


Figure 4.17 Infiltration vs. ΔT for day no. 350 & 39.

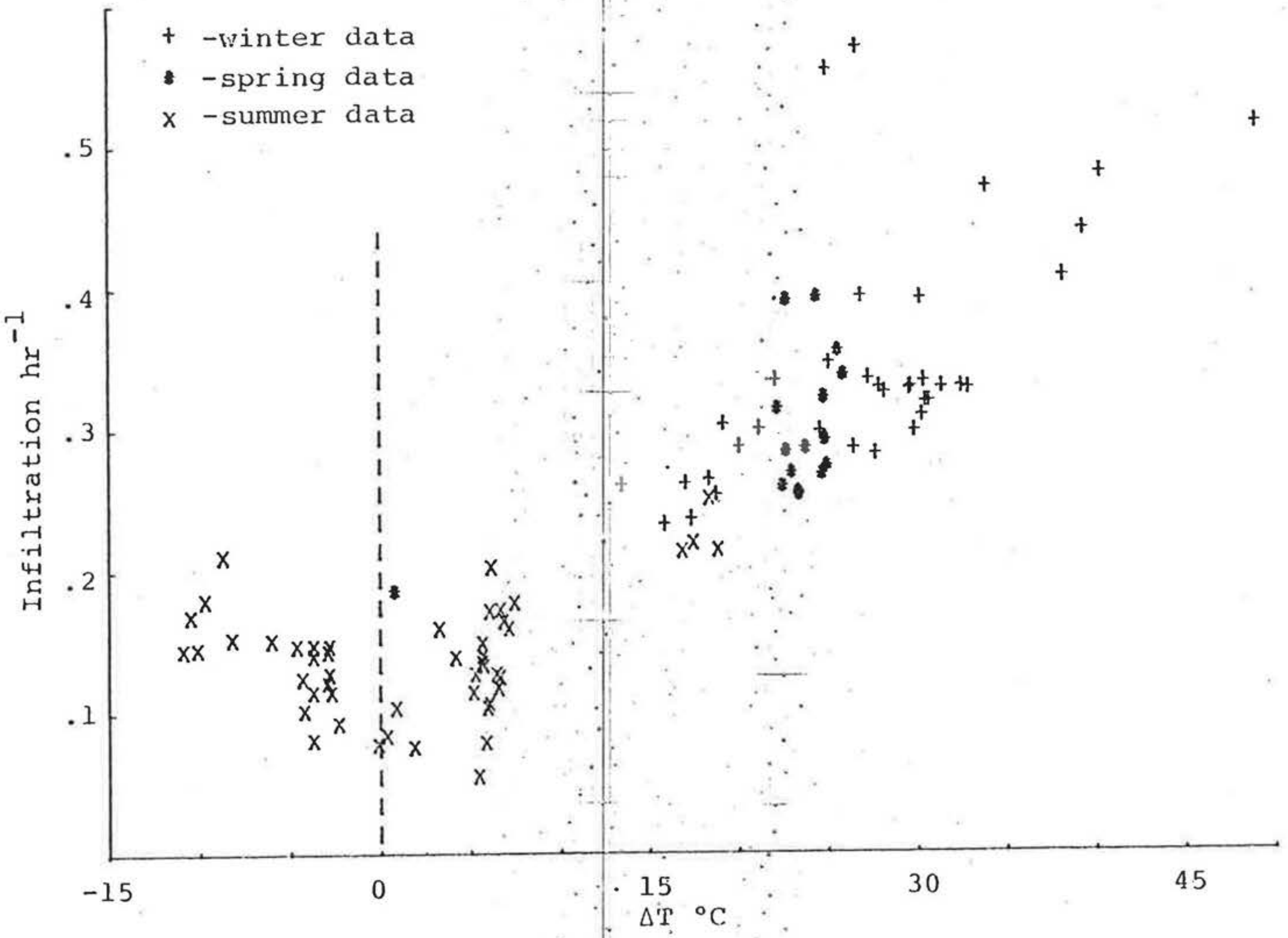


Figure 4.18 Infiltration vs. ΔT for W<1.4 m/s for the north home

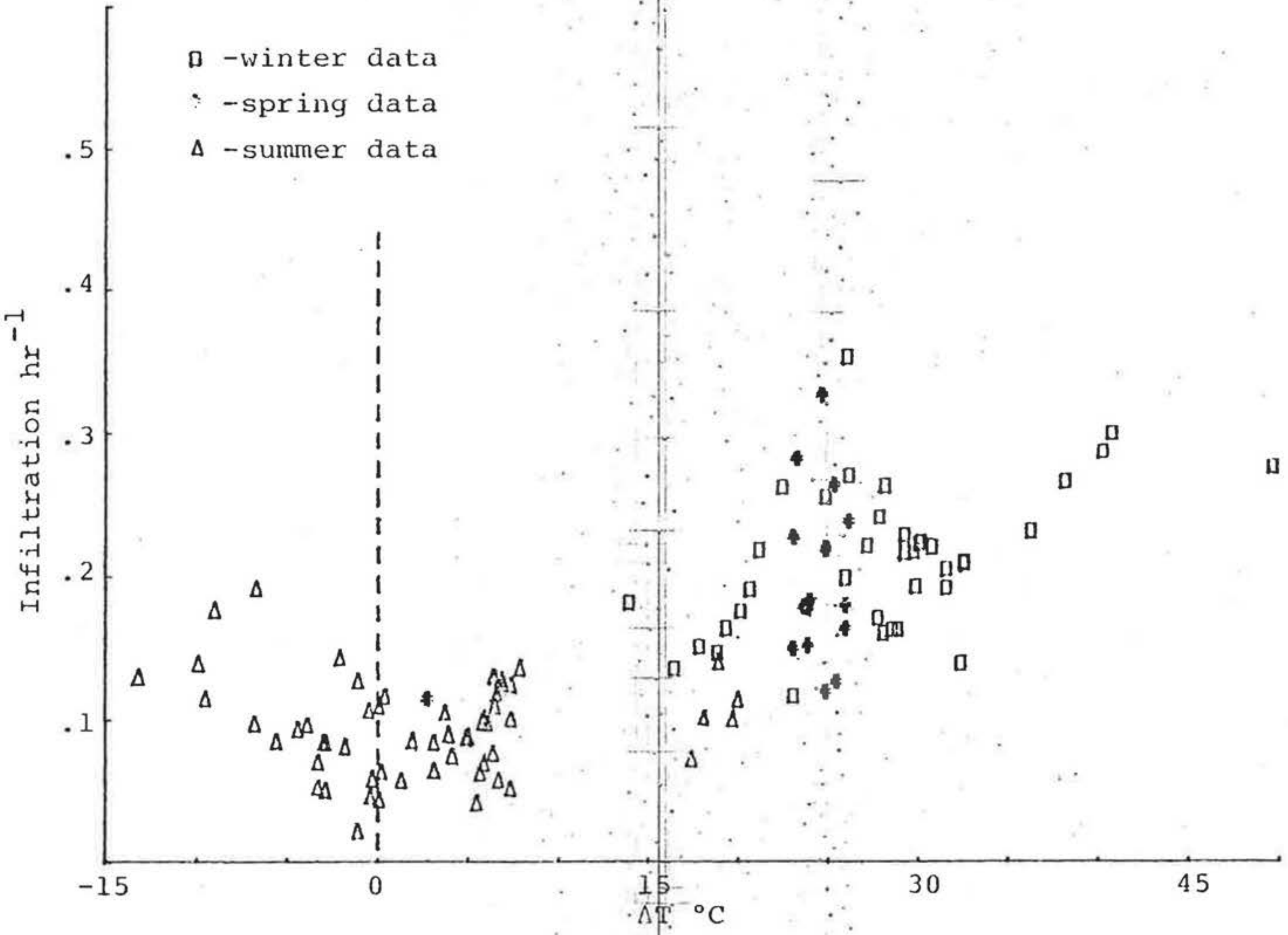


Figure 4.19 Infiltration vs. ΔT for W<1.4 m/s for the south home

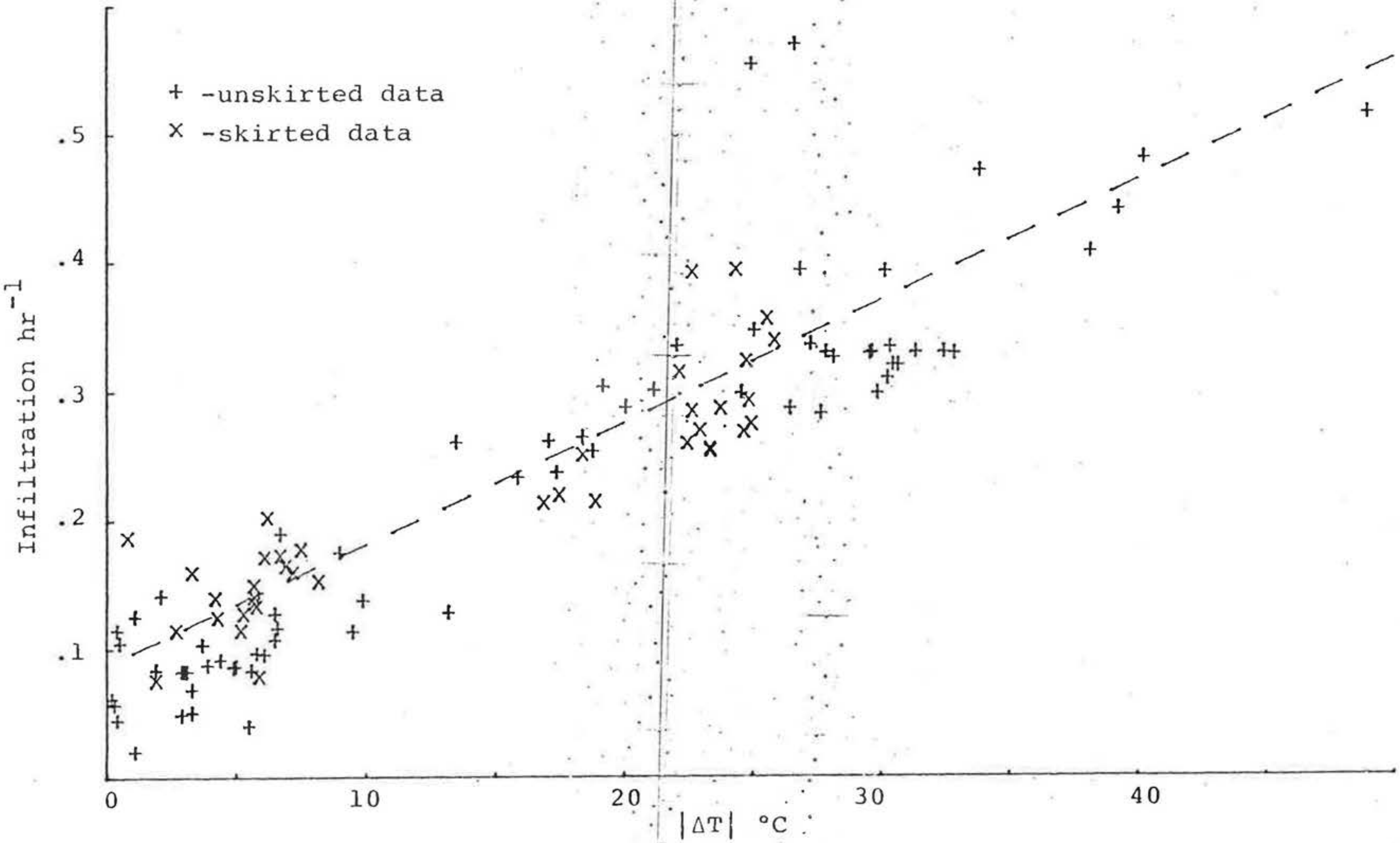


Figure 4.20 Infiltration vs. |ΔT| for W<1.4 m/s for the north home

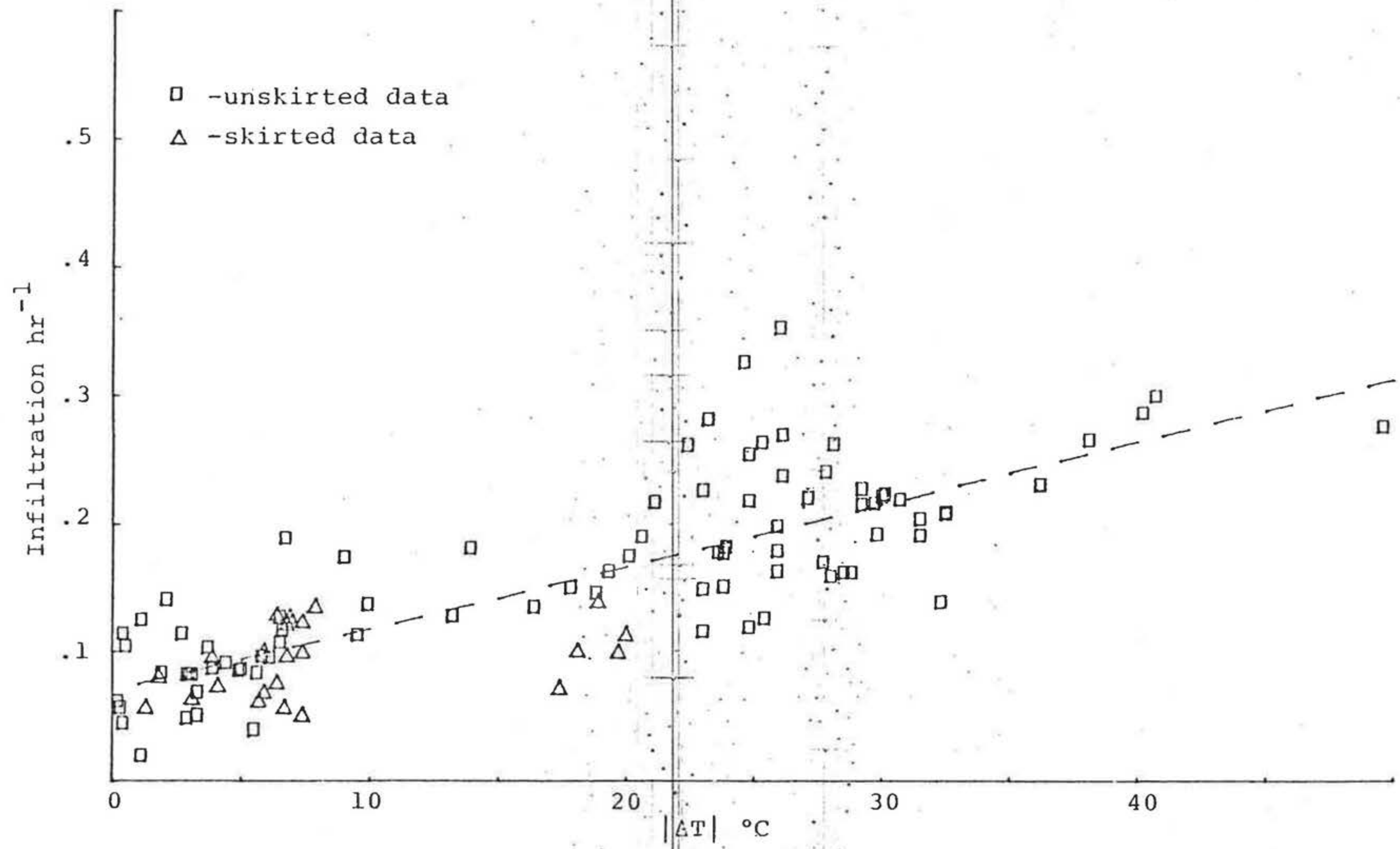


Figure 4.21 Infiltration vs. |ΔT| for W<1.4 m/s for the south home

value of temperature difference. A curve of the form $I = A + B|\Delta T|$ was fitted to the data and is plotted in figures 4.20 and 4.21. Best fits were

$$I_N = .088 + .0097|\Delta T| \qquad (4.4)$$

and

$$I_S = .071 + .0049|\Delta T|. \qquad (4.5)$$

4.2.3 Combined Effects of Wind and Temperature

The next step was to find the combined effect of wind and temperature. Plots of infiltration vs. ΔT for $5<W<6$ m/s are given in figure 4.22 and 4.23. It can be seen that even at high winds, infiltration is still temperature dependent. The dependence on ΔT and W combined can be partly obtained by modifying the coefficient C of equation 4.3 and making it a function of ΔT. The corresponding function $C(\Delta T)$ is plotted in figure 4.24. Best fits of C against ΔT and $|\Delta T|$ are also shown. The fits against $|\Delta T|$ are clearly the best for both homes. These fits are given by:

$$C_N = .0140 + .00030|\Delta T| \qquad (4.6)$$

for the north home and

$$C_S = .0060 + .00018|\Delta T| \qquad (4.7)$$

for the south home.

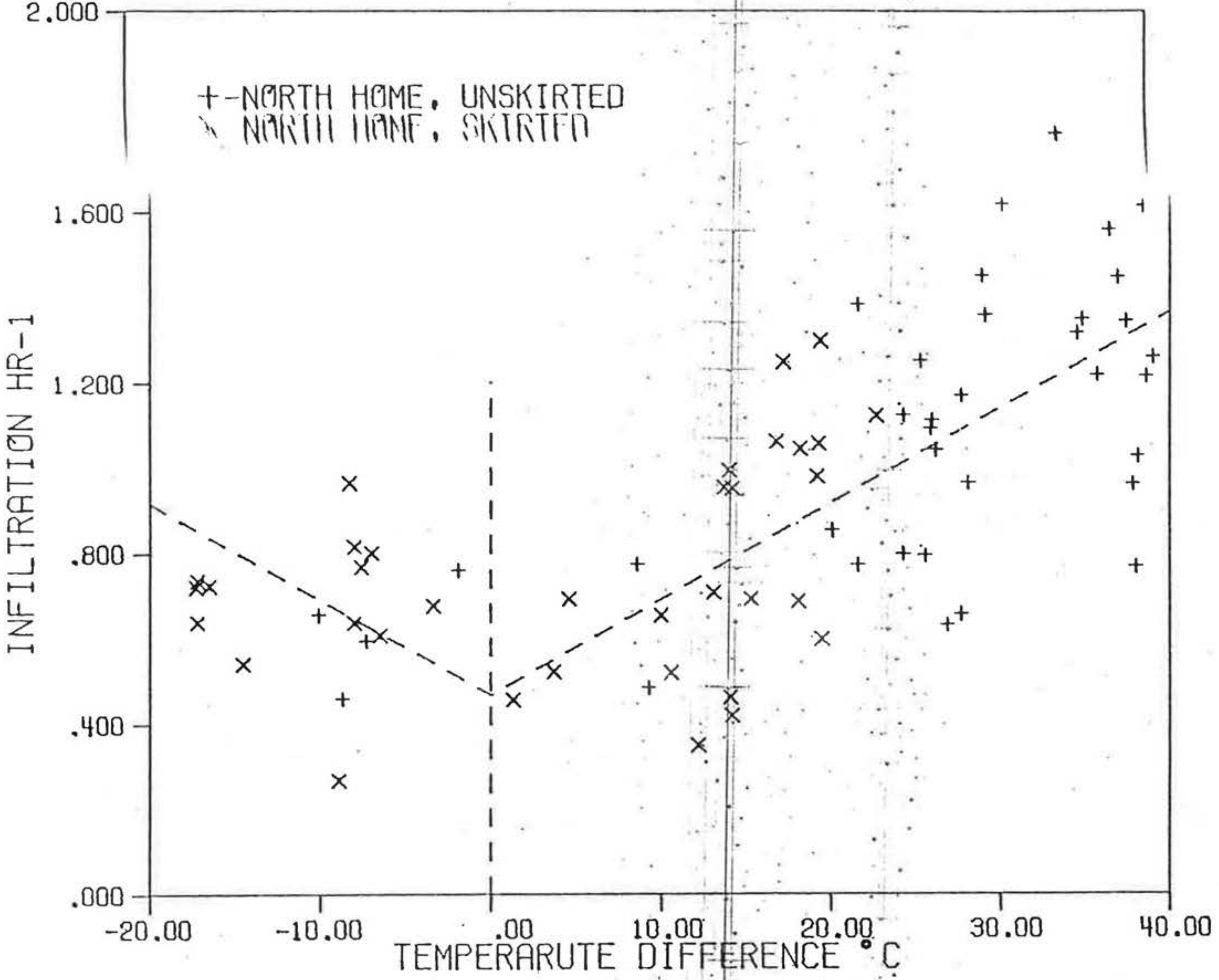


Figure 4.22 Infiltration vs. ΔT for 5 < W < 6

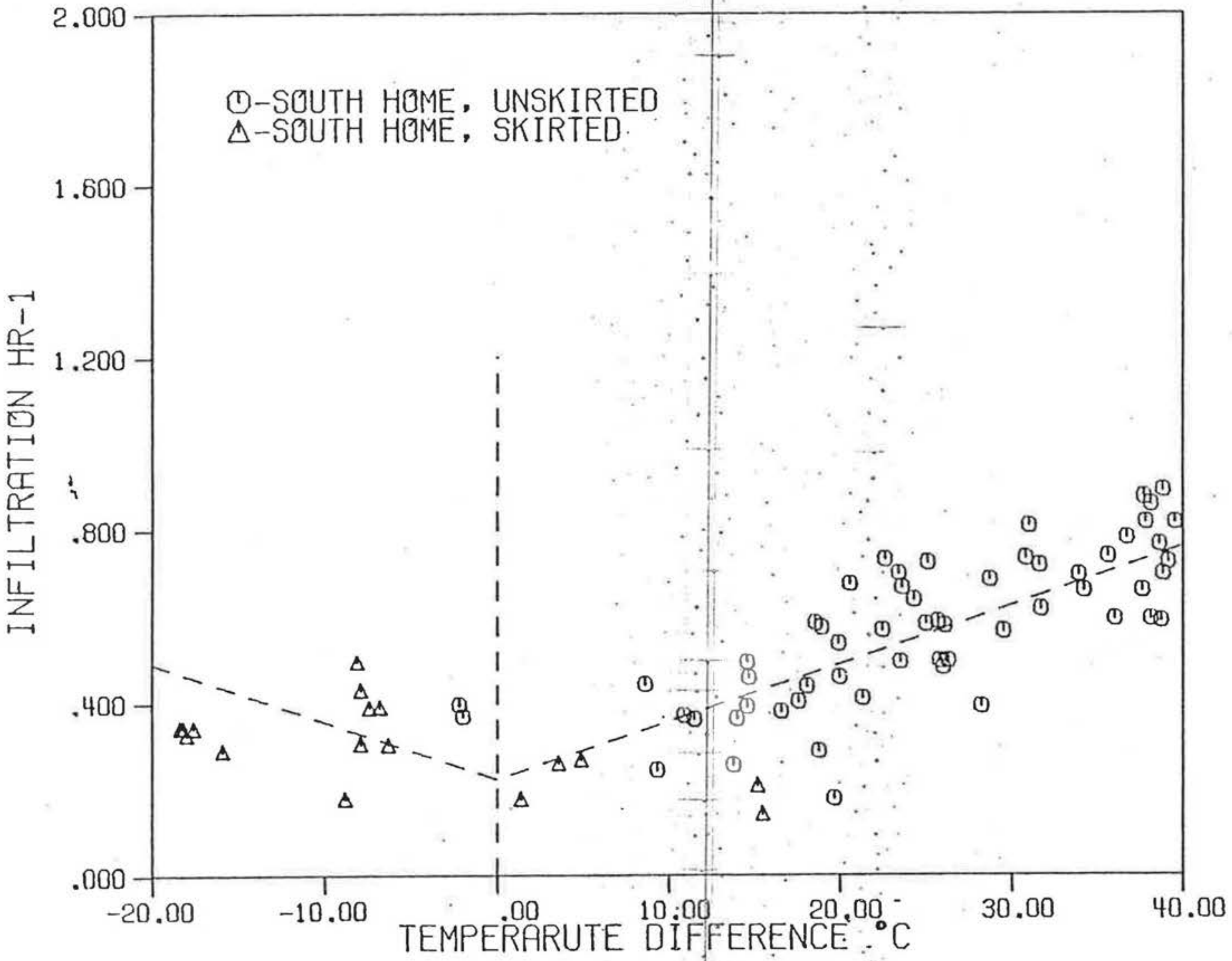


Figure 4.23 Infiltration vs. ΔT for 5 < W < 6, south home

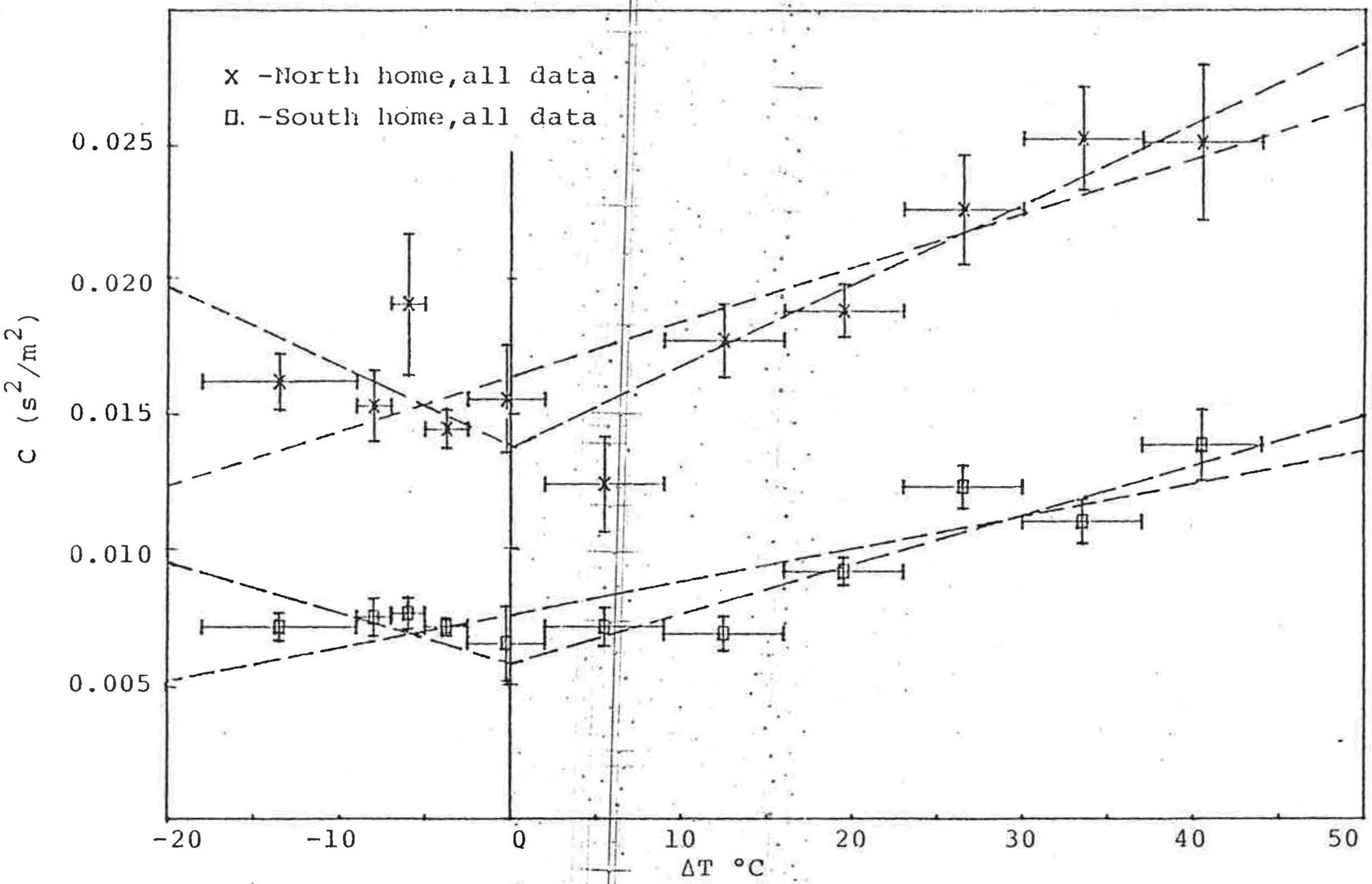


Figure 4.24 C vs. ΔT

Note that A, from equation 4.3, represents infiltration with no wind, and that equations 4.4 and 4.5 give the infiltration for low wind. Equations 4.3, 4.4, and 4.6 yield

$$I_N = .088 + .0097|\Delta T| + (.014 + .00030|\Delta T|)W^2 \quad (4.8)$$

and Equations 4.3, 4.5, and 4.7 give

$$I_S = .071 + .0049|\Delta T| + (.006 + .00018|\Delta T|)W^2 \quad (4.9)$$

These became approximate relationships based on limited data to be refined based on the entire set of field data. They clearly show: a) a square dependence on W, b) a linear dependence on ΔT (partly explained in Appendix E.) and c) the consistently lower infiltration rates for the south home.

4.2.4 Correlation of Infiltration to Weather

With the approximate dependence of infiltration on wind and temperature difference determined, the next step is to find the best fit correlation for the coefficients using a least squares procedure. To do this, two library programs at the Purdue Computing Center were used. Both were part of the SPSS[58] (Statistical Package for the Social Sciences) library. When the best fit equation was linear in the coefficients to be fit, the linear regression routine was used.[59] This program was simply a least square routine written for more than one independent variable. For equations that were nonlinear, the SPSS nonlinear regression program[60] was used. This particular method uses an iterative technique to find the smallest sum of squares of the error. See reference 61 for a complete discussion of the method used.

The programs' output included the coefficients for the model, estimated error in the coefficients (95% confidence interval), the R^2 value, and standard deviation, s. Correlations were run for both the model derived in Equations 4.8 and 4.9 and alternate models. The alternate models were based partly on empirical results (such as Equations 4.8 and 4.9) and on physical intuition (see Appendix E). No single physical model appears to fully describe the infiltration mechanism. It was hoped that possible correlation to the data could exhibit the validity of different models, some of which are explained later in the chapter or in Appendix E. Results are presented in Table 4.3. Let Y represent the dependent variable in question, $\bar{Y}$ the average value of the dependent variable, $\hat{Y}$ the predicted value of the dependent variable and n the number of data points. Then

$$R^2 = (\sum_{i=1}^{n} (Y-\bar{Y})^2 - \sum_{i=1}^{n} (Y-\hat{Y})^2) / \sum_{i=1}^{n} (Y-\bar{Y})^2 .$$

A simple way of expressing R^2 is that it is the fraction of the deviation from the mean value of the dependent variable explained by the correlation. The standard deviation, s, is given by

Table 4.3 Models of the data

North home

Equation number	Results	R^2	s
4.10	$I = .020(\pm.0402) + .012(\pm.0020)\lvert\Delta T\rvert + .019(\pm.0020)W^2 + .000097(\pm.000086)\lvert\Delta T\rvert W^2$	.893	.177
4.13	$I = .025(\pm.031) + 967.(\pm112.)\frac{\lvert\Delta T\rvert}{T_i T_o} + 5.83(\pm.22)\frac{W^2}{T_o}$	.896	.175
4.14	$I = .035(\pm.043) + .012(\pm.0020)\lvert\Delta T\rvert + .019(\pm.0018)W^2 + .000113(\pm.000077)W^2\Delta T$	.894	.177
4.15	$I = .20(\pm.020)\ e^{.017(\pm.0020)\Delta T}(1. + .071(\pm.0087)W^2)$	.886	.183
4.16	$I = \left(969.(\pm105)\frac{\lvert\Delta T\rvert}{T_i T_o} + 6.12(\pm.32)\frac{W^2}{T_o}\right)^{.95(\pm.050)}$	.896	.174
2.1	$I = .170(\pm.0054)\ (4\Delta P_T + \sqrt{2}\Delta P_W)^{1/2}$	.747	.272
4.17	$I = .0444(\pm.00096)\ (10\Delta P_T + \Delta P_W)^{.90}$	.878	.188

Table 4.3, cont.

South home

Equation number	Results	R^2	s
4.10	$I = .026(\pm.019) + .0080(\pm.00090)\lvert\Delta T\rvert + .0097(\pm.00093)W^2 + .000033(\pm.000038)\lvert\Delta T\rvert W^2$	.908	.0893
4.13	$I = .034(\pm.015) + 599.(\pm53.)\dfrac{\lvert\Delta T\rvert}{T_i T_0} + 2.92(\pm.10)\dfrac{W^2}{T_o}$	.909	.0889
4.14	$I = .034(\pm.020) + .0076(\pm.00093)\lvert\Delta T\rvert + .0093(\pm.00090)W^2 + .000049(\pm.000036)W^2\Delta T$	.909	.0890
4.15	$I = .14(\pm.010)\ e^{.018(\pm.0018)\Delta T}\ (1. + .051(\pm.0019)W^2)$	.894	.0957
4.16	$I = \left(539.(\pm59.)\dfrac{\lvert\Delta T\rvert}{T_i T_o} + 3.08(\pm.11)\dfrac{W^2}{T_o}\right)^{.87(\pm.040)}$	.912	.0871
2.1	$I = .097(\pm.0023)\ (4\Delta P_T + \sqrt{2}\Delta P_W)^{1/2}$	.809	.128
4.17	$I = .0247(\pm.00041)\ (10\Delta P_T + \Delta P_W)^{.90}$	.909	.0885

$$s = \sqrt{\frac{\sum_{i=1}^{n} (Y-\hat{Y})^2}{n-v-1}}$$

where v is the number of variables used in the predicting equation. The higher the value of R^2, the better the model fits. The smaller the standard deviation, the smaller the error in predicting the dependent variable.

The first model tried was similar to equations 4.8 and 4.9:

$$I = A + B|\Delta T| + CW^2 + D|\Delta T|W^2 \qquad (4.10)$$

The second model is based on the equations for pressure difference due to wind and temperature difference:

$$\Delta P_W = 176.5 \frac{W^2}{T_o} \qquad (4.11)$$

$$\Delta P_T = 3460h(\frac{1}{T_o} - \frac{1}{T_i}) \qquad (4.12)$$

Taking the absolute value of each term and adding, we get an equation of the type

$$I = A + \frac{B|\Delta T|}{T_i T_o} + \frac{CW^2}{T_o}. \qquad (4.13)$$

The third equation is a simplification of the second, where one notes that

$$\frac{1}{T_o} = \frac{1}{T_i - \Delta T} = \frac{1}{T_i} (1 - \frac{\Delta T}{T_i})^{-1},$$

which when expanded with a binomial expansion (neglecting higher order terms) yields

$$\frac{1}{T_o} \cong \frac{1}{T_i} [1 + \frac{\Delta T}{T_i}].$$

Substituting into equation (4.13):

$$I = A + \frac{B|\Delta T|}{T_i{}^2} [1 + \frac{\Delta T}{T_i}] + \frac{CW^2}{T_i} [1 + \frac{\Delta T}{T_i}]$$

Since $T_i \cong$ constant this can be rewritten as:

$$I = A + B|\Delta T| + CW^2 + DW^2\Delta T \qquad (4.14)$$

where the $|\Delta T|\Delta T$ term was neglected due to its small size.

A casual inspection of some of the data in Table 2.1 suggests that possibly

$$\frac{\frac{\partial I}{\partial \Delta T}}{I} \approx \text{const.}$$

Let

$$I = \Phi(\Delta T)\Omega(W)$$

Then

$$\frac{d\Phi}{d(\Delta T)}/\Phi \approx c,$$

from which

$$\Phi = \Phi_o e^{c\Delta t}$$

where Φ_o is the infiltration rate when $\Delta T = 0$. From the parabolic dependence,

$$\Omega(W) = A' + B'W^2,$$

hence

$$I = \Phi_o e^{c\Delta t}(A' + B'W^2),$$

or

$$I = Ae^{c\Delta t}(1 + BW^2), \qquad (4.15)$$

as used for the fourth model.

The fifth model is a nonlinear function of the pressure differences due to wind and stack,

$$I = \left(\frac{A|\Delta T|}{T_i T_o} + \frac{BW^2}{T_o}\right)^n. \qquad (4.16)$$

It is a slight modification of the second model where now the exponent n is found from a least square fit as well as the values of A and B. The primary reason for using this model was to check on the assumption of linearity made in the second model.

The last model tried was that suggested by Reeves, McBride, and Sepsy at Ohio State (reference 18 and equation 2.1).

It gives poorer results than any of those previously tried. It does have the advantage of having only one fitted coefficient. This makes comparison of different data sets much easier than a model with three coefficients. The model is semiempirical. The ratio of infiltration caused by wind to that caused by temperature differences and the flow exponent were based on previous experimental work as well as theory. With this in mind the model was modified based on the present data to give instead

$$I = A(10\Delta P_T + \Delta P_W)^{.90}. \qquad (4.17)$$

For the values chosen, this equation gives excellent results for the south home and acceptable results for the north home.

Of the models used, the nonlinear model (4.16) gave the best results for both homes, being only slightly better than model 4.13 for the north and south homes. Both model 4.13 and model 4.16 have the advantage of having only 3 coefficients, while equations 4.10 and 4.14 have 4 coefficients. Note that model 4.16 predicted zero infiltration with no wind and temperature difference present, while the other three models predict a positive value. One may well expect zero infiltration at zero wind and temperature difference, but it was found that the furnace blower could account for .03 and .04 changes per hour for the south home and north home, respectively, with low wind and small temperature differences. With this in mind, and because model 4.13 was linear, thus, easier to work with, it was adopted as the most suitable model.

Earlier phases of this research have already been published.[61,62] The first of these gave an empirical model based on most of the wintertime data. The second suggested an improved model based on summertime data as well (some 710 sets of data points). Presently the empirical correlation is based on all the unskirted data (525 sets of data points). (The correlations for reference 62 included some skirted data.)

Based on most of wintertime data[*] (reference 61)

$$I_N = 0.072 + 0.0135|\Delta T| + 0.0199W^2 + 0.67\times 10^{-4}\Delta T\cdot W^2 \tag{4.18}$$

$$I_S = 0.0466 + 0.0074|\Delta T| + 0.0130W^2 + 0.10\times 10^{-4}\Delta T\cdot W^2. \tag{4.19}$$

Based on 710 sets of data, winter and summer (reference 62) (some skirted data included),

$$I_N = 0.0635 + 0.0103|\Delta T| + 0.018W^2 + 1.53\times 10^{-4}\Delta T\cdot W^2 \tag{4.20}$$

$$I_S = 0.0503 + 0.0065|\Delta T| + 0.0086W^2 + 0.89\times 10^{-4}\Delta T\cdot W^2 \tag{4.21}$$

Based on 525 sets of data, current work (same form as model of reference 62) (no skirted data),

$$I_N = 0.035 + 0.012|\Delta T| + 0.019W^2 + 1.13\times 10^{-4}\Delta T\ W^2 \tag{4.22}$$

$$I_S = 0.034 + 0.0076|\Delta T| + 0.0093W^2 + 0.49\times 10^{-4}\Delta T\ W^2 \tag{4.23}$$

Based on 885 sets of data (same form as model of reference 62) (all of the data, including the unskirted),

$$I_N = .098 + .011|\Delta T| + .014W^2 + 2.3\times 10^{-4}\Delta T\ W^2 \tag{4.24}$$

$$I_S = .067 + .0071|\Delta T| + .0066W^2 + 1.1\times 10^{-4}\Delta T\ W^2 \tag{4.25}$$

---

[*] Reference (61) did not have the absolute value signs properly designated as the data was limited to wintertime data.

Based on 525 sets of data (model 4.13) (no skirted data)

$$I_N = .025 + \frac{967|\Delta T|}{T_i T_o} + 5.83\frac{W^2}{T_o} \qquad (4.26)$$

$$I_S = .034 + \frac{599|\Delta T|}{T_i T_o} + 2.92\frac{W^2}{T_o}\ . \qquad (4.27)$$

Based on 885 sets of data (model 4.13) (all of the data),

$$I_N = .047 + \frac{1160|\Delta T|}{T_i T_o} + 4.86\frac{W^2}{T_o} \qquad (4.28)$$

$$I_S = .043 + \frac{708|\Delta T|}{T_i T_o} + 2.33\frac{W^2}{T_o}\ . \qquad (4.29)$$

The design conditions in Lafayette, Indiana (using ASHRAE Standard 90-75 criteria) are given in Table 4.4. Also given are the infiltration rates determined using the various correlations. As noted by the table, the predicted values compare with earlier models (such as used in references 56, 61 and 62) well within the experimental scatter - justifying, from that point of view, any of the suggested correlations.

4.2.5 Wind Direction, Humidity and Solar Radiation

The effects of wind direction, θ, humidity ratio, ω, and solar radiation, H, on infiltration were not immediately apparent. To try to separate the effects of the above variables from the effects of wind and temperature difference the following procedure was used: a) the cards were

Table 4.4 Infiltration at design conditions

	T_i	T_o	W	ΔT
Summer	298.7°K (78°F)	305.9°K (91°F)	6.7m/s (15mph)	-7.2
Winter	295.4°K (72°F)	257.0°K (3°F)	6.7m/s (15mph)	38.3

Corresponding values of I, at the design conditions for Lafayette, IN. given above:

Equation	Winter		Summer	
	I_N	I_S	I_N	I_S
4.18 & 4.19 (winter data)	1.60	0.88	0.87	0.58
4.20 & 4.21 (winter and summer)	1.53	0.84	0.90	0.45
4.22 & 4.23 (unskirted data).	1.54	0.83	0.94	0.49
4.24 & 4.25 (all of the data)	1.54	0.82	0.73	0.37
4.26 & 4.27 (unskirted data)	1.53	0.85	0.96	0.51
4.28 & 4.29 (all of the data)	1.48	0.81	0.85	0.44
4.16 (unskirted data)	1.52	0.83	0.97	0.54

sorted, b) all wind direction data with standard deviations greater than 20° were eliminated from the consideration for wind direction, c) all nonpositive values of solar radiation were eliminated from consideration for solar radiation, and d) all data with incorrect values for wet bulb temperature were eliminated from consideration for humidity; and b) the difference between the infiltration determined from the measurement I_M, and the infiltration predicted using equations 4.26 and 4.27

$$\Psi(\theta,\omega,H) = \frac{I_M - I_C}{I_M} \qquad (4.30)$$

was plotted against each of the variables under consideration. These plots are given in figures 4.25 through 4.30.

The difference function Ψ showed a slight dependence on wind direction, being smallest with winds from the south and north and largest with winds from the west and east. In an attempt to grasp the magnitude of directional effects, the following equation was fitted to the data sample now considered (that with limited standard deviations of θ)

$$I = A + \frac{B|\Delta T|}{T_i T_o} + \frac{CW^2}{T_o} + \frac{DW^2}{T_o}(\cos 2\theta). \qquad (4.31)$$

The coefficients found were C_N, 5.47(±.25); D_N, -.56(±.29); C_S, 2.87(±.12); and D_S, .056(±.15). (The coefficients found for A and B were well within the estimated error of the coefficients of equations 4.26 and 4.27.) The effect of direction on the wind term was statistically significant for the north home but not for the south.

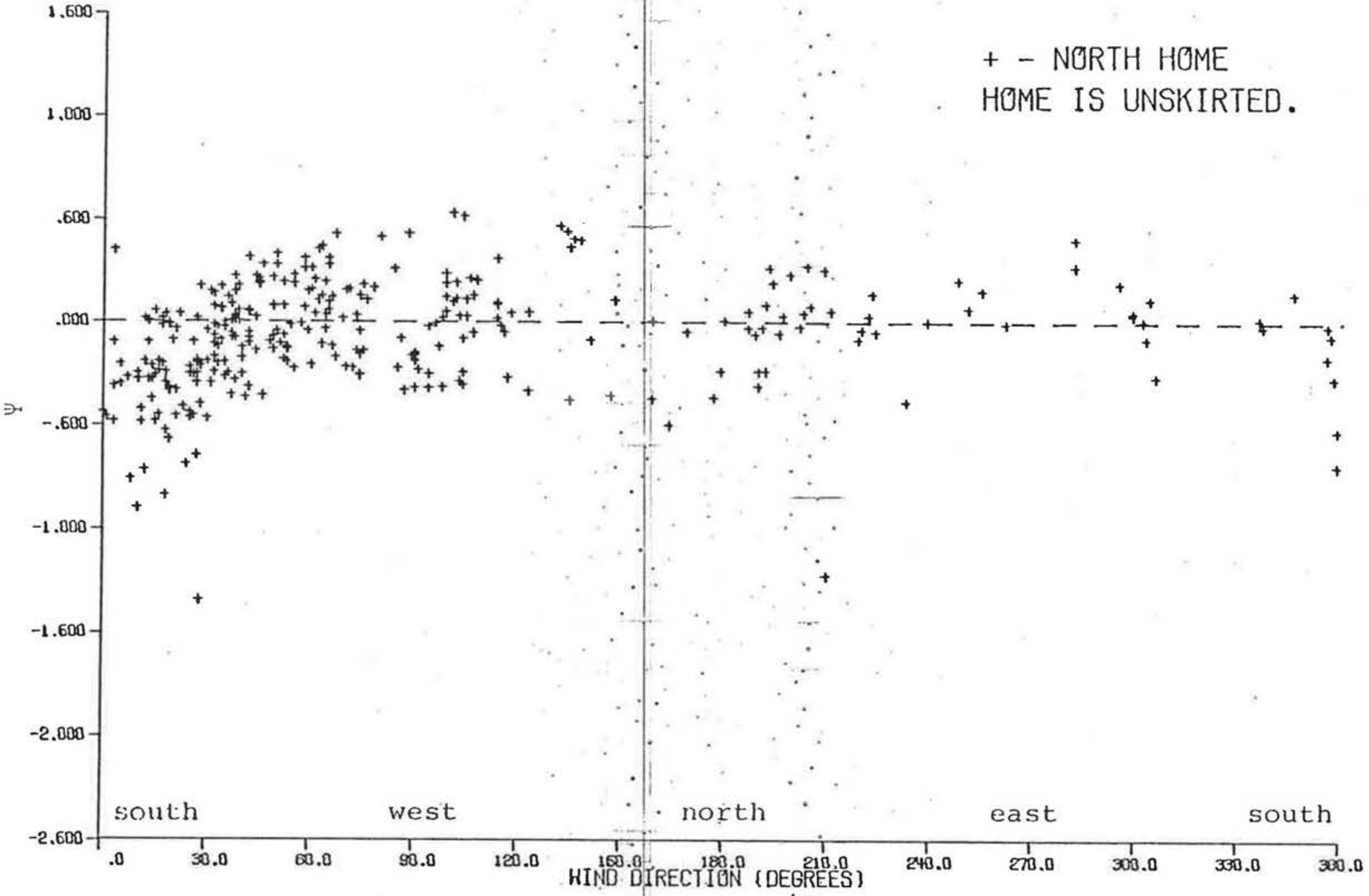


Figure 4.25 Error in the data vs. wind direction, north home

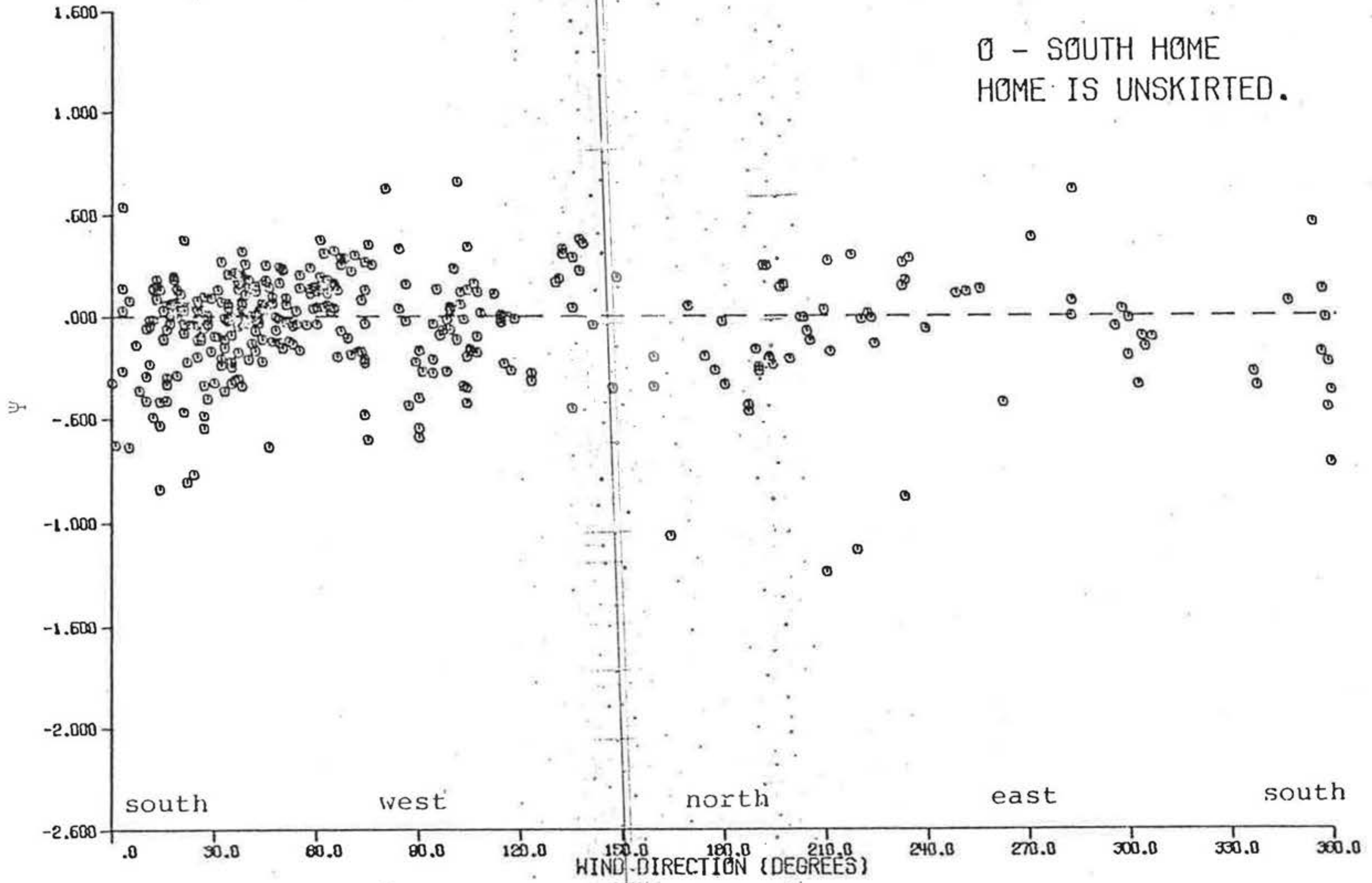


Figure 4.26 Error in the data vs. wind direction, south home

Because the data is weighted heavily to south (and west) winds, and because the directional dependence is much larger for the north home, the conclusion can be drawn that the effect of wind direction on infiltration was due mainly to the south home shielding the wind from the north home and to a lesser extent on the large aspect ratio of the homes.

Figures 4.27 and 4.28 show the plots of Ψ against humidity. The difference function Ψ tends to decrease with increasing humidity. The effect is very small and data is not sufficient in quantity or quality to provide a correlation.

Figures 4.29 and 4.30 show the difference function, Ψ, versus solar radiation. They suggest a weak dependence, if any, of I on H.

4.2.6 Data Scatter

The scatter in the data can be explained through the error analysis of section 4. The major sources of scatter are: a) error in I due to zero drift of the concentration meters (see Table C.6), b) errors in the average value of wind and temperature difference due to the method of averaging (over some four or more data points within the averaging time interval) and c) error in the measurement of wind and/or temperature. The error in measurement of the wind and/or temperature has a negligible effect.

Typical values of C were in range of 30 to 130 ppm. Zero drifts were usually of the order of ±5 ppm. The

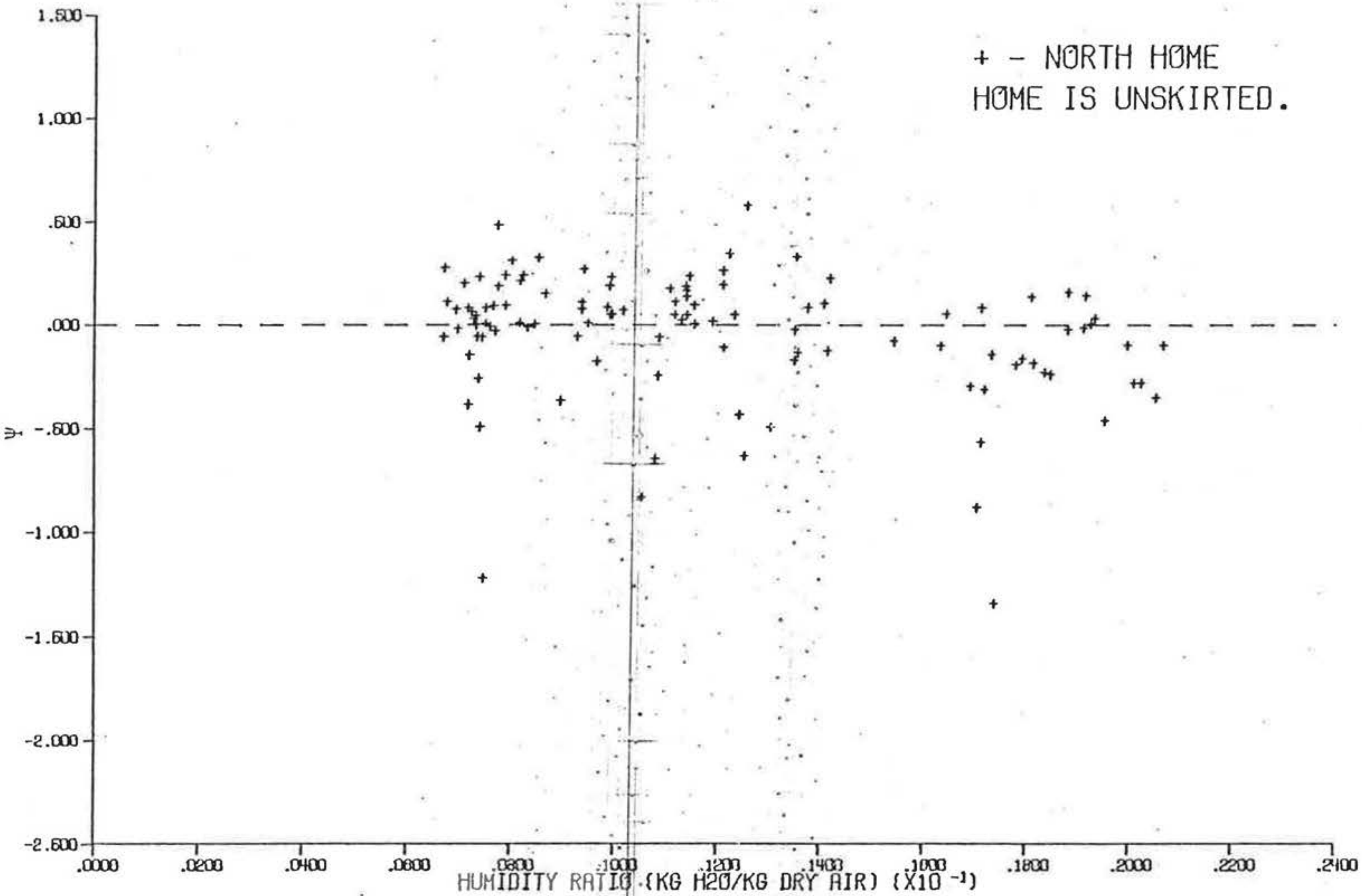


Figure 4.27 Error in the data vs. humidity, north home

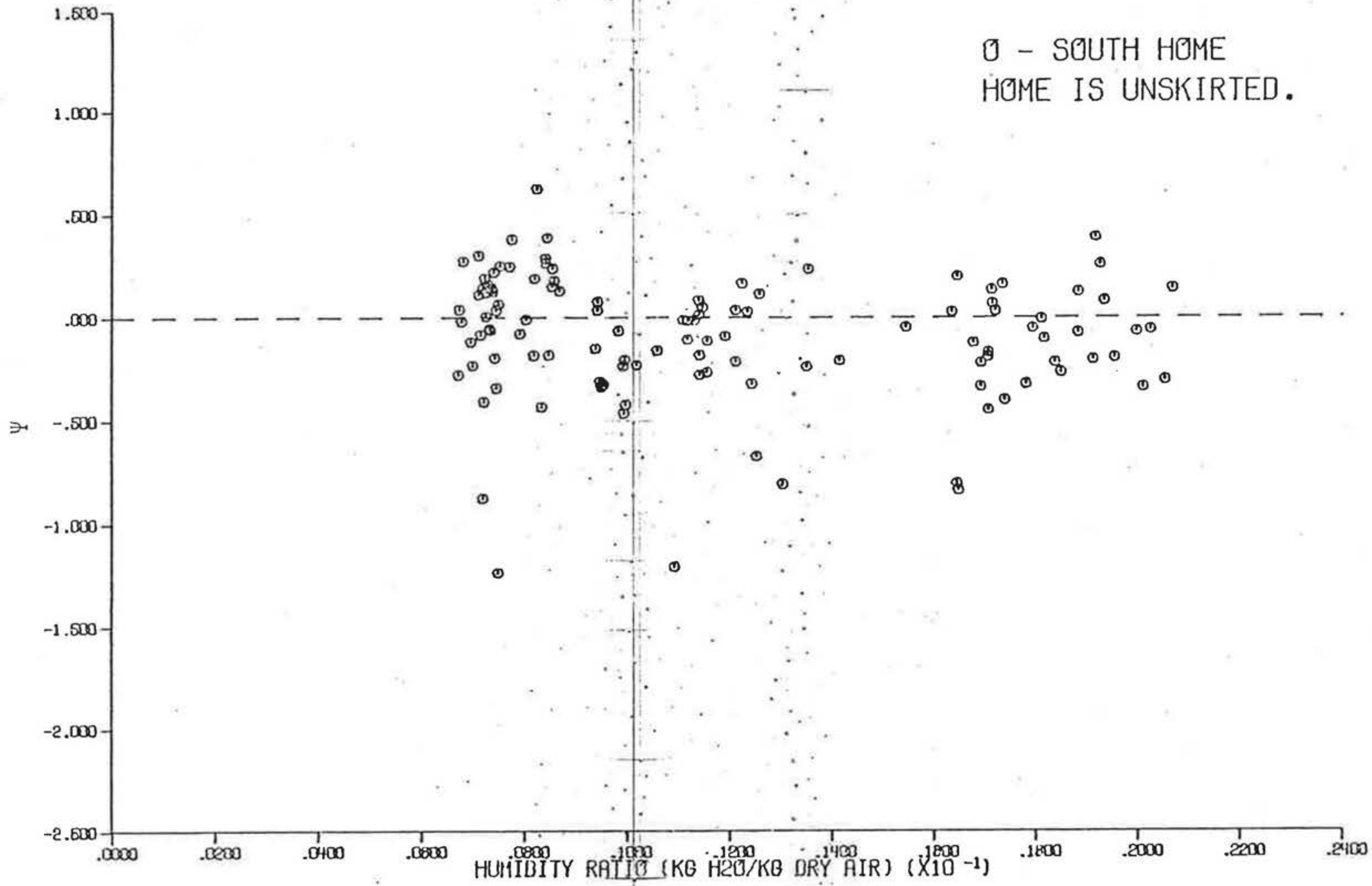


Figure 4.28 Error in the data vs. humidity, south home

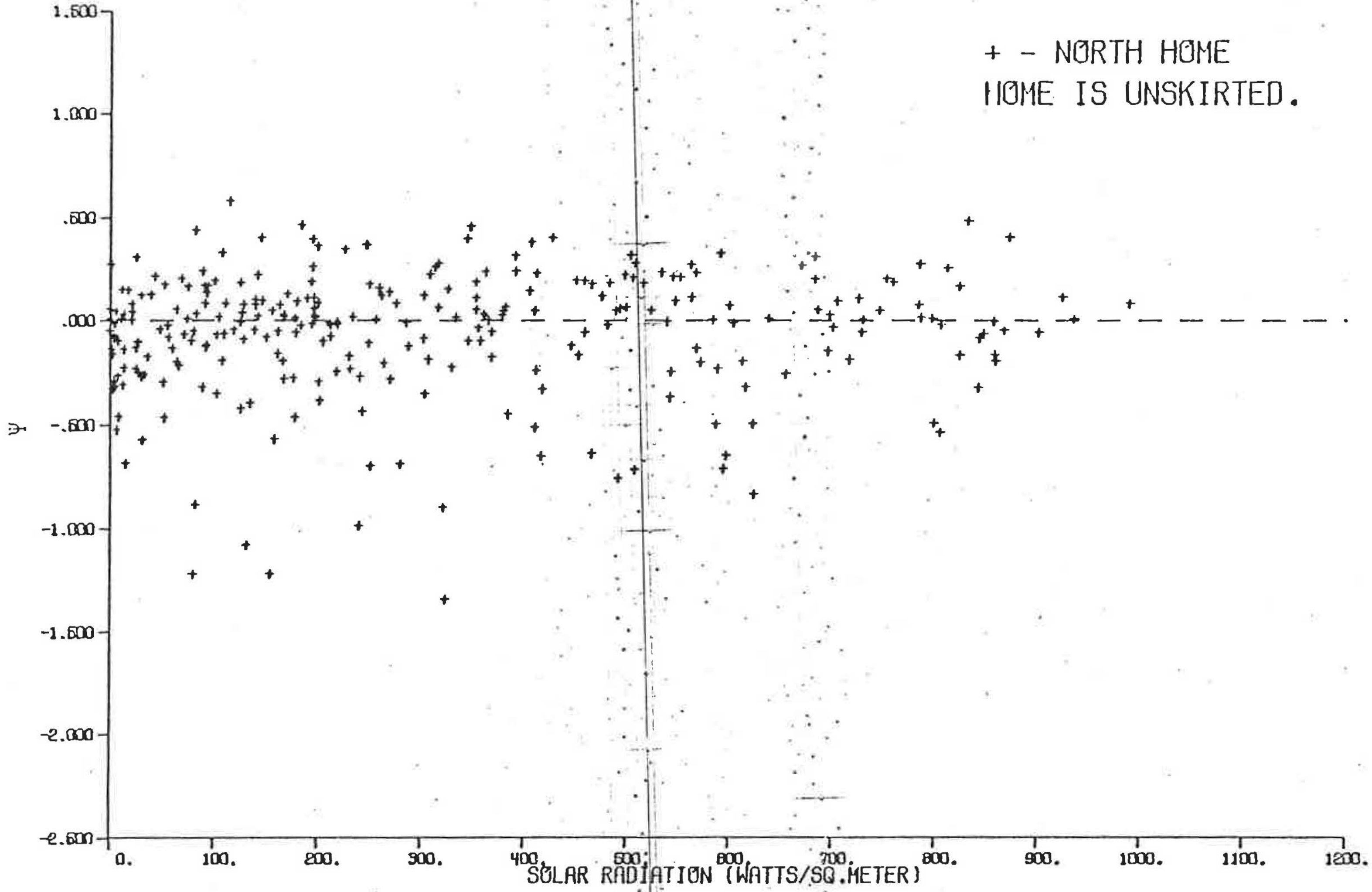


Figure 4.29 Error in the data vs. solar radiation, north home

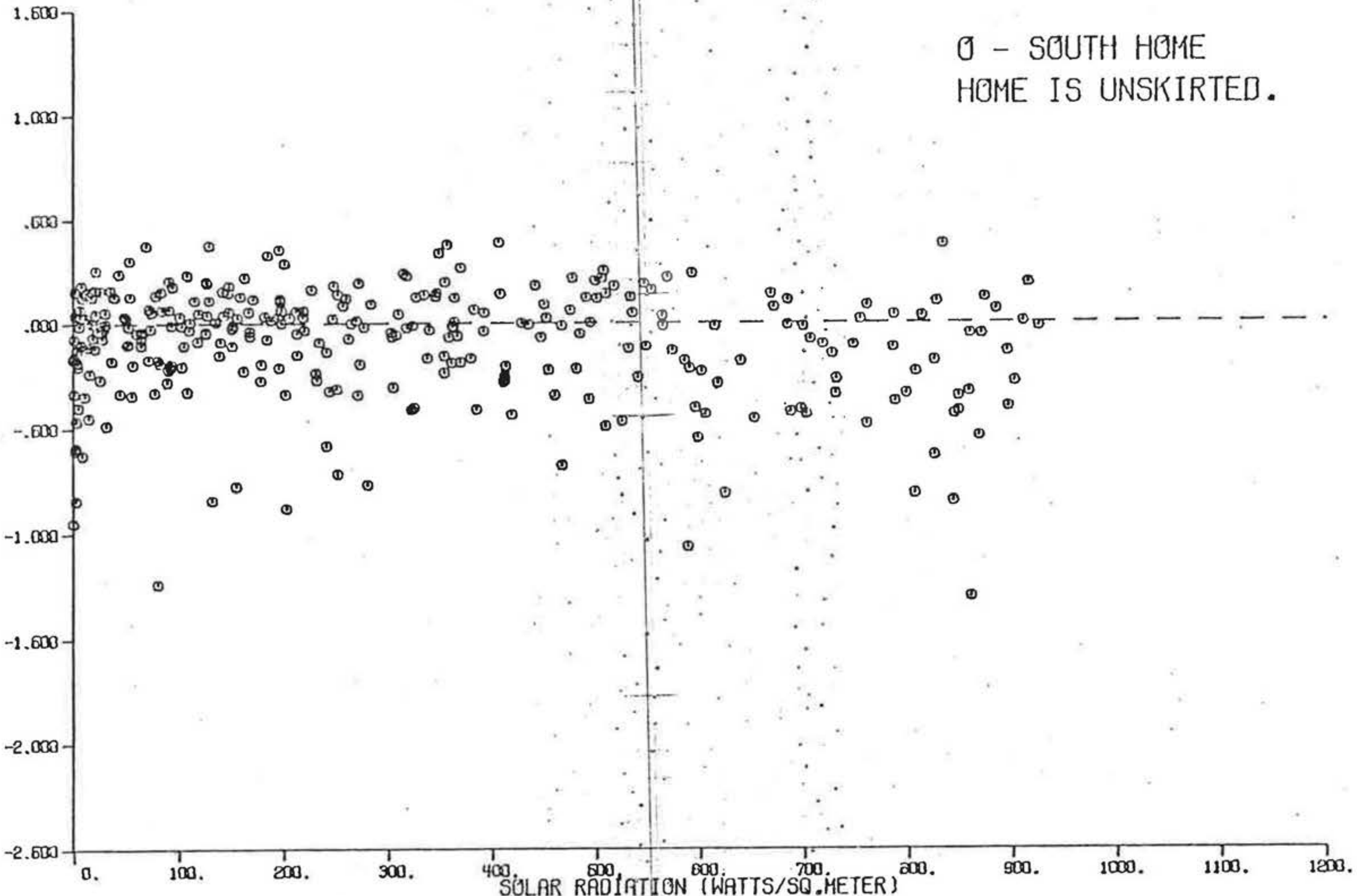


Figure 4.30 Error in the data vs. solar radiation, south home

corresponding errors in I would typically be between .25 and -.25 (for I = 1 cph, C_m = 40 ppm, and t = 30 min.) but could go as high as ±1.0 (for I = .5 cph, C_m = 30 ppm, and t = 30 min).

At 6.7 m/s (15 mph) (which corresponds to the usual reference "design" conditions) the standard deviation and expected error of wind (over usual averaging times) was in the order of m/s. (See also Table C.6). The expected "errors", @ 15 mph, are shown, as an example, in figure 4.12. The experimental scatter is within the expected uncertainty, justifying the need for large statistical samples and exhibiting the inherent challenges of measurements in natural environments.

4.3 Furnace Blower Test

In order to accomplish mixing within the home, and aid injection of tracer gas, the furnace blowers[*] operated continuously. Their possible influence on the infiltration rate should be determined before attempting to generalize the results. The air in the air supply ducts was pressurized by the blower. Thus, some air leakage out cracks in

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[*] The "furnace" blowers are the main blowers located in the furnace chamber. They operate both while air conditioning and while heating. (The air conditioners were split systems with the evaporator coil in the furnace chamber).

the ducts could result. Part of this leakage would be into the living area, part to the outside through the subflooring. This leakage to the outside from the subfloor space leads to a slight depressurization in the living area of the home itself and a slight amount of infiltration.

4.3.1 Experimental Procedure

To measure the infiltration caused by the furnace blower by itself, a calm day with small ΔT was chosen (day 243). Recirculation fans on the sample loop and the psychrometers were connected to the electrical outlets from the instrument shed with extension cords. Infiltration measurements were started as usual except that 1 1/2 hours into the run the electricity to the homes was turned off. This caused the furnace blower to shut off. Fourty minutes later the electricity was turned back on, and left on for 1 hour. The electricity was then turned off again for another 40 minutes, then on for a final 50 minutes. At this time, the run was completed. By turning the furnace blower on and off, a comparison could be made between those periods when the blower was on with those periods when the blower was off.

4.3.2 Results

The results are given in table 4.5. The results were evaluated by simply comparing averages, and assuming that the wind dependence for the low winds noted was small. The

Table 4.5 Furnace blower test

Day of run: 243

Blower	Start time	$I_N(hr^{-1})$	$I_S(hr^{-1})$	W(m/s)	ΔT_N(°C)	ΔT_S(°C)	Wind dir.
on	20.92	.123	.091	2.20	-6.3	-6.3	S
off	21.92	.078	.066	1.86	-4.5	-4.5	S
on	22.58	.102	.092	1.27	-4.3	-4.3	S
off	23.58	.061	.042	1.36	-3.1	-3.9	SSW
on	24.25	.093	.083	.40	-2.3	-2.8	SSW

Table 4.6 Volume test

Home	Home temp. (°C)	Shed temp. (°C)	Circ. of Ballon (m)	Volume Balloon (ℓ)	Pressure balloon (Pa)	Atmospheric pressure (Pa)	Volume* corrected for pres. temp (ℓ)	Initial conc. (ppm)	Volume (m^3)
north	297	292	.832	9.72	1570	100,090	10.04	61.6	163
south	297	292	.841	10.06	1520	100,090	10.34	60.1+	173
south	298	294	.867	11.01	1640	100,970	11.34	63.3	179
north	298	294	.867	11.01	1570	100,970	11.33	65.4	173
north	295	288	.902	12.38	2715	99,050	13.03	75.7+	172
south	292	286	.902	12.38	2590	99,050	12.97	74.8	173†

*The volume of the gas in the balloon at the temperature and pressure of the home.
†The CO meter was calibrated wrong for this run and the data was corrected.
+ Runs with the least error.

average infiltration with the blower was around 0.11 for the north home and 0.09 for the south home. The average with the blower off appeared to be around .07 for the north home, and 0.06 for the south home. The resulting infiltration caused by the blower was of the order of 0.04 for the north home, and .03 for the south home. Note that these values are in surprisingly good agreement with the A coefficients of equations 4.22 through 4.25.

4.4 Volume of the Homes

The technique used to measure the infiltration rates was independent of the actual volume of the homes. Results were given in changes per hour (the amount of air leaking into the home in one hour equals the volume of the home). In order to find the actual amount of air leaking in or out of the homes, the actual volume of the homes has to be known. Measurement of the volume of the homes can be difficult, since furniture, interior walls, cupboards, and closets all take up space in the homes. Also, a problem arises as to what extent the subfloor and attic space have to be included as part of the volume.

In order to overcome these difficulties the volume of the homes was determined using the infiltration measurement process itself. If a known amount of CO is injected into the homes, volume of the homes can be determined from the initial concentration of the injected CO. Unfortunately, there is a finite amount of mixing time for the carbon monoxide after it enters the home, of the order of 15 minutes, before measurements are valid. If the infiltration process is allowed to proceed as it normally would, the decay rate can be found. Then, with the decay rate known, the concentration can be extrapolated to time zero, and the initial concentration found.

4.4.1 Experimental Procedure

The first problem was to find some way of measuring the volume of the CO injected. This was accomplished by filling a large spherical balloon with CO, measuring the volume and pressure of the balloon, and then allowing the balloon to empty into the homes. This method was chosen because a) the equipment was readily available, other low flow meters were not, b) it was simple, and c) the pressure of the balloons was sufficient to allow self injection of the volume of CO into the homes.

The balloon was placed in the CO supply line between the safety shut-off solenoid and the injection solenoids. See the schematic in figure 4.31. To fill the balloon the safety solenoid was opened. When the balloon was full, the safety solenoid was closed, the balloon's circumference was measured with a cloth tape measure, and the pressure of the gas in the balloon was measured. Then one of the injection solenoids was opened and the gas emptied into the home. Time equal to 0 was taken as that time when the last of the CO was gone from the balloon. (The balloon took about 120

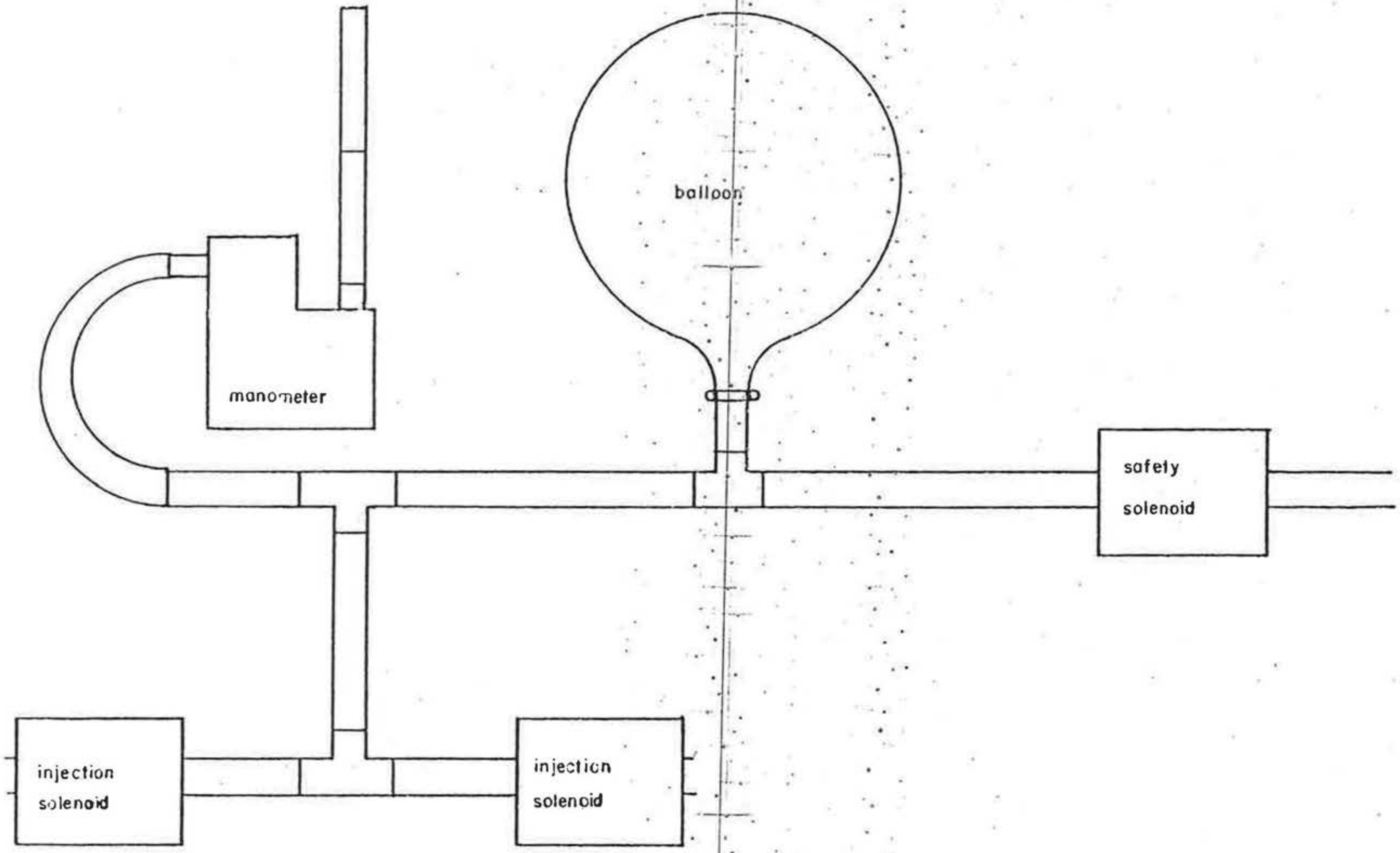

Figure 4.31 Schematic of system to measure CO

seconds to empty.) Thereafter, the concentration was measured every 5 minutes for approximately one hour. A plot of one of the tests is shown in figure 4.32.

Immediately before and after each day's runs, the CO meters were zeroed and calibrated using 50 ppm CO test gas in air. The meter was zeroed, a sample bag was filled with CO, this CO was run through the meter for about 15 minutes, and calibration was adjusted. The zero position was then checked again and if zero drift was over 1 ppm, the process was started over. When calibration was finished, the test was run. After the test the zero drift was checked as was the span drift. If very large, data was corrected by multiplying each point by 50/reading on 50 ppm gas. Of the 6 tests done (see Table 4.6) only one had a large enough error in calibration to require this to be done. In this run, the north home was run in the afternoon and the south home was run several hours later in the evening without recalibrating before the second run. Both homes were run with the same meter at different times.

4.4.2 Results

The measurements taken are given in table 4.6. The average volume of the homes was found to be 172(±5) m^3; 87% of the volume which would be predicted using only the outside dimensions of the homes. (The homes are expected to have the same volume since they were identical homes and were furnished exactly the same.)

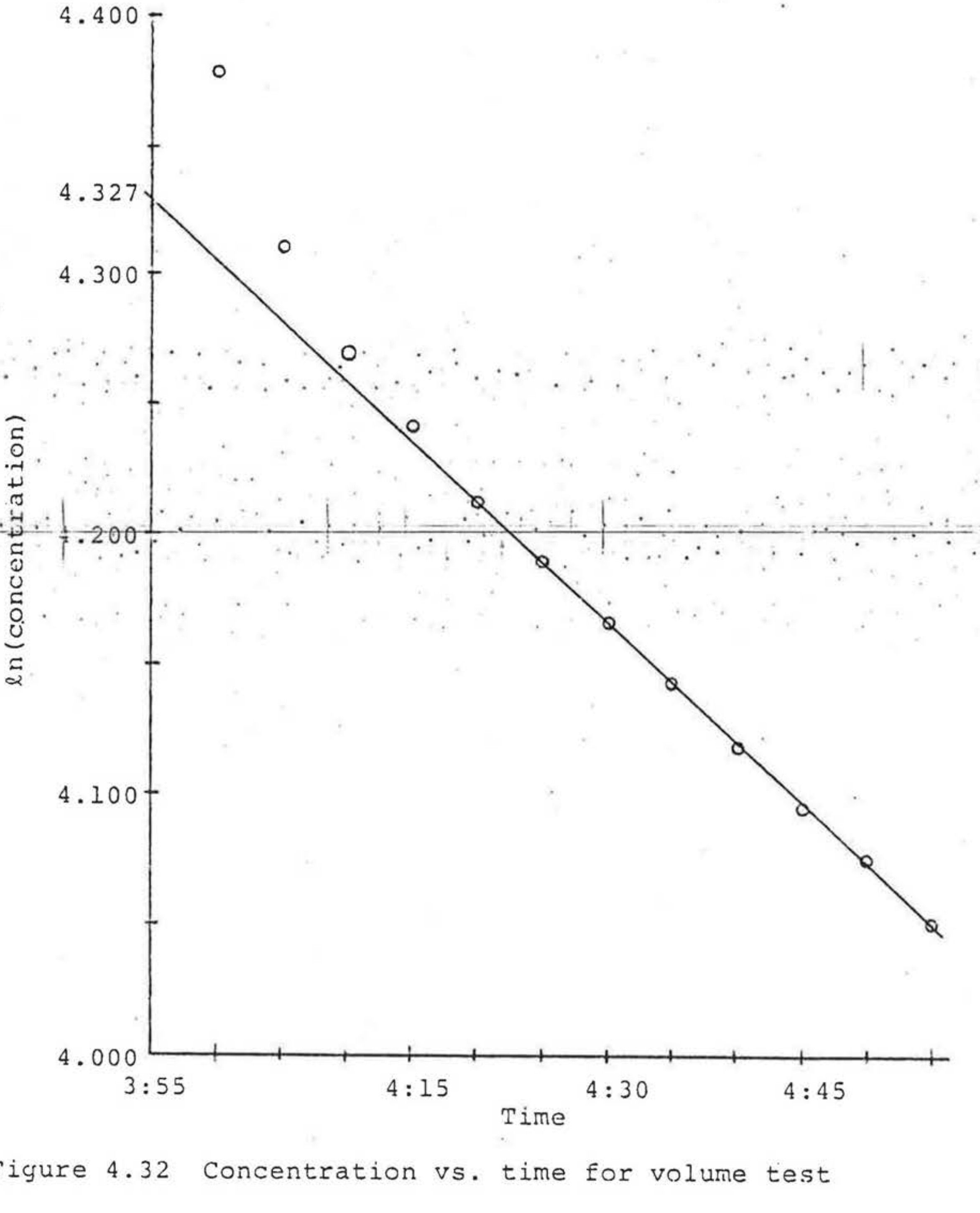

Figure 4.32 Concentration vs. time for volume test

4.5 Energy Used by Homes

As part of the tests the amount of energy used to heat (or cool) each home was recorded. This energy, which was read from the electric meters for the homes, represented the electricity used by the furnace (or air conditioner) as well as that used by the psychrometer fans, the fans in the sample line, and the continuous operation of the furnace blower. These extra fans would be a heat source in the winter and a heat load in the summer. The amount of power needed for these fans was measured by timing the rotation of the disc in the electric meter. The amount of energy being used in watts-hours is given by the number of rotations of the disc times the K_H value printed on the face of the meter. The power, in Watts, needed to run the fans is given by the number of rotations of the disc times the K_H value of the meter divided by the amount of time for the rotations, in hours. The time for one rotation for the north home was 39.9 seconds, and for the south, 37.5 seconds. The K_H value for the meters was 7.2. Thus, the power requirements for the fans were .65kW for the north home and .69kW for the south home.

The energy consumption plots show only that used by the heating coils of the furnace (or the air conditioning unit) (that is the energy usage read from the meters minus the energy used by the fans). The plots are shown in figures 4.33 through 4.46. Plots from November, 1976, through

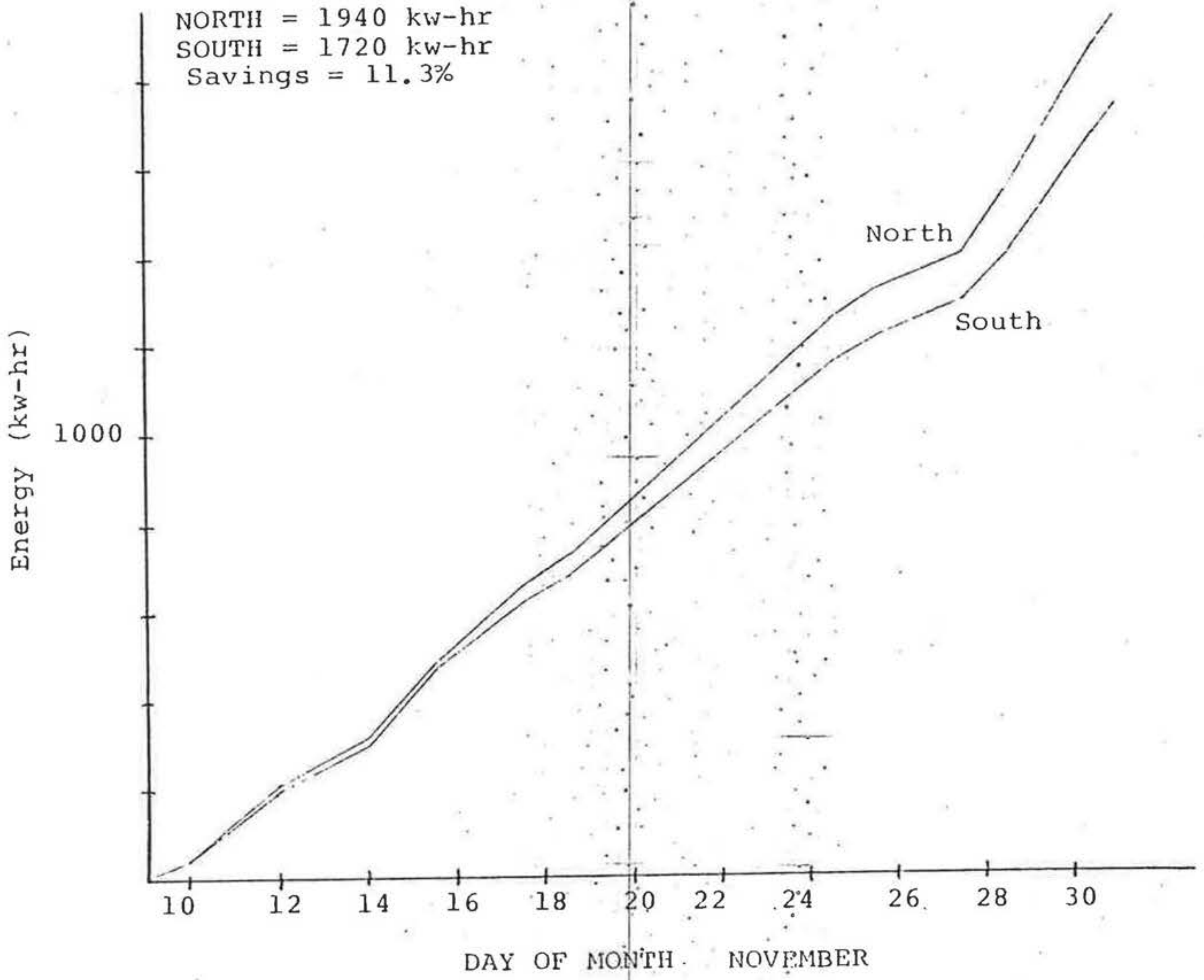

Figure 4.33 Energy used to heat homes November, 1976

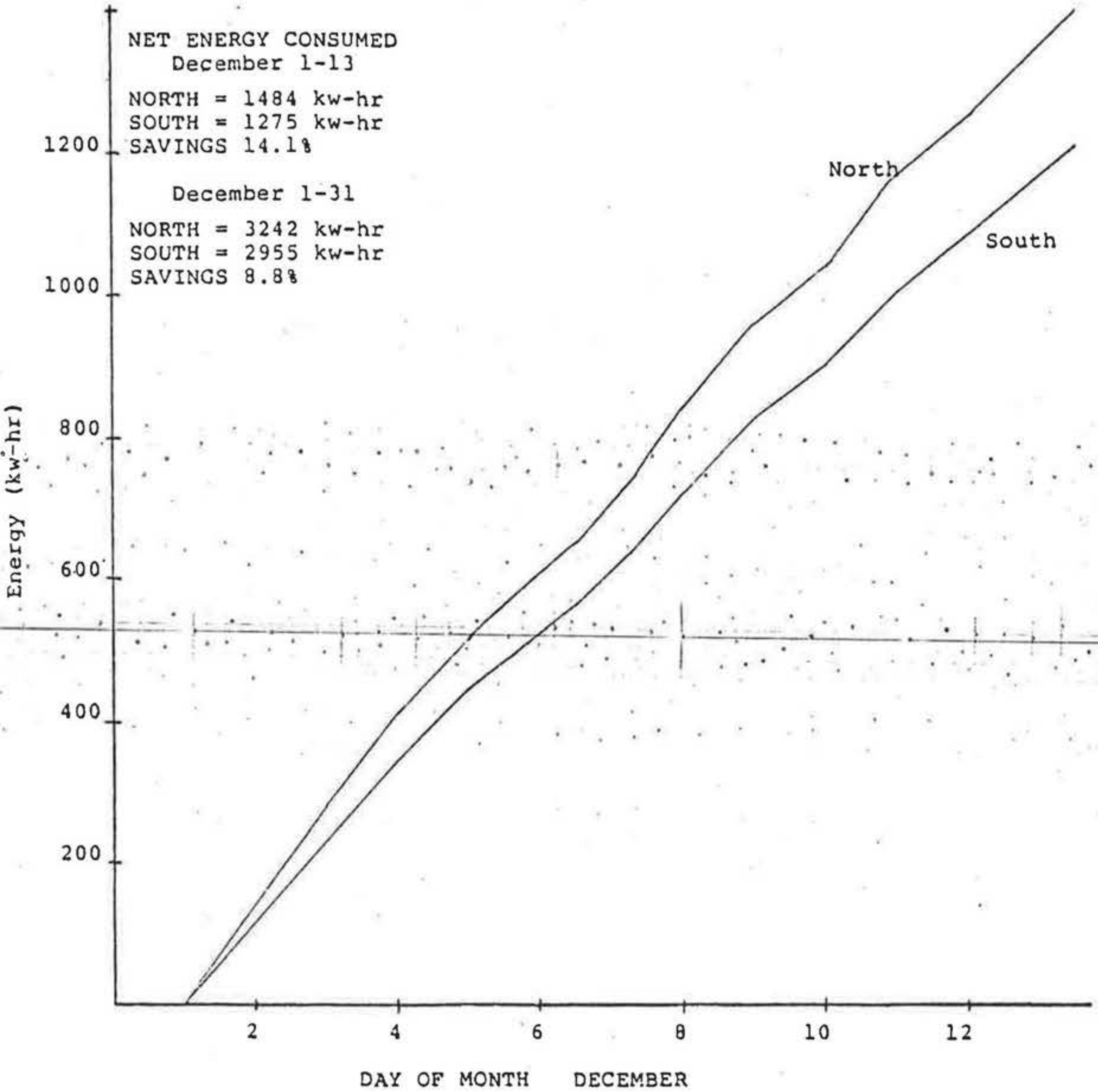

Figure 4.34 Energy used to heat homes December, 1976

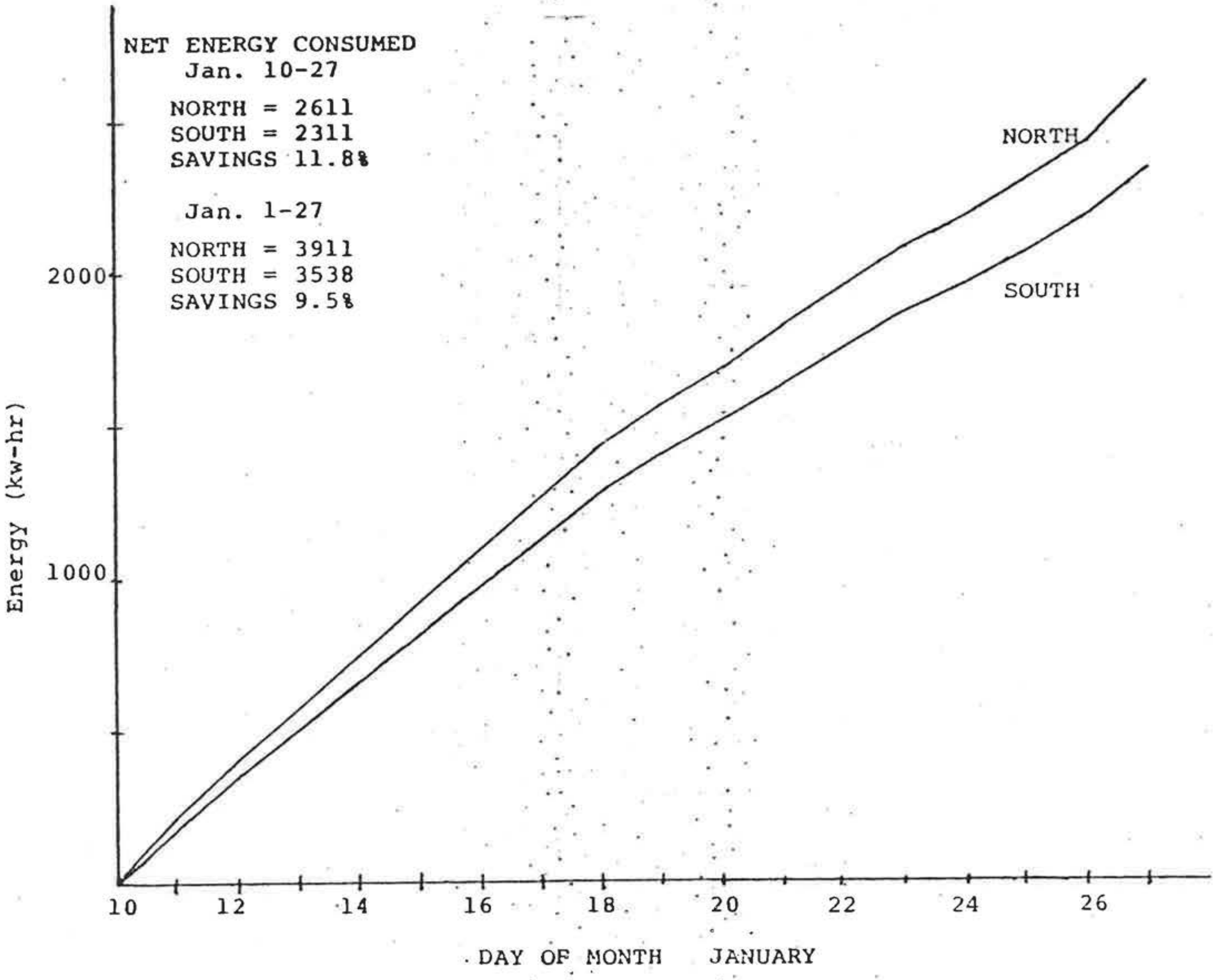

Figure 4.35 Energy used to heat homes January, 1977

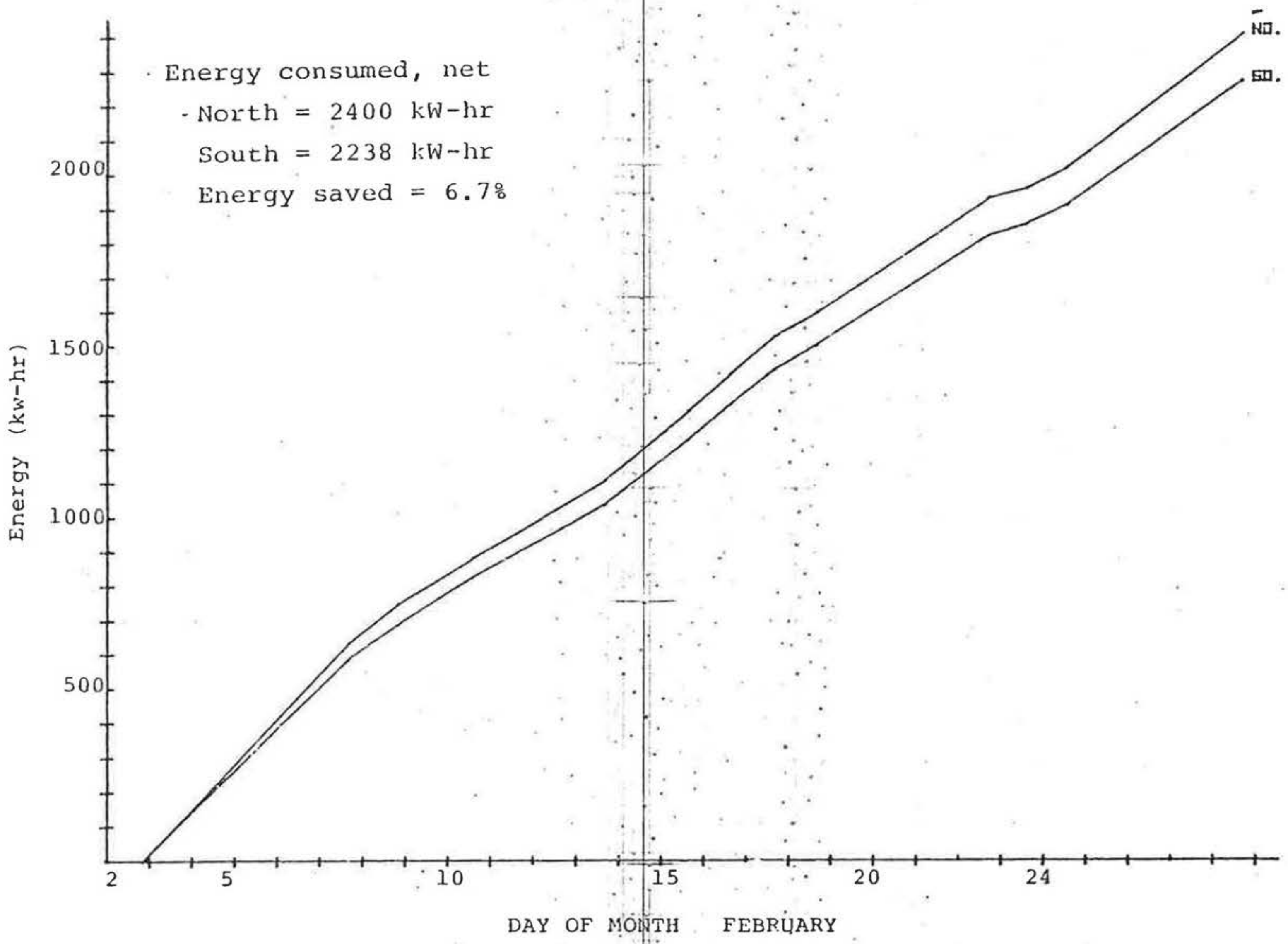

Figure 4.36 Energy used to heat homes February, 1977

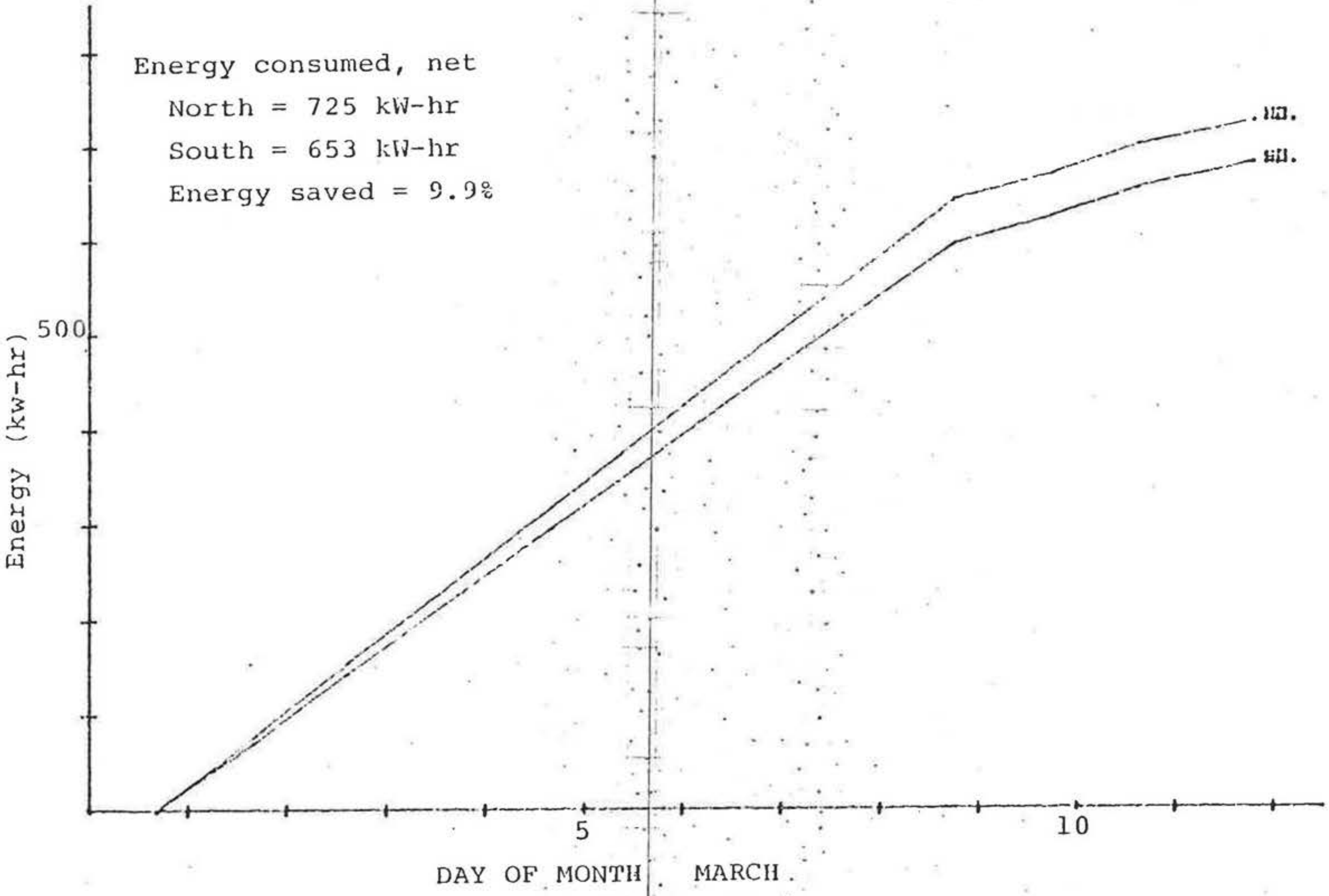

Figure 4.37 Energy used to heat homes March, 1977

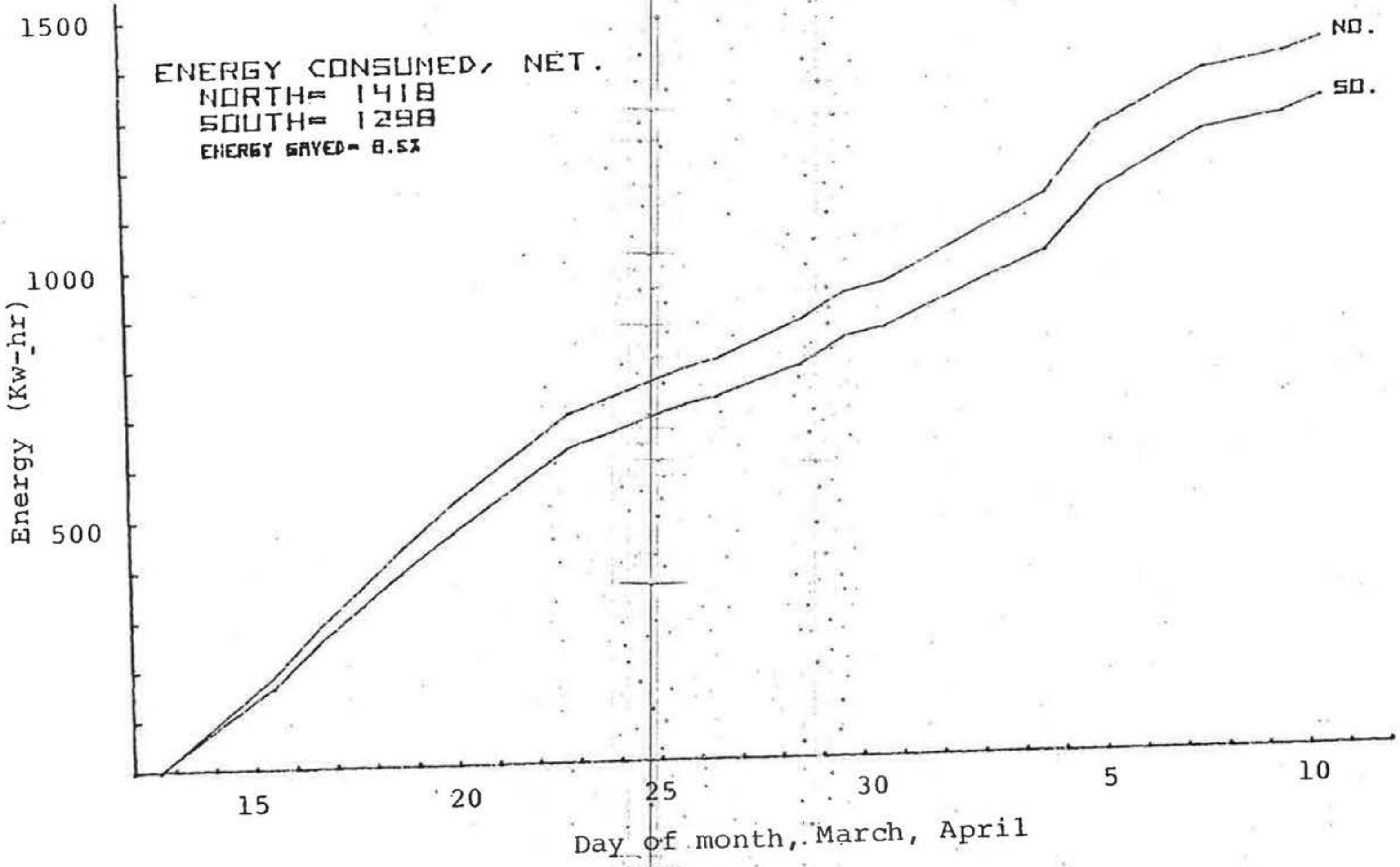

Figure 4.38 Energy used to heat homes March, April, 1977

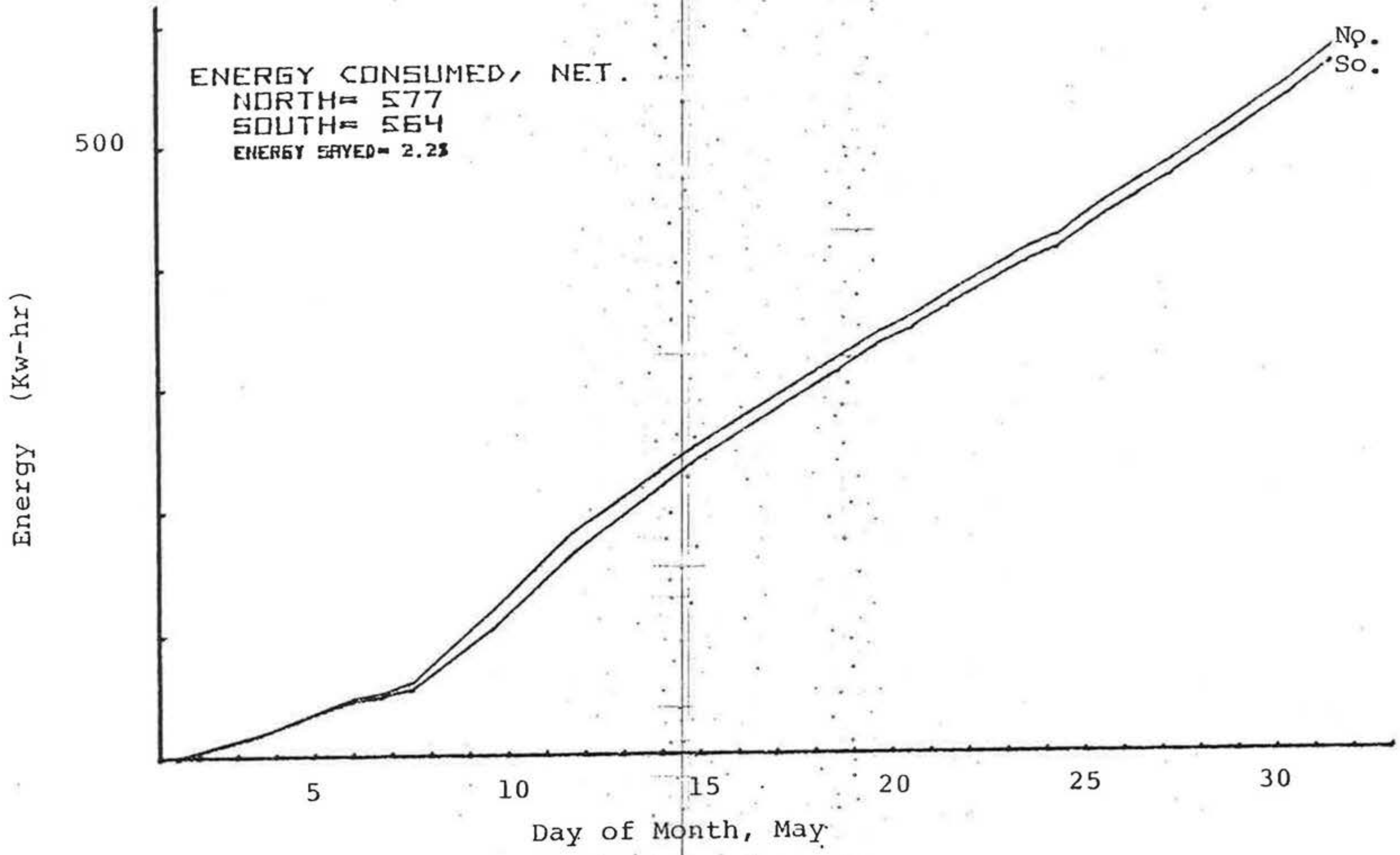

Figure 4.39 Energy used to cool homes May, 1977

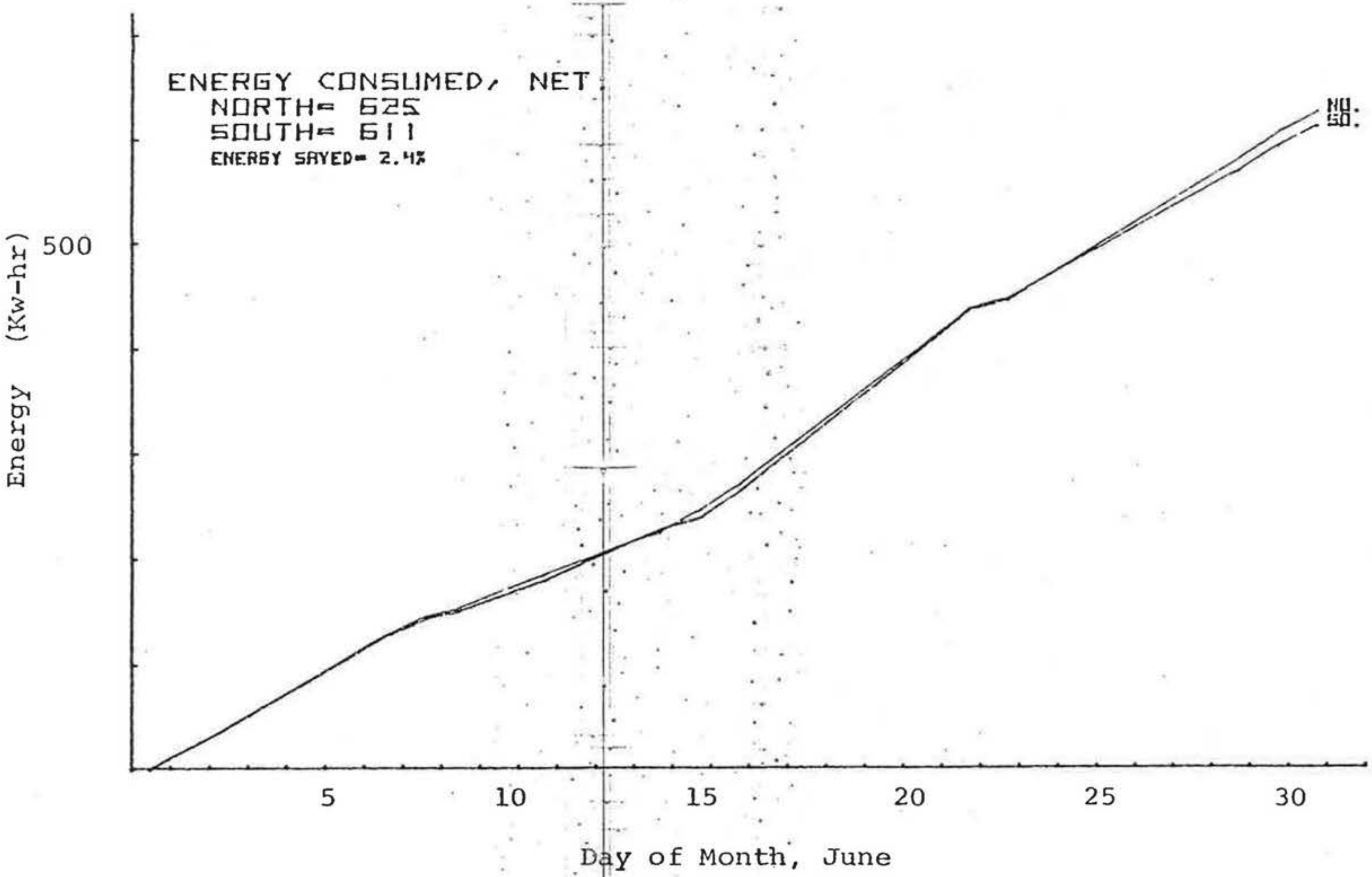

Figure 4.40 Energy used to cool homes June, 1977

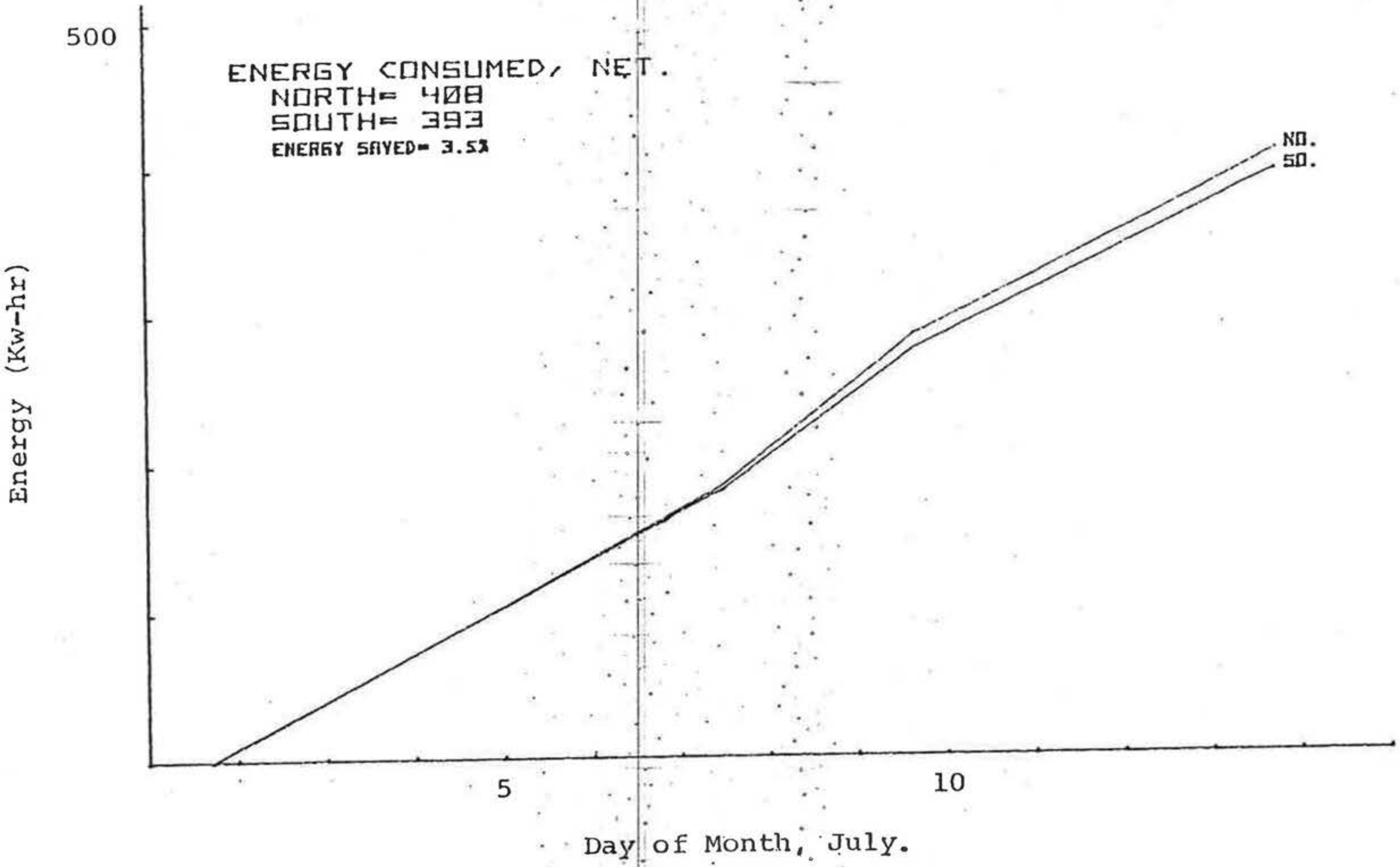

Figure 4.41 Energy used to cool homes July 1-14, 1977

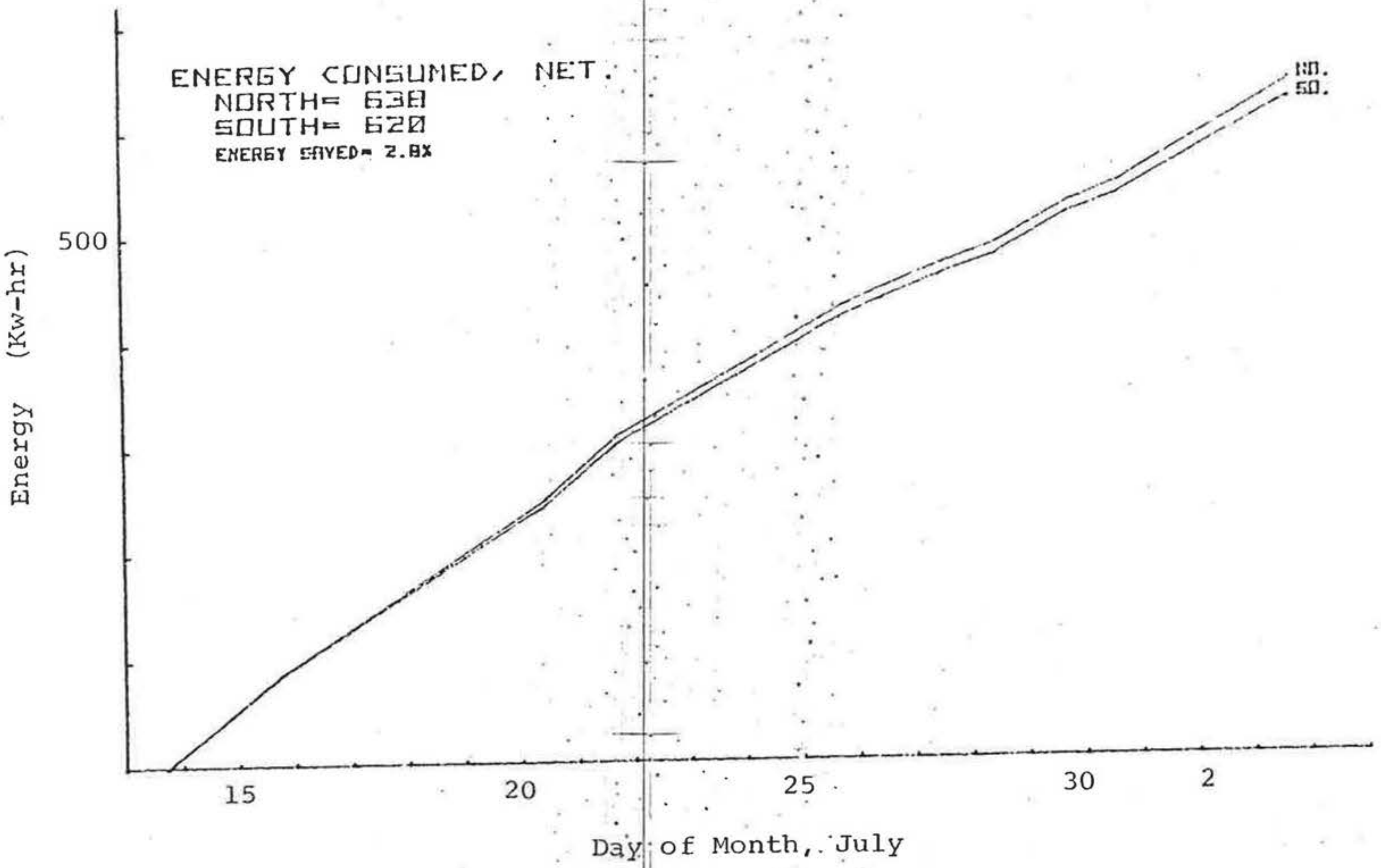

Figure 4.42 Energy used to cool homes July 14-August 2, 1977

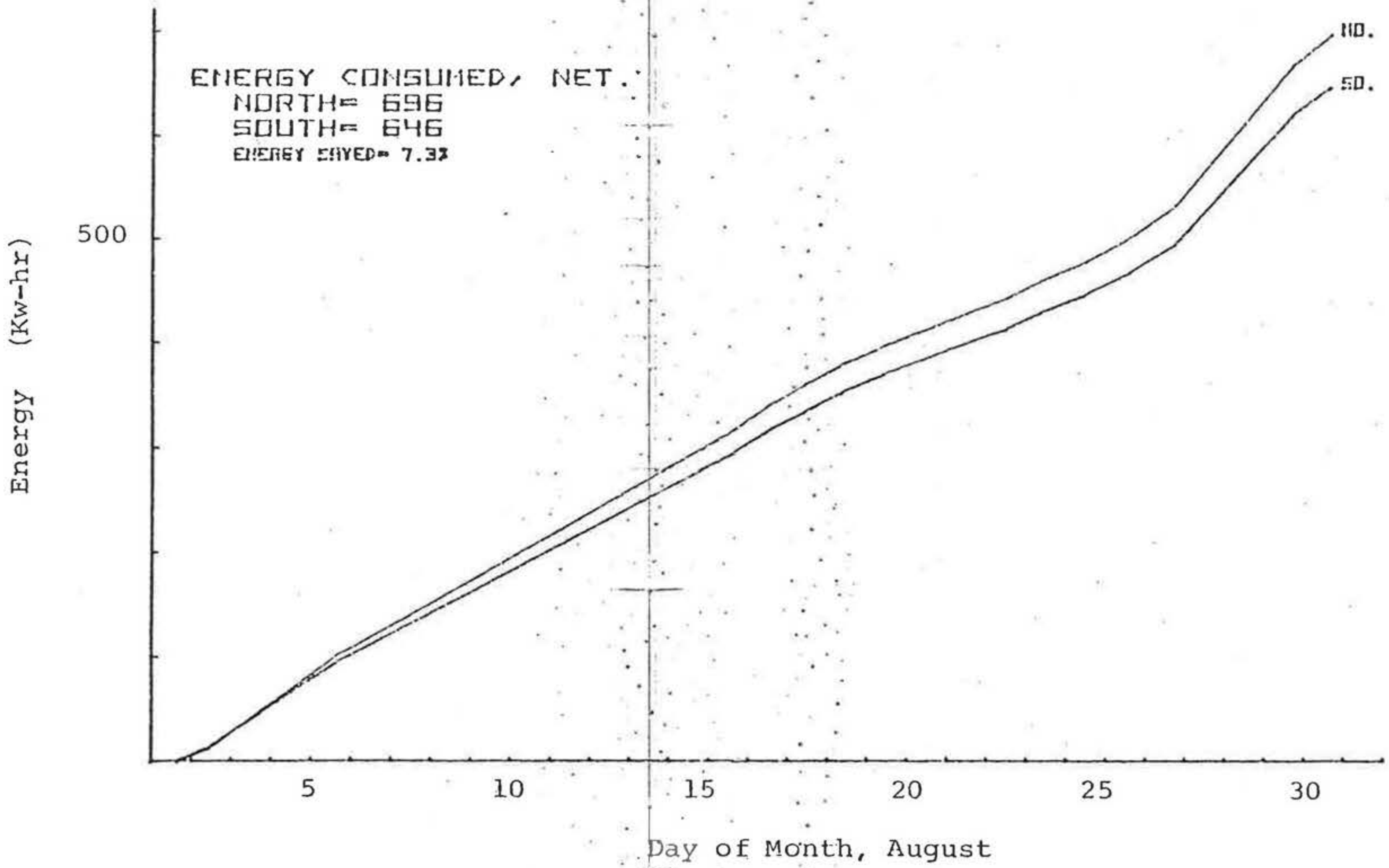

Figure 4.43 Energy used to cool homes August, 1977

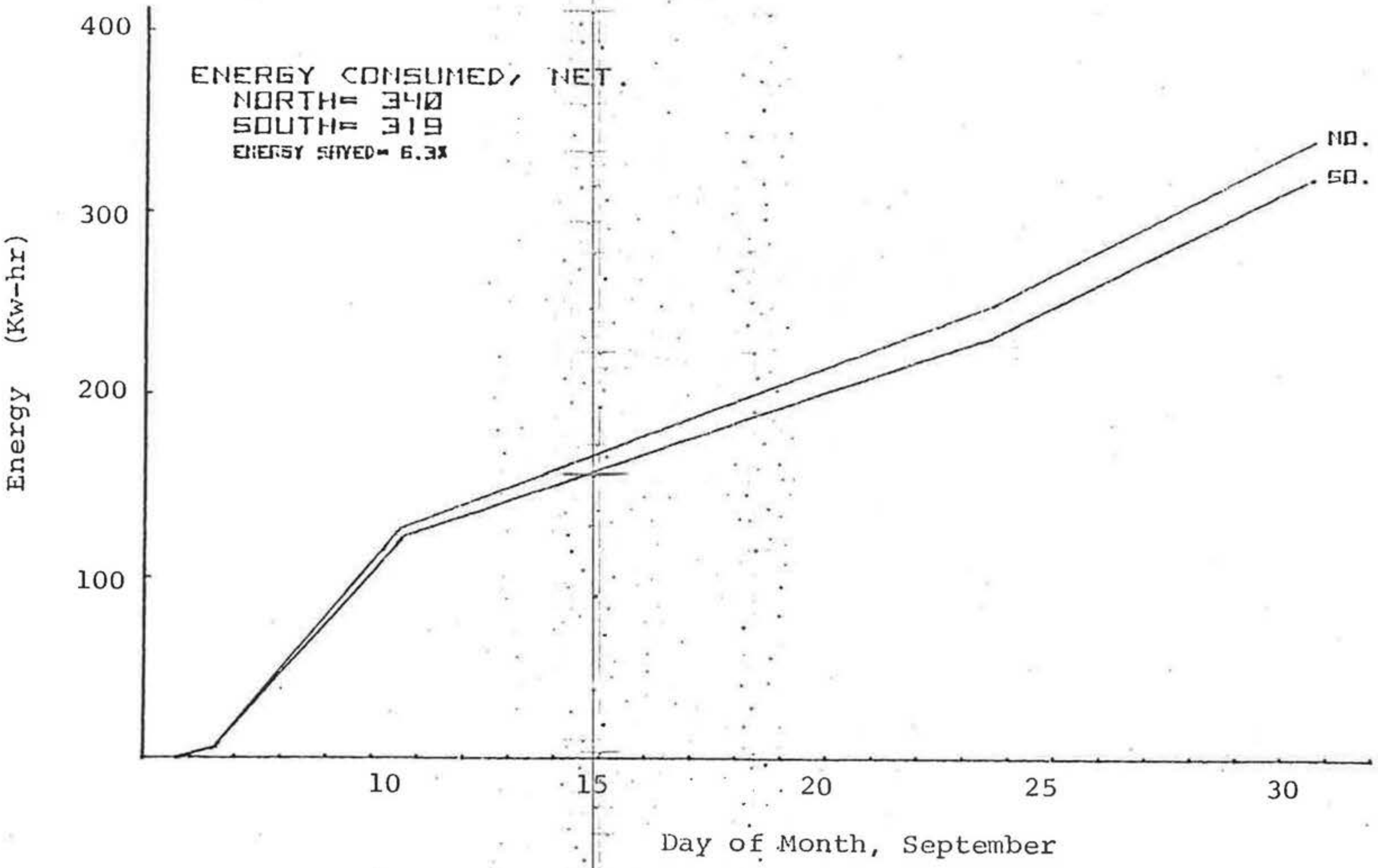

Figure 4.44 Energy used to cool homes September, 1977

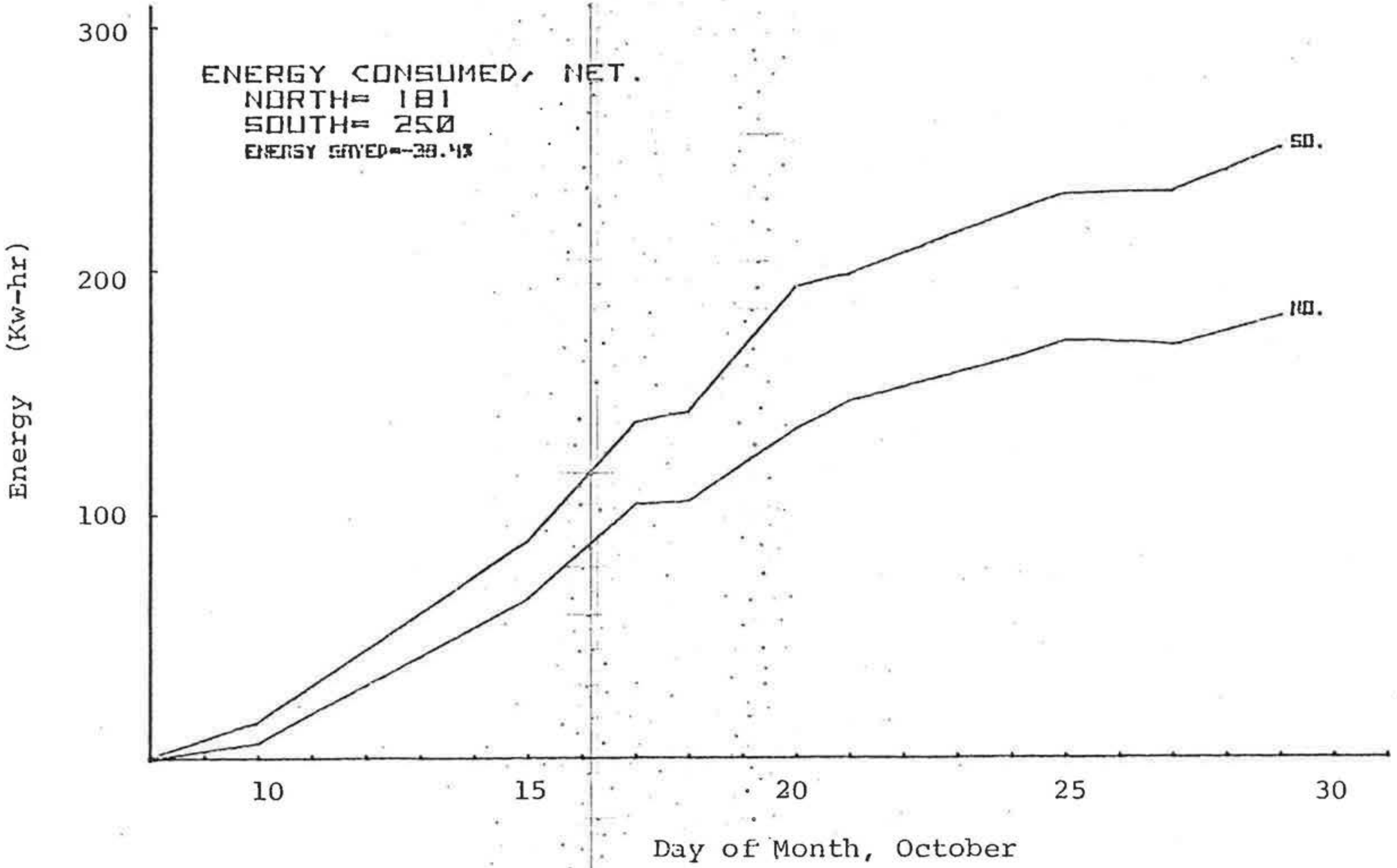

Figure 4.45 Energy used to heat and cool homes October, 1977

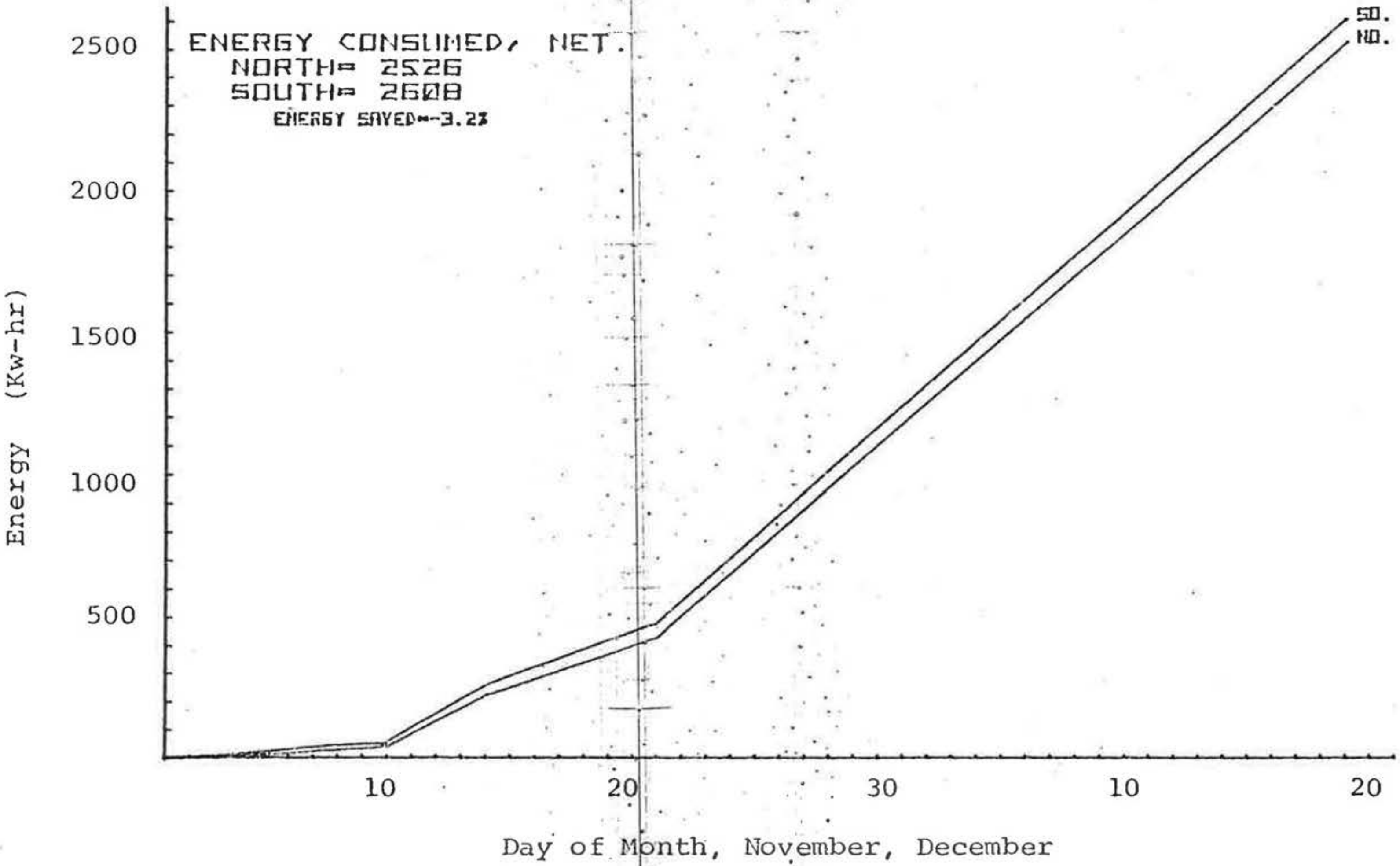

Figure 4.46 Energy used to heat homes November, December, 1977

August, 1977, represent that data for which the south home was sheathed. Data for September through December of 1977 represent the south home after sheathing had been removed.

Energy saved by the south home in winter was on the order of 10%, and in the summer was on the order of 3%. For the following winter, after the sheathing had been removed from the south homes, the north home used about 3% less energy than the south home.

Of special interest are the months of May, 1977, and September, 1977. During these months the energy savings were less than or the opposite of that expected. During many days of these two months, the outside air was cooler than the inside air, yet, due to the high heat load from the solar radiation, the air conditioning was still required. On these days the cool air infiltrating into the homes would reduce the cooling load. Thus, the home with higher infiltration would have less energy consumption. (The logical thing to do would be to open the windows on a day such as this, but for our tests, windows were kept closed throughout.)

A further analysis of the consumption of the homes and impact of sheathing board on energy utilization is part of the research by J.E. Ball reported in part in reference 56.

5 COMPARISON OF DIFFERENT CONFIGURATIONS

5.1 The Effect of the Sheathing Board Option

One of the goals of the research was to determine the effect of the sheathing board option on a mobile home. The north home was equipped with sheathing board, the south home was caulked at all structural joints and was equipped with two roof vents. These were the ways the homes were equipped when sold. The manufacturer claimed the roof vents were needed when the home was not sheathed and they were not needed when the home was sheathed (the sheathing board was permeable to water vapor but not to liquid water, thus, water condensed between the foam core and roof could not reenter the home.)

The ratios of the infiltration in the caulked (north) home to the infiltration in the sheathed (south) home are given in table C1-C4. The values of the ratios varied from .84 on day #129 to 3.97 on day #127. Only two points fell below 1.0. Nine points fell above 2.80. The average value of the ratio was 1.72. 69% of the points fell between 1.3 and 2.0.

From figures 4.20, 4.21 and 4.9 it can be seen that the infiltration ratio of the caulked to the sheathed home with no wind and temperature difference was about 1.25 (The correlations did not predict the constant accurately enough to yield a good ratio.) Looking at the correlation one can see that as the temperature difference increased, the infiltration rate in the north home increased at a rate 1.6 times that of the south home. As the wind increased the infiltration rate in the north home increased at a rate double that of the south home. Thus, it is seen that the ratio is a function of temperature difference and wind. The highest values of the ratio were obtained with a high wind and small temperature difference, the smallest values with low wind and temperature difference, and with high temperature differences the ratio lies somewhere in between the previous values.

From equation 4.17, the ratio of infiltration in the north home to that in the south home would be 1.80.

5.2 Effect of Sheathing Board

To try to determine the actual effects of sheathing board on infiltration, the sheathing board was removed from the south home in September of 1977 and two more months of data were taken. During this time, the north home remained unchanged so it could be used as a standard against which to make comparisons. The data is given in table C5. The scatter in the data is substantial and unfortunately, the test conditions were limited to a small range of ΔT. The following observations apply:

a) For the ranges in weather tested, the average value of I_N/I_S (without sheathing.) was 0.99 (based on 152 data points), showing that the infiltration rate of the home without sheathing was essentially the same as that for the home with caulking and vents.

b) Figure 5.1 shows I_N/I_S (without sheathing) as a function of wind, for relatively small values of ΔT (-5 to 5). There may be a very slight dependence on wind, with I_N/I_S (without sheathing) going above unity at low wind velocities. This could have been attributed to a stack effect on the vents becoming more dominant at low levels of wind.

c) Figure 5.2 compares I_N/I_S (without sheathing) against wind for slightly larger ΔT's than in Figure 5.1, but still quite small (from 13 to 5°C). In general, I_N/I_S (without sheathing) appears to be slightly larger (The average is now around 1.08 for this sample, compared to 0.93 of figure 5.1). This again could have been interpreted as a possible stack effect on the vents of the north home. However, the wind effect noted in figure 5.1 is not noted now.

d) Figure 5.3 compares I_N/I_S (without sheathing) to ΔT for a relatively limited range of wind (2 to 3 m/sec). The possible stack effect due to the vents in the caulked home was not strong enough, if present, to be confirmed in this plot.

e) The <u>average</u> values of I_N/I_S (sheathed) and I_N/I_S (unsheathed) were 1.72 and 0.99, respectively. This means that the south home, with sheathing would have (in the

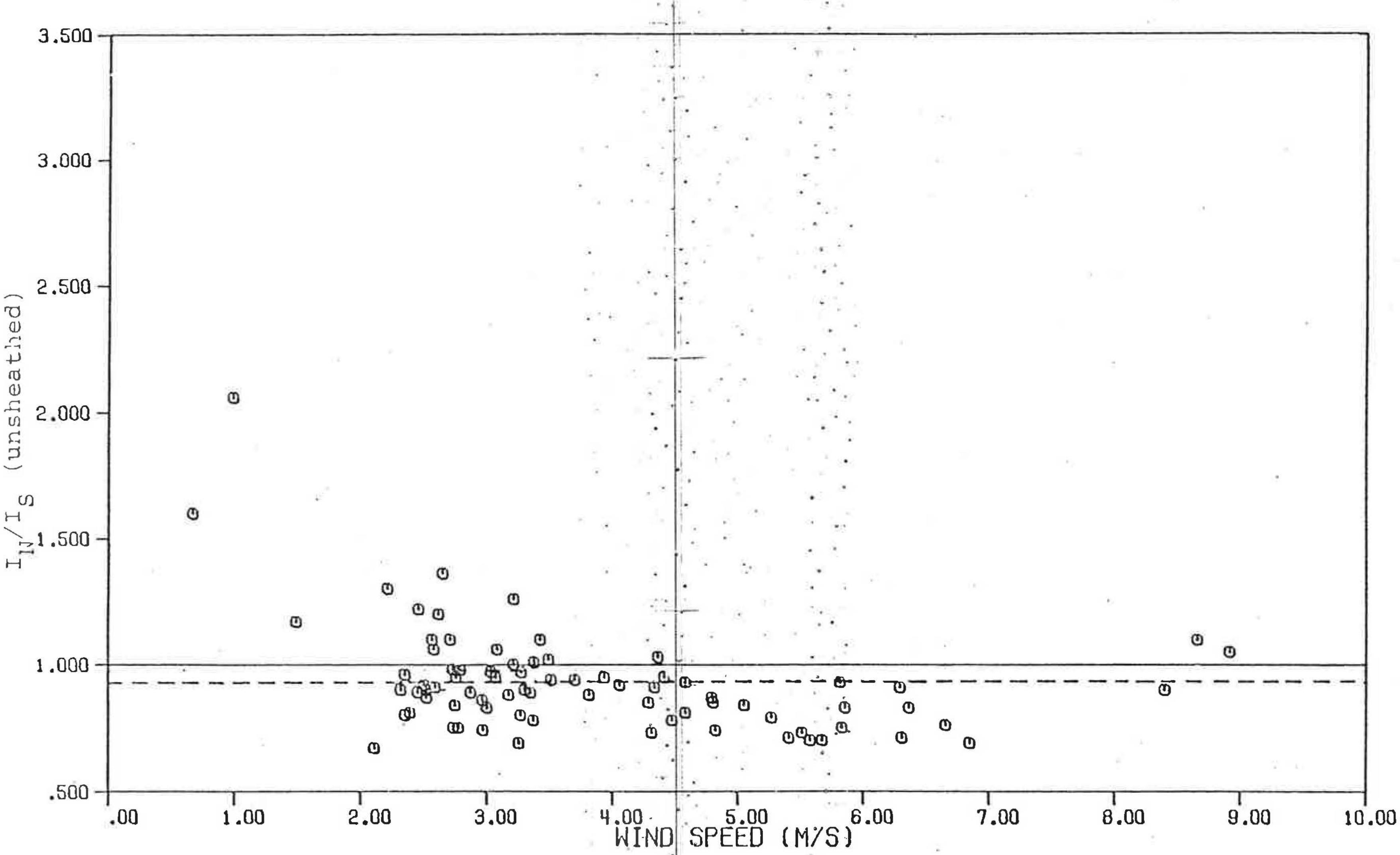

Figure 5.1 I_N/I_S vs. W for $-5<\Delta T<5$

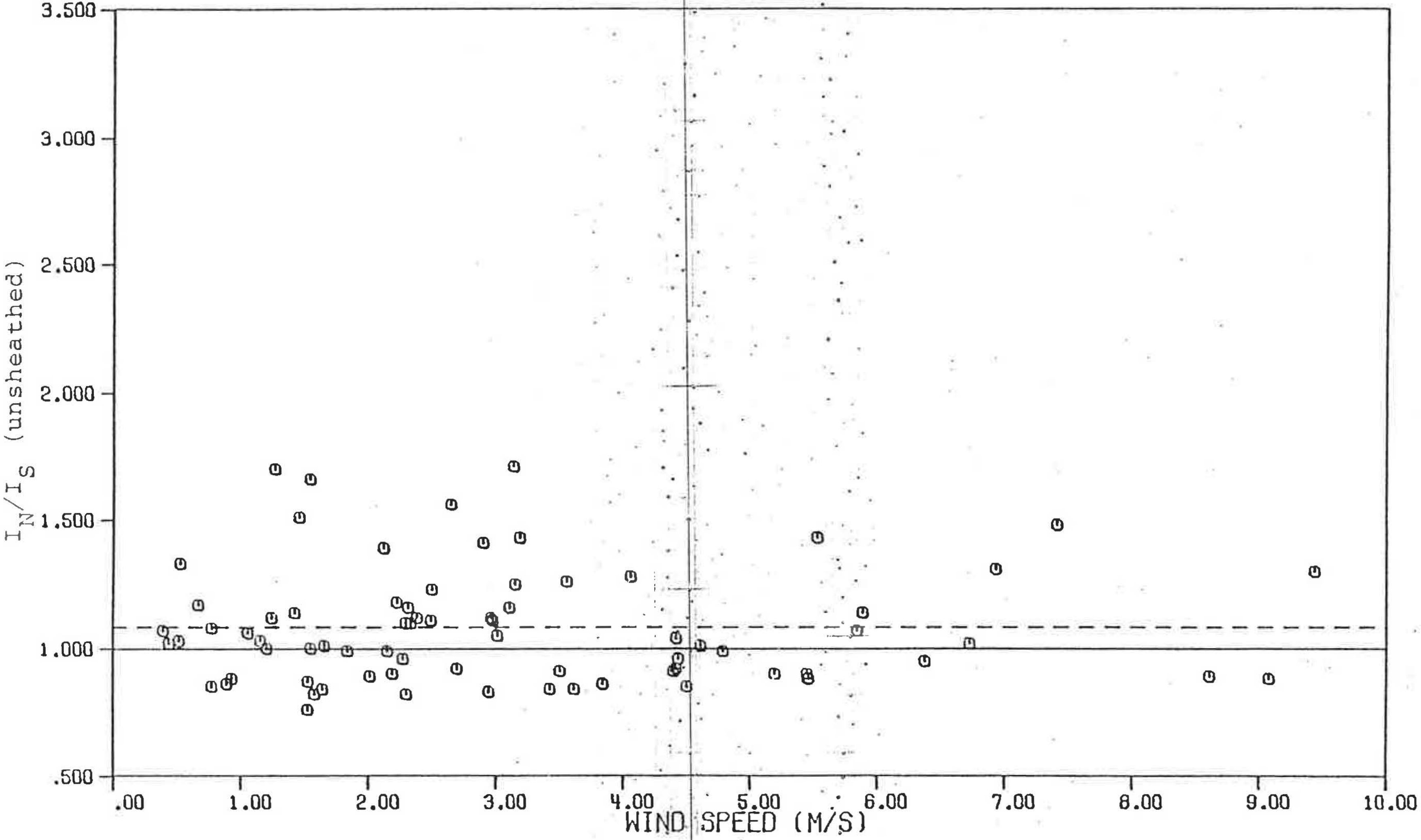

Figure 5.2 I_N/I_S vs. W for $5<\Delta T<13$

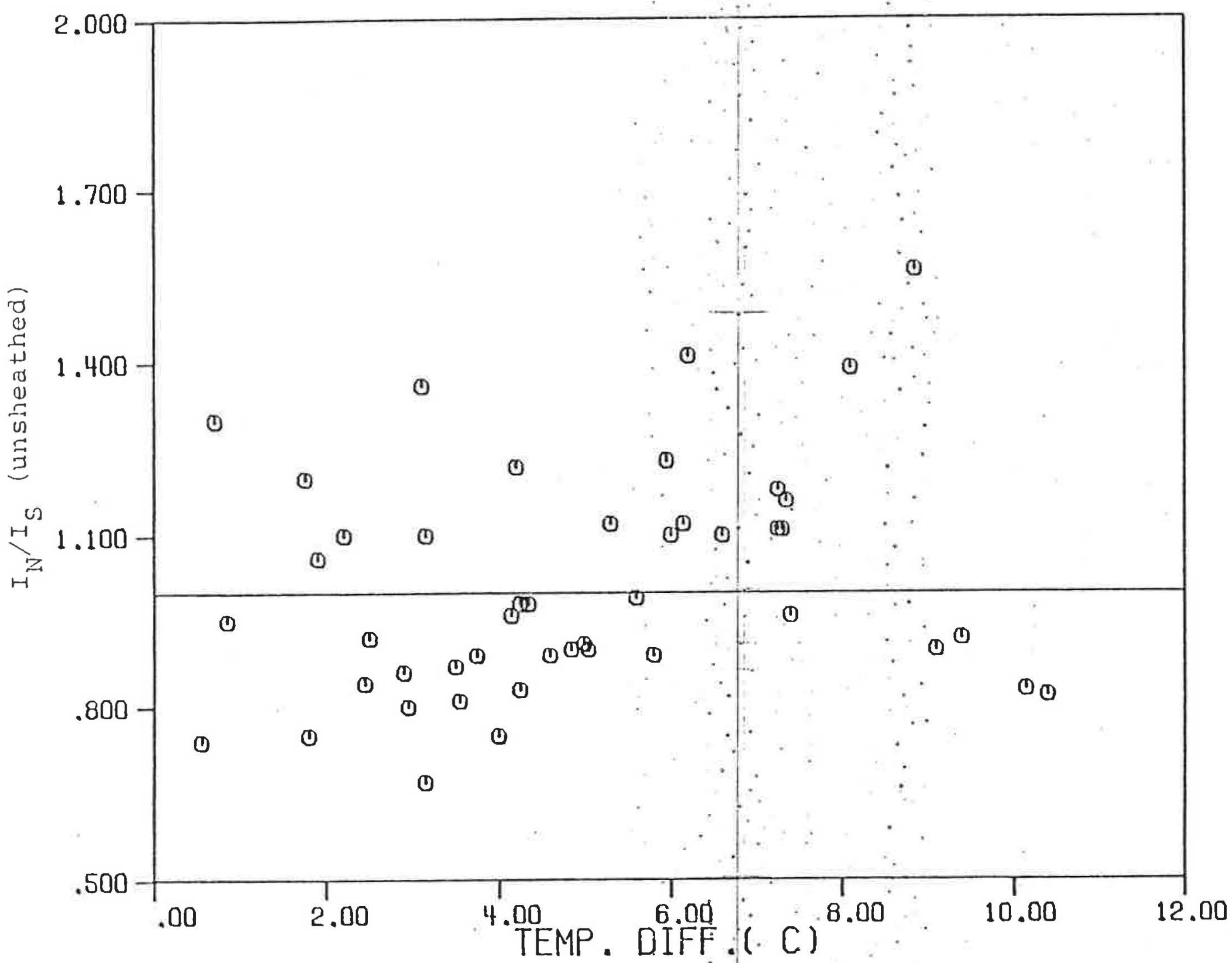

Figure 5.3 I_N/I_S vs. ΔT for $2<W<3$

average of the test data) I_S(sheathed)/I_S(unsheathed)=1.74 (i.e., I_S(unsheathed/I_S(sheathed) = [I_N/I_S (sheathed)]/[I_N/I_S (unsheathed)] $\cong$ 1.74.)

5.3 The Effect of Skirting

Skirting data was taken during two periods of time, spring 1977 when only the north home was skirted, and the first half of the summer 1977 when both homes were skirted. Skirting was added to one home at a time to compare the infiltration ratio of two homes when both had skirting, when one had skirting, and when neither home had skirting. However, the large variance of the ratios hid any effect that skirting might have had, suggesting that its benefits, if any, were within the experimental scatter of the ratio.

In order to further investigate the possible effect of skirting, the difference function*

$$\Psi \text{ (skirting)} = \frac{I_M - I_C}{I_C}$$

can be determined. Three cases were considered, summer data (both homes unskirted), spring data (one home, north, skirted) and summer data (both homes skirted). The corresponding measured values were compared against the prediction (based on all data) of equations 4.26 and 4.27 (which were based on the winter and unskirted summer data). The results are plotted in figures 5.4 through 5.9. An average

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*This is slightly different from the Ψ of equation 4.30.

difference function can be determined giving the results shown in Table 5.1.

Inspection of the table does not suggest any convincing trend.

Figures 5.4 - 5.9 do show a tendency toward lower values of Ψ at higher infiltration rates with no skirting. Since high values of infiltration correspond to higher wind velocities for the data under consideration, the average values of Ψ were found for winds in the range of 4 to 6 m/sec and for winds greater than 6 m/s. The results are shown in Table 5.2.

For the range 4-6 m/s no definite conclusions can be reached. For winds greater than 6 m/s infiltration is approximately 18% less than predicted for a skirted home and 15% less than predicted for the unskirted home. Thus, the difference was more likely due to error in the model than to the addition of skirting. All that really can be said is that the change in infiltration due to skirting, if any, was less than 15% (Since the sum of the errors is less than 15% in all cases) and, most probably, less than 5%.

Table 5.1 Average Ψ for the skirted and unskirted homes

	North home (%)	South home (%)
Unskirted summer	5.6(±5.3)	-1.6(±6.1)
Spring unskirted		-4.3(±5.2)
Spring skirted	3.1(±6.3)	
Summer skirted	10.0(±6.2)	1.2(±5.7)

Table 5.2 Average Ψ for high winds

Wind 4<W<6 m/s	North home (%)	South home (%)
Unskirted summer	0.9(±10.2)	-3.5(±14.2)
Spring unskirted		-0.3(±8.9)
Spring skirted	12.9(±12.6)	
Summer skirted	-5.4(±11.8)	-11.0(±11.8)
Wind W>6		
Spring unskirted		-15.7(±9.3)
Spring skirted	-16.4(±12.7)	
Summer skirted	-18.5(±11.3)	-21.9(±12.7)

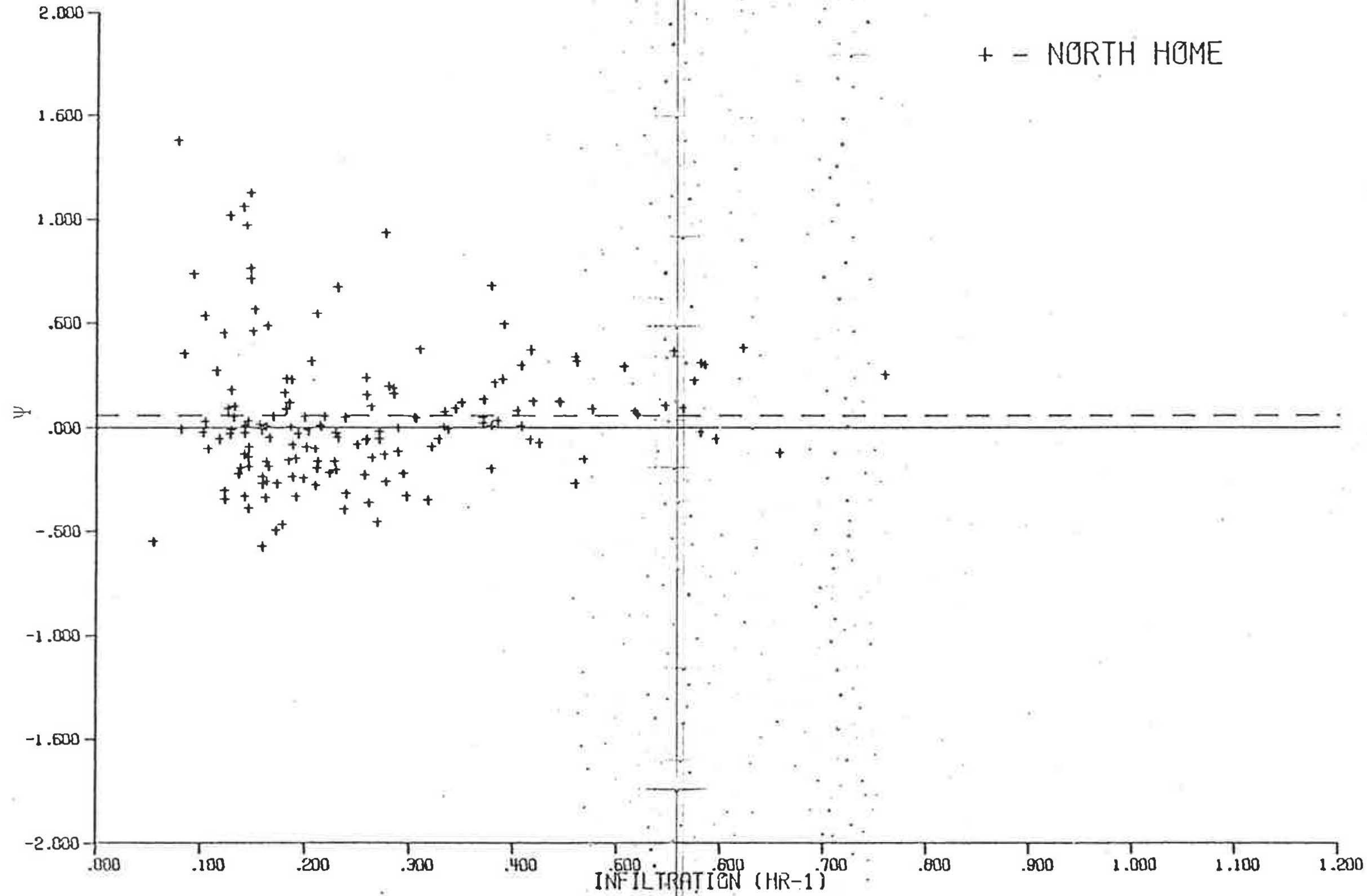

Figure 5.4 Error in unskirted summer data, north home

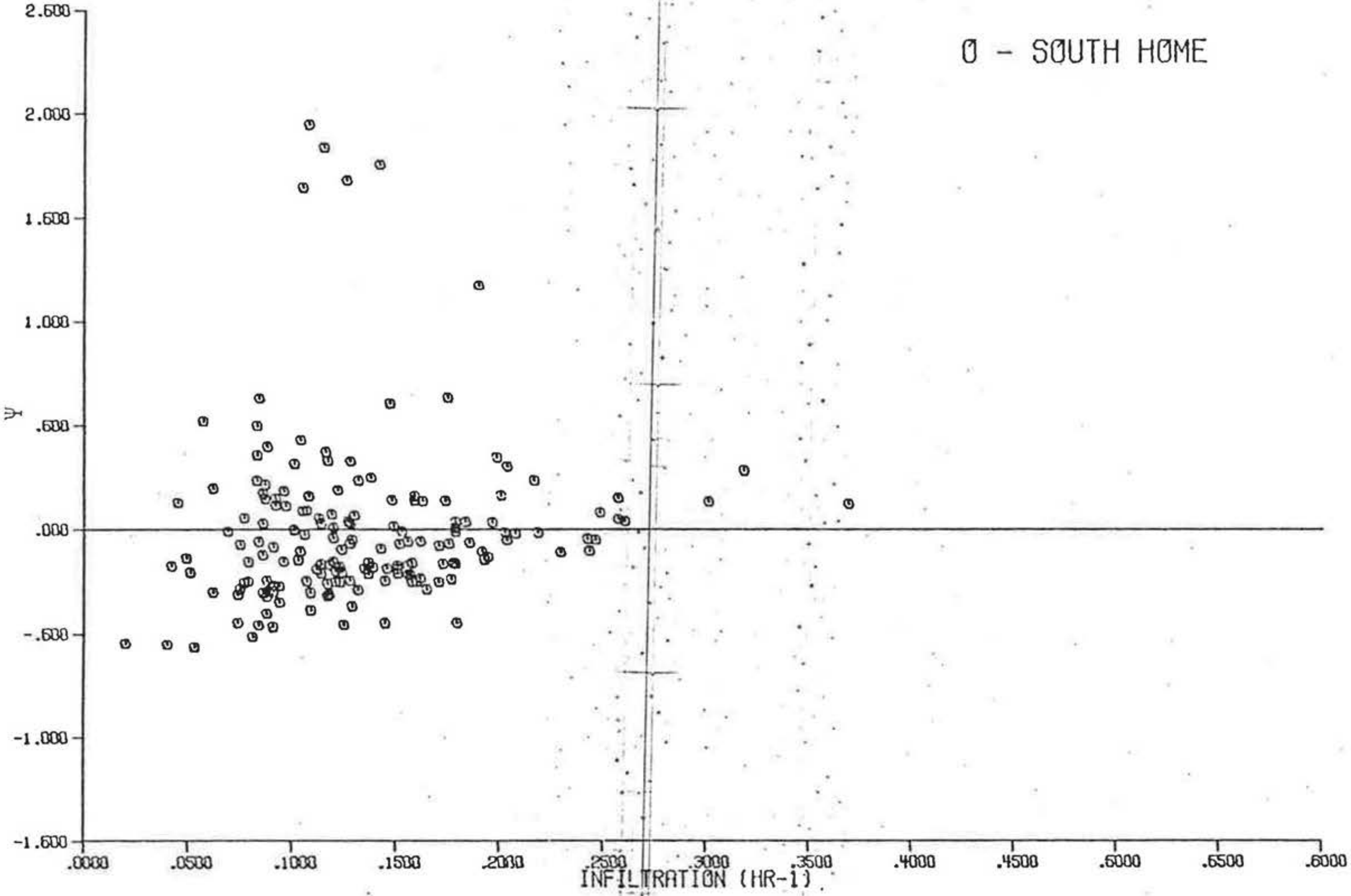

Figure 5.5 Error in unskirted summer data, south home

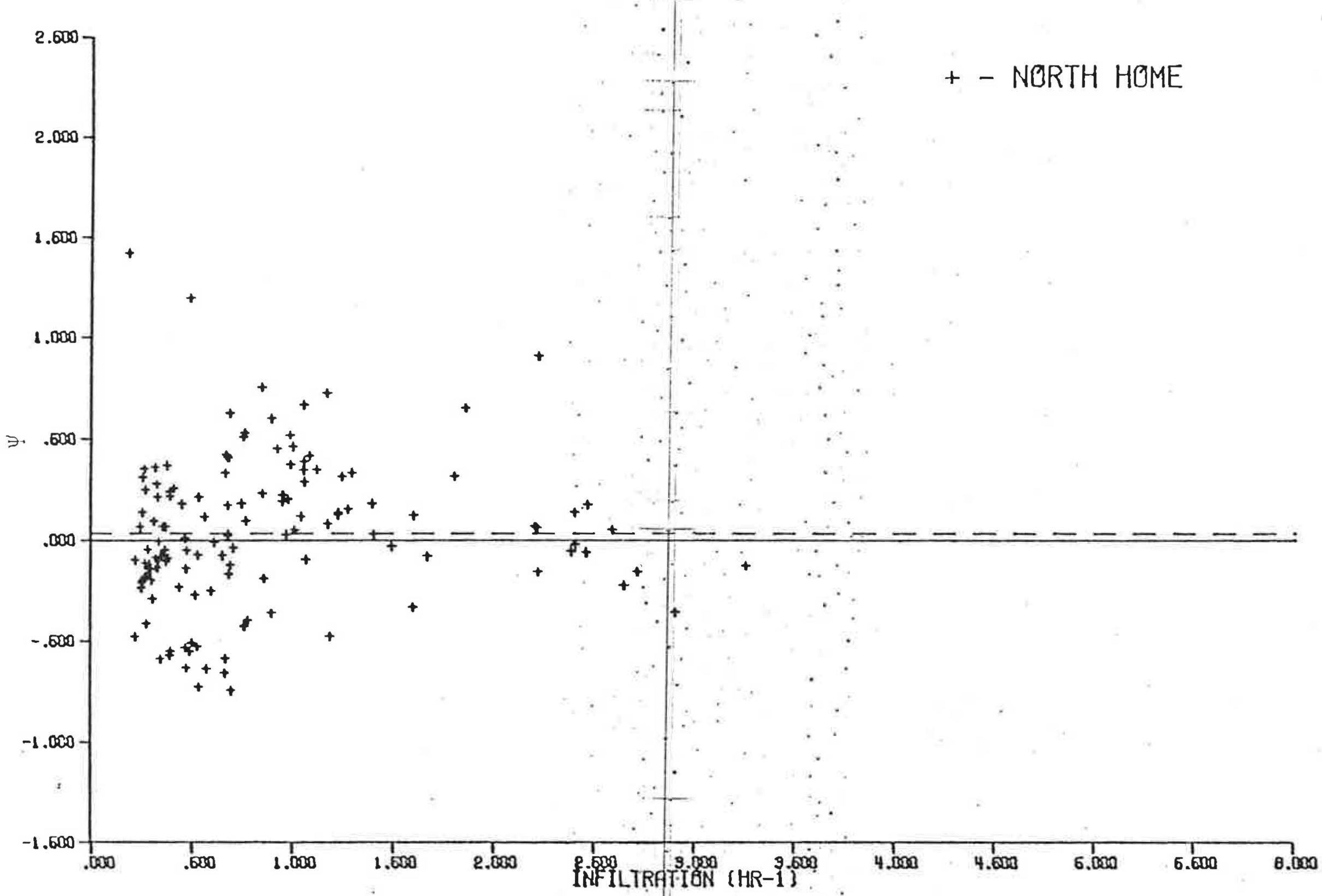

Figure 5.6 Error in spring data, skirted north home

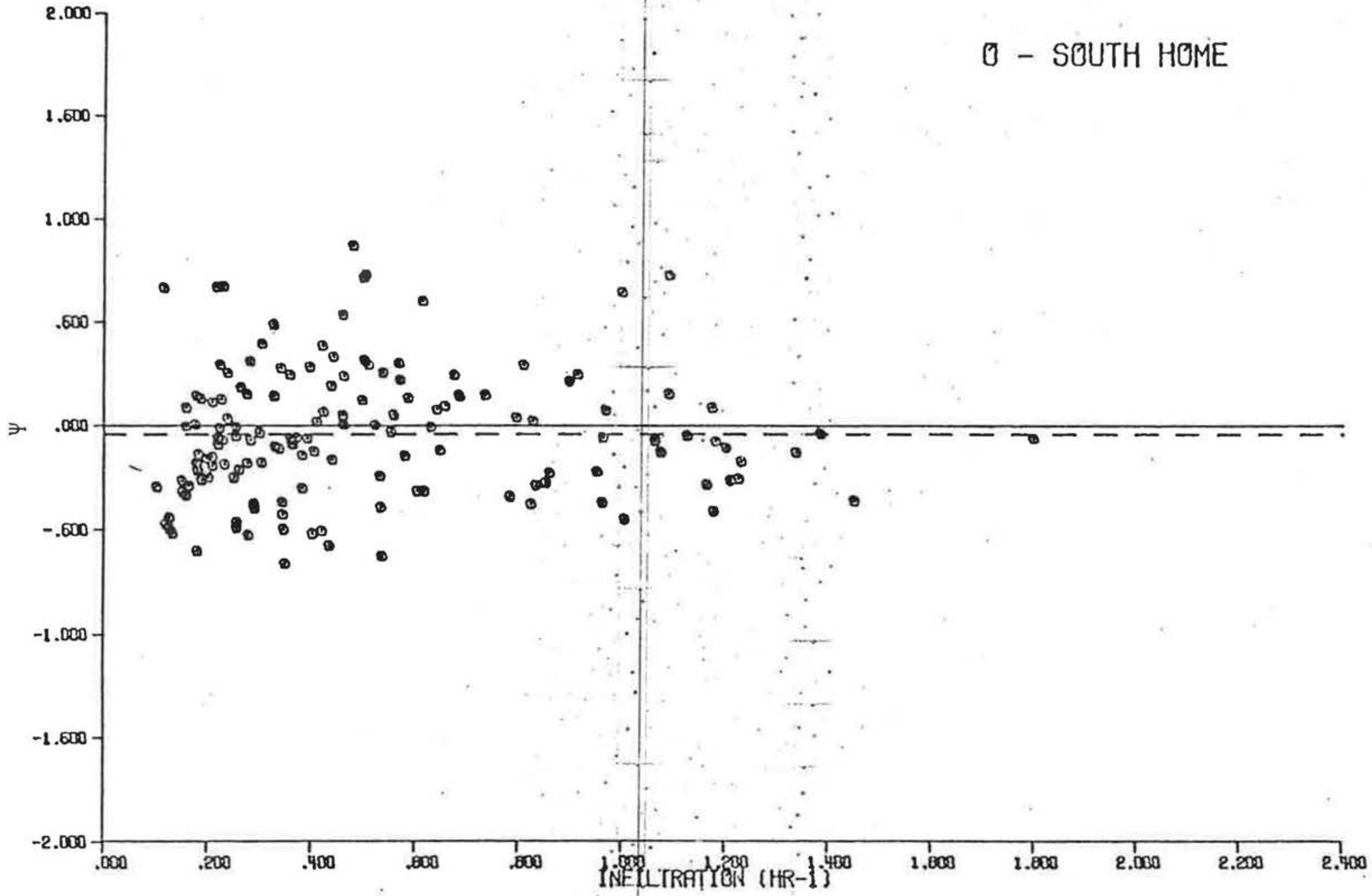

Figure 5.7 Error in spring data, unskirted south home

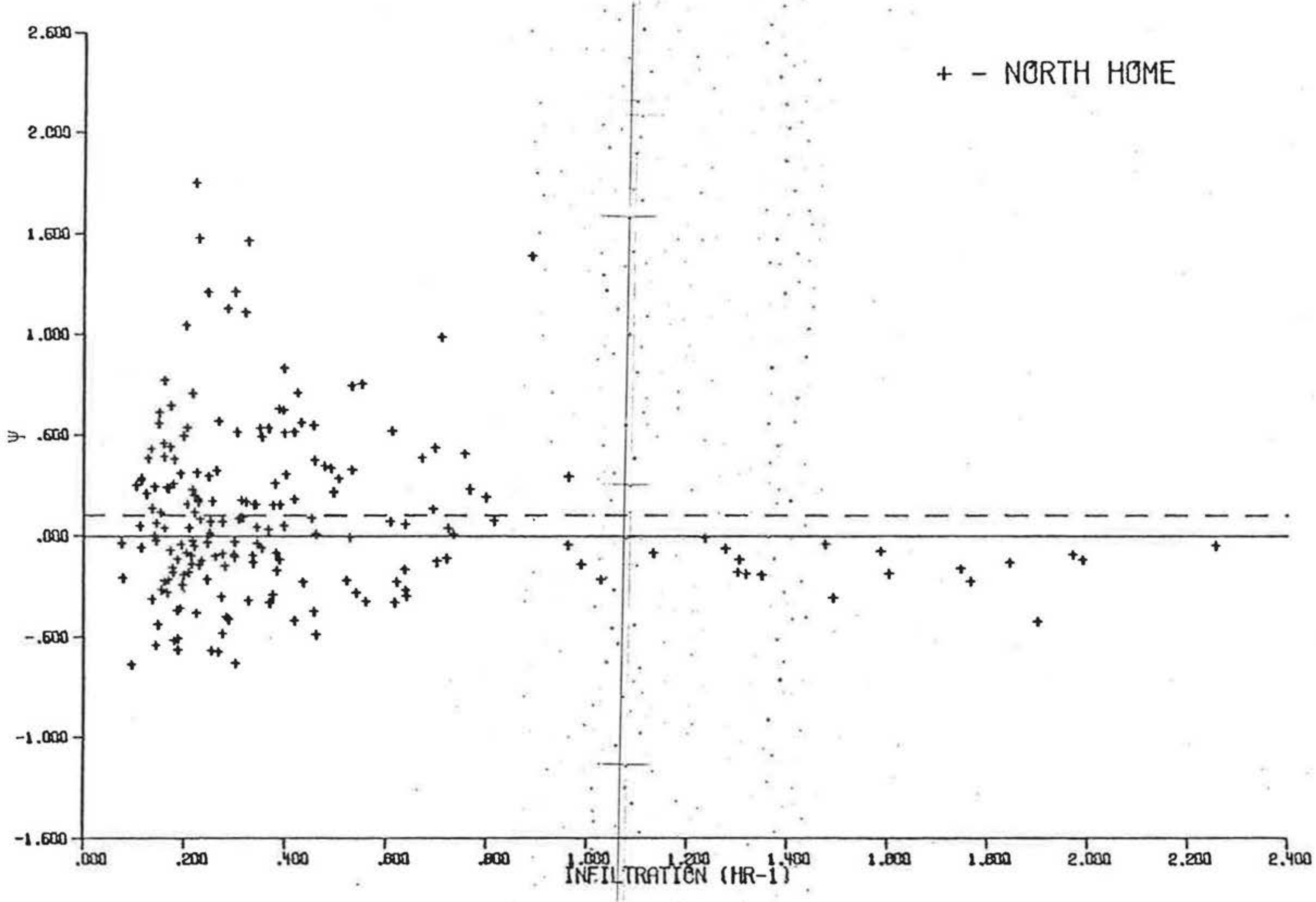

Figure 5.8 Error in skirted summer data, north home

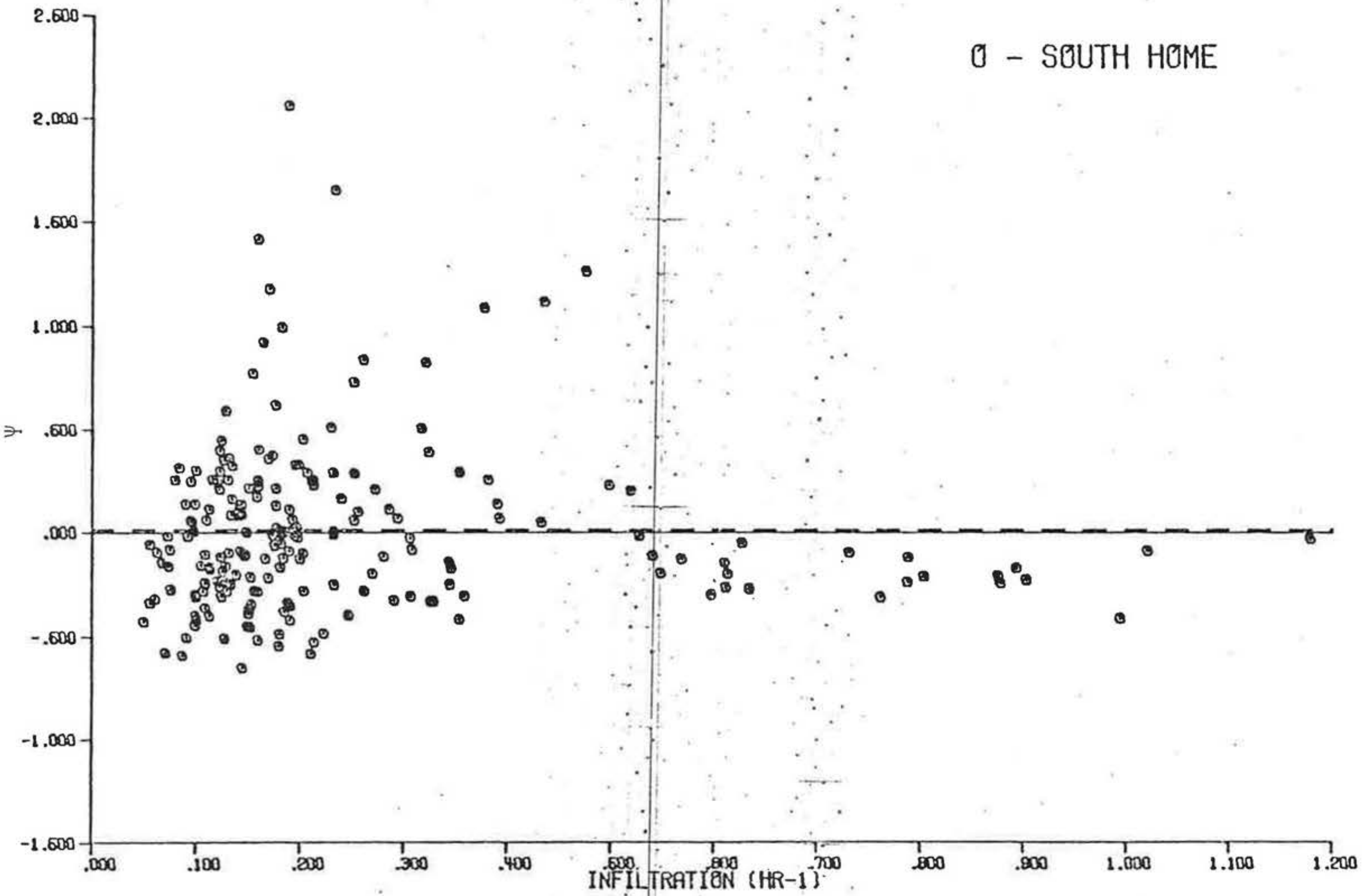

Figure 5.9 Error in skirted summer data, south home

6 CONCLUSIONS AND SUMMARY

The original goals of the research were to: a) find the effects of weather on infiltration, b) to find the effects of a continuous sheathing board on infiltration and energy consumption and c) to find the effects of skirting on infiltration and energy consumption.*

6.1 Weather Parameters

Weather parameters expected to affect infiltration were wind velocity, wind direction, temperature difference between the inside and the outside air, and to a lesser extent, humidity and solar radiation.

It was found that infiltration was almost linearly dependent on the square of the wind velocity and on the temperature difference. Wind direction played only a minor role, caused mostly by the homes shielding one another from north and south winds, and to a smaller degree on their aspect ratio.

From previous research one would have expected a linear dependence on wind, and a linear dependence on the square root of the temperature difference. The pressure drop

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*This latter aspect was treated mainly by Ball. (See reference 56.)

through a crack (see Ethenridge[50]) occurs by two mechanisms, entrance and exit losses (which depend on the square of the flow velocity) and frictional losses (which depend on the flow velocity through the crack). As the ratio of the distance through the crack to the width of the crack goes up, so does the ratio of the frictional losses to the entrance and exit losses, leading to a linear dependence of flow on pressure difference, and hence, a quadratic dependence on wind and a linear dependence on ΔT.

The effect of temperature difference on inducing infiltration was almost 3.5 times as high as would be predicted using a straight forward stack method (see reference 4). However, as pointed out by Blomsterberg and Harrje,[27] the distribution of cracks is very important in the ratio of wind induced infiltration to stack induced infiltration. To have such a high ratio, our homes had to contain a large distribution of cracks high and low in the homes providing for a larger amount of stack induced infiltration and for a slightly smaller amount of wind induced infiltration.

The effects of wind and temperature difference on infiltration were approximately additive. Some theories (for instance, reference 63) predict the effects to be subadditive. Additive characteristics were noted by earlier researchers (references 10, 14 & 16 for example), while others have found infiltration to be subadditive (references 13 & 25). The best correlation found for the present work was of the form

$$A + \frac{B|\Delta T|}{T_i T_o} + \frac{CW^2}{T_o},$$

which is additive (when the wind term is measured at the same outside temperature as the ΔT term).

Due to the large length to width ratio (aspect ratio) of the mobile homes, wind direction was expected to play an important role in infiltration. However, studies of wind direction effects on infiltration in past research have been inconclusive. Some researchers have found wind direction to be very important (references 3 and 14) while others have found it to be insignificant (reference 18). Potter[64] found that the turbulence in wind accounts for almost as much of the wind induced infiltration as does the pressure from the dynamic head. Thus, for our buildings which were exposed on all sides (except when shielded by the second home) the directional dependence would be small. (At the same time it must be noted that the percent window area and, crack distribution was similar for all four walls of the test homes.)

Humidity was found to have effects which were barely discernable; not surprising for homes with a metal skin and window frames. Solar radiation had no discernable effects on infiltration.

6.2 The Effect of Sheathing Board

Comparing a sheathed home with another with caulking and vents showed an average ratio of infiltration rates of

1:1.72. (For no wind and no ΔT, the ratio was of the order of 1:1.25.) As ΔT increases, the ratio approaches 1:1.6, whereas as the wind dependence predominates, the ratio approaches 1:2.0. The presence of sheathing board would supposedly eliminate the cracks in between sections of siding. However, due to joints in the sheathing at the top and bottom, the cracks where the siding meets the floor and roof would not be fully eliminated but they would be considerably reduced in size by the sheathing board. Cracks around windows and doors probably will not be affected a great deal by sheathing board.

The actual reduction in infiltration caused by sheathing would depend on the importance of the crack to infiltration, for example, removing a crack near the neutral level (level where the pressure difference due to the stack effect equals zero) would have little effect on infiltration induced by temperature difference, while it may change wind induced infiltration by a great deal. In our mobile homes, the eliminated cracks in the siding would have a much greater effect on wind infiltration and the reduction of structural cracks at the top and bottom would have a greater effect on stack infiltration. Due to the fact that wind induced infiltration was reduced more than stack induced infiltration, it appears as if the sheathing was more effective in reducing the cracks in the side of the home than those at the top or bottom of the home.

Infiltration rates are listed in table 6.1 for winter and summer design conditions with 6.7 m/s (15 mph) winds (Some of these values were already given in table 4.4) The maximum infiltration rates allowed for mobile homes is given by ANSI A119.1. This states that the heat loss (in BTU/hr) due to infiltration measured with 15 mph winds can not exceed an amount given by the perimeter of the home (in feet) x 0.7 x ΔT. For our homes, with a perimeter of 48.8m (160 ft), and the inside air at 21°C (70°F) the maximum allowable infiltration rate would be 1.03 changes per hour ($177 m^3/hr$). The unsheathed homes did not meet this standard. The sheathed homes did.

Further research should be conducted to determine the effects of the roof vents in the north home on infiltration. One recent attempt (B. Hays, unpublished) proved to be inconclusive due to limited data. Not knowing the effect of the roof vents on infiltration, a determination could not be made as to which had more effect on reducing infiltration at low winds: removing the roof vents or replacing caulking with a continuous sheathing board. What can be said is that, since a home with no caulking and no roof vents had approximately the same infiltration as a home with caulking and roof vents, the effect of caulking was essentially offset by the effect of roof vents.

Table 6.1 Measured and predicted infiltration at design conditions

	Summer	Winter
Outside temperature	32.8°C	-16.1°C
Inside temperature	25.6°C	22.2°C
Wind speed	6.7m/s	6.7m/s
Infiltration (cph)		
Caulked home *	0.96	1.53
Sheathed home **	0.51	0.85
Unsheathed home ***	0.97	1.55
Predicted infiltration ****		
Air change method	1.66	1.66
Crack method (based on average fit window)		
Sheathed home	1.27	1.27
Home which is not sheathed	1.82	1.82

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* Based on equation 4.26

** Based on equation 4.27

*** Based on I_N/I_S (unsheathed) = 0.987

**** See Appendix E

6.3 Effect of Skirting

The effect of skirting would be to affect the C_p values due to the wind on the surface of the home, decreasing them on the forward side and increasing them on the rear side of the home.[65] Thus, we expected to see a small decrease in infiltration. However, if there was any difference it was too small to see.

6.4 Energy Consumption

Energy consumption depends on thermal and radiation gain as well as infiltration. The effect of reducing infiltration on heat gain/or losses depends on the relative proportion of heat gain or losses due to infiltration with respect to the total heat gain/or loss. A reduction of about 10% was found for the heating load over a monthly period during the winter. Since infiltration was reduced by about 40% over the same period, the percent of the thermal losses due to infiltration in the north home would be about 25% and the south home about 15%. During the summer, the reduction was about 3%. However, the reduction in infiltration was smaller, about 25%. The cooling load now due to infiltration would be about 12% and 9% of the total cooling load for the north and south home.

6.5 Final Comments

Much work has yet to be done on air infiltration, both theoretically and experimentally. Understanding of the phenomena which affect infiltration is still at an early stage. Yet a lot of work has been done and is being done and the amount of knowledge is increasing.

At the present time, given a home, only rough estimates of the infiltration can be made. Recommended for design purposes[4] are the air change method and crack method. The air change method assumes a given amount of infiltration for each room and sums over the rooms. The crack method uses the amount of crack in the home to predict infiltration amounts. (See Appendix E and Table 6.1).

For good analysis of building thermal loads, the infiltration needs to be known fairly accurately. At present, the main recourse appears to be the experimental means of determining air infiltration. To get accurate results many measurements must be taken over long periods of time.

What is needed is an accurate way of determining infiltration with only a few measurements. This should be the major goal of future research.

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APPENDICES

APPENDIX A: Condensate

As a check of infiltration the condensate from the air conditioners was collected and measured. In theory, the amount of condensate collected should depend on the outside humidity, the humidity of the home and the amount of infiltrating air. If ω_i is the humidity ratio of the home in kg per kg dry air, and ω_o is the outside humidity, then the amount of condensate collected, M, would be

$$M = tI\forall\rho(\omega_o - \omega_i).$$

Then I would be given

$$I = \frac{M}{t\forall\rho(\omega_o - \omega_i)}.$$

Unfortunately we found no correlation between I measured this way and in the usual manner. On several occasions we found that we were collecting condensate even when the humidity ratio in the homes was equal to or exceeded the outside humidity ratio. Later we found the reason for this was moisture migrating from the ground into the homes. This was especially prevalent when the skirting was on the homes.

APPENDIX B: Computer Programs

On the following pages are listed computer programs used in the data reduction process. Program TP was used to read the paper tape and punch the data on cards. Program IFLT was used to plot the natural log of the concentration against time. DATAR was used to reduce the data.

Some of the symbols used in the program and what they stand for are as follows:

LINOUT	An array in whith the data is held until all of the data is converted.
IDATE	Date (day number).
CSTH	Concentration of the CO in the south home.
CNTH	Concentration of the CO in the north home.
DATA	Two dimensional array into which all of the data is read for one day number.
FLN	Infiltration for the north home.
ERN	Error in the infiltration rate for the north home.
FLS	Infiltration rate for the south home.
ERS	Error in the infiltration rate for the south home.
RET	Array in which calculated values are held until printed.

The following are library subroutines: READBYT, PLOTS, PLOT, AXIS, NUMBER, SYMBOL, LINE, and LSTSQ, and are loaded automatically when the MNF compiler is used.

```
JOBCARD.
PASSWORD.
FORTRAN.
REQUEST(TAPE1,NNNN,PR)  NNNN-NUMBER ASSIGNED TO THE PAPER TAPE
LOADX(LGO,RUNLIB)
PROCEED.
COPYBF(TAPE2,PUNCH,,RIB)
7/8/9  (EOR)
      PROGRAM TP(TAPE1,TAPE2,OUTPUT,TAPE6=OUTPUT)
C
C READ PAPER TAPE USING *NXT*, OUTPUT DATE, TIME,
C AND CHANNEL VALUES
C
      DATA ICNT/1/
      INTEGER HOLD(5)
      LOGICAL SW
      REAL LINOUT(12)
C
C DECODE DATE AND STORE IN *IDATE*
C
      CALL NXT(LINE,ICNT)
      IDATE=(LINE-60B)*100
      CALL NXT(LINE,ICNT)
      IDATE=(LINE-60B)*10+IDATE
      CALL NXT(LINE,ICNT)
      IDATE=(LINE-60B)+IDATE
C
C DECODE TIME AND STORE IN *TIME*
C
      DO 1 I=1,5
        CALL NXT(HOLD(I),ICNT)
1     CONTINUE
      TIME=FLOAT((HOLD(1)-60B)*10+(HOLD(2)-60B))
     *+(FLOAT((HOLD(4)-60B)*10+(HOLD(5)-60B))/60.)
      IF(HOLD(3).EQ.72B)GO TO 5
        WRITE(6,3)
3       FORMAT(*-PAPER TAPE MISPOSITIONED*)
        A=0./0.
        A=A+A
C
C OUTPUT DATE AND TIME
C
5     WRITE(2,6)IDATE,TIME
6     FORMAT(2X,I3,5X,F6.3)
      WRITE(6,7)IDATE,TIME
7     FORMAT(1H1,1X,I3,5X,F6.3)
C
C PRODUCTION LOOP DECODE TWELVE CHANNEL VALUES,BUT
C SKIP TWO DATE TIME LINES
C
10    DO 30 I=1,12
        J=0
13      CALL NXT(LINE,ICNT)
        IF(LINE.NE.103B)GO TO 13
          CALL NXT(LINE,ICNT)
          IF((LINE.LT.60B).OR.(LINE.GT.71B))GO TO 13
      IF(LINE.NE.60B.AND.I.EQ.1)GO TO 45
            CALL NXT(LINE,ICNT)
       IF (((LINE.NE.60B).AND.(I.EQ.1)))GO TO 45
C
C CHECK FOR NEGATIVE NUMBER
C
            CALL NXT(LINE,ICNT)
            IF(LINE.NE.55B)GO TO 19
              SW=.TRUE.
16            CALL NXT(LINE,ICNT)
C
C TEST FOR DECIMAL POINT
C
19            IF(LINE.EQ.56B)GO TO 21
```

```
      IF(LINE.LT.60B )              GO TO 13
C
C CONVERT DIGITS IN FRONT OF DECIMAL POINT, STORE IN *J*
C
                 J=(J*10)+(LINE-60B)
                 GO TO 16
C
C CONVERT FRATIONAL PART, STORE IN *X*
C
21               X=0.
                 N=0
24               CALL NXT(LINE,ICNT)
C
C TEST FOR NON-DIGIT, END OF VALUE
C
                 IF((LINE.LT.60B).OR.(LINE.GT.71B))GO TO 27
                   N=N+1
                   X=X+(FLOAT(LINE-60B)/(10.**N))
                   GO TO 24
C
C COMBINE *J* AND *X*, STORE IN *LINOUT(I)*
27                 LINOUT(I)=FLOAT(J)+X
                   IF(SW) LINOUT(I)=-LINOUT(I)
                     SW=.FALSE.
                     ICNT=ICNT+1
30     CONTINUE
C
C OUTPUT TIME AND TWELVE CHANNEL VALUES
C
       WRITE(2,31) TIME, (LINOUT(I),I=1,12)
31     FORMAT(F6.3,2X,2F6.3,2F6.2,2F6.3,2F6.2,2F6.3,2F6.2)
       WRITE(6,32) TIME, (LINOUT(I),I=1,12)
32     FORMAT(1X,F6.3,3X,2(F6.3,1X),2(F6.2,1X),2(F6.3,1X)
     *,2(F6.2,1X),2(F6.3,1X),2(F6.2,1X))
C
C READ IN NEW TIME AND STORE IN *TIME*
C
35     CALL NXT(LINE,ICNT)
       IF((LINE.GT.71B).OR.(LINE.LT.60B))GO TO 35
         CALL NXT(LINE,ICNT)
         CALL NXT(LINE,ICNT)
         DO 40 I=1,5
           CALL NXT(HOLD(I),ICNT)
40       CONTINUE
         TIME=FLOAT((HOLD(1)-60B)*10+(HOLD(2)-60B))
     *   +(FLOAT((HOLD(4)-60B)*10+(HOLD(5)-60B))/60.)
         GO TO 10
45       PRINT 46
46       FORMAT(* READ ERROR, ONE LINE INCORRECT AND OR *,
     1*ONE LINE MISSING.*)
47      CALL NXT(LINE, ICNT)
        IF (LINE.NE.36B)GO TO 47
        GO TO 25
999      STOP
         END

      SUBROUTINE NXT(LINE,ICNT)
C
C PLACE OCTAL VALUE OF ASCII CHARACTER NEXT IN INPUT IN
C *LINE* AFTER REMOVING THE PARITY BIT
C
      INTEGER IBUF(5)
      DATA NEXT/6/
C
C FILL BUFFER IF NECESSARY
C
1     IF(NEXT.LE.5)GO TO 5
        CALL READBYT( 1,IBUF,5,IERR)
        NEXT=1
        IF(IERR.LT.0)STOP
```

```
5          LINE=IBUF(NEXT)
           NEXT=NEXT+1
C
C CHECK AND REMOVE PARITY BIT
C
           K=ICOUNT(LINE)
           IF(MOD(K,2).NE.1)GO TO 10
             LINE=LINE.AND.177B
             RETURN
10           IF(K.EQ.0)GO TO 1
               WRITE(6,15) LINE, ICNT
15             FORMAT(≠ PARITY ERROR, ABORT ≠,O20,3X,I7,≠ SAMPLES≠)
C
C CAUSE CPU ABORT BY DIVISION BY ZERO
C
               A=0./0.
               A=A+A
               RETURN
       END
7/8/9
6/7/8/9  (EOI)
```

```
JOBCARD.
PASSWORD.
FORTRAN.
LOADX,LGO.
COPYPLT(NO,L=48)
7/8/9
      PROGRAM IFLT(INPUT,OUTPUT,PLOT,TAPE5=INPUT)
C     THIS PROGRAM GRAPHS AND LABELS A 5 MINUTE RUN.
      INTEGER CC
      REAL LENGTH
      DIMENSION CSTH(200),CNTH(200),TIME(200)
      DATA CC/1/,TM/0.0/
      READ 3,IDAY
    3 FORMAT(I5,F12.)
    5 READ(5,7) TIME(CC),NT,CSTH(CC),CNTH(CC)
    7 FORMAT(F6.3,I2,24X,F6.3,18X,F6.3)
      IF (CSTH(CC).LE.1.0)CSTH(CC)=1.0
      IF(CNTH(CC).LE.1.0)CNTH (CC)=1.0
      CNTH(CC)=ALOG(CNTH(CC))
      CSTH(CC)=ALOG(CSTH(CC))
      IF (TIME(CC).EQ.0.0.AND.CC.GT.1) TM=24.+TM
      TIME (CC)=TIME(CC)+TM
      IF(EOF,5) 10,9
    9 IF(NT.NE.0) GO TO 10
      IF(          CC.GT.198.OR.CSTH(CC)-.0001.LE.0.0.AND.CNTH(CC)-.0001
     1.LE.0.0) GO TO 11
      CC=CC+1
      GO TO 5
   10 CC=CC-1
   11 PRINT4,IDAY,TIME(1)
    4 FORMAT(* NLOG OF DATA TAKEN ON DAY NO. *I4 *.*/* STARTING AT * F8.
     13,*,*)
      II=CC/4.+.9
      DO 16 J=1,II
   16 PRINT 17, (I,TIME(I),CSTH(I),CNTH(I),I=J,CC,II)
   17 FORMAT(4(1X,I3,F7.3,2F9.4,3X))
      CSTH(CC+1)=0.0
      CNTH(CC+1)=0.0
      CSTH(CC+2)=1./3.
      CNTH(CC+2)=1./3.
      TIME(CC+2)=1./3.
      TIME(CC+1)=        (IFIX (TIME(1)*3) / 3.)
      LENGTH=       (IFIX((TIME(CC)-TIME(CC+1)+ .26    )*3))
      PRINT 27, TIME(CC+1),LENGTH
   27 FORMAT (/2F10.3)
      CALL PLOTS
      CALLPLOT(0.0,0.5,-3)
      CALL AXIS(0.0,0.0,12HTIME(HOURS).,-12,LENGTH,0.0,TIME(CC+1),TIME(
     1 CC+2),0)
      CALL AXIS(0.0,0.0,21HLN(CONCENTRATION/10) ,21,9.,90.,0.,1./3.,-1)
      CALL PLOT(0.,9.,3)
      CALL PLOT(LENGTH,9.,2)
      CALL NUMBER(LENGTH-3.,9.1,.4,IDAY,0.,6HI3,*-*)
      CALL NUMBER(LENGTH-1.97,9.1,.4,IFIX(TIME(1)),0.,2HI3)
      CALL SYMBOL(LENGTH-3.,8.75,.2,14H+ -SOUTH HOME. , 0.,14)
      CALL SYMBOL(LENGTH-3.,8.50,.2,14HX -NORTH HOME. , 0.,14)
      CALL PLOT (LENGTH,9.,3)
      CALL PLOT(LENGTH,0.,2)
      CALL LINE(TIME,CSTH,CC,1,-1,3)
      CALL LINE(TIME,CNTH,CC,1,-1, 4)
      CALL PLOT(0.0,0.0,999)
      STOP
      END
7/8/9
DATA FROM PREVIOUS PROGRAM WITH CARDS WITH IN AND IS LESS THAN ONE REMOVED.
7/8/9
6/7/8/9
```

```
JOBCARD.
PASSWORD.
FORTRAN.
LOADX(LGO,RUNLIB)
PROCEED.
COPYBF(TAPE2,PUNCH ,,DEF,DER,RIB)
COPYBF(TAPE3,PUNCH ,,DEF,DER,RIB,CON)
7/8/9
      PROGRAM DATAR(INPUT,OUTPUT,PUNCH,TAPE1=INPUT,TAPE2,TAPE3)
      REAL INFLS(2   ),INFLN(2   )
      INTEGER STN    ,SPN    ,SPS    ,STS    ,SKN,SKS
      DIMENSION DATA(200,12) ,TIME(200),RET(2,10)    ,NUM(9),HOLDO(40),
     1TIM(40)
      DATA NUM/1,2,3,4,7,8,10,11,12/
      ERROR(D,F,T,CF)=ALOG(CF/(CF-D))/(F*T)
    1 READ(1,3) NDAT
    3 FORMAT(I5)
      IF(EOF,1)16,4
    4 TM=0.00
      DO 10 I=1,198
      READ(1,2) TIME(I), (DATA(I,J),J=1,12)
    2 FORMAT(F6.3,2X,3(2F6.3,2F6.2))
      IF(TIME(I).EQ .0.00)TM=TM+24.
      TIME(I)=TIME (I)+TM
C
C    COLUMN(DATA)   WHAT IT STANDS FOR.
C     1             OLD WIND SET
C     2             NEW WIND SET
C     3             OUTSIDE DRY BULB TEMPERATURE.
C     4             OUTSIDE WET BULB TEMPERATURE
C     5             CONCENTRATION SOUTH
C     6             WIND DIRRECTION
C     7             SOUTH HOME DRY BULB
C     8             SOUTH HOME WET BULB
C     9             CONCENTRATION NORTH HOME
C     10            SOLAR RADIATION
C     11            NORTH HOME DRY BULB
C     12            NORTH HOME WET BULB
C
      DO 20 J=5,9,4
      IF(DATA(I,J).LE.1.)DATA(I,J)=1.0
   20 DATA(I,J)=ALOG(DATA(I,J))
      IF (EOF,1)15,10
   10 CONTINUE
   15 PRINT 7
    7 FORMAT(*1DAY  TIME   INFLT  INFLT  RATIO OLD WIND WIND        *,
     1*OUTSIDE   OUTSIDE  STH HOME STH HOME SOLAR    NTH HOME NTH HOME
     2WIND DELT  DELT*,
     3       /6X,*START  NORTH  SOUTH  IN/IS SET*,6X,
     4*SPEED     DRY BULB  WET BULB DRY BULB WET BULB RADIAT.  DRY BULB
     5WET BULB  DIR SOUTH NORTH*/33X,
     63(*AVG*,7X),5(*AVG*,6X),*AVG*,6X,*AVG*/33X,3(*STD.DEV.  *), 5(*STD
     7.DEV. *),*STD.DEV. STD.DEV.*)
      READ 11, DS,DN
   11 FORMAT(2F5.1)
      DO 8J=1,50
      READ(1,12) STS    ,SPS    ,SKS,STN    ,SPN    ,SKN
   12 FORMAT(6I5 )
      IF(EOF,1)1,14
   14 FLN=0.0
      ERN=0.0
      IF(STN.EQ.0) GO TO 5
      N=0
      DO 35 I=STN,SPN
      IF(I.EQ.SKN) GO TO 25
      N=N+1
      HOLDO(N)=DATA(I,9)
      TIM(N)=TIME(I)
      GO TO 35
   25 READ 13,SKN
```

```
   13 FORMAT(25X,I5)
   35 CONTINUE
      CALL LSTSQ(N,1,TIM,HOLDO,INFLN)
      FLN=-INFLN(2)
      ERN=ERROR(DN,FLN,TIM(N)-TIM(1),EXP(HOLDO(N)))
      FLS=0.0
      ERS=0.0
      RATIO=0.0
      IF(STS.EQ.0) GO TO 56
    5 N=0
      DO 50 I=STS,SPS
      IF(I.EQ.SKS) GO TO 27
      N=N+1
      HOLDO(N)=DATA (I,5)
      TIM(N)=TIME(I)
      GO TO 50
   27 READ 9, SKS
    9 FORMAT(10X,I5)
   50 CONTINUE
      CALL LSTSQ(N,1,TIM,HOLDO,INFLS)
      FLS=-INFLS(2)
      ERS=ERROR(DS,FLS,TIM(N)-TIM(1),EXP(HOLDO(N)))
      RATIO=FLN/FLS
      IF (SPN-STN.GE.SPS-STS) GO TO 56
      SPN=SPS
      STN=STS
   56 CALL WIND(DATA(STN,6),SPN-STN+1,RET(1,10))
      DO 30 K=1,9
      I=NUM(K)
C
C      COLUMN(RET)     WHAT IT STANDS FOR.
C       1              OLD WIND SET.
C       2              NEW WIND SET
C       3              OUTSIDE DRY BULB TEMPERATURE
C       4              OUTSIDE WET BULB TEMPERATURE
C       5              SOUTH HOME DRY BULB
C       6              SOUTH HOME WET BULB
C       7              SOLAR RADIATION
C       8              NORTH HOME DRY BULB
C       9              NORTH HOME WET BULB
C      10              WIND DIRRECTION
C
      HOLD=0.
      HOLD2=0.
      NN=0
      DO 32 L=STN,SPN
      HOLD=HOLD+DATA(L,I)
      NN=NN+1
   32 HOLD2=HOLD2+DATA(L,I)**2
      RET(1,K)=HOLD/NN
   30 RET(2,K)=SQRT( ABS(HOLD2-HOLD**2/NN)/(NN-1))
      RET(1,2)=2.*RET(1,2)+.87
      RET(2,2)=2.*RET(2,2)
      RET(1,7)=65.25*RET(1,7)
      RET(2,7)=65.25*RET(2,7)
      DTN=RET(1,8)-RET(1,3)
      DTS=RET(1,5)-RET(1,3)
      PRINT17,NDAT,TIME(STN),  FLN   ,  FLS   ,RATIO,(RET(1,K),K=1,10)
     1,DTS,DTN
      PRINT 19, TIME(SPN),ERN,ERS,(RET(2,K),K=1,10)
   17 FORMAT (I4,4F7.3, F5.2, 3F10.2, 5F9.2, F8.0, 2F6.2)
   19 FORMAT(5X, 3F7.3, 7X, F6.3, 3F10.3, 5F9.3, F9.1/)
      WRITE(2,18) NDAT,TIME(STN),FLN,FLS, RATIO,(RET   (1,K),K=2,10)
     1,DTS,DTN
   18 FORMAT(I3, F6.2, 2F6.3, F5.2, F6.2, 4F5.1, F4.0, 2F5.1, F3.0, 2F5.1)
     11)
      WRITE(3,23) NDAT,TIME(STN),FLN,FLS, RATIO,(RET   (1,K),K=2,10)
      WRITE(3,21) NDAT,TIME(STN),TIME(SPN),ERN,ERS,(RET(2,K),K=2,10)
   23 FORMAT(I4, F6.2,2F6.3,F5.2,5F6.2,F6.1,2F6.2,F4.0)
   21 FORMAT(I4,2F6.2,2F6.3,5F6.3,F6.2,2F6.3,F4.1)
```

```
    8 CONTINUE
   16 J=J-1
      PRINT 22,J,NDAT
   22 FORMAT(*  TOTAL NO. OF RUNS= *,I2,* ON DAY NO.  *I4)
      STOP
       END
      SUBROUTINE WIND(DATA,NP,RETN)
      DIMENSION DATA(1),RETN(2)
      HOLD=DATA(1)
      HOLD2=DATA(1)**2
      DO 10 J=2,NP
      IF(DATA(J)-HOLD/(J-1).LE.-1.30)DATA(J)=DATA(J)+2.60
      IF (DATA(J)-HOLD/(J-1).GE.1.30)DATA(J)=DATA(J)-2.60
      NN=J
      HOLD=HOLD+DATA(J)
   10 HOLD2=HOLD2+DATA(J)**2
      RETN(1)=HOLD/NN*360./2.60
      RETN(2)=(SQRT(ABS(HOLD2-HOLD**2/NN)/(NN-1)))*360./2.60
      IF (RETN(1).GE.360.)RETN(1)=RETN(1)-360.
      IF (RETN(1).LT.0.)RETN(1)=RETN(1)+360.
      RETURN
      END
7/8/9
DATA DECK USED IN PREVIOUS PROGRAM.
7/8/9
ZERO DRIFT FOR THE SOUTH HOME AND ZERO DRIFT FOR THE NORTH HOME PUNCHED
   IN COLUMNS 1-5 AND 6-10, REAL FORMAT.
DATA INDICATING THE DIVISION OF THE DATA INTO TIME PERIODS.  STARTING AND
   STOPPING POINT NUMBERS ARE PUNCHED WITH THE FOLLOWING INTEGER FORMAT.
  SST  SSP  SSK  NST  NSP  NSK  (6I5)
      SST-STARTING POINT SOUTH HOME, LEAVE BLANK IF SOUTH HOME NOT TO BE
         CONSIDERED DURING THIS TIME PERIOD
      SSP-STOPPING POINT SOUTH HOME
      SSK-SKIP THIS POINT WHICH WAS INCORRECT SOUTH HOME
      NST-STARTING POINT NORTH HOME, LEAVE BLANK IF NORTH HOME IS NOT TO BE
         CONSIDERED DURING THIS TIME PERIOD.  (ABNORMAL TERMINATION WILL OCCUR
         IF SST AND NST ARE LEFT BLANK.)
      NSP-STOPPING POINT NORTH HOME
      NSK-SKIP THIS POINT WHICH WAS INCORRECT NORTH HOME
         FOR EACH POSITIVE VALUE OF SSK AND NSK READ, THE PROGRAM WILL READ
         ONE MORE CARD.  SO ONE BLANK CARD MUST BE LEFT IN THE DECK AFTER THE
         LAST POSITIVE VALUE OF BOTH SSK AND NSK.  IF NO POINTS ARE IN ERROR
         PUNCH A ZERO FOR SSK AND NSK OR LEAVE BLANK.
7/8/9
6/7/8/9
```

APPENDIX C: Data

In the following tables is a list of all the infiltration data.

TABLE C1: WINTER DATA.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	SOUTH DRY BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	WIND DIR. DEG.
344	2.75	.543	.322	1.69	1.82	-7.5	22.5	-0	22.7	346
344	3.67	.618	.391	1.58	2.32	-6.7	22.8	-1	22.8	359
344	6.25		.722		3.63	-5.2	23.1	-0	22.9	353
345	1.67	.852	.540	1.58	5.65	3.9	23.8	-0	24.0	34
345	2.25	.936	.598	1.57	6.50	4.2	24.2	-0	24.0	25
345	3.00		.759		7.01	4.6	24.1	-0	24.1	29
345	3.00	1.257			7.13	4.6	24.3	-0	24.0	30
345	3.83		.696		6.87	4.6	24.3	-0	24.0	25
345	8.97	.855	.578	1.48	6.21	4.7	23.9	30	26.3	35
345	9.33	.876	.563	1.56	6.51	4.9	24.2	51	24.1	31
345	9.93	.927	.591	1.57	6.50	5.1	24.1	66	23.9	28
345	10.33		.577		5.90	5.2	24.1	72	24.3	32
345	10.37	.945			6.04	5.2	24.3	71	24.4	32
345	10.97		.539		6.03	5.4	24.3	73	24.2	34
346	10.73	.621	.263	2.36	1.02	-4.7	23.4	247	23.7	266
346	12.07	.570	.270	2.11	.53	-2.4	23.7	408	24.3	309
346	12.50	.638	.353	1.81	.79	-1.6	24.4	349	24.0	43
346	12.93	.554	.255	2.17	.60	-1.2	23.6	346	23.8	324
346	13.37	.504	.250	2.02	1.78	-.2	24.2	354	24.3	327
347	3.17	.591	.294	2.01	1.98	-.2	23.4	-1	24.7	42
347	3.58	.638	.319	2.00	2.51	-.2	23.4	-1	23.3	58
347	4.33	.751	.406	1.85	3.64	-.2	23.3	-1	22.7	55
347	4.67	.861	.437	1.97	3.94	-.1	23.5	-1	23.3	60
347	5.25	1.092	.519	2.10	3.87	-.2	23.6	-0	23.3	67
347	5.75		.667		5.01	-.2	23.4	-1	23.5	68
347	8.83	.848	.490	1.73	4.47	-1.1	22.9	39	23.2	74
347	9.17	1.122	.639	1.76	5.38	-.9	23.3	94	23.3	56
347	9.75	.897	.543	1.65	4.84	-.6	23.3	147	23.4	65
347	10.75		.699		5.35	.5	23.9	370	23.7	74
349	5.58	.487	.318	1.53	3.15	-3.9	24.5	0	24.9	33
349	7.25	.598	.342	1.75	3.43	-3.7	24.6	0	24.2	35
349	8.42	.537	.408	1.32	4.40	-2.8	24.6	52	26.0	30
349	9.08	.632	.501	1.26	5.02	-1.1	25.1	135	25.8	28
349	9.67	.793	.584	1.36	5.56	.1	25.2	219	25.8	18
349	10.42	.797	.498	1.60	5.49	1.8	25.3	308	26.0	27
349	10.92	.781	.729	1.07	4.91	2.8	25.1	357	25.5	21
349	19.42	.509	.373	1.36	3.54	2.3	24.8	0	25.8	63
349	20.25	.406	.289	1.40	2.99	1.5	24.9	0	24.9	60
349	21.50	.322	.228	1.41	2.33	1.1	24.9	0	25.0	42
349	23.17	.389	.251	1.55	2.66	.8	24.7	0	25.3	53
350	5.92	.329	.228	1.44	.53	-4.7	24.5	-0	24.9	52
350	7.42	.299	.193	1.55	.85	-5.1	24.7	-1	24.8	11
350	7.92	.310	.222	1.40	.63	-5.4	24.6	3	24.9	10
350	8.42	.330	.216	1.53	.41	-4.7	24.5	36	25.0	356
350	8.92	.336	.241	1.39	.46	-3.4	24.4	103	23.9	357
350	19.00	.335	.226	1.49	.62	1.3	22.7	0	22.4	255
350	19.83	.288	.191	1.51	.59	-.3	20.3	0	19.8	203
350	20.83	.254	.164	1.55	.74	-1.2	18.1	0	17.6	224
350	22.00	.237	.151	1.56	.73	-1.7	16.1	0	15.7	189
350	23.00	.233	.136	1.70	.84	-1.8	14.6	0	14.1	115
351	2.17	.261	.182	1.43	1.01	-2.3	11.6	-1	11.2	353
351	2.58	.337	.244	1.38	1.73	-1.3	11.5	-1	11.0	65
351	3.25	.373	.285	1.31	2.55	-1.3	11.0	-1	10.8	71

TABLE C1 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	SOUTH DRY BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	WIND DIR. DEG.
351	3.58	.475	.365	1.30	3.29	-.4	10.7	-0	10.3	75
351	3.83	.352	.266	1.32	2.68	-.9	10.3	-1	9.9	76
351	4.42	.571	.377	1.52	3.62	-.2	9.9	-0	9.4	84
352	19.00	.319			2.00	.7	25.9	-0	24.7	192
352	19.17		.218		2.06	.9	25.8	-0	24.6	193
352	20.50	.371	.253	1.47	2.03	1.4	26.0	-1	24.5	220
352	21.25	.299	.199	1.50	1.11	.1	25.9	-1	24.7	279
352	22.58	.287	.171	1.68	.50	-1.8	26.0	-1	24.8	14
352	23.67	.283	.163	1.74	.47	-2.5	26.3	-1	25.2	14
357	14.67	1.828	1.123	1.63	8.38	.7	26.1	335	24.8	12
357	15.33	1.470	.873	1.68	7.39	.9	26.0	257	24.7	13
357	16.00		.773		6.25	1.3	26.5	148	25.0	13
357	16.33		.952		7.56	1.2	25.9	39	24.4	12
358	13.25	2.239			7.98	-7.4	25.3	460	24.4	52
358	13.42		1.135		8.28	-7.3	25.4	450	24.6	51
358	14.42		.973		8.17	-7.2	25.0	392	24.2	54
358	16.17	1.405	.794	1.77	6.63	-7.4	24.9	143	24.2	44
358	16.75	1.557	.757	2.06	6.92	-3.0	25.2	64	24.5	42
359	15.33	.573	.394	1.45	6.93	4.1	25.1	155	24.7	85
359	16.00	.514	.324	1.58	6.19	4.2	26.2	132	24.8	48
359	16.83	.473	.292	1.62	4.71	3.3	26.0	31	24.7	56
362	14.00	1.468	1.004	1.46	8.07	6.5	26.5	347	27.1	13
362	14.42	1.358	.810	1.68	8.44	6.7	26.9	241	25.7	7
362	14.83		.635		7.13	6.9	26.6	151	25.0	15
362	14.92	1.047			7.27	6.9	26.5	177	25.4	13
362	16.58	.826	.505	1.63	4.67	7.1	26.5	91	25.1	34
362	16.83	.441	.305	1.45	3.70	6.8	26.4	64	25.9	29
362	17.08	.733	.420	1.75	4.23	6.0	26.1	17	25.6	31
362	17.75		.303		3.22	5.1	26.1	0	24.4	21
362	18.17		.242		2.36	4.4	26.3	-0	24.7	21
362	18.83		.277		3.02	4.1	26.1	-0	25.0	24
362	19.42		.352		3.49	4.3	25.9	0	24.3	27
363	11.33	1.360			6.42	-3.8	25.1	164	24.7	49
363	11.75	1.198	.696	1.72	6.29	-3.5	25.2	195	24.6	54
363	12.17	1.345	.791	1.70	6.50	-3.5	25.3	197	24.3	39
363	12.50		.736		6.81	-2.7	25.6	324	24.1	49
363	12.50	1.236			6.95	-3.0	25.8	289	24.3	53
363	13.17		.943		8.27	-2.0	25.5	340	24.3	43
363	13.50		.875		7.20	-1.8	25.4	284	24.3	47
363	13.83		.758		6.84	-2.4	25.4	188	24.2	43
363	15.25	1.600	.861	1.86	7.51	-2.9	26.1	198	24.2	38
363	15.58	1.167	.685	1.70	5.25	-3.1	25.6	126	24.6	55
363	15.92	.962	.568	1.69	5.54	-3.2	26.3	110	25.0	52
363	16.17	1.290			6.17	-3.2	26.3	129	24.8	52
363	16.25		.759		6.58	-3.2	25.5	148	24.3	51
363	16.67		.760		6.45	-4.2	26.0	84	24.5	47
363	16.92		.681		6.20	-5.1	25.6	21	24.4	48
364	11.33	2.184			7.74	-10.7	26.5	251	25.9	39
364	11.75		1.129		7.68	-10.3	26.6	252	26.0	40
364	12.83		1.253		9.32	-10.0	26.4	277	25.8	43
364	15.00	1.326	.779	1.70	6.69	-9.1	26.0	151	25.4	42
364	15.50	1.475	.767	1.92	6.71	-3.5	26.2	168	25.4	33
364	15.83	1.626			7.27	-8.5	25.6	168	24.9	27

TABLE C1 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	SOUTH DRY BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	WIND DIR. DEG.
364	15.83		.869		7.26	-8.7	25.8	152	25.2	33
364	16.75		.749		6.20	-9.5	25.9	50	25.1	43
364	17.08		.549		4.67	-9.9	25.7	17	25.1	41
365	12.08	1.446	.806	1.79	5.67	-4.4	26.6	315	24.5	58
365	12.58	1.354	.734	1.85	5.28	-4.5	26.3	318	24.7	50
365	13.08	1.613	.718	2.25	5.39	-5.6	26.0	248	24.5	63
365	13.58		.825		6.01	-5.6	25.9	272	24.6	61
365	14.08		.618		5.40	-5.7	26.0	310	24.9	60
365	14.92	.804	.444	1.81	4.90	-7.0	26.0	162	24.5	74
365	15.83	1.391	.693	2.01	6.50	-9.1	25.9	105	24.4	69
365	16.25		.595		5.60	-10.6	25.4	64	24.4	69
365	16.25	1.344			5.50	-10.2	25.5	75	24.5	78
365	16.92		.724		6.62	-12.1	25.0	20	24.0	52
366	12.08	1.256	.815	1.54	5.15	-14.0	25.5	477	25.0	36
366	12.50	1.093	.689	1.59	4.88	-13.6	25.4	490	25.1	42
366	12.83	1.607	.889	1.81	5.78	-13.0	25.7	499	25.3	38
366	13.50	1.966	1.015	1.94	7.80	-12.7	25.8	494	25.6	42
366	13.92		.908		6.87	-12.1	25.7	475	25.4	44
366	14.25		1.079		7.09	-11.6	26.1	441	25.6	40
366	16.33	1.553	.816	1.90	5.74	-11.4	26.4	142	25.1	44
366	17.00		.857		5.92	-12.2	25.9	35	25.2	37
366	17.33		.591		5.39	-12.9	25.9	13	25.7	25
366	17.67		.765		5.99	-12.9	25.7	1	24.9	44
366	18.25		.668		4.98	-13.7	26.0	-0	25.7	38
3	12.67	.462	.316	1.45	2.50	-0.0	26.7	198	25.0	17
3	13.00	.445	.301	1.48	2.43	.3	27.0	219	25.4	19
3	13.75	.489	.306	1.60	2.85	.5	27.3	220	25.9	17
3	14.08	.498	.339	1.47	2.96	.7	27.0	212	25.5	19
4	12.50	1.079	.613	1.76	3.95	-.2	26.1	196	24.5	138
4	13.00	.948	.517	1.83	3.65	.1	26.3	201	25.0	135
4	13.50	1.169	.561	2.09	3.75	.1	26.3	185	25.4	132
4	13.92		.483		3.76	.2	26.2	163	24.7	137
4	14.42		.417		4.04	.3	26.4	127	24.7	135
4	15.42	1.218			4.40	.3	26.5	146	24.8	136
4	15.50		.675		4.29	.3	26.3	129	24.6	137
4	16.00	1.342			4.52	.2	26.4	82	24.8	134
4	16.33		.646		4.56	.1	26.3	53	24.8	132
4	16.92		.539		4.57	0.0	26.2	20	25.0	130
4	17.25		.596		4.96	0.0	25.7	7	25.1	131
5	12.33	.502	.326	1.54	3.25	-1.0	26.4	447	25.3	97
5	12.92	.489	.287	1.70	3.30	-1.0	26.3	454	25.3	69
5	14.00	.527	.291	1.81	4.05	-1.4	26.7	419	25.8	87
5	15.08	.486			3.39	-1.5	26.0	331	25.7	85
5	15.50	.427	.262	1.63	2.90	-1.8	26.5	232	25.1	91
5	16.50	.357	.238	1.50	2.28	-2.8	26.2	69	25.1	94
5	17.33	.324	.205	1.58	1.22	-5.7	25.8	4	24.7	90
6	15.00	.880	.610	1.43	4.93	-.2	26.6	127	25.5	18
6	16.75	.690	.420	1.65	3.89	-1.1	26.6	21	25.3	22
7	12.33	1.442	.874	1.65	5.44	-11.6	26.1	507	25.3	45
7	12.92	1.177	.682	1.72	4.65	-11.4	25.9	517	25.6	45
7	13.50	1.242	.619	2.01	4.37	-11.2	25.9	509	24.9	46
7	14.00		.361		3.39	-10.7	25.7	481	25.0	44
7	14.58		.527		4.43	-10.7	25.9	435	24.8	34

TABLE C1 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	SOUTH DRY BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	WIND DIR. DEG.
7	15.25		.485		4.02	-10.7	25.7	362	24.1	38
7	17.25	.516	.349	1.48	1.74	-13.9	25.5	27	24.1	42
7	17.83	.441	.287	1.54	.59	-14.9	25.3	0	24.4	35
7	18.33	.481	.300	1.61	.72	-15.6	25.1	-1	24.7	91
10	16.08	2.810	1.349	2.08	10.68	-7.2	29.2	139	27.8	50
10	16.83		1.130		9.62	-7.7	29.3	71	27.8	37
11	15.42	.806	.570	1.41	4.64	-11.9	26.6	265	25.7	17
11	15.75	.958	.698	1.37	5.41	-12.1	26.7	167	25.7	16
11	16.17	1.024	.725	1.41	5.28	-12.1	26.9	129	26.0	20
11	16.67	.765	.595	1.29	5.16	-11.9	26.1	126	26.0	11
11	17.08		.573		4.73	-12.4	26.5	29	26.3	11
11	17.08	.807			4.79	-12.3	26.1	33	26.5	15
12	15.17	.746	.462	1.62	3.02	-12.4	26.1	383	25.3	34
12	15.75	.657	.382	1.72	2.29	-12.7	25.9	318	25.3	34
12	16.08	.570	.328	1.74	1.95	-13.0	26.2	213	24.9	33
12	17.00	.776	.405	1.92	2.32	-14.6	26.1	52	24.8	28
18	2.58	.515	.276	1.86	1.15	-24.7	24.9	-1	24.3	46
18	4.58	.549	.391	1.40	1.43	-25.1	18.4	-1	17.4	67
18	5.00	.494	.340	1.45	1.82	-24.1	14.5	-1	13.0	55
18	5.67	.549	.382	1.44	2.44	-21.3	10.9	-1	9.2	56
18	6.42	.664	.381	1.74	3.53	-19.7	8.8	-1	6.6	96
18	6.83	.984	.506	1.95	4.39	-19.1	7.2	-1	5.0	102
16	7.33	.851	.435	1.95	4.01	-18.7	5.4	-1	3.3	99
18	8.00		.528		4.39	-18.3	4.2	1	2.0	86
18	8.25		.381		3.16	-18.1	3.5	8	1.4	104
18	8.58		.273		2.57	-17.7	2.8	23	.8	94
18	9.00		.359		3.16	-17.3	1.9	54	0.0	95
18	18.67	.408	.266	1.53	.69	-14.4	23.7	-1	23.9	117
18	19.08	.403	.244	1.65	1.56	-13.9	23.6	-1	23.9	135
18	19.50	.424	.264	1.61	2.03	-12.3	23.4	-1	24.4	147
18	20.42	.429	.275	1.56	1.56	-14.9	23.5	-1	24.1	123
18	21.33	.553	.349	1.59	2.83	-16.9	23.4	-1	24.1	99
18	22.42	.964	.521	1.85	4.51	-11.3	23.3	-1	24.8	118
18	23.08	1.312	.660	1.99	5.73	-10.3	23.9	-1	24.2	114
18	23.42		.695		5.41	-10.3	23.5	-1	24.5	112
18	23.42	1.714			5.77	-10.1	23.6	-1	24.6	114
18	24.25		.765		6.96	-11.2	23.5	-1	24.7	107
19	1.33	1.309	.760	1.72	6.29	-12.8	23.6	-1	24.7	116
19	1.67	1.034	.566	1.83	4.82	-13.3	23.7	-1	24.6	114
19	2.08	1.212	.660	1.84	5.51	-14.0	23.6	-1	24.6	98
19	2.83	.861	.526	1.64	4.19	-15.3	23.8	-1	25.2	86
19	17.33	.942	.614	1.53	4.21	-12.1	24.4	21	23.9	49
19	17.58	.680	.413	1.65	3.48	-12.2	24.6	7	24.2	26
19	17.83	.479	.283	1.69	2.24	-12.5	23.3	0	24.0	16
19	18.25	.449	.209	2.15	1.63	-12.6	23.2	-1	24.0	5
19	19.08	.556	.272	2.05	2.95	-11.8	23.5	-1	24.4	27
24	15.50	.805	.604	1.33	3.84	-.4	24.6	69	24.9	61
24	15.92	1.249	.724	1.72	5.53	-.8	24.4	43	24.5	49
24	16.17	1.764	.887	1.99	7.58	-.9	24.5	30	23.8	63
24	16.58	1.642	.752	2.18	6.15	-1.1	24.7	25	24.4	65
24	17.17		.580		5.55	-1.4	24.7	6	24.2	84
31	16.92	2.167	.969	2.24	8.31	-8.6	25.4	140	24.6	12
31	17.50		.824		8.52	-9.3	24.9	44	24.3	16

TABLE C1 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	SOUTH DRY BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	WIND DIR. DEG.
31	18.25	1.764	.867	2.03	6.84	-10.5	25.4	-1	25.2	21
31	18.67	2.165	.912	2.37	8.44	-10.7	25.4	-1	24.6	26
31	19.50	1.847	.983	1.83	7.59	-11.2	25.3	-2	25.2	15
31	20.75	1.678	.932	1.80	6.69	-11.8	25.5	-2	25.5	31
36	2.92	1.215	.738	1.65	5.99	-11.3	24.4	-2	24.5	89
36	3.75	1.339	.781	1.71	5.53	-12.0	24.7	-1	25.4	96
36	4.42		.772		4.90	-12.4	24.9	-1	24.5	100
36	4.42	1.184			4.55	-12.4	25.2	-1	24.8	108
38	15.17	.740	.426	1.74	2.35	-6.4	25.6	505	23.0	49
38	15.42	.791	.401	1.97	3.33	-6.4	24.9	452	23.9	64
38	16.00	.569	.315	1.81	2.98	-7.3	24.9	370	23.9	59
39	3.25	.471	.231	2.03	.59	-17.3	18.9	-1	16.6	262
39	3.75	.393	.140	2.81	.50	-16.7	15.6	-1	13.4	219
39	4.75	.347	.221	1.57	.67	-15.5	11.6	-1	9.6	215
39	5.83	.301	.117	2.57	.61	-14.6	8.4	-1	6.6	188
39	7.08	.304	.218	1.40	.74	-14.5	6.6	-2	4.7	222
39	7.42	.265	.176	1.51	.80	-14.5	5.6	3	3.9	243
39	8.33	.262	.147	1.79	.75	-13.8	5.1	55	3.3	337
39	8.83	.394	.217	1.82	.89	-11.7	18.0	178	15.3	336
39	9.57	.346	.210	1.64	2.53	-8.9	24.6	252	25.4	359
39	10.08	.392	.229	1.72	3.34	-8.3	24.2	280	23.4	24
39	10.56	.486	.301	1.61	3.77	-6.6	24.5	385	23.6	16
39	11.58	.431	.323	1.49	4.58	-4.9	24.3	509	23.5	12
39	12.25	.657	.393	1.67	5.77	-4.1	24.2	598	23.6	27
39	12.75	.669	.394	1.70	4.94	-3.7	24.2	617	23.5	19
39	13.83	.687	.470	1.46	4.70	-3.0	24.4	614	23.6	12
39	14.08	.466	.331	1.41	4.61	-2.6	24.4	595	23.5	6
39	14.42	.641	.399	1.61	4.46	-2.6	24.8	573	23.7	0
39	14.92	.493	.368	1.34	4.96	-2.3	24.9	493	23.6	8
39	15.83	.440	.344	1.28	4.81	-2.2	24.9	322	23.8	10
54	15.50	.490	.270	1.83	4.75	14.8	26.3	25	25.9	69
54	16.58	.390	.300	1.29	4.92	13.1	26.2	15	25.6	195
54	17.50	1.110	.680	1.64	7.80	12.5	26.2	7	25.2	306
54	17.83	2.040	1.010	2.03	9.34	12.6	26.4	5	26.0	299
54	18.67	1.920	.990	1.95	9.67	12.1	26.2	0	25.6	303
54	19.67	2.550	.990	2.57	10.76	11.7	26.2	0	25.7	302
55	13.67	2.106	1.077	1.95	9.34	3.1	26.0	126	25.8	57
55	14.25	1.975	.972	2.03	9.59	3.6	25.5	93	25.6	66
55	15.00	1.730	.991	1.75	8.95	3.8	25.6	60	25.7	53
55	15.33	1.385	.814	1.70	7.48	3.8	26.0	48	25.2	59
55	15.92	1.195	.774	1.54	7.65	4.3	25.6	27	25.6	40
55	16.33	1.102	.615	1.79	6.97	4.3	25.7	13	25.4	44
55	16.83	.771	.412	1.87	5.12	4.1	25.5	3	25.7	49
55	17.33	.582	.240	2.43	4.31	3.8	25.1	1	25.1	75
55	18.00	1.992	1.020	1.95	9.72	3.0	25.6	0	25.4	73
55	18.42	1.548	.695	2.23	8.88	3.0	25.4	-1	25.8	74
55	19.00	1.534	.832	1.84	7.91	2.8	25.6	-1	25.2	74
55	20.17	1.460	.805	1.81	8.58	3.1	25.3	-1	25.2	74
55	21.17	1.340	.786	1.71	7.24	2.8	25.2	-1	24.9	64
55	22.17	1.640	.972	1.69	7.27	3.2	25.8	-0	24.6	70
55	22.58	1.330	.742	1.79	8.00	3.2	25.1	-1	25.3	72
60	13.25	1.090	.500	2.16	5.01	-.2	25.6	754	25.7	108
60	14.42	1.150	.610	1.89	6.09	-.1	25.8	699	25.5	103

TABLE C1 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	SOUTH DRY BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	WIND DIR. DEG.
60	15.42	1.110	.590	1.88	5.06	0.0	25.7	553	26.0	106
60	16.58	.910	.400	2.28	4.76	0.0	25.6	354	25.7	105
60	17.50	.860	.500	1.72	4.50	-.3	25.6	197	25.8	102
60	17.83	.550	.300	1.83	3.16	-2.9	25.5	80	25.5	107
60	18.83	.330	.160	2.06	1.07	-2.8	25.2	2	25.1	90
60	19.92	.320	.220	1.45	.41	-5.6	25.1	0	25.1	94
60	21.92	.330	.210	1.56	.39	-7.4	25.1	0	25.1	103
63	16.83	1.734	1.062	1.63	8.26	6.0	26.8	83	26.3	64
63	17.08	1.360	.816	1.67	7.85	5.8	26.4	25	26.2	49
63	17.33	1.704	.968	1.76	8.81	5.5	26.3	26	26.6	51
63	18.00	1.290	.703	1.83	6.31	5.2	25.9	11	26.0	59
63	19.00	2.034	1.094	1.86	10.26	4.4	26.0	-1	25.9	70
63	19.92	1.666	1.098	1.70	8.49	4.0	25.8	-1	26.1	61
63	20.33	1.735	.944	1.84	7.72	3.9	26.1	-1	25.7	66
63	21.00	1.937	1.013	1.91	8.57	3.7	26.2	-1	26.0	65
63	21.92	1.379	.731	1.89	5.40	3.7	26.3	-1	25.3	62
63	22.33	1.219	.624	1.95	6.18	3.8	25.7	-1	26.6	62
63	22.83	1.350	.772	1.75	6.81	3.7	26.1	-1	25.9	58
63	23.83		.991		7.17	3.6	25.9	-1	26.5	67
64	16.50	1.040	.483	2.15	5.99	-0.0	26.0	360	26.2	105
64	16.83	.835	.398	2.10	4.36	-.1	25.4	304	25.6	93
64	17.50	.871	.493	1.77	4.45	-.4	25.2	171	26.1	107
64	17.83	.654	.365	1.79	3.56	-.5	25.7	111	25.0	114
64	18.08	.476	.263	1.81	2.85	-1.0	25.3	56	25.7	104
64	18.83	.326	.163	2.00	.73	-3.1	25.4	-1	25.1	90
64	19.75	.334	.224	1.49	.41	-5.1	25.0	-1	25.4	90
64	21.33	.330	.192	1.72	.38	-6.5	25.0	-1	24.9	104
64	22.00	.329	.209	1.58	.38	-7.5	25.0	-1	25.3	104
67	18.67	.414	.378	1.10	4.31	16.5	27.4	6	27.5	18
67	19.00	.339	.310	1.09	3.93	15.4	26.7	0	26.9	14
67	19.50	.307	.257	1.19	3.46	14.4	26.0	-0	26.1	5
67	21.00	.506	.449	1.13	4.95	14.1	26.2	0	26.1	18
67	21.83	.459	.378	1.21	4.94	13.8	26.0	0	26.3	25
67	22.33	.512	.394	1.30	4.84	13.3	26.3	0	25.9	25
67	22.92	.433	.385	1.12	4.26	13.2	26.2	0	26.2	36
67	23.17	.564	.429	1.31	4.64	13.0	26.3	0	25.8	38
67	24.00	.513	.387	1.33	3.55	12.3	26.6	0	26.1	38
67	24.42	.617	.424	1.45	4.17	12.4	26.4	0	26.0	32
69	18.42	.773	.444	1.74	5.70	18.5	27.1	74	27.1	38
69	19.67	.486	.245	1.98	5.08	16.6	26.0	2	25.9	21
69	20.67	.396	.301	1.32	4.64	15.5	26.2	0	26.1	21
69	21.67	.453	.209	2.16	4.53	14.7	26.3	-0	26.1	27
69	22.00	.643	.290	2.21	4.94	14.7	26.2	0	26.0	35
69	23.00	.462	.310	1.49	3.79	13.5	26.3	0	26.2	37
69	23.33	.325	.230	1.41	3.61	12.9	26.3	0	26.5	41
69	23.92	.292	.201	1.45	2.37	11.3	26.3	0	26.2	37
69	24.92	.292	.151	1.94	2.54	11.1	26.1	0	26.0	33
69	25.75	.238	.205	1.16	2.42	10.9	26.7	0	26.0	19
69	26.50	.260	.213	1.22	2.50	11.2	26.6	0	26.5	26
69	27.17	.228	.173	1.32	2.57	10.6	26.4	0	26.3	11
69	28.00	.241	.207	1.16	2.55	10.3	26.4	-0	26.2	23
69	28.67	.247	.205	1.20	2.74	9.9	26.4	-0	26.2	15
69	29.33	.227	.169	1.34	2.30	8.7	26.3	-0	26.3	3

TABLE C1 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	SOUTH DRY BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	WIND DIR. DEG.
69	30.00	.227	.190	1.19	2.21	8.5	26.4	0	25.3	26
69	30.67	.242	.154	1.57	1.78	7.8	26.3	0	26.2	10
69	31.33	.239	.164	1.46	1.78	7.8	26.7	0	26.4	358
69	32.00	.238	.137	1.74	2.36	8.3	26.7	8	26.4	1
70	22.00	1.594	.861	1.85	7.00	17.7	26.3	-0	26.1	233
70	22.42	1.714	.852	2.01	7.40	18.0	26.3	-0	25.2	139
70	23.00	1.724			6.88	17.8	26.2	-1	25.5	235
70	23.08		.788		7.43	17.8	26.1	-1	25.3	221
70	23.83	2.598	1.293	2.01	8.76	17.5	26.0	-1	25.4	164
70	23.92	2.420	1.095	2.21	9.46	17.5	26.2	-0	25.6	150
70	24.67	2.056	1.083	1.90	9.89	17.7	26.2	-0	25.3	134

TABLE C2: SPRING DATA.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	SOUTH DRY BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	WIND DIR. DEG.
73	18.08	.246	.158	1.55	2.14	19.2	30.9	59	29.7	337
73	18.92	.267	.102	2.63	1.43	16.2	29.3	0	28.0	298
73	19.92	.259	.158	1.64	1.43	14.8	27.9	-0	26.5	313
73	21.25	.329	.224	1.47	2.49	15.4	26.4	-0	25.0	310
73	22.33	.273	.178	1.54	1.88	14.0	26.3	-0	24.8	292
73	22.75	.378	.209	1.81	2.43	13.2	26.6	0	24.8	277
73	23.58	.259	.187	1.39	1.71	12.1	26.6	0	24.7	291
73	24.50	.333	.239	1.39	2.43	13.0	26.8	0	24.5	305
73	25.50	.298	.223	1.34	3.10	13.2	26.6	-0	24.5	300
73	25.83	.223	.176	1.26	2.00	12.3	26.6	0	24.6	319
74	20.00	1.277	.687	1.86	6.76	11.9	26.2	-0	25.5	116
74	20.42	.952	.460	2.07	5.42	11.7	26.4	-0	25.4	112
74	21.17	.690	.480	1.44	3.35	11.0	26.2	-0	25.9	102
74	21.42	.535	.341	1.57	3.50	11.0	26.2	-0	25.6	102
74	22.58	.970	.523	1.85	6.06	10.8	26.5	-0	25.7	107
74	23.58	1.060	.405	2.62	5.42	8.9	26.6	-0	25.8	94
74	24.17	1.247	.440	2.83	5.94	8.4	26.5	-0	25.6	95
74	24.58	1.226	.642	1.91	6.45	8.0	25.5	0	26.0	88
74	24.92	.687	.290	2.37	5.35	7.4	26.2	-0	25.5	100
74	25.50	.599	.180	3.33	5.13	6.0	25.7	-0	25.5	99
76	12.08	2.224	1.093	2.04	6.96	13.6	29.0	396	28.0	168
76	13.17	1.660	1.001	1.86	6.89	15.3	29.1	526	28.4	254
76	13.67		.810		6.97	14.7	29.2	220	28.4	110
76	14.33	1.806	.915	1.97	7.70	14.7	29.1	178	28.4	208
76	14.67	.992	.365	2.72	5.18	14.9	28.9	118	28.9	248
76	15.42	.756	.505	1.50	3.98	15.1	29.3	74	29.2	274
76	15.67	1.171	.614	1.91	4.98	14.7	29.0	56	28.4	239
76	16.08	.950	.498	1.91	5.53	14.6	29.2	37	28.8	278
77	13.08	1.603	.797	2.01	7.73	17.3	37.5	145	36.9	105
77	14.25	1.396	.736	1.90	6.87	17.7	38.1	60	38.2	109
77	22.33	.309	.133	2.31	2.56	2.4	25.8	-1	25.5	175
77	23.50	.304	.189	1.61	1.90	.9	24.5	-1	24.3	186
78	1.25	.411	.305	1.35	1.35	3.7	26.6	-1	26.4	140
78	1.75	.392	.282	1.39	1.14	3.7	26.9	-1	26.4	128
78	2.92	.315	.227	1.39	.46	4.6	27.6	-1	26.9	117
78	3.83	.295	.150	1.90	.70	4.5	27.5	-1	27.2	279
78	5.00	.254	.179	1.41	1.29	3.9	27.4	-1	27.3	189
78	6.08	.256	.178	1.44	1.12	3.9	27.7	-0	27.3	185
78	7.17	.476	.283	1.68	3.17	4.4	27.5	11	27.3	210
78	8.08	.565	.300	1.89	3.25	4.6	27.8	43	27.1	215
78	9.17	.468	.232	2.02	2.98	5.4	27.6	78	27.4	264
78	10.25	.666	.421	1.58	3.33	6.3	27.9	142	27.5	263
78	11.42	.925	.462	2.00	4.25	6.6	27.8	141	27.3	267
78	12.33	1.085	.569	1.91	4.93	6.7	27.8	170	27.3	261
78	13.42	.770	.410	1.88	4.70	9.2	29.2	189	29.0	292
78	13.75	1.004	.510	1.97	4.62	9.7	29.7	198	29.5	272
78	14.42	1.058	.538	1.97	4.99	9.9	29.6	151	29.9	275
78	14.83	.682	.359	1.90	4.50	10.0	30.0	114	29.6	274
78	15.92	1.055			5.13	9.5	29.3	195	29.8	263
78	16.75	.978	.462	2.12	5.27	9.1	29.1	139	28.4	260
78	17.08	1.295	.676	1.91	5.94	8.9	29.5	92	23.3	264
78	17.92	.989	.502	1.97	4.38	7.9	29.0	35	28.1	257
78	18.83	.851	.423	2.01	4.59	9.9	30.9	0	30.8	261

TABLE C2 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	SOUTH DRY BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	WIND DIR. DEG.
78	19.75	.672	.359	1.87	3.25	10.9	32.0	-1	31.7	269
78	20.67	.848	.500	1.70	3.38	11.6	31.9	-1	31.7	279
78	20.92	.452	.276	1.64	2.62	12.2	31.8	-1	31.9	313
78	21.75	.763	.460	1.66	3.50	11.8	32.2	-1	31.9	266
78	22.83	1.121	.571	1.96	5.18	9.2	31.7	-1	31.8	262
78	23.75	.897	.442	2.03	3.73	9.9	32.1	-1	32.2	266
81	17.17	.394	.327	1.21	.64	-.2	24.4	-1	24.2	50
81	17.75	.356	.264	1.35	.38	-1.1	24.2	-1	24.5	40
81	18.25	.339	.238	1.42	.54	-1.8	24.2	-1	24.0	18
81	19.00	.347	.229	1.51	1.47	-1.3	24.2	-0	24.3	48
81	19.50	.323	.219	1.48	1.22	-.5	24.3	-0	24.3	34
81	19.92	.374	.254	1.47	2.16	-.3	24.7	-0	24.2	37
87	19.75	.471	.344	1.37	6.62	16.0	26.0	0	25.6	347
87	20.42	.529	.345	1.53	7.04	15.9	26.0	0	25.1	341
87	20.83	.576	.403	1.43	8.54	15.9	26.1	0	25.7	353
87	21.58	.763	.533	1.43	7.69	15.4	26.2	0	26.0	316
87	22.00	.861	.554	1.55	6.76	15.2	26.3	0	25.7	312
87	23.08	.538	.350	1.54	9.67	17.2	26.0	0	25.7	352
88	.42	.699	.537	1.30	11.54	17.5	26.0	0	25.5	20
88	1.17	.666	.435	1.53	9.63	17.7	25.9	0	25.6	14
88	2.42	.477	.347	1.37	7.72	17.4	26.0	0	25.6	15
88	3.67	.503	.383	1.31	6.74	17.4	26.1	0	25.8	22
88	4.75	.670	.420	1.59	8.71	17.8	26.0	0	26.3	25
88	5.08	.492	.279	1.77	7.02	17.4	26.0	0	25.7	26
88	6.00	.394	.256	1.54	6.29	16.2	26.2	1	25.6	12
88	7.08	.398	.291	1.37	6.15	16.5	26.2	74	26.0	12
88	8.25	.781	.581	1.35	7.71	18.8	25.7	251	26.8	33
88	8.67	.900	.649	1.39	8.10	19.8	27.2	331	27.2	35
88	9.42	1.188	.834	1.42	10.50	21.1	28.1	488	27.9	39
88	9.83	1.601	1.077	1.49	10.80	21.5	28.5	550	28.0	53
88	10.75	1.673	1.092	1.53	9.38	22.4	29.0	684	28.0	56
89	18.83	3.260	1.800	1.81	13.34	15.8	29.4	18	27.0	55
89	19.33	2.207	1.176	1.88	9.76	15.2	27.5	0	26.0	41
89	20.17	2.594	1.183	2.19	10.67	13.4	26.4	-1	25.8	67
89	20.75		.952		10.33	12.2	26.8	-0	26.1	65
89	21.42	2.215			9.62	11.0	26.9	0	26.3	79
89	21.50		.860		9.74	11.0	25.8	0	26.0	78
89	22.00		.604		8.45	10.8	27.1	0	26.0	83
89	22.58	2.403			9.65	10.2	27.2	0	26.3	78
89	22.58		1.128		10.04	10.3	26.8	0	26.2	79
89	22.92		1.387		11.17	9.6	27.3	0	26.2	78
89	23.83	2.387			10.52	7.7	27.1	0	26.1	55
89	23.83		1.203		10.64	7.4	26.8	0	26.0	57
89	24.33	2.221			10.74	7.2	26.3	-0	25.5	49
89	25.00		1.233		11.27	7.0	26.1	-0	25.6	56
89	26.00	2.462			10.68	6.3	26.4	-0	25.8	62
89	26.17		1.339		11.40	6.1	25.7	-1	25.6	66
90	8.23	1.404	.899	1.56	7.31	5.9	26.4	23	25.4	90
90	8.43	1.229	.625	1.80	6.34	6.1	26.1	30	25.3	87
90	8.70	1.176	.658	1.79	6.40	6.5	26.1	79	25.0	98
90	9.30	1.043	.587	1.77	5.82	7.5	26.1	174	25.7	84
92	16.40		1.453		14.94	24.1	32.6	420	31.5	63
92	16.40	2.906			15.04	24.2	32.6	431	31.5	60

TABLE C2 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	SOUTH DRY BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	WIND DIR. DEG.
92	17.03		1.006		13.26	23.4	32.8	325	31.3	55
92	17.63	2.719	1.223	2.21	12.50	20.9	32.2	129	30.6	79
92	18.75	2.652			12.75	16.4	30.1	10	28.1	87
92	18.92		1.179		13.63	16.1	29.9	5	27.9	68
92	19.33		.963		11.76	15.1	29.2	0	26.9	79
92	19.75		.825		10.86	14.5	28.6	0	26.3	60
92	20.42	2.406			10.62	14.1	27.4	0	26.1	69
92	20.58		1.212		12.24	13.4	26.9	0	27.5	79
92	22.08		.534		8.43	10.5	27.0	0	26.2	90
95	16.33	2.470			9.41	4.9	25.9	365	24.8	90
95	16.33		1.066		9.61	5.4	26.3	360	24.7	84
95	16.67		.853		9.71	4.5	26.0	348	24.9	84
95	17.08		1.166		11.74	4.7	25.8	236	25.0	82
97	2.25	.270	.183	1.48	.56	1.4	25.3	-1	24.4	45
97	3.25	.385	.201	1.91	2.61	2.9	25.2	-1	24.5	32
97	4.33	.316	.220	1.44	2.10	3.2	25.5	-1	24.0	32
97	5.33	.336	.209	1.61	2.13	2.9	25.5	-1	24.3	30
97	6.42	.260	.152	1.71	1.20	1.6	25.4	-1	24.2	23
97	7.67	.332	.127	2.62	2.38	3.9	25.5	62	24.3	11
97	8.58	.531	.277	1.92	3.97	6.2	25.7	118	25.0	27
97	9.00	.682	.338	2.02	4.53	7.7	26.5	265	26.8	29
97	9.75	.693	.382	1.82	5.36	10.1	26.6	364	25.4	29
97	10.08	1.011	.559	1.81	6.20	11.7	26.7	489	25.4	30
97	10.83	1.066	.631	1.69	7.10	13.8	26.6	674	25.5	23
97	11.67	1.495	.829	1.80	8.37	16.2	26.6	743	26.3	18
97	13.08		.618		9.06	18.9	26.0	841	25.9	20
97	14.00		.725		10.55	19.2	26.0	854	25.2	23
97	15.17		.970		9.08	19.9	26.9	788	25.8	22
97	16.17		.965		9.69	19.6	27.9	649	25.8	23
99	1.08	.287	.120	2.38	1.08	.3	25.1	-1	24.2	235
99	2.92	.275	.164	1.68	.76	-.6	25.3	-1	24.4	250
99	3.83	.293	.180	1.63	.66	-.7	25.3	-1	24.2	230
99	4.25	.269	.127	2.12	.76	-.5	24.9	-1	24.1	235
99	5.08	.368	.255	1.44	1.94	.4	25.2	-1	24.1	260
99	6.08	.355	.188	1.88	1.93	.8	25.6	16	24.5	266
99	7.17	.371	.197	1.88	1.84	2.8	25.5	90	24.2	307
99	8.25	.614	.330	1.86	4.19	4.7	25.4	145	24.2	289
99	8.53	.474	.261	1.81	3.82	5.7	25.9	220	24.7	334
99	9.42	.748	.304	2.46	4.43	7.2	25.7	228	24.7	351
99	9.83	1.056	.439	2.40	4.47	8.2	26.0	361	25.1	293
99	10.67	.440	.251	1.75	4.29	10.4	26.4	451	25.4	342
99	11.08	.681	.329	2.07	3.74	10.9	26.6	473	26.1	311
99	11.67	.708	.392	1.81	5.26	12.2	26.8	840	25.3	325
99	12.08	.350	.257	1.37	5.84	13.1	26.9	765	25.3	338
99	12.92	.520	.363	1.43	5.30	14.6	26.1	837	25.2	317
99	14.08	.655	.372	1.76	5.33	15.5	26.3	771	25.5	306
108	13.67	.320	.230	1.39	2.46	33.0	26.0	-0	24.0	0
118	16.33	.279	.209	1.33	4.55	34.8	30.2	386	28.9	1
118	16.92	.223	.159	1.41	4.30	34.1	29.9	269	29.0	9
118	17.42	.678	.397	1.71	5.22	32.2	29.9	195	28.8	53
118	18.00	.494	.217	2.28	3.09	30.4	29.8	138	28.8	66
118	18.33	.187	.115	1.63	1.31	27.0	29.8	23	28.8	70

TABLE C3: SUMMER DATA FOR SKIRTED HOMES.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	OUT WET BULB (C)	SOUTH DRY BULB (C)	SOUTH WET BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	NORTH WET BULB (C)	WIND DIR. DEG.
123	15.83	.672	.294	2.28	4.80	25.0	25.1	27.3	27.4	255	26.1	26.1	303
123	16.92	.528	.185	2.85	4.95	23.8	23.9	27.2	27.3	196	26.4	26.4	313
123	18.08	.694	.270	2.57	5.22	21.9	22.0	26.8	26.9	70	26.5	26.5	308
126	20.50	.172	.135	1.27	1.18	19.2	20.1	27.1	27.1	-0	25.2	25.7	210
126	21.08	.150	.099	1.52	.50	19.5	20.4	26.9	26.9	-1	25.2	25.7	234
126	21.50	.134	.050	2.67	.48	19.4	20.5	26.8	26.8	-1	25.2	25.6	339
126	22.50	.128	.056	2.30	.71	19.8	20.6	26.4	26.5	-1	25.0	25.3	273
126	23.42	.141	.127	1.11	1.13	19.2	20.0	26.1	26.2	-0	24.9	25.2	216
126	23.83	.115	.075	1.54	.62	19.6	20.5	26.0	26.0	-0	24.8	25.1	204
126	24.58	.192	.177	1.09	1.89	20.0	20.7	25.8	25.8	-1	24.6	25.0	48
126	24.92	.145	.110	1.32	1.69	19.7	20.6	25.7	25.8	-0	24.6	24.9	273
127	14.17	.274	.233	1.18	4.14	23.2	23.2	27.5	27.5	822	26.1	26.1	-0
127	15.50	.299	.188	1.59	3.53	22.8	22.8	27.3	27.3	668	26.3	26.3	-0
127	16.67	.367	.230	1.60	3.00	22.8	22.8	27.1	27.1	490	26.2	26.2	-0
127	17.08	.285	.150	1.90	4.52	21.7	21.7	27.0	27.0	419	26.2	26.2	-0
127	17.83	.390	.128	3.05	4.19	19.9	19.9	27.2	27.2	245	26.2	26.2	-0
127	18.92	.338	.176	1.92	3.08	18.7	18.7	27.3	27.3	68	25.8	25.8	-0
127	20.08	.344	.087	3.97	3.10	15.3	15.3	26.8	26.8	0	25.2	25.2	-0
127	21.25	.367	.160	2.29	3.06	12.8	12.8	26.0	26.0	0	25.2	25.2	-0
127	22.42	.256	.129	1.98	1.39	11.8	11.8	26.0	26.0	0	25.3	25.3	-0
127	23.50	.235	.131	1.79	1.53	10.0	10.0	26.2	26.2	0	27.1	27.1	-0
127	24.75	.214	.071	3.01	.94	8.9	8.9	26.3	26.3	0	25.8	25.8	-0
127	25.75	.220	.100	2.20	.52	8.3	8.3	26.4	26.4	0	25.8	25.8	-0
129	16.33	.370	.281	1.32	4.47	15.4	15.8	27.2	27.2	554	26.6	26.5	153
129	17.50	.437	.191	2.29	4.44	13.8	14.1	27.3	27.3	329	26.5	26.5	170
129	18.50	.463	.211	2.19	5.95	12.4	12.8	27.6	27.6	159	26.5	26.4	166
129	18.92	.420	.145	2.90	5.14	11.8	12.1	27.2	27.2	92	26.0	25.9	157
129	19.75	.398	.152	2.62	2.94	9.8	10.2	26.2	26.2	2	25.3	25.3	174
129	20.92	.313	.153	2.04	1.80	8.3	8.9	26.1	26.1	0	25.2	25.2	167
129	22.00	.251	.139	1.81	.72	7.3	8.1	26.2	26.3	0	25.7	25.6	177
129	23.08	.096	.113	.84	1.01	6.5	7.4	26.5	26.4	-0	25.5	25.5	185
129	23.50	.215	.099	2.18	.55	6.7	7.6	26.4	26.4	0	25.6	25.6	189
133	22.42	.203	.100	2.03	.46	18.6	14.8	24.5	24.5	-1	24.9	22.4	92
133	23.00	.173	.129	1.34	.52	17.9	14.5	24.3	24.3	-0	24.6	22.2	99
133	23.67	.160	.123	1.30	.72	17.1	14.2	24.1	24.1	-0	24.2	21.9	123

TABLE C3 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	OUT WET BULB (C)	SOUTH DRY BULB (C)	SOUTH WET BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	NORTH WET BULB (C)	WIND DIR. DEG.
133	24.50	.178	.123	1.44	1.27	16.4	13.9	23.8	23.9	-1	23.9	21.7	187
133	25.08	.165	.121	1.36	1.23	16.8	14.2	23.7	23.7	-0	23.7	21.4	224
138	17.75	1.030	.549	1.88	8.07	22.6	23.2	23.6	23.6	3	23.4	23.3	151
138	18.08	.711	.436	1.63	3.93	20.8	19.1	23.6	23.6	1	23.4	23.3	118
138	18.42	.301	.234	1.29	2.28	23.1	20.7	23.5	23.6	2	23.9	23.8	3
138	18.92	.247	.171	1.45	2.01	22.9	21.3	23.6	23.7	3	23.6	23.5	25
138	19.63	.552	.378	1.46	3.81	22.9	21.1	23.5	23.6	2	23.4	23.4	55
138	20.08	.397	.252	1.58	3.18	22.2	22.0	23.9	24.0	-0	24.1	24.0	67
138	20.92	.321	.132	2.43	2.21	21.8	21.9	23.9	24.0	-0	24.6	24.5	71
138	21.83	.160	.063	2.53	1.23	20.8	21.0	23.8	23.8	-1	24.0	24.1	226
138	22.83	.149	.073	2.03	1.10	20.0	20.1	24.1	24.2	-1	24.2	24.2	202
138	23.75	.136	.061	2.23	1.25	18.3	18.5	24.0	24.1	-1	24.0	24.0	134
138	24.17	.079	.068	1.16	.69	18.1	18.2	24.0	24.0	-1	23.9	23.9	54
139	17.92	.388	.261	1.49	3.04	26.5	26.6	23.9	24.0	80	23.4	23.3	74
139	18.33	.532	.321	1.66	3.58	25.9	26.0	23.4	23.5	76	23.0	23.0	63
139	18.58	.216	.165	1.31	2.01	25.7	25.8	23.9	24.0	52	23.6	23.5	12
139	19.17	.491	.317	1.55	4.03	26.5	26.4	23.8	23.8	17	23.8	23.8	261
139	19.50	.891	.476	1.87	4.08	25.9	26.0	23.8	23.8	1	23.6	23.5	300
139	19.92	.222	.189	1.18	1.64	23.9	24.3	23.7	23.7	-0	23.6	23.6	357
139	20.50	.229	.160	1.42	1.65	22.9	23.0	23.7	23.8	-0	24.2	24.1	152
140	15.50	.255	.160	1.59	4.97	32.8	21.2	23.8	16.8	657	23.6	17.8	355
140	15.83	.269	.181	1.49	5.19	32.7	21.0	23.8	16.8	613	23.7	17.8	344
140	16.25	.303	.214	1.42	6.12	32.2	20.4	23.7	16.8	519	23.7	17.7	340
143	15.33	.262	.213	1.23	3.21	30.0	20.1	24.0	17.4	521	23.6	22.2	22
143	15.67	.419	.240	1.74	3.67	30.4	20.7	24.0	17.4	565	23.7	22.3	40
143	16.33	.337	.203	1.66	3.90	30.7	21.2	23.9	17.0	572	23.9	22.4	33
143	17.08	.462	.286	1.62	4.40	29.0	20.6	23.7	17.1	194	23.4	22.1	45
143	17.58	.299	.197	1.52	3.55	29.3	20.6	23.8	17.3	299	23.4	22.0	36
143	17.92	.187	.144	1.31	2.61	28.6	20.4	23.8	17.3	160	23.5	22.2	27
144	10.33		.092		1.55	29.8	22.2	24.3	17.4	677	24.1	23.0	325
144	10.92	.141	.098	1.44	1.62	30.1	22.2	24.4	17.5	611	24.0	22.9	302
144	11.58	.161	.131	1.23	1.74	30.6	22.4	24.4	17.5	730	23.9	22.8	209
144	11.92	.228	.170	1.34	2.30	30.0	22.2	24.0	17.3	316	23.8	22.7	82
144	12.33	.144	.113	1.27	1.52	30.9	22.3	24.1	17.5	722	23.6	22.6	105
144	13.17	.221	.141	1.57	2.21	31.5	22.0	24.0	17.1	778	24.0	22.9	305

TABLE C3 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	OUT WET BULB (C)	SOUTH DRY BULB (C)	SOUTH WET BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	NORTH WET BULB (C)	WIND DIR. DEG.
144	14.17	.155	.113	1.38	2.31	31.7	21.8	24.1	17.1	645	23.8	22.8	360
144	14.92	.188	.151	1.24	4.14	31.4	21.7	24.1	17.1	668	23.8	22.7	358
145	12.25	.459	.195	2.36	3.48	33.9	24.0	26.4	19.9	601	26.2	19.1	255
145	12.92	.506	.200	2.53	3.91	33.7	23.8	26.2	19.9	576	26.1	19.2	252
145	13.50	.478	.190	2.52	3.57	34.5	24.0	26.3	19.9	716	25.9	19.0	251
145	14.00	.639	.308	2.07	5.12	33.9	23.7	25.9	19.5	451	25.9	18.9	223
145	14.92	.816	.433	1.89	5.67	34.0	23.9	26.1	19.6	432	26.0	18.9	260
145	15.50	.758	.382	1.99	4.77	34.5	23.8	26.2	19.7	620	26.4	19.3	254
145	16.00	.965	.499	1.93	5.80	34.3	23.7	26.2	19.5	462	26.0	18.8	262
145	16.58	.768	.391	1.96	5.24	33.5	23.2	26.1	19.6	244	25.9	18.9	253
146	11.17	.424	.199	2.13	3.04	30.6	20.8	26.5	20.2	852	26.2	19.3	238
146	11.58	.322	.147	2.19	3.25	31.0	21.0	26.5	20.3	881	26.4	19.6	225
146	12.08	.402	.183	2.20	3.45	31.6	21.5	26.2	20.1	899	26.2	19.6	226
146	12.42	.276	.130	2.12	3.44	31.0	21.3	26.0	19.9	908	26.1	19.5	196
146	12.75	.354	.170	2.08	3.90	31.9	21.5	26.2	20.2	910	26.1	19.7	222
146	13.25	.609	.306	1.99	5.00	32.4	21.1	26.1	20.1	903	25.9	19.4	228
146	14.08	.453	.252	1.80	4.12	32.6	21.4	26.2	20.0	861	26.0	19.3	222
146	14.42	.698	.354	1.97	4.52	33.0	21.3	26.2	20.0	813	26.0	19.2	236
146	15.17	.801	.393	2.04	5.49	32.9	20.6	26.0	19.8	748	25.8	18.8	249
146	15.58	.613	.324	1.89	4.01	33.0	20.6	26.1	19.8	691	26.1	19.0	232
147	9.92	.286	.155	1.84	2.34	27.1	20.5	27.1	20.3	733	26.8	19.9	250
147	10.58	.159	.090	1.77	1.60	30.2	21.0	27.1	20.3	795	26.9	20.1	258
147	10.92	.198	.095	2.08	1.83	30.8	21.2	27.2	20.5	834	26.7	20.0	266
147	11.42	.327	.183	1.79	1.69	31.6	21.4	27.0	20.5	870	26.6	19.9	267
147	11.83	.180	.116	1.55	1.63	32.0	21.3	27.0	20.6	888	26.8	20.3	249
147	12.33	.205	.123	1.66	1.41	33.3	21.5	26.9	20.5	904	26.6	20.3	255
147	13.33	.232	.159	1.46	2.51	33.4	21.7	27.0	20.8	884	26.7	20.7	193
147	13.67	.354	.196	1.81	2.78	33.0	21.6	26.9	20.7	871	26.7	20.9	230
147	13.92	.268	.161	1.66	1.94	33.8	21.8	26.9	20.6	843	26.7	21.0	222
147	14.50	.308	.178	1.73	3.09	34.4	21.9	26.9	20.5	796	26.9	21.4	249
147	15.00	.418	.213	1.96	2.96	34.7	21.5	26.6	20.2	735	26.6	21.4	267
147	15.50	.167	.107	1.57	2.48	35.5	21.7	26.8	20.3	672	26.8	22.1	330
150	12.17	.399	.207	1.92	3.04	31.3	22.5	25.6	19.6	855	25.4	19.0	240
150	12.67	.533	.256	2.09	4.00	32.3	22.6	25.4	19.5	861	25.4	19.0	254
150	13.00	.432	.211	2.05	3.00	32.9	22.7	25.5	19.7	858	25.3	19.0	268

TABLE C3 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	OUT WET BULB (C)	SOUTH DRY BULB (C)	SOUTH WET BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	NORTH WET BULB (C)	WIND DIR. DEG.
150	13.50	.305	.160	1.91	2.20	33.2	22.8	25.5	19.6	850	25.2	18.7	273
150	14.08	.457	.232	1.97	3.14	33.2	23.0	25.3	19.3	754	25.3	18.7	259
150	14.67	.248	.160	1.55	1.99	34.0	23.2	25.4	19.2	738	25.3	18.5	292
150	15.50	.221	.134	1.65	1.80	34.4	23.1	25.4	18.9	662	25.1	17.9	314
150	16.17	.350	.177	1.98	2.42	34.1	23.0	25.5	18.9	559	25.3	18.1	259
150	16.50	.228	.142	1.60	2.03	33.9	23.0	25.3	18.7	451	25.2	17.9	264
150	17.08	.398	.203	1.96	2.29	33.9	23.1	25.4	18.9	354	25.1	18.1	268
150	17.42	.225	.135	1.66	1.73	33.6	22.8	25.4	19.1	322	25.1	18.2	264
150	17.83	.380	.193	1.97	3.17	33.1	22.8	25.2	19.1	179	24.9	18.2	266
150	18.75	.217	.114	1.90	2.49	32.0	22.8	25.1	19.4	63	24.5	18.2	311
151	12.23	.703	.520	1.35	6.01	33.9	23.4	25.5	19.8	903	24.8	24.7	45
151	12.47	.964	.528	1.83	6.86	34.2	23.7	25.6	19.9	920	24.9	24.9	46
151	13.83	1.135	.628	1.81	7.72	34.6	23.3	25.1	19.3	653	25.6	19.1	48
151	14.03	.990	.541	1.83	7.40	33.2	22.6	25.2	19.6	431	24.7	19.5	60
151	14.27	1.319	.598	2.21	8.91	35.2	22.7	25.2	19.4	775	25.3	24.5	64
151	15.23	1.748	.894	1.95	10.22	33.3	21.4	25.3	19.6	489	25.3	25.1	53
151	15.47	1.279	.611	2.09	8.13	33.6	20.9	25.4	19.5	632	25.1	25.0	75
151	15.93	1.478	.732	2.02	8.68	34.4	19.7	25.3	19.2	664	25.2	25.0	64
151	16.40	1.303	.612	2.13	8.83	33.6	19.1	25.3	19.0	588	25.3	25.1	85
152	10.67	1.767	.903	1.96	10.75	28.4	17.5	25.9	18.1	713	25.7	17.1	78
152	11.33	1.493	.762	1.96	10.42	27.8	17.0	25.4	17.7	657	25.1	16.6	83
152	11.83	1.901	.994	1.91	12.98	23.4	16.9	25.5	17.8	715	25.3	16.7	90
152	12.10		.788		10.08	28.3	16.9	25.7	17.9	587	25.2	16.5	87
152	13.07	1.846	.876	2.11	10.37	28.4	16.9	23.4	17.5	509	25.1	16.3	80
152	13.47	1.992	.878	2.27	10.69	28.4	16.7	25.3	17.5	504	25.1	16.3	74
152	14.03	2.258	1.179	1.92	10.96	28.3	16.2	25.6	17.6	331	25.0	16.0	81
152	14.33	1.589	.789	2.01	9.31	27.8	16.2	24.8	17.2	337	25.6	16.3	78
152	14.50	1.973	1.021	1.93	10.49	28.4	16.4	25.6	17.7	501	24.9	15.9	90
152	15.03	1.605	.804	1.99	9.97	29.3	17.1	25.4	17.5	647	25.2	16.2	79
152	15.40	1.306	.614	2.13	8.57	28.6	17.0	25.3	17.4	576	25.1	16.2	96
152	15.40	1.351	.635	2.13	9.17	28.7	17.1	25.1	17.2	537	25.3	16.3	96
152	15.77	1.237	.569	2.17	7.86	23.3	16.9	25.4	17.5	589	25.0	16.2	97
153	10.00	.188	.181	1.04	4.07	19.9	15.0	22.5	15.7	724	22.5	15.2	165
153	10.33	.390	.252	1.55	3.80	20.5	15.6	23.2	16.6	794	23.0	15.9	174
153	11.42	.383	.232	1.65	4.37	21.5	15.9	23.0	16.5	838	23.0	16.0	167

TABLE C3 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	OUT WET BULB (C)	SOUTH DRY BULB (C)	SOUTH WET BULB (C)	SOLAR RAD. WATTS/ SCMT	NORTH DRY BULB (C)	NORTH WET BULB (C)	WIND DIR. DEG.
153	12.08	.345	.198	1.74	4.07	22.1	16.1	22.8	16.5	916	22.8	16.0	171
153	12.75	.496	.272	1.83	4.38	23.2	16.8	22.9	16.5	926	22.5	15.9	158
153	13.00	.336	.184	1.83	4.15	23.7	17.0	22.8	16.5	926	22.8	16.0	161
153	13.75	.313	.177	1.77	3.38	24.5	17.0	23.0	16.7	887	22.9	16.2	158
157	14.50	.300	.182	1.65	3.84	20.1	16.4	21.8	16.7	472	21.8	16.5	139
157	15.00	.458	.180	2.55	5.92	20.5	16.1	21.9	16.6	694	21.8	16.3	143
157	15.70	.623	.223	2.79	6.24	20.8	16.1	22.1	16.9	707	22.0	16.4	145
157	16.03	.639	.247	2.59	6.03	20.3	16.0	22.0	16.8	478	22.2	16.5	139
157	16.70	.561	.307	1.83	6.26	19.6	15.8	21.8	16.5	552	21.9	16.0	144
157	17.20	.642	.326	1.97	6.55	18.9	15.2	21.9	16.5	435	22.1	16.1	140
157	17.73	.523	.262	1.99	5.50	18.2	14.6	21.9	16.4	249	22.0	15.9	147
161	13.08	.277	.191	1.45	4.98	24.3	16.9	22.1	16.3	518	21.9	16.1	317
161	13.58	.148	.121	1.22	3.26	24.6	17.1	21.8	16.2	468	21.8	16.1	4
161	14.42	.144	.091	1.58	3.60	25.3	17.5	22.1	16.4	554	21.9	16.2	340
161	15.50	.137	.105	1.31	2.72	24.5	17.4	21.8	16.4	287	21.8	16.3	353
161	16.58	.264	.142	1.86	2.71	24.9	17.5	21.7	16.3	354	22.0	16.3	308
161	16.92	.301	.184	1.64	3.61	24.7	17.3	21.7	16.2	297	21.8	16.2	309
161	17.58	.377	.193	1.95	3.70	25.1	17.4	21.7	16.1	324	21.8	16.2	306
161	17.67	.281	.167	1.68	3.73	24.9	17.3	21.9	16.4	207	21.8	16.2	321
161	18.50	.317	.190	1.67	3.49	24.3	17.1	21.8	16.4	141	21.8	16.1	310
161	19.50	.210	.144	1.46	2.84	23.4	17.2	21.5	16.4	38	21.7	16.1	327
161	20.00	.105	.084	1.26	1.72	21.6	16.7	21.7	16.5	3	21.7	16.1	327
161	20.92	.076	.056	1.37	1.28	20.1	16.1	21.4	16.3	-0	22.0	16.3	321
186	18.00	.619	.359	1.72	6.23	34.8	23.6	17.9	12.9	203	19.3	13.3	48
186	18.67	.542	.291	1.86	5.50	33.9	23.6	18.0	13.2	155	19.4	13.5	45
186	19.25	.385	.204	1.89	3.94	32.7	23.9	17.9	13.5	60	19.3	13.7	51
186	21.08	.216	.174	1.24	1.65	28.1	23.6	18.4	14.3	-0	19.1	14.8	45
186	21.92	.206	.151	1.36	1.88	27.2	23.7	19.0	14.3	-0	19.5	14.8	39
186	22.92	.125	.095	1.31	1.27	26.3	23.3	22.4	14.0	-0	22.0	14.8	53
186	23.92	.115	.080	1.43	1.34	25.5	23.0	23.7	14.1	-0	22.8	14.7	36
187	12.33	.725	.344	2.10	5.17	37.6	26.4	20.0	14.0	903	21.1	14.2	65
187	12.92	.736	.346	2.13	5.31	38.0	26.3	19.8	13.9	897	20.8	13.9	69
187	13.83	.722	.345	2.09	5.69	38.2	26.2	19.8	13.9	871	20.9	14.3	54
187	14.50	.640	.329	1.94	5.98	37.7	26.0	19.6	13.6	707	20.5	13.7	40
187	15.50		.354		6.92	37.5	26.0	19.4	13.0	614	20.4	13.7	50

TABLE C3 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	OUT WET BULB (C)	SOUTH DRY BULB (C)	SOUTH WET BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	NORTH WET BULB (C)	WIND DIR. DEG.
189	12.58	.197	.126	1.56	2.39	31.9	24.0	20.7	13.8	887	20.2	13.9	123
189	13.50	.199	.126	1.57	2.22	31.5	23.8	20.5	13.7	714	19.7	13.7	173
189	14.33	.205	.132	1.56	1.98	31.0	23.3	19.9	13.4	378	19.6	13.9	149
189	14.92	.252	.149	1.69	2.12	31.0	23.5	20.4	14.1	212	19.5	14.0	267
189	15.67	.342	.174	1.96	2.77	31.1	23.3	21.0	14.3	276	19.7	14.3	271
189	16.17	.276	.143	1.92	2.40	31.0	23.0	20.9	14.4	205	19.6	14.1	270
189	16.92	.173	.109	1.58	1.60	29.9	23.3	20.5	14.4	63	19.6	14.4	293
189	17.58	.153	.096	1.60	1.06	27.8	23.9	21.0	14.6	14	19.6	14.6	324
189	18.33	.168	.125	1.35	1.65	25.5	23.9	21.7	14.9	6	20.2	14.8	45
190	12.50	.169	.149	1.13	2.08	30.0	23.9	19.2	14.0	939	20.1	14.4	129
190	12.92	.246	.148	1.66	2.57	29.5	23.7	19.5	14.2	781	20.0	14.3	150
190	13.83	.209	.123	1.70	2.52	30.1	23.7	19.6	13.9	793	20.1	14.4	186
190	14.83	.194	.124	1.56	1.85	30.4	23.3	19.5	13.6	586	20.1	14.4	233
190	15.50	.177	.109	1.63	1.92	30.7	23.2	19.7	13.5	710	20.2	14.2	166
190	16.25	.161	.100	1.61	1.94	30.3	22.8	19.7	13.3	574	20.2	14.1	164
190	16.83	.230	.101	2.27	2.59	30.7	22.8	19.8	13.5	556	20.1	13.9	133
190	18.17	.289	.153	1.89	4.52	27.0	22.2	20.3	13.9	173	20.4	14.3	160
190	19.08	.246	.134	1.83	3.46	25.5	21.2	21.6	14.2	67	20.5	14.5	152
190	19.92	.193	.109	1.77	3.54	23.8	20.2	21.9	14.6	6	21.0	14.9	140
190	20.67	.178	.100	1.79	3.08	22.5	19.4	24.8	15.0	-1	22.0	15.0	175
190	21.42	.115	.076	1.50	2.03	21.6	18.5	25.9	14.9	-0	23.0	15.0	228
190	22.08	.112	.074	1.52	1.69	20.6	17.9	24.4	14.9	-0	22.9	15.0	180
192	16.42	.180	.154	1.17	3.97	29.0	24.9	22.0	14.8	263	24.8	15.0	34
192	16.75	.328	.189	1.74	4.52	29.3	24.8	21.7	14.9	300	23.3	15.0	31
192	16.75	.377	.233	1.62	4.81	29.7	25.0	21.9	14.9	398	23.9	15.0	40
192	17.92	.225	.157	1.43	3.81	28.3	24.3	22.0	15.2	162	22.9	15.2	32
192	18.92	.186	.125	1.48	3.32	27.7	23.9	22.0	15.2	95	22.6	15.1	24

TABLE C4: SUMMER DATA FOR UNSKIRTED HOMES.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	OUT WET BULB (C)	SOUTH DRY BULB (C)	SOUTH WET BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	NORTH WET BULB (C)	WIND DIR. DEG.
194	13.50	.145	.129	1.13	1.20	33.4	25.9	20.2	14.3	859	22.5	14.7	146
194	14.83	.184	.143	1.29	1.71	34.1	26.2	19.7	13.6	718	21.2	14.3	108
194	15.92	.165	.123	1.34	1.43	34.0	26.3	19.5	13.1	550	21.0	13.9	120
194	16.83	.211	.137	1.54	2.47	32.1	25.9	19.9	13.6	412	20.9	13.8	190
194	18.08	.229	.152	1.51	2.30	31.3	25.9	19.6	13.8	184	21.2	14.3	181
194	18.83	.259	.153	1.69	2.13	31.0	25.4	19.6	14.2	93	20.6	14.4	223
195	17.83	.239	.173	1.38	3.12	33.3	26.8	21.2	13.9	179	20.3	14.0	25
195	18.50	.223	.162	1.37	2.57	32.9	27.1	21.7	14.0	168	20.4	14.1	10
195	19.08	.201	.159	1.26	1.97	31.9	27.1	22.0	14.0	78	20.6	14.5	3
195	20.67	.211	.190	1.11	.93	29.0	26.5	22.3	14.6	-0	20.3	15.1	3
195	21.42	.152	.142	1.07	.54	28.0	26.1	25.8	14.7	-1	21.9	15.4	11
195	22.25	.148	.126	1.18	.76	26.9	25.6	25.8	14.8	-1	22.3	15.5	80
195	23.92	.148	.108	1.37	.45	26.1	25.2	26.2	14.9	-1	22.4	15.4	101
195	23.17	.141	.057	2.49	.39	26.3	25.3	26.0	14.8	-1	22.6	15.6	104
195	24.67	.148			1.23	25.6	24.7	26.0	14.9	-1	22.9	15.7	88
195	25.33	.144			.91	25.3	24.4	25.7	15.0	-0	22.4	15.6	41
195	26.08	.128	.115	1.11	.63	25.2	24.3	25.6	15.0	-0	22.4	15.5	53
196	17.50	.159	.165	.97	3.29	35.1	26.0	20.8	13.7	325	21.7	14.3	28
196	18.08	.257	.160	1.60	2.99	34.6	25.6	20.3	13.5	202	21.6	14.3	27
196	18.67	.212	.128	1.65	2.25	33.3	25.8	20.2	14.0	108	21.0	14.3	30
196	19.42	.215	.199	1.08	1.94	31.5	26.2	19.9	14.3	21	20.6	14.5	39
196	19.75	.203	.118	1.72	1.94	30.6	25.9	19.9	14.5	4	20.6	14.9	32
196	20.58	.145	.105	1.38	1.45	28.9	25.6	22.6	14.6	-1	22.0	15.3	73
205	18.42	.178	.158	1.13	3.19	29.6	24.4	21.2	15.4	62	19.1	13.6	18
205	19.08	.159	.128	1.24	2.04	28.5	24.2	21.1	15.0	12	19.1	13.9	3
205	17.92	.261	.258	1.01	3.72	30.2	24.6	21.7	15.7	159	19.3	13.6	19
205	20.08	.142	.122	1.17	1.55	27.8	24.1	21.1	14.2	-0	19.5	14.4	358
206	20.67	.159	.114	1.40	3.03	17.7	18.9	19.2	16.0	0	18.5	19.7	159
206	21.00	.185	.132	1.41	2.31	16.5	18.7	19.2	15.8	0	19.4	19.8	148
206	22.08	.138	.106	1.29	2.27	15.9	18.4	19.1	15.3	-0	19.6	20.0	179
206	22.67	.173	.114	1.53	2.89	15.8	18.6	19.5	15.0	-0	19.6	20.0	177
206	23.42	.228	.137	1.67	3.17	15.7	18.6	19.6	14.8	-0	19.6	20.0	181
206	24.00	.188	.121	1.56	2.91	15.2	18.7	19.6	14.6	-0	19.6	19.9	190
206	24.83	.142	.101	1.41	1.63	13.8	18.6	19.5	14.4	-0	19.6	19.9	202
206	25.25	.107	.097	1.11	1.08	13.6	18.4	19.4	14.8	-0	19.7	19.8	179

TABLE C4 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	OUT WET BULB. (C)	SOUTH DRY BULB (C)	SOUTH WET BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	NORTH WET BULB (C)	WIND DIR. DEG.
207	2.83	.128	.128	1.01	1.26	12.2	11.1	18.6	13.4	-0	18.6	13.4	191
207	3.92	.126	.117	1.08	.78	11.5	10.6	18.1	13.1	-0	18.2	13.2	192
207	4.92	.118	.108	1.10	1.05	11.2	10.3	17.8	12.8	0	17.8	12.9	196
207	5.58	.104	.096	1.09	.53	11.6	10.4	17.7	12.8	13	17.6	12.7	197
207	6.17	.055	.040	1.35	1.29	13.7	11.5	19.1	13.6	80	19.2	13.5	210
207	6.83	.210	.091	2.29	3.26	16.1	12.2	20.3	14.3	203	20.7	14.3	233
207	7.58	.289	.156	1.86	3.44	18.2	13.2	20.1	14.1	367	20.7	14.4	239
207	8.50	.520	.302	1.72	4.82	20.2	13.9	20.4	14.5	500	20.4	14.4	251
207	8.92	.585	.319	1.83	4.58	21.1	14.4	20.1	14.2	568	20.1	14.2	252
207	9.33	.760	.370	2.06	5.34	22.1	14.5	20.1	14.4	684	20.2	14.2	243
207	10.25	.622	.261	2.38	4.51	22.5	14.3	20.1	15.1	786	20.1	14.3	240
207	13.42	.419	.208	2.01	3.86	24.5	15.1	19.8	14.1	925	19.4	14.0	208
207	14.00	.328	.156	2.10	3.69	24.4	15.0	19.7	14.1	902	19.3	13.8	169
207	14.42	.271	.135	2.01	3.13	24.8	15.4	19.5	13.8	807	19.4	14.0	191
207	14.83	.404	.192	2.11	3.87	24.6	15.3	19.6	13.5	785	19.5	13.8	205
207	15.50	.276	.132	2.09	3.45	24.8	15.6	19.6	13.4	697	19.4	13.4	177
207	16.42	.259	.123	2.10	3.17	24.2	15.6	19.5	13.1	460	19.5	13.5	168
207	17.92		.179		3.96	23.2	15.2	19.5	13.0	273	19.4	13.3	174
207	18.75		.171		3.68	22.0	14.5	19.5	13.2	118	19.4	13.5	164
207	21.08		.116		1.74	16.3	11.9	19.1	13.4	-0	19.0	13.7	210
207	22.08		.104		1.11	15.1	11.7	18.8	13.2	-0	19.2	13.9	217
208	11.58		.130		2.10	26.6	16.5	20.0	14.0	884	20.0	13.9	309
208	12.08		.217		3.12	26.7	16.3	19.8	14.0	915	19.8	13.9	266
208	13.17		.179		3.11	27.2	16.5	19.8	14.0	910	19.4	14.0	244
208	13.92		.204		3.61	27.9	16.8	19.8	13.8	870	19.6	13.9	279
208	15.58		.201		2.88	28.2	16.8	19.6	12.9	668	19.6	13.3	262
208	16.50		.148		1.94	28.3	17.0	19.6	12.9	533	19.6	13.2	311
208	17.25		.174		2.53	28.0	16.8	19.6	12.2	364	19.5	13.0	307
208	18.33		.179		3.02	27.0	16.6	19.6	13.0	182	19.3	13.1	297
208	20.50		.105		.46	19.6	14.6	19.1	13.5	-1	19.1	13.8	282
208	21.33		.084		.69	17.3	13.9	19.1	13.3	-0	19.0	13.7	270
208	22.33		.083		.72	16.1	13.4	19.2	13.3	-0	19.6	13.9	232
208	23.33		.088		.43	15.1	13.0	18.9	13.2	-0	19.5	13.9	234
208	24.33		.086		.66	14.3	12.8	19.2	13.3	-0	19.6	13.9	232
208	25.33		.087		.43	14.2	12.8	19.2	13.2	-0	19.4	13.8	233

TABLE C4 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	OUT WET BULB (C)	SOUTH DRY BULB (C)	SOUTH WET BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	NORTH WET BULB (C)	WIND DIR. DEG.
209	17.75		.177		3.79	28.6	18.8	19.8	12.9	251	18.8	12.9	36
209	18.75		.107		2.45	26.9	18.3	19.6	13.2	77	18.6	13.2	35
209	19.33		.084		1.29	25.0	17.9	19.3	13.5	18	18.5	13.5	16
209	20.17		.049		.53	22.3	17.6	19.4	13.5	-0	18.7	13.6	31
209	21.25		.020		.50	20.6	17.3	19.5	13.4	-0	19.2	13.7	95
210	15.92	.658			5.67	32.0	22.8	21.7	13.2	569	21.8	14.0	61
210	16.33	.581			4.94	31.4	22.6	19.6	13.4	482	21.7	14.0	94
210	17.25	.344			3.16	30.1	22.4	21.4	13.3	277	21.0	14.2	113
210	17.75	.507			3.69	30.5	22.8	21.5	13.7	310	20.6	13.9	70
210	18.08	.350			3.13	29.7	22.5	21.1	13.5	190	20.5	14.0	90
213	13.58	.476			4.14	26.8	16.3	20.1	16.8	990	19.6	18.2	356
213	13.92	.297			4.18	26.8	16.5	19.9	16.9	800	19.5	18.2	356
213	14.42	.379			3.71	27.1	16.7	19.8	16.8	936	19.3	17.9	359
213	14.92	.229			3.12	26.3	16.3	19.8	16.9	656	19.6	18.1	355
213	15.58	.306			3.18	25.6	16.0	19.3	16.7	381	19.2	17.9	359
213	16.83	.461			3.47	27.9	17.8	19.7	17.0	393	19.4	18.0	357
213	17.67	.263			2.70	25.6	16.3	19.9	17.2	181	19.1	17.7	1
213	18.00	.158			1.90	25.2	16.1	19.7	17.1	287	19.4	18.1	358
213	18.50	.182			1.76	25.1	16.2	19.9	17.2	195	19.5	18.3	1
213	18.92	.206			1.93	24.5	16.4	19.7	17.1	89	19.2	18.0	358
214	11.50	.460			5.14	28.9	18.5	20.3	17.7	543	20.2	18.5	21
214	12.17	.468			4.73	28.1	18.8	20.4	17.9	370	19.6	18.2	40
214	12.50	.596			5.19	26.3	17.9	19.9	17.5	162	19.0	17.8	42
214	12.92	.517			4.40	25.8	17.8	23.8	17.4	140	18.8	17.9	32
214	13.42	.564			4.61	26.1	18.3	19.8	17.8	201	19.0	18.2	37
214	13.83	.416			4.22	25.5	18.9	19.6	17.6	179	19.3	18.3	37
214	14.42	.209			2.66	25.3	19.8	19.6	17.7	250	19.1	18.2	32
214	15.58	.269			4.43	28.5	19.6	20.2	18.0	625	20.3	18.4	18
214	16.08	.379			4.30	23.7	19.9	20.1	17.8	544	20.4	18.6	32
214	17.08	.237			3.79	28.2	19.7	19.9	17.4	417	20.1	18.4	6
217	16.58		.230		3.89	32.6	25.0	20.6	14.3	531	19.6	12.4	47
217	17.33		.193		3.44	31.9	25.0	20.2	14.2	338	19.7	12.5	29
217	18.67		.139		2.58	30.3	24.5	19.7	14.3	90	19.1	12.6	22
217	19.58		.118		2.73	29.2	24.3	19.6	14.9	14	19.0	13.4	358
217	20.33		.125		3.71	28.7	23.8	19.5	15.1	2	19.3	14.1	14

TABLE C4 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	OUT WET BULB (C)	SOUTH DRY BULB (C)	SOUTH WET BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	NORTH WET BULB (C)	WIND DIR. DEG.
217	20.92		.180		4.89	28.4	23.7	19.6	15.4	-0	19.5	14.3	22
224	11.83		.092		1.35	24.7	17.9	20.2	20.4	827	22.9	19.7	345
224	13.00		.086		1.73	25.2	18.1	20.1	20.1	895	20.7	19.4	32
224	14.00		.075		1.77	26.1	18.3	20.2	20.2	896	20.5	19.4	61
224	15.00		.089		2.19	26.7	18.3	20.0	20.0	848	20.5	19.4	99
224	16.00		.088		2.23	26.8	18.1	19.8	19.9	760	20.1	19.2	82
224	16.75		.074		1.67	26.6	17.7	19.8	19.7	652	20.1	19.3	1
227	16.92	.169	.138	1.22	1.01	29.9	24.1	20.0	14.3	355	19.3	12.8	12
227	17.50	.146	.114	1.28	1.15	29.4	23.9	19.9	14.2	206	19.3	12.9	327
227	18.33	.182	.119	1.52	1.55	27.9	24.0	20.0	14.7	91	19.2	13.5	246
228	14.25	.284	.159	1.78	2.83	26.2	24.6	22.1	16.8	260	20.8	16.0	60
228	14.83	.321	.186	1.73	3.56	28.2	25.8	22.0	16.7	359	20.6	15.7	48
228	16.00	.277	.162	1.70	3.64	28.9	26.3	21.6	16.3	305	20.3	15.3	37
228	16.83	.294	.158	1.87	3.67	28.7	26.0	21.7	16.3	271	20.3	15.2	38
228	17.58	.425	.243	1.75	4.24	28.6	23.1	21.6	16.2	213	20.6	15.3	37
229	10.33	.271	.121	2.24	3.43	23.5	17.6	21.7	20.4	730	20.7	14.9	161
229	11.00	.318	.145	2.19	4.64	24.1	17.6	21.6	20.8	806	20.3	14.7	116
229	11.58	.258	.117	2.21	3.24	24.4	18.2	21.3	20.7	848	20.3	15.0	135
229	12.83	.337	.145	2.32	3.59	25.8	19.1	21.0	20.6	858	20.0	15.1	127
229	13.92	.264	.109	2.43	3.39	25.4	18.8	20.8	20.4	825	20.0	14.8	119
229	15.42	.547	.244	2.25	4.51	27.0	19.9	21.0	14.9	548	20.0	14.3	101
229	16.00	.371	.203	1.83	3.76	25.7	19.3	20.7	14.8	363	20.0	14.5	113
229	16.50	.581	.258	2.25	4.21	26.9	19.8	21.1	15.0	535	20.0	14.4	99
229	16.83	.371	.157	2.36	3.63	26.4	19.6	20.8	14.6	411	19.8	14.2	123
230	10.00	.122	.069	1.78	1.14	22.8	15.6	19.5	14.9	684	19.8	14.3	259
230	11.25	.277	.147	1.89	2.04	23.2	15.5	20.8	15.1	833	19.9	14.3	223
230	11.67	.132	.075	1.76	1.73	23.1	15.6	20.6	14.9	706	19.9	13.6	189
230	12.75	.186	.096	1.93	2.48	23.4	16.2	20.6	15.1	585	19.8	14.4	119
230	13.42	.164	.101	1.63	1.50	23.5	16.3	20.5	15.1	592	19.8	14.5	115
230	14.08	.115	.083	1.39	1.14	23.5	16.0	20.5	15.1	546	19.9	14.7	136
230	14.92	.142	.079	1.78	1.85	24.1	16.2	20.3	14.6	639	19.7	14.1	126
230	15.92	.129	.062	2.07	1.65	24.3	16.4	20.2	14.2	605	19.6	13.5	150
230	16.75	.129	.087	1.50	1.54	22.9	16.2	20.2	14.4	327	19.5	13.4	153
231	10.25	.231	.101	2.28	2.03	22.9	15.4	19.1	16.6	428	20.0	14.8	282
231	11.25	.150	.077	1.96	1.44	23.2	15.7	20.5	18.3	392	19.9	14.7	304

TABLE C4 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	OUT WET BULB (C)	SOUTH DRY BULB (C)	SOUTH WET BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	NORTH WET BULB (C)	WIND DIR. DEG.
231	11.75	.081	.051	1.58	.88	23.7	16.3	20.4	19.1	540	20.0	15.0	354
231	12.67	.163	.053	3.09	2.40	25.2	17.5	20.6	19.8	860	20.0	14.9	53
234	11.83	.187	.107	1.74	1.56	27.4	19.9	21.4	14.9	760	20.1	17.2	68
234	12.83	.280	.120	2.32	2.53	28.0	20.1	21.2	14.8	825	20.2	17.4	94
234	13.25	.238	.124	1.91	2.47	27.6	19.8	21.1	15.1	747	20.0	17.5	70
234	13.92	.333	.151	2.21	3.34	28.3	20.3	21.0	14.9	731	20.0	17.4	62
234	15.17	.444	.219	2.03	3.82	27.9	19.9	21.0	14.8	564	19.9	17.4	69
234	15.58	.382	.179	2.13	3.24	27.5	19.7	20.8	14.5	467	19.6	17.1	85
234	16.17	.285	.149	1.91	2.78	26.1	19.5	20.6	14.7	270	19.7	17.4	76
234	17.00	.156	.091	1.71	1.85	25.5	19.7	20.8	15.2	234	19.9	17.7	101
234	17.67	.131	.085	1.52	1.48	24.8	19.8	20.7	15.0	156	19.7	17.6	99
235	9.75	.142	.074	1.91	2.37	27.7	21.2	21.0	15.4	624	20.5	17.9	357
235	10.42	.146	.088	1.66	2.62	27.6	20.8	20.7	15.2	467	20.2	17.7	351
235	11.25	.123	.088	1.40	2.10	26.2	20.3	20.4	15.2	244	20.2	17.8	0
235	12.25	.191	.112	1.71	2.66	25.6	20.9	20.4	15.4	231	20.1	17.8	32
235	13.00	.289	.156	1.85	3.70	23.4	20.7	20.5	15.7	92	20.5	18.2	40
235	13.67	.391	.204	1.91	3.45	21.3	19.6	20.8	15.9	108	21.3	18.2	50
235	14.33	.258	.127	2.03	2.80	19.8	18.0	21.3	16.1	101	22.3	18.0	45
235	14.83	.104	.062	1.67	1.29	21.0	18.5	21.2	15.9	227	21.9	18.1	95
235	15.92	.084	.042	2.01	1.28	21.0	18.4	21.1	15.9	196	21.4	17.7	193
235	16.67	.078	.045	1.76	.63	21.4	18.9	21.1	15.9	115	21.4	17.9	177
236	8.25	.390	.151	2.58	3.57	17.7	15.4	21.3	16.9	354	21.0	14.9	194
236	8.75	.408	.151	2.71	3.63	18.7	15.8	21.1	17.0	413	21.1	15.1	199
236	9.17	.304	.117	2.59	3.51	19.3	16.0	21.4	17.4	525	21.0	14.9	187
236	9.58	.334	.146	2.29	3.72	20.1	16.5	21.3	17.4	601	21.1	14.9	162
236	10.08	.218	.091	2.40	3.02	20.6	16.5	21.3	17.7	687	20.5	14.4	180
236	11.33	.460	.197	2.34	3.91	21.7	16.4	20.9	17.9	813	20.1	14.5	209
236	11.67	.250	.109	2.29	3.38	22.0	16.3	20.6	17.7	844	20.0	14.5	158
236	12.33	.379	.163	2.32	2.93	22.8	16.0	19.2	17.8	873	19.9	14.6	212
236	13.00	.231	.094	2.45	3.04	23.2	16.2	20.4	17.9	868	20.0	14.8	168
236	13.50	.198	.084	2.36	3.17	23.4	16.5	20.2	17.9	843	19.8	14.6	180
236	14.25	.214	.094	2.27	2.70	23.7	16.8	20.3	18.1	787	19.8	14.4	189
236	15.00	.193	.086	2.24	2.56	23.7	16.7	20.1	18.0	702	19.6	13.8	187
236	15.75	.191	.081	2.34	3.31	23.8	16.9	20.1	18.1	588	19.6	13.5	164
236	17.17	.188	.120	1.57	2.69	23.0	16.3	20.1	18.4	303	19.6	13.4	141

TABLE C4 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	OUT WET BULB (C)	SOUTH DRY BULB (C)	SOUTH WET BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	NORTH WET BULB (C)	WIND DIR. DEG.
236	18.17	.166	.113	1.48	2.47	22.0	16.1	20.1	18.6	119	19.4	13.3	169
236	19.08	.163	.077	2.11	2.62	19.5	15.3	19.7	17.6	10	19.4	14.0	159
236	20.00	.162	.079	2.05	2.41	17.8	14.6	19.7	18.5	-0	19.6	14.4	180
236	20.92	.310	.128	2.41	2.93	17.2	14.5	19.6	18.4	-0	19.7	14.3	204
236	21.58	.199	.103	1.93	2.55	16.5	14.4	19.5	18.4	-1	19.4	14.2	211
237	14.17	.408	.171	2.38	3.99	26.1	18.0	20.3	15.7	798	19.7	14.8	314
237	14.92	.445	.195	2.28	3.93	26.1	17.9	20.2	16.6	727	19.5	14.4	304
237	15.42	.555	.249	2.23	4.01	26.0	17.9	20.3	17.2	671	19.8	14.7	282
237	15.75	.417	.184	2.27	3.29	26.0	17.9	20.4	17.8	563	19.7	14.4	301
237	16.42	.575	.247	2.33	4.40	25.8	18.0	20.4	18.1	484	19.6	14.3	295
237	16.75	.385	.178	2.17	3.83	25.4	17.8	20.3	18.3	361	19.8	14.6	299
237	17.42	.372	.176	2.12	3.53	25.0	17.7	20.2	18.6	262	19.6	14.6	277
243	15.75	.180	.175	1.03	1.13	29.3	25.6	20.3	16.6	406	19.7	14.1	360
243	16.50	.162	.124	1.31	2.16	31.9	26.5	20.4	19.3	412	19.8	13.3	360
243	17.25	.172	.129	1.34	3.18	31.3	25.7	20.4	19.8	241	19.9	13.2	359
243	18.08	.163	.118	1.38	2.10	30.1	25.4	20.3	19.9	103	19.9	13.6	359
243	18.83	.146	.120	1.22	1.70	28.6	25.1	20.2	19.8	13	19.6	13.9	359
243	19.50	.136	.104	1.30	1.80	27.8	24.9	20.3	20.1	-0	19.8	14.4	359
243	20.92	.123	.091	1.35	2.20	26.4	23.9	20.1	20.0	-1	20.2	15.1	359
243	22.58	.102	.092	1.11	1.27	24.6	23.0	20.2	20.1	-1	20.3	14.9	356
243	24.25	.093	.083	1.12	.39	23.2	22.3	20.3	20.2	-0	20.9	14.9	22

TABLE C5: FALL DATA.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	SOUTH DRY BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	WIND DIR. DEG.
252	0.00	.800	.900	.89	6.08	30.0	22.0	-0	20.6	
270	14.25	.569	.617	.92	4.05	21.9	20.6	655	20.3	
270	15.00	.560	.663	.85	4.81	21.5	20.6	507	20.0	
270	15.83	.392	.447	.88	3.81	20.9	20.4	389	20.1	
270	16.17	.510	.588	.87	4.79	20.3	20.4	203	20.0	
270	17.08	.387	.416	.93	4.58	18.4	20.1	78	19.9	
270	17.75	.232	.241	.97	3.27	17.1	20.1	25	20.1	
272	11.17	.127	.158	.80	2.35	23.3	20.5	655	20.3	
272	12.83	.216	.250	.87	2.52	24.0	20.7	567	20.3	
272	14.17	.120	.134	.89	2.45	24.9	20.6	452	20.0	
272	14.83	.166	.174	.96	2.35	24.5	20.7	360	19.8	
272	16.17	.074	.036	2.06	.98	20.3	20.3	84	19.8	
273	17.75	.319	.351	.88	3.17	20.3	20.6	1	20.6	
273	18.33	.188	.255	.74	2.97	19.9	20.5	0	20.4	
273	19.17	.407	.433	.94	3.70	19.1	20.6	0	20.4	
273	19.75	.173	.213	.81	4.58	18.7	20.2	0	20.5	
273	20.08	.290	.387	.75	5.83	18.5	20.6	0	20.9	
273	20.50	1.094	1.171	.93	5.82	18.3	20.7	0	21.4	
273	20.92	.343	.312	1.10	3.42	19.1	20.7	0	22.1	
273	21.50	.065			1.74	18.8	20.6	-0	21.3	
277	15.25	.293	.373	.78	3.37	21.2	23.2	402	22.7	
277	16.08	.217	.288	.75	2.73	21.2	23.3	332	22.6	
277	16.83	.251	.325	.80	3.27	20.4	23.4	210	22.5	
277	17.33	.137	.204	.67	2.11	19.6	23.1	114	22.3	
277	17.83	.095	.116	.82	1.58	17.2	21.4	16	22.5	
279	13.92	.315	.348	.90	2.32	18.0	22.9	655	22.8	
279	14.42	.232	.255	.91	2.59	18.0	23.0	602	22.9	
279	15.00	.244	.271	.90	3.30	18.1	23.2	503	22.7	
279	15.83	.250	.278	.90	2.52	17.8	23.2	347	22.5	
279	16.75	.140	.157	.89	2.01	17.0	23.1	164	22.5	
279	17.67	.140	.183	.76	1.52	14.5	22.9	25	22.6	
280	10.33	.394	.441	.89	2.87	13.2	17.3	144	16.6	
280	10.75	.476	.534	.89	3.35	13.7	17.6	129	16.9	
280	11.50	.452	.452	1.00	3.21	14.3	17.7	122	17.2	
280	12.58	.250	.299	.84	2.74	15.4	18.1	119	17.7	
280	13.17	.196	.214	.92	2.50	15.7	18.3	99	18.0	
280	13.67	.307	.358	.86	2.96	15.5	18.6	86	18.2	
280	15.00	.316	.322	.98	2.73	14.4	18.8	38	18.4	
280	15.42	.385	.406	.95	3.07	14.0	18.7	26	18.5	
280	16.00	.550	.586	.94	3.51	13.7	18.5	19	18.6	
282	10.42	.249	.340	.73	5.51	17.5	20.5	556	20.3	
282	11.58	.266	.382	.70	5.67	19.2	21.5	667	21.6	
282	12.33	.264	.380	.70	5.58	19.9	22.1	614	22.1	
282	13.17	.171	.233	.73	4.31	20.2	22.8	483	22.7	
282	13.92	.227	.308	.74	4.82	19.6	22.5	233	22.7	
282	15.17	.189	.242	.78	4.47	19.3	22.7	140	22.5	
282	16.42	.155	.187	.83	3.00	18.1	22.2	36	22.5	
281	15.42	1.141	1.034	1.10	8.65	18.5	22.8	412	22.8	
281	16.17	1.389	1.071	1.30	9.43	17.0	22.9	293	22.7	
281	11.83	.897	.986	.91	6.29	22.7	23.0	510	22.9	
281	12.17	1.139	1.267	.90	8.40	23.4	22.9	711	23.1	
281	12.92	1.390	1.323	1.05	8.91	21.5	22.8	432	22.6	
284	15.00	1.814	2.066	.88	9.08	13.1	19.2	236	19.4	

TABLE C5 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	SOUTH DRY BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	WIND DIR. DEG.
284	16.83	1.558	1.759	.89	8.61	11.9	18.3	53	18.5	
285	12.50	.635	.694	.92	4.42	13.7	19.4	357	19.6	
285	13.08	.925	1.047	.88	5.46	14.7	19.8	494	20.0	
285	13.83	.795	.789	1.01	4.61	14.5	20.3	330	20.4	
285	14.67	.813	.957	.85	4.50	14.6	20.5	353	20.9	
285	15.00	.434	.506	.86	3.84	14.3	20.6	235	20.7	
285	15.33	.604	.626	.96	4.43	15.4	20.9	438	21.2	
285	15.83	.503	.550	.91	4.40	14.3	21.7	227	21.8	
285	17.00	.431	.513	.84	3.42	13.5	22.1	122	22.5	
285	18.50	.162	.186	.87	1.53	8.3	19.9	-0	20.4	
285	19.33	.144	.168	.86	.89	6.5	18.9	-0	19.3	
285	20.08	.147	.168	.88	.93	5.8	17.7	-0	18.2	
285	21.08	.139	.162	.85	.77	5.1	16.5	-0	17.0	
286	13.50	.233	.212	1.10	2.29	16.3	23.0	633	22.6	
286	13.83	.263	.263	1.00	1.55	16.8	23.4	618	23.3	
286	14.17	.139	.128	1.08	.77	16.9	23.9	574	23.8	
286	14.67	.196	.173	1.14	1.42	16.8	23.4	519	23.2	
286	15.58	.189	.168	1.12	1.24	16.8	23.7	373	22.8	
286	16.17	.131	.112	1.17	.67	16.4	23.7	261	23.2	
286	16.83	.114	.086	1.33	.52	15.6	23.3	136	22.9	
287	13.00	.416	.491	.85	4.29	19.0	23.5	639	23.2	
287	14.08	.532	.587	.91	4.34	20.5	23.4	587	22.9	
287	15.00	.394	.413	.95	3.93	20.8	23.6	467	23.2	
287	15.58	.467	.493	.95	4.41	20.5	23.4	375	22.6	
287	16.17	.422	.411	1.03	4.36	20.0	23.3	252	23.0	
287	17.33	.265	.355	.75	2.77	18.8	23.3	84	22.3	
287	17.58	.193	.172	1.12	2.38	17.7	23.0	35	23.0	
287	18.00	.129	.085	1.51	1.46	14.6	23.0	1	22.5	
287	19.83	.156	.156	1.00	1.20	10.6	21.6	-0	21.3	
287	20.67	.137	.129	1.06	1.06	10.4	20.7	-0	20.5	
287	23.00	.150	.177	.84	1.64	9.8	19.4	-0	18.8	
287	23.92	.260	.313	.83	2.95	8.9	19.6	-0	18.5	
287	24.58	.202	.246	.82	2.30	8.6	19.4	-0	18.6	
290	15.25	.404	.528	.76	6.66	19.9	23.6	415	22.8	
290	15.83	.481	.700	.69	6.85	19.6	23.3	282	23.1	
290	16.58	.371	.446	.83	6.37	19.2	23.3	169	22.9	
290	17.42	.349	.385	.91	3.50	17.7	22.5	21	23.0	
290	18.00	.222	.159	1.12	2.96	16.6	22.7	1	22.8	
290	18.33	.204	.145	1.41	2.90	16.2	22.4	-0	22.4	
290	19.83	.304	.364	.84	3.62	15.5	21.4	-0	21.6	
290	20.75	.276	.248	1.11	2.98	13.8	21.0	-0	21.1	
290	22.00	.234	.260	.90	2.19	11.1	20.1	-0	20.3	
290	22.75	.234	.253	.92	2.70	10.2	19.6	-0	19.8	
291	13.83	1.079	1.129	.95	6.37	14.8	20.3	175	20.6	
291	14.17	1.354	1.332	1.02	6.73	14.5	20.1	152	20.5	
291	14.67	1.319	1.233	1.07	5.84	15.5	20.5	290	20.7	
291	15.00	1.116	.854	1.31	6.93	14.4	20.1	72	20.5	
291	16.08	1.024	.898	1.14	5.89	13.6	20.0	134	20.3	
291	16.83	.863	.605	1.43	5.53	14.9	20.3	67	20.7	
291	17.17	1.093	.740	1.48	7.41	14.4	20.1	17	20.3	
291	18.00	.286	.297	.96	2.27	12.2	19.4	0	19.7	
291	18.25	.849	.947	.90	5.45	10.7	19.3	0	19.5	
292	13.42	.359	.341	1.05	3.01	13.5	20.0	123	20.0	

TABLE C5 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	SOUTH DRY BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	WIND DIR. DEG.
292	13.75	.222	.180	1.23	2.50	14.5	20.5	198	20.4	
292	14.75	.258	.235	1.10	2.33	14.7	20.8	83	20.5	
292	15.75	.243	.246	.99	2.15	15.1	20.6	80	20.7	
292	16.25	.178	.177	1.01	1.65	15.3	20.5	71	20.6	
292	16.92	.138	.134	1.03	1.15	14.6	20.6	42	20.5	
292	18.08	.143	.134	1.07	.39	10.5	19.6	-0	19.9	
292	19.00	.135	.132	1.03	.51	8.4	19.3	-0	19.1	
292	20.42	.161	.158	1.02	.44	6.7	19.2	-0	18.6	
293	10.83	.361	.366	.98	2.79	18.6	22.9	572	23.0	
293	11.50	.291	.239	1.22	2.45	19.1	23.2	557	23.4	
293	12.00	.319	.327	.97	3.03	19.4	23.3	597	23.6	
293	12.42	.258	.256	1.01	3.38	19.6	23.6	615	23.1	
293	12.83	.324	.256	1.26	3.21	19.9	23.8	617	22.9	
293	13.25	.145			2.37	20.0	22.6	609	23.8	
293	13.50	.309	.227	1.36	2.65	20.2	23.8	574	22.8	
293	13.92	.154			2.07	20.1	23.5	530	23.1	
293	14.42	.192			2.04	20.1	23.5	443	23.2	
293	15.17	.176			2.64	19.9	23.3	326	23.0	
293	15.92	.136			1.75	18.6	23.5	139	23.1	
293	17.17	.096			.88	16.4	23.3	38	22.8	
294	10.50	.490	.685	.71	5.41	20.9	23.4	-0	23.6	
294	10.83	.338	.404	.84	5.05	21.5	23.8	-0	23.8	
294	11.67	.300			5.59	22.3	23.0	-0	23.6	
294	12.83	.446	.628	.71	5.31	23.6	23.4	-0	23.0	
294	13.50	.390	.470	.83	5.86	24.0	23.5	-0	23.0	
294	15.33	.310	.390	.79	5.27	24.3	22.9	-0	23.0	
294	15.83	.230			4.39	24.2	23.2	-0	23.3	
297	18.25	.168	.243	.69	3.25	20.5	23.4	-0	23.7	
297	18.75	.134	.166	.81	2.39	19.9	23.3	-0	23.6	
298	14.58	.530	.456	1.16	3.11	15.2	22.3	136	22.6	
298	14.92	.442	.352	1.25	3.15	15.5	22.3	118	22.5	
298	15.25	.300	.175	1.71	3.14	15.2	22.1	87	22.4	
298	16.08	.297	.267	1.11	2.49	14.8	22.0	50	22.2	
298	16.83	.192	.138	1.39	2.12	13.8	21.8	16	22.0	
298	17.33	.279	.241	1.16	2.31	14.3	21.5	3	21.7	
298	18.33	.285	.242	1.18	2.22	13.9	21.0	0	21.3	
298	19.00	.180	.109	1.65	1.54	13.7	20.8	0	21.1	
298	19.58	.147	.087	1.70	1.27	13.8	20.6	0	20.9	
298	20.83	.219	.222	.99	1.84	13.5	20.3	0	20.5	
300	11.50	.165	.150	1.10	2.56	18.1	21.4	590	21.1	
300	12.25	.143	.130	1.10	2.70	19.8	22.1	608	21.9	
300	13.42	.174	.164	1.06	2.57	21.4	23.4	578	23.2	
300	13.75	.140	.117	1.20	2.61	22.0	24.0	553	23.6	
300	14.17	.245	.230	1.06	3.08	22.4	23.3	524	22.9	
300	14.50	.318	.314	1.02	3.49	22.6	23.6	490	23.0	
300	14.83	.177	.136	1.30	2.21	22.5	23.3	445	23.1	
300	15.67	.286	.301	.95	2.75	22.3	23.3	311	23.0	
300	16.17	.133	.114	1.17	1.48	21.7	23.4	192	23.0	
300	16.92	.090	.056	1.60	.66	19.8	23.4	53	22.8	
301	10.75	.637	.613	1.04	4.42	14.6	23.4	474	22.3	
302	16.50	.803	.892	.90	5.20	15.6	24.0	162	23.1	
302	16.92	.618	.624	.99	4.79	15.1	24.0	76	23.5	
302	17.42	.466	.326	1.43	3.19	14.3	23.6	19	22.2	

TABLE C5 CONT.

DAY NO.	START TIME	NORTH HOME INFLT HR-1	SOUTH HOME INFLT HR-1	RATIO IN/IS	WIND SPEED M/S	OUT DRY BULB (C)	SOUTH DRY BULB (C)	SOLAR RAD. WATTS/ SQMT	NORTH DRY BULB (C)	WIND DIR. DEG.
302	17.75	.286	.184	1.56	2.65	13.9	23.1	1	22.4	
302	18.33	.460	.359	1.28	4.05	13.4	22.3	0	21.8	
302	19.08	.477	.379	1.26	3.56	12.6	21.6	0	21.3	

TABLE C6: TYPICAL ERRORS IN THE DATA.

DAY NO.	START TIME STOP TIME	NORTH HOME INFLT ERROR HR-1	SOUTH HOME INFLT ERROR HR-1	RATIO IN/IS	WIND SPEED ERR M/S	OUT DRY BULB TEMP ERROR (C)	OUT WET BULB TEMP ERROR (C)	SOUTH DRY BULB TEMP. ERROR (C)	SOUTH WET BULB TEMP ERROR (C)	SOLAR RAD. ERROR WATTS/ SQMT	NORTH DRY BULB TEMP ERROR (C)	NORTH WET BULB TEMP ERROR (C)	WIND DIR. ERR. DEG.
344	2.75	.543	.322	1.69	1.82	-7.5	-8.0	22.5	22.4	-1	22.7	22.4	346
	3.67	-.203	-.771		.33	.1	.1	1.2	1.2	0	1.3	1.1	16
346	13.50	.477	.179	2.66	2.11	23.4	-.1	24.0	23.6	341	23.8	23.5	347
	14.43	-.157	.052		.80	6.1	.1	1.0	.9	53	1.1	1.1	23
351	2.58	.337	.244	1.38	1.73	-1.3	-1.9	11.5	11.4	-1	11.0	10.6	65
	3.25	.031	-.037		.32	.4	.3	.1	.1	0	.2	.1	14
362	14.00	1.468	1.004	1.46	8.07	6.5	3.5	26.5	26.2	347	27.1	26.7	13
	14.42	-.066	.042		2.26	.2	.1	1.1	.9	43	2.6	2.4	4
364	15.50	1.475	.767	1.92	6.71	-8.6	-9.1	26.2	25.9	168	25.4	25.1	38
	15.83	-.364	.101		.89	.3	.1	1.5	1.3	34	1.6	1.4	9
366	17.00	1.802	.857	2.10	5.92	-12.2	-12.5	25.9	25.8	35	25.2	24.9	37
	17.33	-.750	-.013		.83	.2	.1	1.8	1.5	14	1.9	1.7	12
5	17.33	.324	.205	1.58	1.22	-5.7	-5.9	25.8	25.6	4	24.7	24.5	90
	19.00	-.134	.132		.28	1.8	1.8	1.1	1.1	8	1.6	1.6	4
18	19.50	.424	.264	1.61	2.03	-12.3	-12.5	23.4	23.2	-1	24.4	24.0	147
	20.00	-.483	1.055		.56	.3	.3	1.5	1.3	0	2.0	1.9	8
28	20.42	1.578	.994	1.59	10.22	-18.5	-18.6	25.6	25.4	-0	26.1	26.1	54
	20.92	.164	.446		1.86	.1	.2	1.9	1.9	0	1.0	.9	10
29	13.58	2.299	1.189	1.93	10.31	-13.0	-13.5	25.1	24.9	585	25.5	25.4	42
	14.42	.108	.235		2.00	.2	.3	1.8	1.6	14	1.6	1.4	21
39	14.08	.466	.331	1.41	4.61	-2.6	-3.8	24.4	13.4	595	23.5	11.3	6
	14.42	.030	1.427		.77	.2	.6	.9	.5	10	1.3	.6	30
64	16.50	1.040	.483	2.15	5.65	-.0	-.3	26.0	18.3	380	26.2	16.6	105
	16.83	.170	.893		.68	.0	.1	1.3	.7	26	1.2	.8	12
70	22.00	1.594	.861	1.85	7.00	17.7	15.7	26.3	26.4	-0	26.1	26.1	233
	22.42	.073	.121		1.15	.1	.0	.9	.8	0	1.1	1.0	44

TABLE C6, CONT.

DAY NO.	START TIME STOP TIME	NORTH HOME INFLT ERROR HR-1	SOUTH HOME INFLT ERROR HR-1	RATIO IN/IS	WIND SPEED ERR M/S	OUT DRY BULB TEMP ERROR (C)	OUT WET BULB TEMP ERROR (C)	SOUTH DRY BULB TEMP ERROR (C)	SOUTH WET BULB TEMP ERROR (C)	SOLAR RAD. ERROR WATTS/ SQMT	NORTH DRY BULB TEMP ERROR (C)	NORTH WET BULB TEMP ERROR (C)	WIND DIR. ERR. DEG.
78	16.75	.978	.462	2.12	5.27	9.1	9.1	29.1	26.7	139	28.4	22.3	260
	17.08	.022	.328		.95	.1	.1	1.0	.9	15	1.0	.7	13
88	2.42	.477	.347	1.37	7.72	17.4	17.6	26.0	25.4	0	25.6	25.5	15
	3.17	.349	.239		1.42	.2	.2	.8	.6	0	.8	.9	9
92	17.63	2.719	1.228	2.21	12.50	20.9	20.9	32.2	31.9	129	30.6	30.3	79
	18.07	.026	.111		2.07	.7	.8	.2	.3	20	.3	.4	8
118	16.92	.223	.158	1.41	4.30	34.1	34.6	29.9	23.2	269	29.0	23.1	9
	17.42	.034	.773		.78	.6	.5	1.0	.6	83	.9	.6	11
123	18.08	.694	.270	2.57	5.22	21.9	22.0	26.8	26.9	70	26.5	26.5	308
	18.58	.083	.393		1.22	.4	.4	.6	.6	32	.1	.1	12
133	23.00	.173	.129	1.34	.52	17.9	14.5	24.3	24.3	-0	24.6	22.2	99
	23.67	.258	.469		.19	.3	.3	.1	.1	0	.1	.1	1
145	16.00	.965	.499	1.93	5.80	34.3	23.7	26.2	19.5	462	26.0	18.8	262
	16.58	.006	.297		.79	.6	.3	.6	.7	148	.7	.8	16
150	12.67	.533	.256	2.09	4.00	32.3	22.6	25.4	19.5	861	25.4	19.0	254
	13.00	.348	1.415		.86	.8	.2	.7	.6	6	.8	.8	43
152	14.50	1.973	1.021	1.93	10.49	28.4	16.4	25.6	17.7	500	24.9	15.9	90
	14.77	.314	.726		2.02	1.0	.5	.7	.4	323	.9	.4	13
161	19.50	.210	.144	1.46	2.84	23.4	17.2	21.5	16.4	38	21.7	16.1	327
	20.00	1.204	2.422		.58	.4	.1	.6	.5	17	.7	.6	10
190	13.63	.209	.123	1.70	2.52	30.1	23.7	19.6	13.9	793	20.1	14.4	186
	14.75	.332	.983		1.06	.4	.3	.5	.7	240	.6	.7	48
196	19.75	.203	.118	1.72	1.94	30.6	25.9	20.0	14.5	4	20.6	14.9	32
	20.58	.574	.967		.47	.5	.3	.6	.6	5	.6	.7	7
207	9.33	.760	.370	2.06	5.34	22.1	14.5	20.1	14.4	684	20.2	14.2	248
	10.25	-.008	.148		.89	.6	.2	.7	.6	47	.7	.8	18

TABLE C6, CONT.

DAY NO.	START TIME STOP TIME	NORTH HOME INFLT ERROR HR-1	SOUTH HOME INFLT ERROR HR-1	RATIO IN/IS	WIND SPEED ERR M/S	OUT DRY BULB TEMP ERROR (C)	OUT WET BULB TEMP ERROR (C)	SOUTH DRY BULB TEMP ERROR (C)	SOUTH WET BULB TEMP ERROR (C)	SOLAR RAD. ERROR WATTS/SQMT	NORTH DRY BULB TEMP ERROR (C)	NORTH WET BULB TEMP ERROR (C)	WIND DIR. ERR. DEG.
227	17.50	.146	.114	1.28	1.15	29.4	23.9	19.9	14.2	206	19.3	12.9	327
	18.33	.011	1.143		.47	.6	.3	.6	.7	74	.8	1.0	34
234	11.83	.187	.107	1.74	1.56	27.4	19.9	21.4	14.9	760	20.1	17.1	68
	12.83	.014	.941		1.02	1.1	.7	.6	.7	287	1.0	1.0	60
237	15.42	.555	.249	2.23	4.01	26.0	17.9	20.3	17.2	671	19.8	14.7	282
	15.75	.014	1.329		.85	.2	.2	.7	.6	20	.9	.9	13
243	24.25	.093	.083	1.12	.39	23.2	22.3	20.4	20.2	-0	20.9	14.9	22
	25.00	.072	.429		0.00	.5	.3	.6	.5	0	1.0	.8	29
273	17.75	.319	.361	.88	3.17	20.3	20.4	20.6	20.4	1	20.6	23.7	0
	18.33	.055	.141		.81	.2	.2	.5	.6	1	.8	.6	0
281	15.42	1.141	1.034	1.10	8.65	18.5	14.3	22.8	22.8	412	22.8	23.5	0
	16.17	0.000	0.000		1.31	.7	.4	.5	.5	124	.7	.7	0
287	15.00	.394	.413	.95	3.93	20.8	20.7	23.6	23.5	467	23.2	23.2	0
	15.58	.052	.190		.81	.1	.1	.9	.8	29	1.1	1.1	0
292	16.25	.178	.177	1.01	1.65	15.3	15.3	20.5	20.5	71	20.6	21.0	0
	16.92	.071	.469		.40	.2	.1	.2	.0	8	.1	.0	0
298	18.33	.285	.242	1.18	2.22	13.9	14.0	21.0	20.9	0	21.3	22.1	0
	19.00	.138	.371		.59	.2	.2	.2	.1	0	.1	.1	0

APPENDIX D: COP of Air Conditioners

As part of the energy usage study, the COP values of both air conditioners were measured on one particular afternoon in late August. Both air conditioners were measured consecutively at nearly the same conditions. The outside air was cool and dry, and the afternoon was sunny (unfortunately the weather data was not recorded).

The method used was similar to that used by Murphy.[66] The wet and dry bulb temperatures of the air flowing through the evaporative coils of the air conditioner were measured before and after the air passed through the coils. With the wet and dry bulb temperatures known, the enthalpy and humidity ratio of the entering and leaving air could be determined, and the energy balance determined:

$$q = \dot{m}(-h_{ai} + h_{ao}) + (\omega_i - \omega_o)h_\omega.$$

The south home was run first. At the beginning of the test the air conditioner was allowed to cycle on in the normal manner. Then the thermostats were turned down to increase the on time of the system and reach a steady state condition. Data collection began 5 minutes after the air conditioners were turned on. Temperatures were measured once every minute for 20 minutes. After the temperature measurements were completed the electric consumption was measured by timing the rotation of the electric meter disc and measuring and subtracting the background electric use.

With this completed the procedure was repeated for the north home.

In order to complete the COP measurements the flow rate of air through the air conditioner had to be measured. Four procedures were used. The air flow was measured using a pitot-static tube to measure the air velocity on a grid of 1.27 cm (1/2") by 1.27 cm (1/2") over each supply register and integrating over the register and finally by summing all of the registers. Secondly, the air flow in the return register was measured using a vane anemometer and measuring the velocity at six positions over the register and summing. Thirdly, the air flow was measured by measuring the flow rate from the supply registers using the vane anemometer (two readings were taken for each register by placing the anemometer on each half of the register and summing the results), and fourthly, measurements were taken in the supply duct with the vane anemometer.

The data and results are presented in table D1. The COP values were much larger than expected due to the cool outside conditions. (Unfortunately the exact outside conditions were never recorded.) The south homes' air conditioner was determined to be about 2% more efficient than the north homes' air conditioner (using rated flow). However, due to the error involved (which was much larger than the difference) this difference is really not significant.

Table D1 Results of COP measurements

Home	North	South
time of run (min.)	20	21
Output of thermocouples avg.		
Return dry bulb (mV)	.696(±.011)	.736(±.012)
wet bulb (mV)	.496(±.011)	.543(±.016)
Supply dry bulb (mV)	.184(±.003)	.221(±.013)
wet bulb (mV)	.151(±.005)	.205(±.014)
Temperatures		
Return dry bulb °C	17.7(±.3)	18.7(±.3)
wet bulb °C	12.7(±.3)	13.9(±.4)
Supply dry bulb °C	4.7(±.1)	5.7(±.3)
wet bulb °C	3.9(±.1)	5.3(±.4)
Humidity ratio kg/kg dry air		
Return air	.00712(±.00018)	.00796(±.00026)
Supply air	.00469(±.00004)	.00538(±.00016)
Condensate removed kg/kg dry air	.00243(±.00022)	.00258(±.00042)
Enthalpy kJ/kg dry air		
Return air	53.51(±.75)	56.65(±.96)
Supply air	34.24(±.20)	36.99(±.70)
Condensate	0.04(±.004)	0.05(±.008)
Enthalpy removed kJ/kg dry air	19.23(±.95)	19.61(±1.66)
Time for 5 rev. of power meter	36.0 s	35.7 s
Backgroung (1 rev.) sec	40.0	37.5
Net power used kW	2.95	2.94
Volume flow rate #1, #2	.438 .510	.432 .538
#3, #4 m^3/s	.587 .504	.592 .514
Average of #1 #2 #3 #4 m^3/s	.510(±.112)	.516(±.130)
Cooling kJ/s	11.94(±3.21)	12.28(±4.13)
COP*	4.05(±1.08)	4.17(±1.40)

---

* Under rating conditions this value would have been 2.3 The high value is mostly due to the low outside temperatures of this particular test (estimated as around 70°F or less), and partly due to the apparently high flow rates measured. (The fans were rated at 0.364 m^3/s, flow rates were measured as 0.51 and 0.52 m^3/s.)

APPENDIX E: Calculation of Infiltration

The present methods suggested by ASHRAE for predicting air infiltration are first considered. However as these methods do not predict trends in infiltration due to changes in wind speed or temperature accurately this appendix also considers a possible physical model to represent the measured data.

E.1 ASHRAE Methods

ASHRAE[4] recommends two methods for determining infiltration: a) the crack method, and b) the air change method.

E.1.1 Expected Infiltration Rates Based on the Crack Method

The procedure for determining the infiltration using the crack method is as follows: a) estimate the length of crack on each wall, b) take the crack length from the wall with the most crack length or half of the total crack length, whichever is larger, c) estimate the crack geometry, (this is usually in terms of window crack, i.e. loose, average, or tightly fitting windows), and d) determine the air flow through the crack using one of the tables in reference 4.

The estimated crack lengths for the homes are given in Table 3.1. (The crack length for the sheathed home was approximately 30% less than for the caulked home assuming that the sheathing board completely seals the siding cracks.) Crack width was estimated as that of a typical, average fit, metal frame window giving an expected flow of $2.15\ m^3/h\text{-}m$ at 6.7 m/s (15 mph) wind speed. Using the values in Table 3.1, the expected air flow into the homes would be $314\ m^3/h$ for the north home and $220\ m^3/h$ for the south home (with sheathing). Using $172\ m^3$ for the volume of the homes (see section 4.4) infiltration would be 1.82 cph for the north home and 1.27 cph for the south home.

Infiltration here was based on only the pressure difference due to wind. The crack method considers combined forces on wind and stack only when they are of the same order of magnitude. If either wind or stack induced pressure difference is much larger than the other, infiltration is based on only the larger pressure difference. For the homes considered, at design conditions, $\Delta P_W \approx 12\Delta P_T$, and thus wind induced pressure difference was used for the calculations.

E.1.2 Expected Infiltration Based on the Air Change Method

The air change method determines infiltration as follows: a) from Table 1 of reference 4 determine the air change rate for each room, b) estimate the volume of each room, and c) sum over all of the rooms.

The assumed air change rate and estimated volume for each room of the mobile homes are: kitchen, 2 cph, 36.0 m^3; living room, 1.5 cph, 44.8 m^3; central bedroom, 1 cph, 18.2 m^3; hallway, 2 cph, 13.4 m^3; bathroom, 1 cph, 10.4 m^3; and the master bedroom, 2 cph, 30.7 m^3. Summing for all of the rooms gives 1.66 cph for the homes. This method does not take into account different temperatures (again wind is expected to dominate), or the benefits of sheathing board added to the walls.

E.2 A Semi-Empirical Model

Both of the above methods give acceptable values of infiltration for sizing a furnace or an air conditioner, but hardly acceptable for a detailed heat (or cooling) load analysis. For such calculations a model must be developed to predict infiltration for all values of wind and temperature. But developing such a model theoretically can be extremely difficult due to the large number of assumptions which must be made.

Assumptions must be made concerning the flow characteristics of the home, crack distribution, crack geometry, pressure coefficients for wind impinging on the surface of the home, and the effects of the surroundings on wind. Once these assumptions are made the problem reduces to one of calculating the pressure differences and the resulting air flow.

Using empirical data as the basis for making these assumptions a simplified, semi-empirical model for infiltration can be developed. (In this case a model is developed for the south, sheathed home.)

The pressure on the surface of the home due to wind is the stagnation pressure of the wind. If $\overline{P}_o$ is the average stagnation pressure and $\overline{P}_a$ is the average free stream pressure,

$$\overline{P}_o - \overline{P}_a = \frac{1}{2}\,\overline{\rho\ Cp\ W^2}\ . \qquad \text{E1}$$

The pressures P_o, P_a, and P_i (inside pressure) are all functions of height. The dependance of these pressures on height can be obtained assuming an adiabatic atmosphere, for which $\frac{P}{\rho^k}$ = constant. The relationship is then

$$\frac{P}{P_{H/2}} = [\ 1 - \frac{k-1}{k}\,\frac{g}{RT}(h-H/2)\ ]^{\frac{k}{k-1}}\ , \qquad \text{E2}$$

where $P_{H/2}$ and T are measured at H/2 (half the height of the home). Noting that $\frac{k-1}{k}\,\frac{g}{RT}\,(h - \frac{H}{2}) << 1$, Equation E2 can be written (using the binomial expansion) as

$$\frac{P}{P_{H/2}} \simeq 1 - \frac{g}{RT}(h-\frac{H}{2})\ . \qquad \text{E3}$$

Integrating to find an average pressure gives $\overline{P}/P_{H/2} \simeq 1$. Thus $P_{H/2}$ can be taken as $\overline{P}$.

The outside, inside pressure difference is then:

$$\Delta P = P_o - P_i \simeq \overline{P}_o - \frac{g\overline{P}_o}{RT_o}\,(h - \frac{H}{2}) - \overline{P}_i + \frac{g\overline{P}_i}{RT_i}\,(h - \frac{H}{2})\ ,$$

or

$$\Delta P \simeq \overline{P}_o - \overline{P}_i - (h - \frac{H}{2})\cdot(\ \frac{g\overline{P}_o}{RT_o} - \frac{g\overline{P}_i}{RT_i}\ )\ . \qquad \text{E4}$$

Substituting equation E1 for $\overline{P}_o$ gives

$$\Delta P \simeq \overline{P}_a - \overline{P}_i + \frac{1}{2}\,\overline{\rho CpW^2} - (h - \frac{H}{2})\,[\,\frac{g}{R}(\,\frac{\overline{P}_a}{T_o} - \frac{\overline{P}_i}{T_i} + \frac{1}{2}\,\frac{\overline{\rho CpW^2}}{T_o})\,]. \qquad E5$$

Equation E6 can be rewritten as

$$\begin{aligned}\Delta P \simeq\ & (\overline{P}_a - \overline{P}_i)[\ 1 - \frac{g}{RT_i}(h - \frac{H}{2})\ ] \\ & + \frac{1}{2}\,\overline{\rho CpW^2}[\ 1 - \frac{g}{RT_o}(h - \frac{H}{2})\ ] \\ & - \frac{g\overline{P}_a(T_i - T_o)(h - \frac{H}{2})}{RT_iT_o}\,,\end{aligned} \qquad E6$$

or simply

$$\Delta P \simeq \overline{P}_a - \overline{P}_i + \frac{1}{2}\,\overline{\rho CpW^2} - \frac{g\overline{P}_a}{RT_iT_o}(h - \frac{H}{2})(T_i - T_o), \qquad E7$$

since $\frac{g}{RT}(h - \frac{H}{2}) << 1$ for all values of T under consideration.

Equation E7 gives an estimate of the pressure difference driving the infiltration process. It assumes adiabatic relationships for the air and gives the pressure difference as a function of height. It does not account for the pressure difference due to the blower and leaks to the subflooring (an effect which will be considered as additive). With the pressure difference function known, the corresponding infiltration can be determined.

The flow through a crack can be approximated as laminar flow between two flat plates. In the limit as these plates become infinite, entrance and exit effects can be neglected. Flow is then given by[67]

$$\frac{Q}{\ell} = \frac{y^3}{12\mu\Delta x}\,\Delta P \qquad \text{E8}$$

where $\frac{Q}{\ell}$ is the volume flow rate per unit length of crack, y is the crack width, Δx is the length through the crack, μ is the kinematic viscosity, and ΔP is the outside, inside pressure difference across the crack. The flow can then be determined by integrating equations E8 and E7 over all of the cracks, and finding the value of $\overline{P}_a - \overline{P}_i$ ($=\Delta P_a$) such that mass is conserved (i.e. same mass of air entering and leaving home).

For the sake of simplicity the following substitutions will be made

$$C_T = \frac{\overline{P}_a g\Delta T}{RT_iT_o}\,, \qquad C_W = \frac{1}{2}\,\rho CpW^2, \text{ and } Y_{(\ )} = \frac{y^3_{(\ )}}{12\mu\Delta x}\,,$$

where $\Delta T = T_i - T_o$. In order to proceed it is necessary to assume some crack distribution. For example, consider the home as having a uniform crack distribution over the four walls(where $F = d\ell/Ldh$; L=horizontal length of wall), and two cracks along the floor-wall and ceiling-wall joints. The flow rate, Q from the floor to the neutral level h_n (where $\Delta P = 0$), is given by

$$Q_1 = LFY_W \int_0^{h_n} (\Delta P_a + C_W - \frac{C_T}{2}\,(h - \frac{H}{2}))\, dh$$

for each wall, or

$$Q_1 = LFY_W h_n\ (\Delta P_a + C_W - \frac{C_T}{2}(h_n - H)). \qquad \text{E9}$$

And similarly, Q above the neutral level becomes,

$$Q_2 = LFY_W(H - h_n)(\Delta P_a + C_W - \frac{C_T}{2}\,h_n) \qquad \text{E10}$$

for each wall. In the above equations L is the length of each wall of the home, and Y_W is as defined above using the crack width of the wall. The neutral pressure level, h_n, is given by $\Delta P = 0 = \Delta P_a + C_w - C_T(h_n - \frac{H}{2})$, or

$$h_n = \frac{\Delta P_a + C_W}{C_T} + \frac{H}{2} , \qquad \text{E11}$$

when $0 \leq h_n \leq H$. (If h_n is less than zero it is set equal to zero, and if h_n is greater than H it is set equal to H.)

In addition to the uniform crack on the wall of the home two cracks were assumed located around the perimeter of the home, one at the floor-wall joint, and one at the ceiling-wall joint. For the crack at the bottom

$$Q_3 = Y_P L \ (\Delta P_a + C_W + C_T \frac{H}{2}) . \qquad \text{E12}$$

For the crack at the top

$$Q_4 = Y_P L \ (\Delta P_a + C_W - C_T \frac{H}{2}) \qquad \text{E13}$$

Note that Q_1 through Q_4 must be evaluated for each wall since each wall has a different Cp value for wind. Y_P is as defined on the previous page using the perimeter crack width, y_p.

The signs of Q_1, Q_2, Q_3, and Q_4 depend on the sign of ΔT, whether they are above or below the neutral level, and whether or not the area faces the wind. By properly summing all of the Q's over all of the walls, the value of ΔP_a can be determined such that $\rho_o Q^+ = \rho_i Q^-$ (Q^+ = flow into the home, Q^- = flow out of the home). With this criteria met infiltration can be found by considering the sum of either the positive or negative terms by themselves.

In order to obtain a numerical value the following assumptions are made:

$\overline{Cp}$ = .65 on the forward wall; $\overline{Cp}$ = -.65 on the rear wall; $\overline{Cp}$ = -0.4 on the side walls;

$\overline{Cp}$ values for the top and bottom perimeter cracks are half of the values of $\overline{Cp}$ on the walls;

Δx = .05 m;

T_i = 297°C;

$\overline{P_a}$ and g are standard values;

and the furnace blower causes a constant exfiltration of 0.0019 m^3/s.

The values of y_w and y_p (the crack width for the wall and perimeter cracks) are adjusted in an attempt to force the theoretical model to match the empirical model for I at $\Delta T = 0°C$, $W = 10$ m/s, and $\Delta T = 50°C$, $W = 0$ m/s. Unfortunately the values of y could not be chosen so that the theoretical and empirical model matched at the above two points. With $I_t = I_e$ at $\Delta T = 0°C$, $W = 10$ m/s, $I_t < \frac{1}{2} I_e$ at $\Delta T = 50°C$, $W = 0$ m/s independent of the values of y chosen (I_t - theoretical infiltration, I_e - empirical infiltration).

This led to the following conjecture: suppose that the attic space is acting independently of the home in that the cracks at the top perimeter are communicating with the attic space rather than the home, and furthermore, leaks are possible through the ceiling from the living area to the attic space (see figure E1). The outside, free stream, inside pressure difference in the attic space will be approximately $\Delta P_r = 0.035 \frac{\rho}{2} W^2$ and

$$\Delta P_c = \Delta P_a - C_T \frac{H}{2} - .035 \frac{\rho}{2} W^2 \qquad E14$$

where ΔP_c is the pressure difference across the ceiling.

The ceiling is assumed to have the same crack width, y_p, as the wall. $F = \ell_c/A_c = 0.9$ m/m^2 (the same value assigned to the walls). Using Equations E9, E10, E11, and E14 and E8, infiltration was again calculated by letting the value of $\overline{P_a}$ float so that mass flow in equals mass flow out. Then by adjusting y_w and y_p the theoretical model is made equal to the empirical model at the points indicated previously. The y values become: $y_p = 0.001$ m; and $y_w = 0.0003$ m. Values of infiltration for the empirical model are shown in Table E1, and values of the theoretical model are shown in Table E2. Surface plots of infiltration are shown in figure E2 for the empirical model and figure E3 for the theoretical model. The computer program used to calculate infiltration is shown in Table E3. Values of ΔP_a are typically between -0.01 and 4.0 Pa. See Table E4.

Overlapping figures E2 and E3 show suprising agreement between them. It must be noted that two coefficients were varied to relate the prediction to the data. However, the theoretical (semi-empirical) model does justify the form of Equation 4.13 (and the corresponding Equations 4.26 through 4.29).

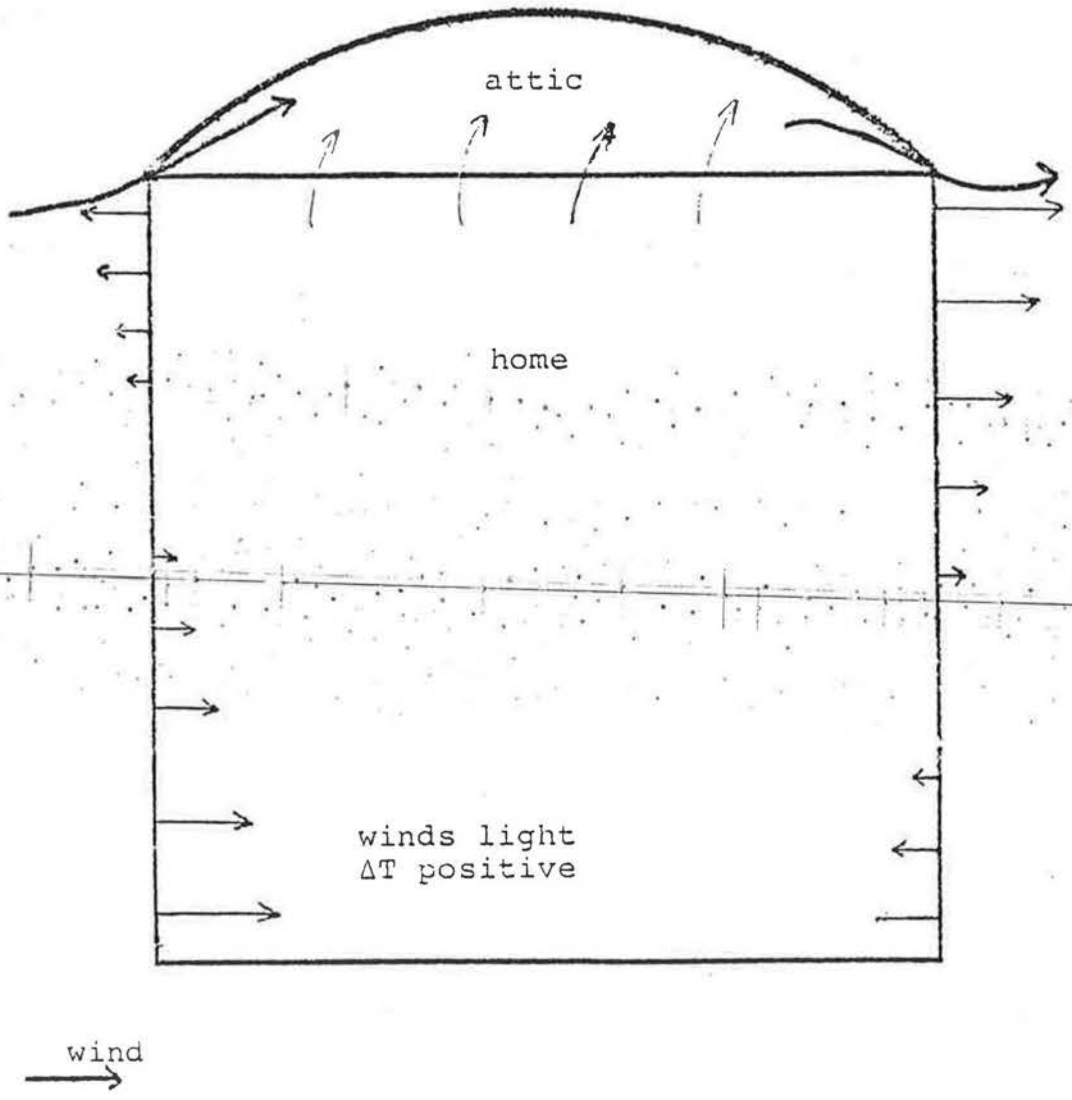

Figure E1 Typical air flow pattern

Table E1: Infiltration at various ΔT and W for the empirical model

W \ ΔT	-30.0	-20.0	-10.0	0	10.0	20.0	30.0	40.0	50.0
0	.219	.161	.100	.034	.104	.180	.261	.348	.442
1.0	.228	.170	.109	.044	.114	.190	.272	.359	.454
2.0	.255	.198	.138	.073	.145	.222	.304	.393	.490
3.0	.299	.244	.185	.122	.199	.274	.359	.450	.549
4.0	.362	.309	.252	.191	.257	.348	.436	.530	.631
5.0	.442	.392	.337	.280	.359	.443	.534	.632	.738
6.0	.540	.493	.442	.388	.471	.559	.654	.757	.868
7.0	.657	.613	.566	.516	.603	.699	.799	.905	1.022
8.0	.791	.751	.708	.663	.755	.854	.991	1.075	1.199
9.0	.942	.907	.870	.830	.923	1.033	1.146	1.268	1.400
10.0	1.112	1.082	1.051	1.017	1.122	1.234	1.354	1.484	1.624
11.0	1.300	1.276	1.251	1.224	1.335	1.455	1.584	1.723	1.873
12.0	1.505	1.488	1.469	1.450	1.583	1.698	1.835	1.984	2.145

Units: W-m/s, ΔT-°C, I-cph(air charges per hour)

Table E2: Infiltration at various ΔT and W for the theoretical model

W \ ΔT	-30.0	-20.0	-10.0	0	10.0	20.0	30.0	40.0	50.0
0	.164	.123	.079	.040	.079	.145	.225	.317	.422
1.0	.164	.123	.077	.041	.079	.145	.225	.317	.422
2.0	.169	.125	.093	.070	.080	.148	.227	.318	.424
3.0	.191	.169	.145	.118	.127	.172	.233	.324	.430
4.0	.250	.231	.210	.187	.201	.246	.302	.374	.459
5.0	.327	.312	.294	.273	.296	.350	.412	.484	.571
6.0	.421	.410	.397	.393	.412	.476	.551	.637	.738
7.0	.531	.525	.518	.510	.549	.628	.715	.817	.935
8.0	.659	.659	.658	.657	.703	.799	.904	1.024	1.163
9.0	.804	.811	.817	.823	.837	.995	1.118	1.250	1.423
10.0	.963	.980	.994	1.009	1.083	1.214	1.358	1.523	1.712
11.0	1.145	1.167	1.190	1.214	1.310	1.456	1.623	1.814	2.033
12.0	1.340	1.372	1.405	1.439	1.553	1.722	1.913	2.132	2.384

Units: W-m/s, ΔT- C, I- cph(air changes per hour)

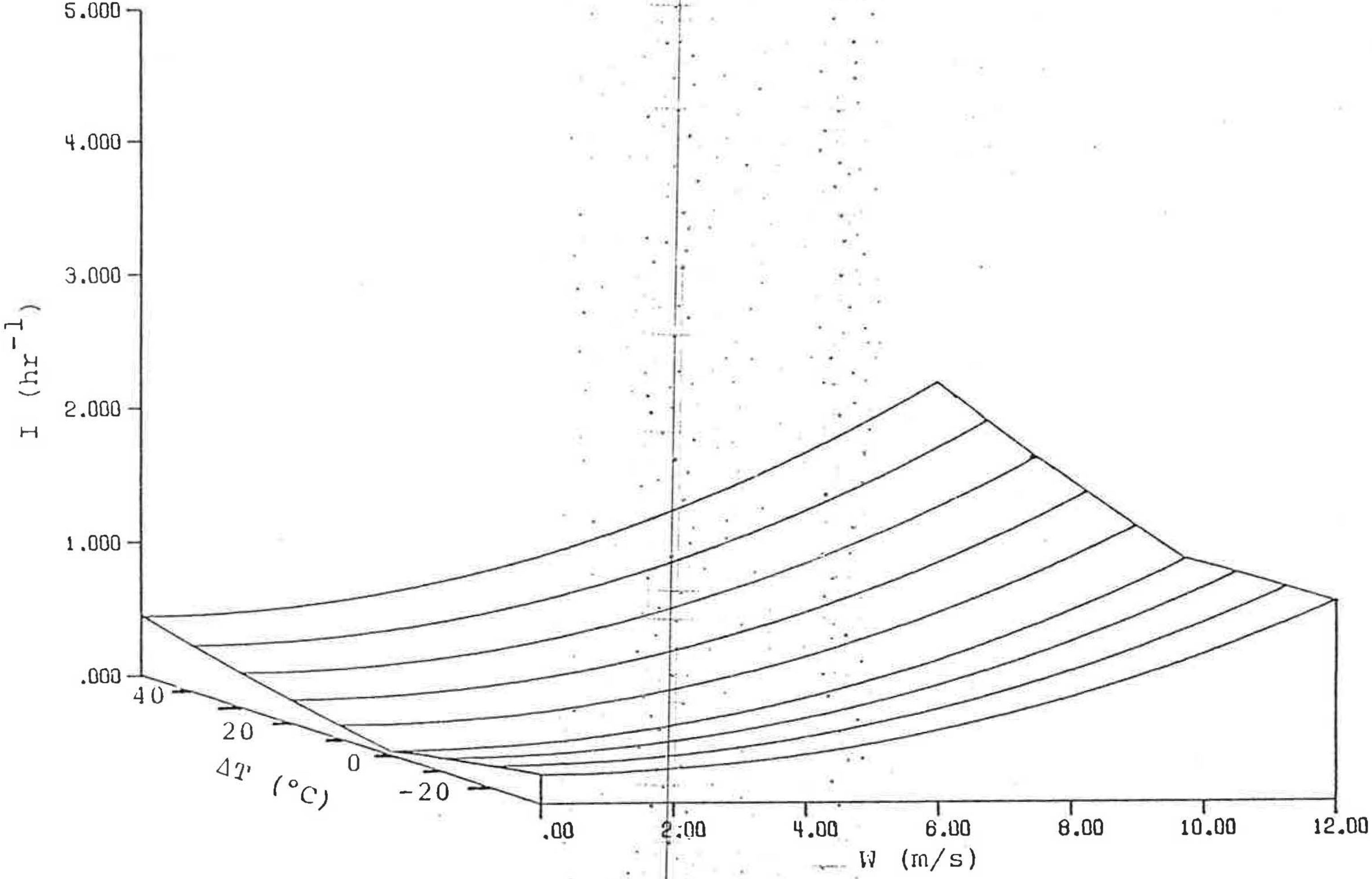

Figure E2 Infiltration vs. W & ΔT; empirical model

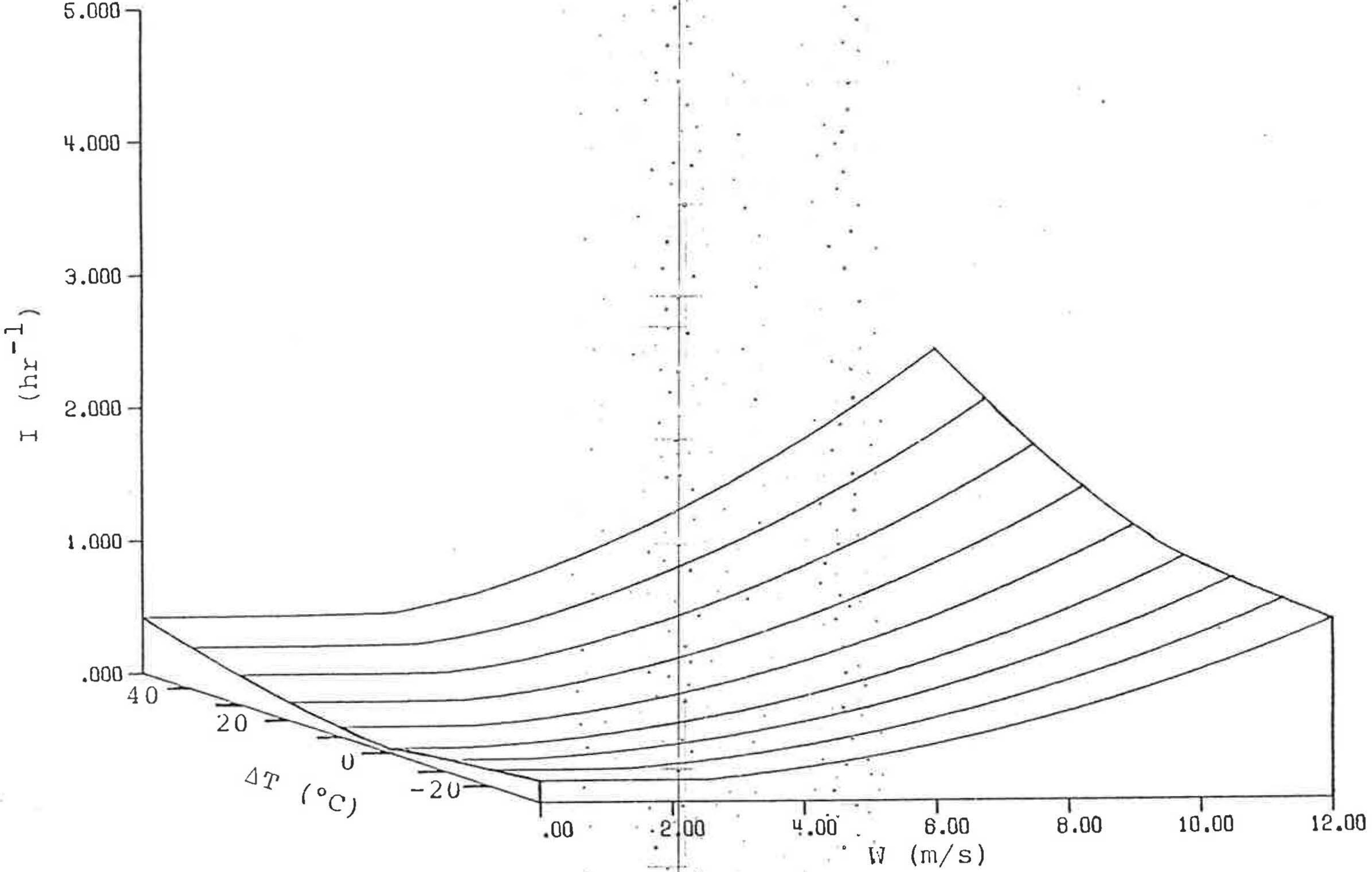

Figure E3 Infiltration vs. W & ΔT, theoretical model.

Table E3: Computer program of theoretical model.

```
UNIVERSITY OF MINNESOTA FORTRAN COMPILER (VERSION 5.3 - 10/27/78) ON PURDUE DU

                    MNF.

      000000B             PROGRAM MODEL(INPUT,OUTPUT,PLOT)
      003075B             REAL L(4),MO,MI,IN(121,9),IW(121)
      003075B             DIMENSION CP(4),DT(9),CPB(4),        Z(350,4)
                    C
                    C   INITIALIZE THE NECESSARY PARAMETERS FOR
                    C   THE CALCULATION OF INFILTRATION
                    C
      003075B             DATA  CP,L/.65,-.4,-.65,-.4,20.1,4.3,20.1,4.3/
      003075B              DATA CPB     /.35,-.2,-.35,-.2/
      003075B              AC=.0003**3
      010206B              F=.9
      010210B              DX=.050
      010211B             AP=.0010**3
      010213B              H=2.45
      010214B             TI=297.
      010216B             R=287.
      010217B             G=9.8
      010221B              PA=101300.
      010222B             MI=1.458E-6*SQRT(TI)/(1.+110.4/TI)
      010232B              RHI=PA/(R*TI)
                    C
                    C   SET THOSE PARAMETERS USED BY SUB. HIDE
                    C
      010234B             NG=-1
      010234B             MAXDIM = 350
      010236B             M1 = 121
      010237B             NFMS = 9
      010240B             CALL PLOTS
      010242B             CALL PLOT(1.,2.,-1)
      010245B             CALL FACTOR(.75)
                    C
                    C   SET TEMPERATURE DIFFERENCE
                    C
                    C   CALCULATE PARAMETERS WHICH DEPEND ON
                    C   OUTSIDE TEMPERATURE
                    C
      010247B             DO 1000 IT=1,9
      010250B             DT(IT)=-40.+10.*IT
      010252B              TO=TI-DT(IT)
      010254B             MO=1.458E-6*SQRT(TO)/(1.+110.4/TO)
      010264B             RHO=PA/(R*TO)
      010266B             CT=-RHO*G*DT(IT)/TI
      010272B              DP = 0.00
                    C
                    C   SET WIND SPEED
                    C
      010273B             DO 999 JW=1,121
      010275B             IW(JW) = JW/10. - .1
      010277B             W=RHO*IW(JW)*IW(JW)/2.
      010301B             J=0
      010302B       190   J=J+1
      010306B             Q1=0.
      010306B             Q2=0.
                    C
                    C   CALCULATE FLOW THROUGH WALL
                    C
```

Table E3, cont.

```
 38.    010307B         IF(ABS(DT(IT)).LT..0001) GO TO 500
 39.    010312B         DO 200 I=1,4
 40.    010314B         HO=(DP+CP(I)*W)/(-CT) + H/2.
 41.    010322B         IF (HO.GE.H) HO=H
 42.    010325B         IF(HO.LE.0)HO=0.
 43.    010327B         Q1=F*L(I)*AC*HO*(DP+CP(I)*W+CT/2.*(HO-H))+Q1
 44.    010341B  200    Q2=F*L(I)*AC*(H-HO)*(DP+CP(I)*W+CT/2.*HO)+Q2
                 C
                 C   CALCULATE FLOW THROUGH BOTTOM CRACK
                 C
 45.    010360B  270    DO 210 I=1,4
 46.    010362B         Q3=L(I)*(DP+CPB(I)*W-CT*H/2.)*AP
 47.    010370B         IF(Q1*Q3.GT.0.) Q1=Q1+Q3
 48.    010377B  210    IF(Q2*Q3.GT.0.) Q2=Q2+Q3
                 C
                 C   CALCULATE FLOW THROUGH CEILING
                 C
 49.    010405B         Q4= 20.1*4.3*F*AP*(DP+CT*H/2.-.035*W)
 50.    010416B         IF(Q1*Q4.GT.0.)Q1=Q1+Q4
 51.    010423B         IF(Q2*Q4.GT.0.) Q2=Q2+Q4
 52.    010430B         IF(Q1.LE.0.) GO TO 260
                 C
                 C   CHANGE FLOW TO CORRECT DIMENSIONS
                 C   NEGETIVE FLOW IS OUT, POSITIVE IS IN
                 C
                 C   .0019 M3/S IS ADDED TO FLOW OUT TO ACCOUNT FOR THE
                 C   FURNACE BLOWER
                 C
 53.    010432B         Q1=Q1/(12.*DX*MO)
 54.    010434B         Q2=Q2/(12.*DX*MI)-.0019
 55.    010440B         ERR=RHO*Q1+RHI*Q2
 56.    010443B         Q=-Q2
 57.    010444B         GO TO 300
 58.    010445B  260    Q1=Q1/(12.*DX*MI)-.0019
 59.    010452B         Q2=Q2/(12.*DX*MO)
 60.    010454B         ERR=RHI*Q1+RHO*Q2
 61.    010457B         Q=-Q1
                 C
                 C   USE THE CORRECTOR,PREDICTOR METHOD TO CALCULATE
                 C   THE NEW VALUE OF DP
                 C
 62.    010461B  300    IF(ABS(ERR).LT. .00001) GO TO 330
 63.    010464B         IF(J.EQ.1) GO TO 310
 64.    010466B         IF (J.GT.10) GO TO 700
 65.    010470B         DPN=DP-ERR*(DP-DPO)/(ERR-ERRO)
(65) - CAUTION   -----------------------------------------------------------------E
(65) - CAUTION   ------------------------------------------------------------------
 66.    010475B          GO TO 320
 67.    010477B  310    DPN=DP+.001
 68.    010500B  320    DPO=DP
 69.    010501B         DP=DPN
 70.    010503B         ERRO=ERR
 71.    010504B         GO TO 190
                 C
                 C   SPECIAL EQUATION FOR FINDING FLOW THROUGH
                 C   THE WALL WHEN DT=0
                 C
 72.    010505B  500    DO 510 I=1,4
 73.    010507B         Q=L(I)*AC*F*H *(DP+CP(I)*W)
 74.    010515B         IF(Q.GT.0.)Q1=Q1+Q
```

Table E3, cont.

```
010522B          IF(Q.LT.0.)Q2=Q2+Q
010526B   510    CONTINUE
010530B          GO TO 270
               C
               C   CHANGE FROM Q TO I AND STORE
               C
010531B   330    IN(JW,IT)=Q/172.*3600
010536B    999   CONTINUE
               C
               C   PLOT THE RESULTS IN TWO DIMENSIONS.
               C
010541B            CALL HIDE(IW,IN(1,IT),Z(1,1),Z(1,2),Z(1,3),Z(1,4),NG,
                 +      MAXDIM, N1, NFNS, 6HNOTTLE , 6.,5.,0.,2.,0.,1.)
010571B   1000   CONTINUE
010573B          CALL PLOT(0.,0.,999)
               C
               C  PRINT THE RESULTS
               C
010576B          PRINT 400, DT
010604B   400    FORMAT(1H1,5X,9F8.1)
010604B          DO 405 I=1,121,10
010605B   405    PRINT 410,IW(I),(IN(I,J),J=1,9)
010626B   410    FORMAT(1X,F5.1,9F8.3)
010626B          STOP
010631B   700    PRINT701
010635B   701    FORMAT(31H   YOU ARE IN AN ENDLESS LOOP.    )
010635B          STOP
010637B          END
```

Table E4: ΔP_a predicted by theoretical model

W \ ΔT	-30.0	-20.0	-10.0	0	10.0	20.0	30.0	40.0	50.0
0	-.01	.02	.03	.16	.25	.32	.36	.37	.33
1.0	.01	.04	.10	.18	.28	.35	.39	.39	.35
2.0	.07	.10	.16	.25	.34	.41	.46	.46	.43
3.0	.19	.22	.28	.35	.44	.52	.57	.58	.55
4.0	.37	.39	.44	.50	.58	.64	.69	.71	.69
5.0	.60	.61	.64	.69	.75	.80	.82	.83	.80
6.0	.83	.83	.90	.93	.97	.99	.99	.96	.89
7.0	1.22	1.20	1.19	1.21	1.22	1.22	1.18	1.11	1.00
8.0	1.60	1.56	1.54	1.53	1.52	1.48	1.40	1.29	1.12
9.0	2.04	1.98	1.93	1.88	1.85	1.77	1.66	1.49	1.26
10.0	2.53	2.44	2.36	2.29	2.22	2.10	1.94	1.72	1.42
11.0	3.07	2.95	2.84	2.74	2.63	2.47	2.25	1.97	1.59
12.0	3.66	3.51	3.37	3.23	3.02	2.87	2.60	2.24	1.78

ΔP_a is in Pa