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COMPARISON OF CALCULATED AND MEASURED VALUES OF HEAT LOSS IN A WELL INSULATED HOUSE

by J.P. Edwards

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SUMMARY

With the aid of the North of Scotland Hydro-Electric Board, heat loss measurements have been made in an unoccupied house at Kemnay, Aberdeenshire.

Constructional details of this well insulated house are given. Recordings of energy and temperatures over two heating seasons are analysed and discussed. Short term ventilation measurements by gas decay method are also reported. Wind measurements show this house to be rather sheltered, as average wind speeds above 5 m/s are rare. This to some extent will account for the extremely low air infiltration rates measured.

The calculated value of fabric heat loss at 2.2 kWh/day ^{o}C* is low for a house of this size. Analysis of results shows the average measured value of 2.3 kWh/day ^{o}C concurring with the calculated figure. The insulation in this house is therefore effective.

ECRC thermal calibration tests are usually made with individually controlled fan convector units with a high degree of air recirculation. Check tests were made during the course of these experiments to see if the conventional natural convector panel heaters behaved in the same way and produced the same energy consumption.

*kWh/day ^{o}C - This is the Fabric Heat Loss Coefficient

It did not matter whether fan or natural convective heaters were used for heating, and there was no significant difference between them in terms of the energy used.

This house has no south facing windows and minimal glass area, and therefore the solar heating is low.

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CONTENTS

1. INTRODUCTION

An unoccupied, pre-fabricated, detached house of Scandinavian design has been the subject of detailed measurements. The house is situated at Kemnay, some 15 miles North-West of Aberdeen. It is of timber construction, with very high levels of thermal insulation, including double glazing and is well sealed. The total floor area is approximately 109 m^2.

The object of the measurements was twofold:-

(a) To see if the measured values of heat loss of a well insulated house agree with the calculated ones.
(b) To identify if the type of heating system affects heat loss by comparing natural convector panels and fan convector heaters.

This report gives details of heat losses, both calculated and measured. Ventilation rates and solar heating data are also reported.

2. HOUSE PLANS, CONSTRUCTIONAL DETAILS AND TEST APPARATUS

2.1 Site Plan

This house is one on an estate of several hundred similarly constructed dwellings, situated on fairly open land in the bend of a river, Figure 1. Figure 2 shows a site plan with the anemometer, Stevenson screen and solarimeter identified.

2.2 Construction and House Plan

The house is of prefabricated timber construction with 100 mm of mineral wool in the external walls, 150 mm in the loft space and under the suspended ground floor. Constructional details are shown in Figure 3. The windows are double-glazed and weatherstripped. The house has a floor area of 101 m^2, excluding the front porch and w.c. The dining room and

kitchen are only partially separated by the use of kitchen units. Figure 4 shows internal floor plans, while Figure 5 shows external elevations.

2.3 Instrumentation and Heating Methods

Figures 4 and 6 show the position of fan and panel heaters used as the means of supplying energy into the house during test periods. The panel heaters are fitted into the houses as the normal form of heating and are electronically controlled, with an internal thermistor as the temperature sensor. The fan heaters are controlled by ordinary ON/OFF room thermostats mounted on stands in the position shown in Figure 6.

Temperatures were monitored in the first instance by chart recording thermographs. Later, these were supplemented and finally replaced by a data logging system using type 'T' (Cu/CuNi) thermocouples as the temperature sensors. The thermocouples were placed in a similar position to the thermographs. The data fed into the logger was recorded on magnetic tape and processed by computer.

Power was measured on a half-hourly printing kWh meter. Wind speed/ direction and solar radiation were measured and recorded.

3. EXPERIMENTAL PROCEDURES AND RESULTS

3.1 Ventilation Measurements

The pressurization method described by Dickson[1] is used in order to find an equivalent leakage area for the house. The trace obtained on an 'x-y' plotter is compared with a family of calibration curves (Figure 7). Figure 8 shows an example of a trace obtained for this dwelling. When overlaid on the calibration curves it can be seen that this house has an equivalent leakage area of approximately 0.075 m^2. The procedure was repeated in a range of weather conditions, without any substantial change in leakage area being detected. This method of measuring equivalent

leakage areas becomes less effective as wind speed increases. As the wind speed approaches 5 m/s the results become meaningless because of the wild fluctuations of the trace on the 'x-y' plotter.

It is shown in the IHVE Guide[2] that the air change rate of a dwelling can be determined by the decay of a tracer gas, which has been thoroughly mixed with the air in that dwelling. Using carbon dioxide as the tracer gas, a series of measurements was conducted with all the exterior doors, windows and ventilators closed. The details of the precise methods used are fully explained by Dickson[1]. The results are shown in Table 1. Unfortunately, because of low wind speeds during the test period, less than 5 m/s, insufficient data is available from which a precise formula for calculating ventilation rates can be extrapolated. However, from the results available a simplified expression of $N = 0.011 \Delta t + 0.079 S \text{ Cos } \theta + .004$ may be derived.

where N = ventilation rate in a.c.h.
S = wind speed in m/s
θ = angle between the wind and the normal to the front or back of the house, whichever is facing the wind.

3.2 Solar Measurements

For a two week period during the early part of winter, the house was left unheated. Internal temperatures were recorded on thermographs placed in each room and shielded from direct sunlight. External temperature was also recorded on a thermograph placed in the Stevenson screen. The temperatures were initially averaged over a 24 hour period midnight to midnight, Table 2. Daily solar radiation on a horizontal plane was measured. Using Basnett's curves[3], Figures 9 and 10 to estimate the solar radiation on a vertical surface, the solar heating through the glass could then be calculated. In houses of standard construction it has been shown by Siviour[4] that daily internal temperatures are not only affected by solar radiation of that day but also by the radiation of preceding days. With this in mind, the solar heating results shown (Table 3) are averaged for continuous periods of 5 and 7 days respectively.

3.3 Heat Loss Measurements

In the first instance the house was continuously heated with fan heaters controlled by room thermostats. Temperatures were monitored inside and out on thermograph chart recorders. The thermostat controls in each room were set to give average temperature of 18°C. The thermograph readings were checked against selected mercury-in-glass thermometers and adjusted as required. All exterior doors, windows and ventilators were closed, while interior doors were kept open. Solar radiation was measured, wind speed and direction were also recorded. Energy was measured half-hourly using a printed aggregate from a kWh meter. All data obtained was collated over a daily period from midnight to midnight. This base data is shown in Table 4. For the second half of the year, February to May, the same procedure was repeated using panel heaters originally installed as the source of energy. The panel heaters have their own internal thermistor control. With this system of control it is more difficult to obtain preselected room temperature without a prolonged period of adjustment. The control settings were estimated and the room temperatures allowed to settle without further adjustment. Table 5 shows the daily averages.

For the third section of these tests a combination of the previous two heating methods was used. The panel heaters were the source of heating with the fans of the fan heaters providing only the means of air circulation. It was for this period of tests, October to May 1979, that a new automatic logging system of monitoring temperatures was introduced. This system used type 'T' thermocouples as the sensors which were placed adjacent to the thermographs. The data is recorded at selected intervals, on magnetic tape cassette and processed by computer. This removes all the time-consuming and tedious process of chart analysis. It also eliminates the human error inevitably associated with this type of analysis. For the first two months of tests the thermograph charts were analysed and compared with computed results. The difference in results proving negligible, the thermographs were then discarded. Daily averages are shown in Table 6.

With the three forms of heating used the daily results were reduced to weekly averages. Solar heating through the windows was calculated from the horizontal solar radiation. Ventilation heat loss was calculated from

temperature difference and wind speed and direction. Tables 7, 8 and 9 show the weekly averages from which the graphs used for analysis were plotted.

Calculations of U values and fabric heat loss are shown in Appendix I.

4. DISCUSSION

The pressurization method of measuring the leakage area showed this house to have an equivalent leakage area of 0.075 m^2. This value is similar to the best of the houses tested at Capenhurst which are some 25% less in volume. The leakage area per unit volume of the Kemnay house is amongst the best yet tested. The low figure obtained as the leakage area of the house is supported by the results of the tracer gas tests. They show an average air change rate of less than 0.25 ac/h at an average wind speed of 2.1 m/s and Δt of 9.1°C. It is possible that the superior tightness of these houses is helped by the all wooden construction, the windows, doors and wall all expanding and contracting at a similar rate. Whereas in a dwelling of standard brick construction the windows, door and frames, usually of wood or metal, move at a different rate from that of the brick structure, thereby causing varying cracks at these joints.

The solar heating in this house is lower than one would normally expect for a dwelling of this size. The obvious reason is that the window area, which is about 10% of the floor area, is less than average. Also there are no south facing windows in this particular house.

The weekly averages shown in Tables 7, 8 and 9 were plotted out graphically to aid analysis. Figures 11 to 13 show plots of input energy, including solar heating through the windows, against inside to outside temperature difference. The tests using the panel heaters with fans were conducted over a whole heating season, whilst the panel heaters and fan heaters were tested independently during part of the heating seasons only. The results tend to suggest that part season testing is not altogether suitable when weekly averages are being considered.

With the fan heaters only being used during the first half of a heating season, most of the results are at similar levels of energy input. The computed line of this analysis has a projected intercept at 16.5 kWh/d with a correlation of 0.76 from 12 points. The range of data obtained for the panel heaters only, during the second half of the heating season, was only slightly better so a further three weeks at the beginning of the following season were devoted to testing. The extra points obtained were all below 30 kWh/d and are included in Figure 12. This analysis has a projected intercept at 5.4 kWh/d with a slightly improved correlation of 0.79 from 17 points. Using the panel heaters with fans over a full six months produced a graph with a much improved correlation of 0.92 from 28 points.

Further graphical analysis of Figures 14 and 15 showed that the experimental fabric heat loss coefficient varied from 2.19 to 2.41 kWh/day ^{o}C. This compares extremely well with the calculated value of 2.2 kWh/day ^{o}C affirming that the insulation in this house is acting as predicted. The variation in experimental value of only 0.22 kWh/day ^{o}C with various heating arrangements demonstrates that it does not matter which type of heating system is used to calibrate a dwelling. It was not possible to plot the results of fan heaters only because of the limited range of data, all at low levels of solar gain. However, when fan heater data was added to that of the panel heaters the graphical analysis was not changed by an significant amount. There is a much greater scatter of points in Figure 14 than in Figure 15, which is reflected in the correlation. A possible explanation is the more widely varying temperatures, Figure 16, of the first test period compared with those of the second period, having a delay effect on the power requirements of a well insulated house. A second explanation is that the house was disturbed on many more occasions in the first year than in the second, including periods of intensive ventilation measurements when the windows and doors were deliberately left open.

5. CONCLUSION

The ventilation rate of this house is very low having a whole house air change rate of approximately 0.25 ac/h, measured with average atmospheric conditions during the winter.

It has been shown that the measured and calculated values of fabric heat loss in this well insulated house compare closely, the average measured value, over two heating seasons, of 2.3 kWh/day ^{o}C being less than 5% higher than the calculated value.

The type of system used, either convective or fan heating, has not affected the measured heat loss by any significant amount. The difference between the systems of 0.22 kWh/day/^{o}C is well within the limits of error of this type of measurement.

6. REFERENCES

1) Dickson, D.J. — Ventilation Measurements. ECRC (to be published).

2) IHVE Guide — Book A (4-3), 1970.

3) Basnett, P. — Estimation of solar radiation falling on vertical surfaces from measurements on a horizontal plane. ECRC/M846, 1975.

4) Siviour, J.B. — Solar heating in unoccupied houses. ECRC/N840, 1975.

7. ACKNOWLEDGEMENTS

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TABLE 1 - MEASURED VENTILATION RATES

REF.	WIND SPEED m/s	WIND* DIRECTION degrees	TEMPERATURE DIFFERENCE Δt ^{o}C	VENTILATION RATE ac/h
1	1.0	150	6	.12
2	0.5	V	9	.13
3	0.8	330	9	.14
4	1.2	140	5	.14
5	1.5	345	8	.14
6	3.1	160	5	.14
7	1.2	210	12	.16
8	1.0	230	13	.17
9	1.9	150	7	.17
10	3.3	150	4	.17
11	0.1	V	12	.19
12	0.2	V	14	.19
13	4.0	140	4	.25
14	4.8	240	7	.36
15	2.9	100	12	.43
16	4.0	90	13	.47
17	4.0	80	15	.48

*Wind direction at 100^{o} is directly towards house front.
V means variable direction.

TABLE 2 - SOLAR HEATING DATA

1977 DAY No. ⁄	HORIZONTAL SOLAR RADIATION kWh/m^2/day	AVERAGE OUTSIDE TEMP. °C	AVERAGE INSIDE TEMP. °C	AVERAGE Δt °C	AVERAGE WIND	
					SPEED m/s	DIRECTION* degrees
277	1.15	8.8	13.2	4.5	0.73	190
278	1.53	7.0	11.7	4.7	1.3	180
279	0.24	8.2	11.2	3.0	1.81	49
280	0.11	10.3	11.5	1.2	3.91	64
281	1.04	8.8	11.6	2.8	0.71	112
291	0.77	10.1	13.3	3.2	1.3	170
292	1.49	12.1	13.6	1.5	1.68	166
293	0.97	13.6	15.0	1.4	2.46	168
294	1.38	13.1	15.5	2.4	1.03	124
295	1.15	12.8	16.1	3.3	1.83	156
296	1.57	11.3	15.5	4.3	1.87	188
297	0.73	12.7	15.1	2.4	2.93	177

⁄The day number referred to in this and subsequent tables is the day of the year, January 1st being day number one of each year, and proceeding arithmetically through to December 31st.
*Wind direction at 100° is directly towards house front.

TABLE 3 - ESTIMATE OF SOLAR HEATING

Middle day number (1977)		279	294
Number of consecutive days		5	7
Average daily solar radiation on a horizontal surface kWh/m^2/day		0.81	1.15
Vertical solar heating through glass:	North	0.08	0.091
	East and West	2.56	3.73
	Total kWh/day	2.64	3.82
Temperature difference inside/out	^oC	2.3	2.6

Glazing area: North 0.28 m^2 East and West 8.2 m^2.
Transmission coefficient: 0.65.
An allowance of 10% has been made for ground reflection.

Table 4 Fan heaters - Daily Averages

1977 Day No.	Horizontal solar radiation kWh/m^2/day	Average outside temp. °C	Average inside temp. °C	Average Δt °C	Average wind Speed m/s	Average wind Direction* degrees	Energy kWh/day
304	0.56	7.0	17.9	10.9	1.58	210	20.0
305	1.38	5.0	18.3	13.3	1.3	70	32.4
306	1.12	5.5	18.4	12.9	0.35	90	26.2
307	0.88	3.0	18.0	15.0	1.21	90	34.0
308	0.85	6.0	17.9	11.9	3.04	46	32.4
309	0.26	5.5	17.9	12.4	1.93	45	36.4
310	0.59	8.0	18.1	10.1	3.69		30.4
311	0.56	10.0	18.2	8.2	3.23	↑	22.4
312	1.17	7.5	17.8	10.3	↑	↑	29.0
313	0.71	8.5	13.0	9.5	↑	↑	31.4
314	0.51	12.5	18.1	5.6	↑	↑	22.8
315	1.04	10.5	18.1	7.6	↑	↑	24.4
316	0.66	6.5	18.0	11.5	↑	↑	39.2
317	0.77	6.5	17.9	11.4	↑	↑	41.0
318	0.35	7.0	17.9	10.9	↑	↑	38.6
319	0.54	6.5	17.8	11.3	↑	↑	40.4
320	0.38	4.0	17.8	13.8	↑	↑	42.2
321	0.31	4.5	17.9	13.4	↑	↑	45.0
322	0.89	4.5	17.9	13.4	DATA	DATA	43.6
323	0.45	7.5	18.0	10.5	NOT	NOT	37.4
324	0.10	2.5	17.9	15.4	AVAILABLE	AVAILABLE	45.4
325	0.51	4.5	17.8	13.3	↓	↓	45.8
326	0.42	6.5	17.8	11.3	↓	↓	41.8
327	0.65	6.5	17.9	11.4	↓	↓	36.2
328	0.50	5.0	17.8	12.8	↓	↓	44.4
329	0.22	5.5	17.8	12.3	↓	↓	42.0
330	0.51	3.0	17.8	14.8	↓	↓	42.6
331	1.05	-0.5	17.7	18.2	↓	↓	42.9
332	0.87	-1.5	17.7	19.2	↓	↓	54.9
333	0.39	4.0	17.7	21.7	↓	↓	46.8
334	0.44	2.0	17.8	15.8	↓	↓	44.6
335	0.27	2.5	17.8	15.3	↓	↓	48.8
336	0.15	4.0	17.8	13.8	↓	↓	46.4
337	0.24	6.5	17.8	11.3	↓	↓	45.2
338	0.15	8.5	17.9	9.4	↓	↓	39.6
339	0.10	6.0	17.8	11.8	3.04	110	45.0
340	0.12	4.5	17.7	13.2	3.54	90	51.6
341	0.31	2.0	17.5	15.5	3.0	80	63.0
342	0.21	3.0	18.1	15.1	1.61	V	45.6
343	0.07	5.0	18.2	13.2	1.55	160	38.6
344	0.06	8.5	18.1	9.6	4.7	130	35.0
345	0.14	7.5	18.2	10.7	3.6	145	33.2

Notes: *Wind direction at 100° is directly towards house front
V means variable direction

Table 4 (continued) Fan heaters - Daily Averages

1977-78 Day No.	Horizontal solar radiation kWh/m^2/day	Average outside temp. °C	Average inside temp. °C	Average Δt °C	Average wind		Energy kWh/day
					Speed m/s	Direction* degrees	
346	0.40	5.0	18.1	13.1	1.14	200	33.0
347	0.29	5.4	18.0	12.6	0.68	200	37.2
348	0.16	9.3	18.2	8.9	1.72	180	29.2
349	0.36	7.1	18.3	11.2	1.55	180	29.6
350	0.27	8.3	18.3	10.0	1.37	180	32.8
351	0.20	6.6	18.3	11.7	1.17	180	33.0
352	0.09	4.1	18.2	14.1	0.06	180	37.0
353	0.36	3.8	18.1	14.3	0.78	210	41.4
354	0.48	2.8	17.9	15.1	1.19	V	39.8
355	0.11	4.0	17.8	13.8	1.30	150	39.8
356	0.34	6.5	18.0	11.5	5.94	150	33.4
357	0.32	7.0	18.1	11.1	1.82	166	29.8
358	0.27	6.5	18.0	11.5	2.84	260	33.6
359	0.33	5.0	18.0	13.0	1.6	250	34.0
360	0.50	3.0	17.9	14.9	0.97	200	39.0
361	0.41	3.0	17.8	14.8	2.07	275	41.0
362	0.18	3.5	17.8	14.3	6.24	320	44.0
363	0.36	4.5	17.9	13.4	3.95	250	39.6
364	0.32	2.0	17.8	14.8	5.93	290	46.6
365	0.14	3.5	17.8	14.3	2.27	250	41.6
1	0.45	4.0	18.0	14.0	3.47	225	34.2
2	0.44	0.0	18.0	18.0	2.85	220	42.6
3	0.22	-1.0	18.0	19.0	3.26	300	46.8
4	0.44	-2.0	18.0	20.0	2.52	230	51.4
5	0.20	5.0	18.0	13.0	2.74	180	40.2
6	0.53	6.0	18.1	12.1	2.91	200	31.2
7	0.33	4.0	18.1	14.1	1.95	180	33.6
8	0.67	3.5	18.0	14.5	2.73	190	41.2
9	0.26	2.5	18.0	15.5	1.32	190	39.2
10	0.42	0.0	17.8	17.8	DATA	DATA	50.2
11	0.34	0.0	17.8	17.8	NOT	NOT	49.8
12	0.25	-0.5	17.9	18.4	AVAILABLE	AVAILABLE	53.0
13	0.39	7.0	18.1	11.1	3.25	250	41.3 ≠
14	0.59	1.0	18.1	17.1	0.45	V	41.3 ≠
15	0.94	-1.0	17.9	18.9	0.34	V	41.3 ≠
16	0.28	1.5	17.9	16.4	1.04	280	41.3 ≠
17	0.58	-0.5	17.9	18.4	1.02	250	41.3 ≠
18	0.98	-2.0	17.9	19.9	0.82	160	47.6
19	0.13	1.0	17.9	16.9	2.19	150	48.0
20	0.27	1.0	18.0	17.0	0.58	V	42.8
21	0.31	0.5	17.9	17.4	2.43	140	47.8
22	0.18	2.5	17.9	15.4	2.0	170	41.6

Notes: ≠ Average of 5 days *Wind direction at 100° is directly towards the house front

V means variable direction

Table 5 Panel heaters - Daily averages

1978 Day No.	Horizontal solar radiation kWh/m^2/day	Average outside temp. °C	Average inside temp. °C	Average Δt °C	Average wind		Energy kWh/day
					Speed m/s	Direction * degrees	
23	0.18	1.5	19.1	17.6	1.38	120	77.0
24	0.36	3.0	20.1	17.1	2.9	300	58.0
25	0.56	2.0	22.5	20.5	2.35	270	55.2
26	0.81	-2.5	15.4	17.9	0.53	180	55.0
27	0.77	-2.0	18.3	20.3	1.32	120	79.0
28	0.20	2.0	19.4	17.4	2.1	V	61.4
29	0.27	1.5	19.5	18.0	4.93	330	59.2
30	0.69	0.0	16.1	16.1	2.32	280	29.8
31	0.39	-1.0	8.5	9.5	1.42	150	43.0
32	0.23	-0.1	18.2	18.3	2.13	100	70.4
33	0.11	2.5	18.8	16.3	1.18	90	58.2
34	0.57	0.0	17.0	17.0	1.77	180	43.6
35	0.95	2.5	17.1	14.6	2.52	180	42.0
36	0.20	3.2	17.6	14.4	0.37	V	38.0
37	0.41	2.0	17.8	15.8	0.53	V	39.2
38	0.14	2.0	17.3	15.3	1.0	150	40.0
39	0.99	0.0	17.9	17.9	0.57	140	39.6
40	1.03	-3.5	17.6	21.1	0.2	V	41.6
41	0.15	-3.0	16.7	19.7	1.68	V	46.6
42	0.17	-4.5	16.2	20.7	1.4	30	47.6
43	0.20	-5.0	15.9	20.9	1.35	280	49.0
44	0.23	-0.5	16.6	17.1	2.25	320	44.2
45	0.93	-3.5	17.2	20.7	1.12	360	41.0
46	1.09	-10.0	16.4	26.4	0.25	V	46.0
47	1.11	-5.5	16.3	21.8	0.77	V	45.4
48	0.98	-7.0	16.3	23.3	0.82	V	47.4
49	1.03	-4.0	16.3	20.3	1.04	V	46.6
50	1.04	-5.5	16.9	22.4	0.51	180	45.0
51	1.86	-11.0	16.7	27.7	0.55	180	45.2
52	0.86	-5.0	16.9	21.9	2.08	180	43.6
53	0.44	-3.5	17.1	20.6	1.23	110	43.2
54	0.17	-0.5	17.3	17.8	3.84	120	39.8
55	0.85	1.0	17.1	16.1	3.06	180	30.4
56	0.37	0.5	18.1	17.6	1.66	150-90	33.2
57	0.43	0.5	18.2	17.7	1.31	150	32.4
58	1.67	3.0	18.9	15.9	0.81	V	27.2
59	1.86	5.5	19.1	13.6	1.51	200	25.4
60	0.47	5.5	18.4	12.9	3.42	120	33.4
61	2.18	6.0	18.6	12.6	3.15	180	26.0
62	1.51	6.0	18.6	12.6	1.22	180	29.4
63	2.17	3.5	19.9	16.4	2.03	270	31.0
64	1.52	3.0	18.8	15.8	0.86	180	40.6

Notes: *Wind direction at 100° is directly towards house front
V means variable direction

Table 5 (continued) Panel Heaters - Daily Averages

1978 Day No.	Horizontal solar radiation kWh/m^2/day	Average outside temp. °C	Average inside temp. °C	Average Δt °C	Average wind		Energy kWh/day
					Speed m/s	Direction degrees *	
65	0.68	5.6	19.5	13.9	1.71	180	48.0
66	1.19	7.5	20.3	12.8	2.33	180	47.2
67	2.46	4.6	21.0	16.4	3.13	270	33.8
68	1.31	9.0	20.4	11.4	0.5	V	44.8
69	1.82	8.5	19.7	11.2	1.35	V	23.4
70	1.21	7.4	19.4	12.0	2.08	180	22.4
71	1.52	4.9	19.1	14.2	2.28	220	26.2
72	2.34	7.0	18.8	11.8	1.72	180	27.0
73	1.17	8.5	18.8	10.3	1.33	150-90	26.8
74	0.45	1.5	18.6	17.1	1.9	270	31.0
75	1.14	4.5	17.9	13.4	4.6	360	37.6
76	2.79	4.5	18.1	13.6	2.6	360	32.6
77	2.20	6.0	18.3	12.3	1.58	210	32.8
78	0.87	6.0	17.8	11.9	3.36	200	35.4
79	2.84	4.5	18.5	14.0	1.82	240	27.8
80	3.33	3.5	19.6	16.1	2.74	180	25.6
81	0.99	4.5	18.0	13.5	1.62	180	33.8
82	3.31	4.5	18.8	14.3	1.9	180	23.3 /
83	3.28	5.5	19.3	13.8	2.98	180	23.3 /
84	2.29	5.5	18.8	13.3	2.26	180	23.3 /
85	3.47	5.0	18.5	13.5	2.3	200	23.3 /
86	3.36	5.0	19.0	14.0	4.65	210	23.3 /
87	1.73	6.0	18.3	12.3	7.0	180	28.2
88	4.39	7.0	18.8	11.8	4.13	180	19.6
89	2.25	6.5	18.9	12.4	2.11	180	23.9
90	3.19	3.5	19.0	15.5	3.9	90	22.8
91	0.27	5.5	18.2	12.7	3.8	90	36.8
92	0.52	6.0	18.3	12.3	2.12	90	34.4
93	0.52	4.0	18.5	14.5	2.46	90	34.4
94	3.33	3.5	19.2	15.7	1.6	60	22.2
95	1.17	4.0	18.9	14.9	1.99	60	30.2
96	3.52	4.5	19.7	15.2	1.37	V	18.4
97	1.27	2.5	18.7	16.2	1.38	V	31.2
98	3.55	7.0	19.6	12.6	1.72	V	19.0
99	2.34	3.5	19.3	15.8	3.27	V	24.6
100	4.72	-0.3	18.8	19.1	3.56	270	26.4
101	4.09	0.8	18.5	17.7	2.56	270	26.4
102	4.21	1.3	18.7	17.4	2.5	270	26.2
103	2.31	1.3	18.1	16.8	3.2	270	33.4
104	4.19	3.8	18.5	14.7	3.43	330	24.4
105	3.54	4.3	19.0	14.7	1.39	90	24.2
106	4.73	7.2	20.1	12.9	1.48	180	14.4

Notes: / Average of 5 days. V means variable direction
*Wind direction at 100° is directly towards house front.

Table 5 (continued) Panel Heaters - Daily Averages

1978 Day No.	Horizontal solar radiation kWh/m^2/day	Average outside temp. °C	Average inside temp. °C	Average Δt °C	Average wind		Energy kWh/day
					Speed m/s	Direction degrees	
107	2.47	6.2	20.3	14.1	1.51	60	17.8
108	0.15	6.5	19.0	12.5	2.16	120	24.8
109	3.41	7.0	19.4	12.4	3.23	120	20.4
110	0.66	6.0	18.8	12.8	2.93	120	30.4
111	2.41	1.5	19.3	17.8	2.25	120	20.8
112	5.41	8.0	20.6	12.6	1.81	120	11.2
113	2.94	9.0	20.5	11.5	2.65	V	14.0
114	2.13	6.3	19.6	13.3	2.38	V	20.8
115	3.76	5.3	19.4	14.1	2.22	330	19.6
116	2.91	3.3	18.6	15.3	4.39	60	30.0
117	1.55	2.8	17.9	15.1	4.57	60	41.0
118	0.64	3.8	17.2	13.4	3.72	60	40.6
119	0.90	4.3	17.8	13.5	3.62	60	38.2
120	2.34	5.3	18.4	13.1	3.15	60	34.6

Notes: *Wind direction at 100° is directly towards house front
V means variable direction

Table 6 Panel heaters and fans - Daily Averages

1978 Day No.	Horizontal solar radiation kWh/m^2/day	Average outside temp. °C	Average inside temp. °C	Average Δt °C	Average wind		Energy kWh/day
					Speed m/s	Direction degrees	
303	1.26	13.0	18.7	5.7	2.38	180	12.6
304	0.33	10.3	18.3	8.0	1.5	200	15.0
305	1.09	6.5	17.1	10.6	3.85	180	23.6
306	1.29	10.4	18.1	7.7	2.15	230	16.0
307	1.06	9.9	17.8	7.9	3.14	230	17.6
308	0.88	9.5	17.4	7.9	1.77	210	19.2
309	0.88	13.2	18.3	5.1	1.9	V	14.4
310	1.16	9.6	18.1	8.5	2.16	180	16.0
311	0.77	9.4	17.7	8.3	3.16	180	18.2
312	0.77	10.9	17.7	6.8	3.26	180	18.0
313	0.47	11.2	17.5	6.3	4.02	180	19.6
314	0.27	9.4	17.3	7.9	2.94	180/330	20.6
315	0.96	8.7	17.4	8.7	1.95	180	20.4
316	0.39	9.5	17.4	7.9	4.33	180/240	20.0
317	0.56	5.0	16.5	11.5	3.4	230	31.6
318	0.82	10.0	16.9	6.9	6.38	210	24.2
319	0.27	6.9	16.7	9.8	3.45	240	25.0
320	0.84	5.4	16.5	11.1	3.97	210	31.8
321	0.41	9.7	16.6	6.9	3.92	180	25.6
322	0.67	10.4	17.3	6.9	2.65	210	20.4
323	0.39	6.0	16.9	10.9	1.72	240	24.4
324	0.36	4.7	16.3	11.6	3.3	180	35.0
325	0.77	8.9	16.4	7.5	2.81	180	25.4
326	0.69	10.8	16.8	6.0	4.36	240	19.8
327	0.55	4.3	17.4	13.1	1.46	180	28.8
328	0.53	1.5	16.7	15.2	1.3	240	35.2
329	0.62	0.3	16.4	16.1	2.64	270	41.6
330	0.86	1.1	16.3	15.2	3.28	300	40.2
331	0.47	0.2	16.2	16.0	4.33	330	44.2
332	0.64	1.1	16.0	14.9	1.35	270	41.2
333	0.29	1.9	16.1	14.2	2.11	180	41.4
334	0.26	2.7	16.4	13.7	1.85	180	38.2
335	0.36	2.1	16.3	14.2	2.01		39.2
336	0.25	3.7	16.3	12.6	3.65		38.4
337	0.08	6.0	16.5	10.5	3.3		30.4
338							
339							
340							
341			NO TEST	IN PROGRESS			
342							
343							
344							

Notes: * Wind direction at 100° is directly towards house front
V means variable direction

Table 6 (continued) Panel Heaters and Fans - Daily Averages

1978-79 Day No.	Horizontal solar radiation kWh/m^2/day	Average outside temp. °C	Average inside temp. °C	Average Δt °C	Average wind Speed m/s	Average wind Direction degrees	Energy kWh/day
345							
346							
347							
348							
349			NO TEST	IN PROGRESS			
350							
351							
352	0.68	-2.2	16.4	18.6	0.56	V	48.8
353	0.35	1.0	16.5	15.5	1.35	180	45.8
354	0.51	-2.5	16.3	18.8	0.21	V	51.0
355	0.04	3.3	16.6	13.3	1.55	75	42.2
356	0.04	3.5	16.7	13.2	0.63	V	38.6
357	0.01	3.5	16.7	13.2	1.91	90	39.6
358	0.08	4.2	16.6	12.4	2.77	90	43.0
359	0.05	3.5	16.6	13.1	4.3	90	44.6
360	0.04	3.7	16.5	12.8	2.72	90	44.2
361	0.09	3.2	16.7	13.5	3.16	60	41.0
362	0.34	1.0	16.4	15.4	4.57	60	50.0
363	0.27	-1.7	16.3	18.0	3.47	60	53.8
364	0.40	-3.4	16.1	19.5	3.02	90	56.6
365	0.38	-6.2	16.1	22.3	2.02	0	60.6
1	0.28	-3.7	16.1	19.8	2.0	255	58.2
2	0.68	-3.0	16.3	19.3	1.19	V	50.6
3	0.28	1.9	16.5	14.6	2.26	195	44.6
4	0.39	-0.3	16.4	16.7	1.46	180/240	47.2
5	0.46	-3.8	16.2	20.0	1.31	180	57.0
6	0.25	4.3	16.5	12.2	1.98	180	42.2
7	0.48	4.3	16.7	12.4	2.8	270	37.4
8	0.56	1.4	16.6	15.2	1.88	240	42.8
9	0.54	0.0	16.5	16.5	1.88	240	46.6
10	0.08	0.0	16.4	16.4	2.22	360	46.6
11	0.06	1.2	16.7	15.5	3.02	330	41.6
12	0.44	-0.7	16.7	17.4	2.59	V	47.8
13	0.65	-4.1	16.2	20.3	1.65	V	48.0
14	0.45	-8.0	15.8	23.8	0.69	180	63.2
15	0.39	2.7	16.4	13.7	1.88	180	41.6
16	0.47	2.8	16.8	14.0	2.99	270	42.2
17	0.63	1.7	17.6	15.9	1.55	V	48.6
18	0.33	2.1	17.2	15.1	1.89	60	44.8
19	0.09	2.5	18.0	15.5	4.79	90	58.8
20	0.14	3.1	18.0	14.9	4.95	90	59.0
21	0.09	3.3	18.8	15.5	1.95	90	54.4

Notes: *Wind direction at 100° is directly towards house front
V means variable direction

Table 6 (continued) Panel Heaters and Fans - Daily Averages

1979 Day No.	Horizontal solar radiation kWh/m^2/day	Average outside temp. °C	Average inside temp. °C	Average Δt °C	Average wind		Energy kWh/
					Speed m/s	Direction degrees *	
22	0.27	1.7	18.4	16.7	0.66	180	39.6
23	0.62	-0.5	16.5	17.0	0.67	V	45.2
24	0.36	1.3	17.4	16.1	2.06	V	48.4
25	0.54	-1.4	16.4	17.8	1.11	V	46.2
26	0.65	-1.1	16.3	17.4	1.26	270	47.0
27	0.40	-3.9	16.2	20.1	1.7	270	45.6
28	0.70	-2.5	15.9	18.4	2.06	150	54.4
29	0.30	1.8	16.3	14.5	1.47	V	43.0
30	1.05	0.7	16.6	15.9	1.04	V	38.4
31	0.92	3.5	16.7	13.2	2.0	V	36.4
32	1.18	-0.8	16.5	17.3	1.9	270	39.4
33	0.76	1.0	16.2	15.2	2.97	255	46.4
34	1.18	1.0	16.5	15.5	3.39	270	39.8
35	1.27	-1.3	16.5	17.8	1.25	270	41.2
36	1.30	-0.8	16.5	17.3	1.11	V	41.8
37	0.84	-4.4	16.2	20.6	0.71	180	49.8
38	0.94	-3.0	16.2	19.2	2.15	330	50.2
39	0.77	0.3	16.3	16.0	1.89	330	45.6
40	0.85	-0.9	16.4	17.3	1.27	180/360	45.0
41	0.50	1.5	16.5	15.0	1.19	60	42.2
42	0.42	1.9	16.5	14.6	1.97	60	41.8
43	0.25	1.6	16.7	15.1	1.77	60	38.0
44	0.31	1.6	16.3	14.7	4.31	60	46.0
45	0.91	-3.0	16.2	19.2	4.26	60	54.2
46	1.16	-3.3	16.2	19.5	2.85	45	55.2
47	1.14	-0.9	16.3	17.2	2.13	90	51.0
48	0.90	-5.7	16.3	22.0	2.51	90	45.6
49	1.33	1.4	16.4	15.0	2.04	150	45.6
50	1.13	2.2	16.8	14.6	1.4	180	37.6
51	0.45	2.6	16.6	14.0	2.05	180	40.2
52	0.74	2.1	16.5	14.4	2.01	180	40.6
53	1.94	3.4	17.1	13.7	0.97	V	30.0
54	1.47	4.8	17.2	12.4	2.96	315	28.4
55	2.10	1.5	17.2	15.7	0.53	V	29.8
56	1.65	4.3	17.2	12.9	1.7	V	29.0
57	0.90	5.9	17.2	11.3	1.79	V	29.0
58	1.40	5.2	17.8	12.6	2.6	180	58.2
59	2.27	1.7	18.5	16.8	1.69	200	12.4
60	2.11	2.5	17.3	14.8	3.6	180	26.4
61	1.84	10.8	17.7	6.9	4.74	210	20.4
62	2.85	6.9	18.3	11.4	4.65	210	16.2
63	2.50	4.3	17.2	12.9	5.67	240	28.8

Notes: *Wind direction at 100° is directly towards house front
V means variable direction

Table 6 (continued) Panel Heaters and Fans - Daily Averages

1979 Day No.	Horizontal solar radiation kWh/m^2/day	Average outside temp. °C	Average inside temp. °C	Average Δt °C	Average wind		Energy kWh/day
					Speed m/s	Direction* degrees	
64	2.10	6.8	17.2	10.4	5.54	195	27.4
65	1.30	5.5	17.0	11.5	5.31	180	29.2
66	1.93	2.4	17.4	15.0	2.41	270	29.8
67	0.76	5.0	16.8	11.8	4.86	180	36.8
68	2.45	2.6	17.2	14.6	5.28	240	30.2
69	2.62	2.9	17.2	14.3	3.37	210	32.0
70	2.65	4.1	17.3	13.2	4.07	240	25.8
71	2.62	5.6	17.4	11.8	6.05	240	25.2
72	1.91	4.0	17.5	13.5	2.94	V	29.6
73	2.23	3.1	17.2	14.1	4.7	330	33.4
74	2.18	1.8	17.1	15.3	3.15	30	35.6
75	1.71	2.0	17.0	15.0	4.18	0	40.8
76	1.62	0.3	16.8	16.5	4.89	0	33.6
77	3.38	1.6	17.2	15.6	2.69	45	32.8
78	4.00	-2.4	17.4	19.8	2.37	180	40.0
79	1.04	1.3	16.7	15.4	2.62	210	39.8
80	0.97	0.7	16.7	16.0	4.64	330	29.8
81	4.07	1.2	17.5	16.3	5.73	270	24.0
82	4.18	1.2	18.1	16.9	3.86	270	38.2
83	1.50	0.5	17.0	16.5	2.82	150	35.0
84	1.05	3.5	16.9	13.4	2.82	V	36.2
85	1.36	1.7	16.9	15.2	2.95	270	28.2
86	2.99	2.3	17.4	15.1	2.95	270	34.4
87	1.84	4.4	17.2	12.8	5.53	360	52.6
88	0.34	3.8	18.8	15.0	6.25	330	32.6
89	2.78	4.7	19.9	15.2	2.28	240	17.4
90	3.67	6.1	18.4	12.3	2.79	270	28.4
91	1.98	4.0	18.1	14.1	2.14	V	21.8
92	2.94	3.2	19.0	15.8	1.59	V	31.0
93	1.95	3.1	18.0	14.9	2.11	0	32.2
94	1.69	3.0	17.6	14.6	1.58	V	30.4
95	2.97	3.9	18.0	14.1	0.92	90	40.4
96	0.93	3.6	18.1	14.5	1.88	60	51.0
97	0.76	4.1	19.2	15.1	3.56	60	44.0
98	2.51	4.4	19.3	14.9	4.4	60	51.4
99	0.97	3.0	19.5	16.5	2.21	60	25.6
100	1.54	5.1	20.1	15.0	1.0	V	26.6
101	1.89	7.4	22.4	15.0	1.25	90	62.6
102	3.24	7.6	20.7	13.1	2.3	120	31.0
103	2.24	8.0	19.7	11.7	3.43	180	22.2
104	4.99	7.9	21.0	13.1	2.28	V	27.8
105	3.65	8.0	21.1	13.1	2.26	300	23.0

Notes: *Wind direction at 100° is directly towards house front
V means variable direction

Table 6 (continued) Panel Heaters and Fans - Daily Averages

1979 Day No.	Horizontal solar radiation kWh/m^2/day	Average outside temp. °C	Average inside temp. °C	Average Δt °C	Average wind		Energy kWh/day
					Speed m/s	Direction * degrees	
106	2.93	5.6	19.3	13.7	2.43	330	29.4
107	1.65	5.7	20.3	14.6	1.09	120	29.0
108	2.56	7.9	20.1	12.2	0.56	V	18.2
109	3.58	9.8	20.2	10.4	1.9	180	20.0
110	3.89	7.9	21.1	13.2	1.76	270	20.0
111	4.48	7.6	22.3	14.7	3.00	260	13.2
112	2.34	7.6	20.2	12.5	1.87	260	17.0
113	1.61	5.6	18.9	13.3	1.25	V	19.8
114	3.90	6.2	19.4	13.2	4.11	310	20.4
115	2.65	6.3	19.9	13.6	4.33	330	30.8
116	1.64	6.3	21.5	15.2	4.21	330	41.2
117	3.40	7.8	23.3	15.5	2.37	230	36.4
118	3.86	9.3	23.9	14.6	3.46	300	30.8
119	2.91	8.5	24.4	15.9	4.36	270	30.2
120	4.27	2.6	20.4	17.8	5.21	270	25.6
121	4.63	1.7	17.9	16.2	3.42	300	22.6
122	4.53	3.0	18.0	15.0	3.68	300	21.0
123	5.46	2.1	18.1	16.0	2.85	300	18.0
124	5.02	3.1	18.0	14.9	2.86	270	21.2
125	4.63	4.2	18.5	14.3	2.76	315	18.2
126	3.14	4.2	17.9	13.7	1.06	V	21.2
127	2.65	4.7	17.6	12.9	0.75	120	25.8
128	5.05	5.5	19.2	13.7	1.5	V	13.2
129	4.33	6.1	19.0	12.9	2.02	0 or 360	11.4
130	5.05	4.7	18.9	14.2	2.66	150	11.4
131	4.59	11.0	19.3	8.3	1.55	V	9.2
132	3.48	12.9	19.8	6.9	1.79	240	5.8
133	6.35	17.9	22.9	5.0	3.67	210	1.2
134	2.48	15.8	22.6	6.8	3.38	195	0.4
135	4.85	12.2	21.9	9.7	1.66	V	0.6
136	0.86	8.7	19.3	10.6	0.97	45	8.6
137	2.33	8.1	18.1	10.0	2.02	V	15.2
138	3.86	6.1	18.3	12.2	2.43	330	14.8
139	5.54	5.9	19.0	13.1	2.22	180	10.2
140	5.26	8.7	18.6	9.9	3.15	150	11.8
141	3.07	9.9	18.7	8.8	1.7	180	12.4
142	5.81	9.7	20.1	10.4	2.65	180	4.2
143	2.24	8.7	18.8	10.1	1.46	90	11.6
144	4.94	10.1	19.6	9.5	1.76	180	5.8
145	3.58	8.1	19.7	11.6	0.92	V	5.8
146	6.32	9.4	20.5	11.1	1.28	120	4.8
147	2.76	9.0	19.4	10.4	1.85	300	7.6

Notes: *Wind direction at 100° is directly towards house front
V means variable direction

Table 7 Fan Heaters Summary - Weekly Averages

Date W/C	Temp. diff Δt °C	Power P kWh/day	Solar through windows S kWh/day	Vent heat loss V kWh/day	P + S kWh/day	P - V + S kWh/day	$\frac{P}{\Delta t}$ kWh/day °C	$\frac{P - V}{\Delta t}$ kWh/day °C	$\frac{S}{\Delta t}$ kWh/day °C
1977									
31.10	12.3	30.26	2.86	5.33	33.12	27.79	2.45	2.02	0.23
7.11	9.1	30.03	2.88	N/A	32.91	N/A	3.28	N/A	0.32
14.11	12.7	41.8	1.48	N/A	43.28	N/A	3.3	N/A	0.12
21.11	13.4	43.18	1.92	N/A	45.1	N/A	3.21	N/A	0.14
28.11	15.2	46.54	1.38	N/A	47.92	N/A	3.06	N/A	0.09
5.12	12.7	44.57	0.66	9.27	45.23	35.96	3.51	2.78	0.05
12.12	11.7	33.11	0.91	3.7	34.02	30.32	2.84	2.52	0.08
19.12	12.9	35.97	1.19	6.85	37.16	30.31	2.79	2.26	0.09
26.12	14.5	40.86	1.21	12.18	42.07	29.39	2.81	1.98	0.08
1978									
2.1	15.8	41.0	1.54	10.3	42.54	32.24	2.6	1.95	0.1
9.1	16.6	45.17	1.66	8.51*	46.83	38.32	2.71	2.2	0.1
16.1	17.4	44.35	1.42	9.98	45.77	35.79	2.56	1.98	0.08

*Average over 4 days only

Table 8 Parel Heaters Summary - Weekly Averages

Date W/C 1978	Temp. Diff. Δt °C	Power P kWh/day	Solar through windows S kWh/day	Vent. heat loss V kWh/day	P + S kWh/day	P - V + S kWh/day	$\frac{P}{\Delta t}$ kWh/day °C	$\frac{P - V}{\Delta t}$ kWh/day °C	$\frac{S}{\Delta t}$ kWh/day °C
23.1	18.4	63.54	1.45	13.59	64.99	51.4	3.46	2.72	0.08
30.1	15.2	46.43	1.15	8.52	47.58	39.06	3.06	2.5	0.08
6.2	18.8	43.37	1.57	10.61	44.94	34.33	2.31	1.74	0.08
13.2	21.7	45.09	3.16	13.22	48.25	35.03	2.08	1.47	0.15
20.2	19.9	38.26	2.52	13.3	40.78	27.48	1.92	1.25	0.13
27.2	14.3	30.43	5.78	7.52	36.21	28.69	2.13	1.61	0.41
6.3	13.1	35.11	4.89	6.49	40.0	33.51	2.68	2.18	0.37
13.3	12.9	31.89	5.48	6.09	37.37	31.28	2.47	2.0	0.42
20.3	14.1	25.78	10.22	6.03	36.0	29.97	1.83	1.41	0.73
27.3	13.0	26.98	8.1	8.5	35.08	26.58	2.08	1.42	0.62
3.4	15.0	25.71	7.55	9.39	33.26	23.87	1.72	1.09	0.5
10.4	16.2	25.06	14.02	12.73	39.08	26.35	1.54	0.76	0.86
17.4	13.4	19.91	8.95	9.14	28.86	19.72	1.49	0.81	0.67
24.4	12.1	32.14	5.53	10.88	37.67	26.79	2.66	1.76	0.46
6.10	6.9	9.97	5.85	2.24	15.82	13.58	1.44	1.11	0.84
13.10	9.5	19.66	4.33	5.66	23.99	18.33	2.08	1.48	0.46
20.10	9.1	23.6	2.58	-	26.18	-	2.61	-	0.29

Table 9 Summary - Panel Heaters and Fans - Weekly Averages

Date W/C	Temp. diff. Δt °C	Power P kWh/day	Solar through windows S kWh/day	Vent. heat loss V kWh/day	P + S kWh/day	P -V + S kWh/day	$\frac{P}{\Delta t}$ kWh/day °C	$\frac{P - V}{\Delta t}$ kWh/day °C	$\frac{S}{\Delta t}$ kWh/day °C
1978									
30.10	7.6	16.91	3.52	2.69	20.43	17.74	2.23	1.87	0.46
6.11	7.8	18.97	2.51	2.41	21.48	19.07	2.44	2.13	0.32
13.11	9.1	26.14	2.2	4.69	28.34	23.65	2.86	2.35	0.24
20.11	12.0	32.29	2.49	7.14	34.78	27.64	2.67	2.08	0.21
27.11	13.8	39.0	1.14	7.52	40.14	32.62	2.84	2.24	0.08
18.12	15.0	44.14	0.92	7.79	45.06	37.27	2.94	2.42	0.06
25.12	16.4	49.38	0.69	13.67	50.51	36.84	3.04	2.21	0.04
1979									
1.1	16.4	47.46	1.47	9.31	48.93	39.62	2.89	2.32	0.09
8.1	17.9	48.06	1.91	11.33	49.97	38.64	2.69	2.05	0.11
15.1	14.9	49.91	0.88	11.64	50.79	39.15	3.34	2.56	0.06
22.1	17.6	46.63	1.78	10.53	48.41	37.88	2.65	2.05	0.1
29.1	15.6	40.69	3.71	10.54	44.4	33.81	2.6	1.93	0.24
5.2	17.4	45.2	2.9	9.81	48.1	38.29	2.61	2.04	0.17
12.2	16.8	47.94	2.99	13.12	50.93	37.81	2.85	2.07	0.18
19.2	14.0	33.66	5.02	6.5	38.68	32.18	2.41	1.94	0.36
26.2	12.4	27.34	8.2	6.78	35.54	28.76	2.21	1.66	0.66
5.3	13.0	30.03	7.28	8.38	37.31	28.93	2.32	1.67	0.56
12.3	14.6	33.0	8.02	9.92	41.02	31.1	2.26	1.58	0.55
19.3	16.3	34.71	9.23	13.3	43.94	30.64	2.13	1.31	0.57
26.3	14.2	30.77	7.08	10.76	37.85	27.09	2.16	1.41	0.5
2.4	14.8	40.06	6.56	9.3	46.62	37.32	2.7	2.07	0.44
9.4	13.9	31.26	8.97	8.13	40.23	32.1	2.25	1.66	0.65
16.4	13.1	20.97	10.14	7.27	31.11	23.84	1.61	1.05	0.78
23.4	14.5	29.94	9.18	11.72	39.12	27.4	2.07	1.26	0.63
30.4	15.4	21.11	15.29	13.03	36.4	23.37	1.37	0.52	0.99
7.5	10.1	11.14	15.06	4.86	26.2	21.34	1.11	0.62	1.5*
14.5	11.0	8.8	11.65	4.58	20.45	15.87	0.8	0.38	1.06
21.5	10.3	7.46	13.3	4.11	20.75	16.64	0.73	0.33	1.29*

*Not shown in figure 15 but included in linear regression

FIGURE 1. "KEMNAY" TEST HOUSE

SITE PLAN

Showing Anemometer(A), Stevenson Screen(T), & Solarimeter(S)

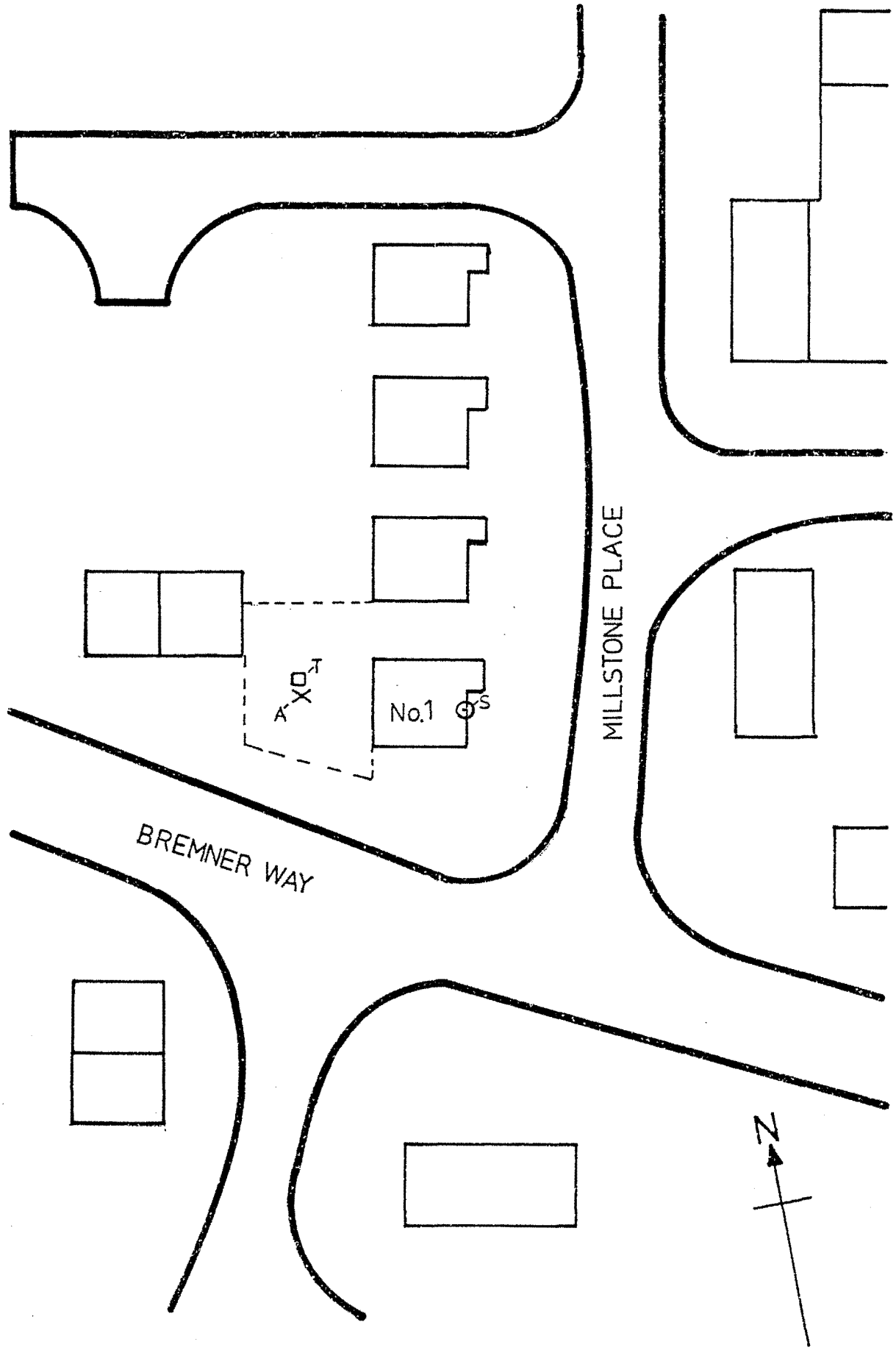

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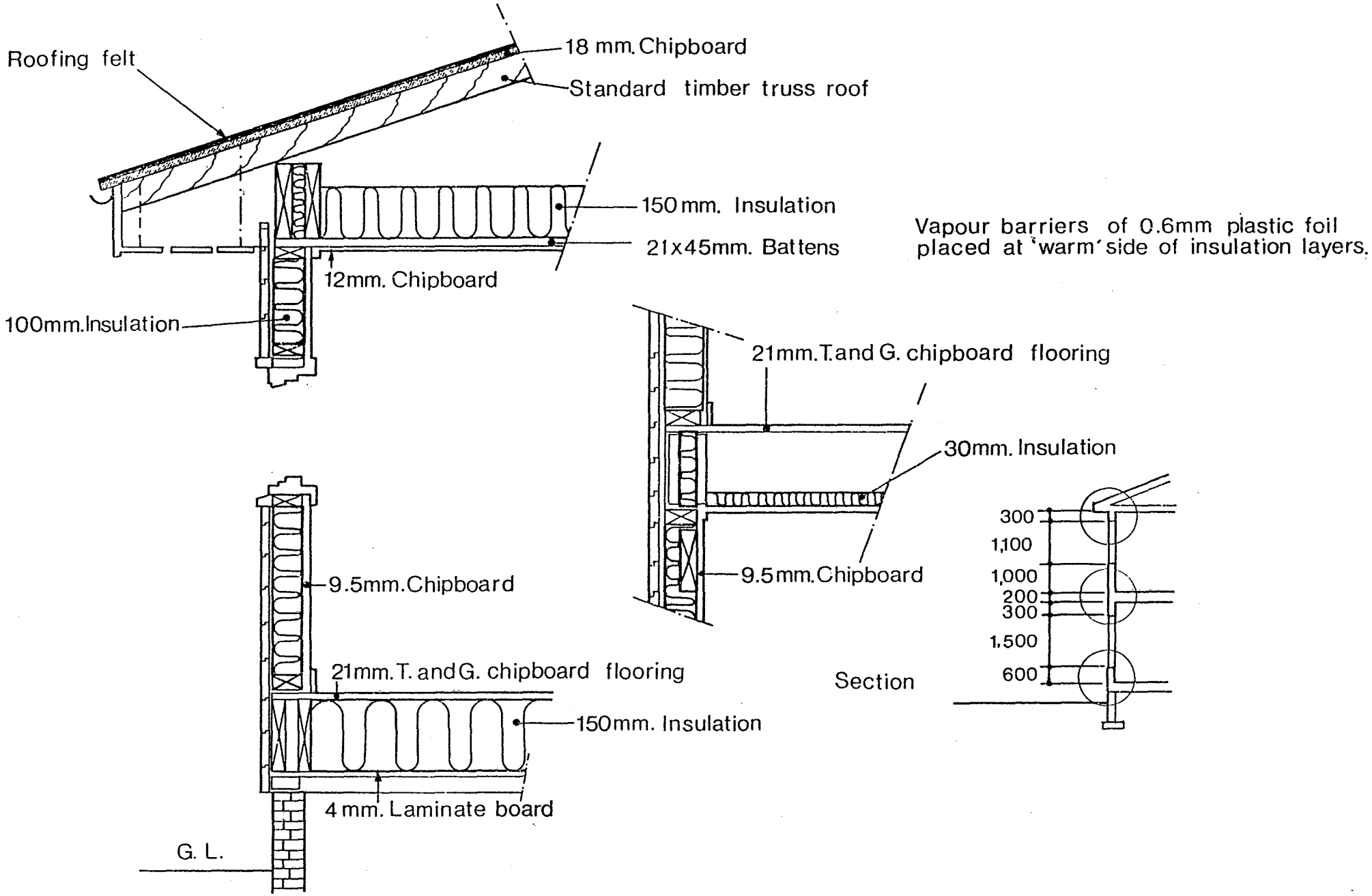
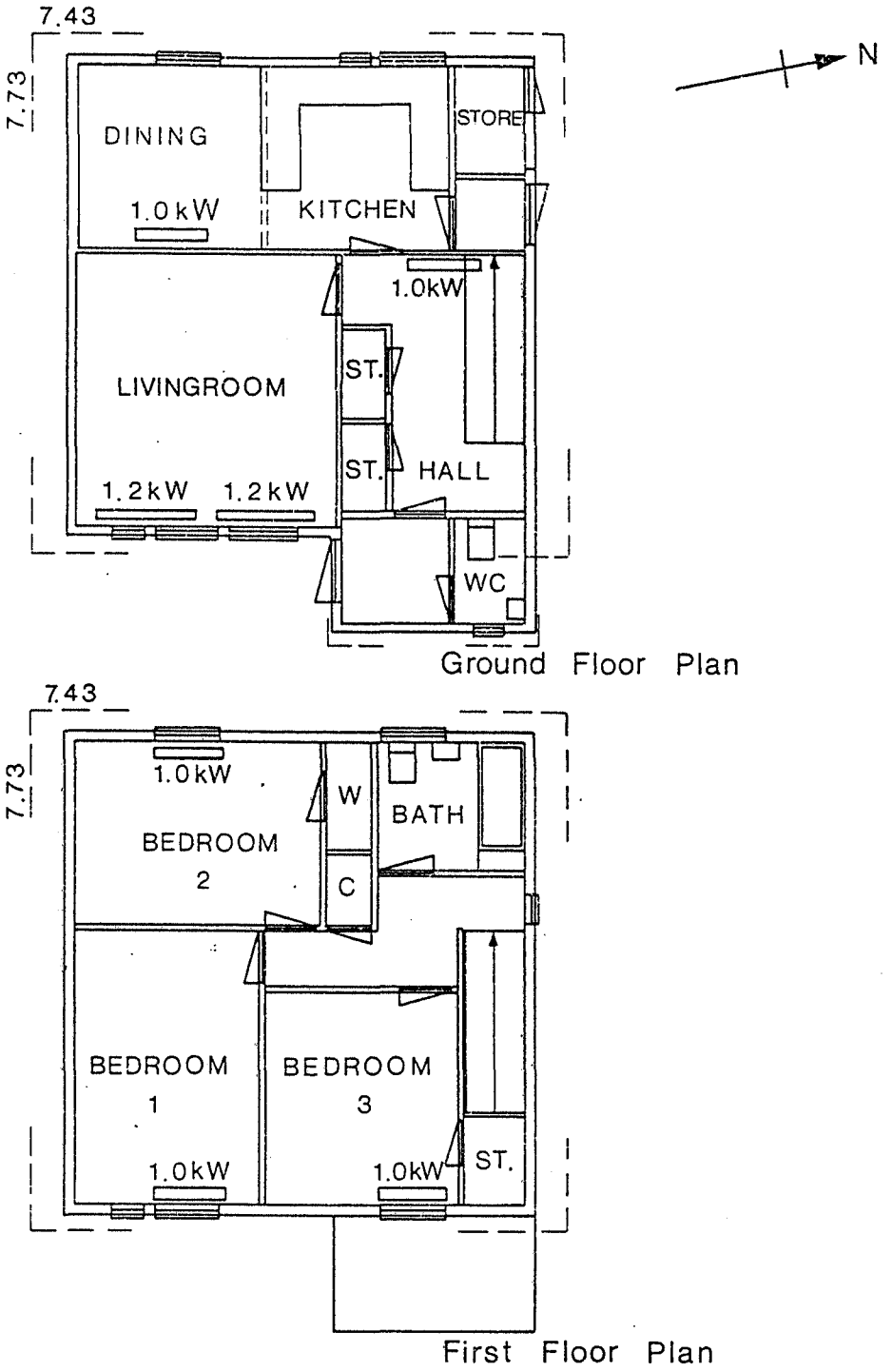
FIG. 2



EC RC/M1365

Figure 3. CONSTRUCTION DETAILS



Existing Panel Heaters

Area Ground Floor - 51.4 m^2

Area First Floor - 49.8 m^2*

Area Total Floor - 101.2 m^2

CONFIRMED.

*Excluding Front Porch and W.C.

Figure 4 KEMNAY - DETACHED TYPE HOUSE

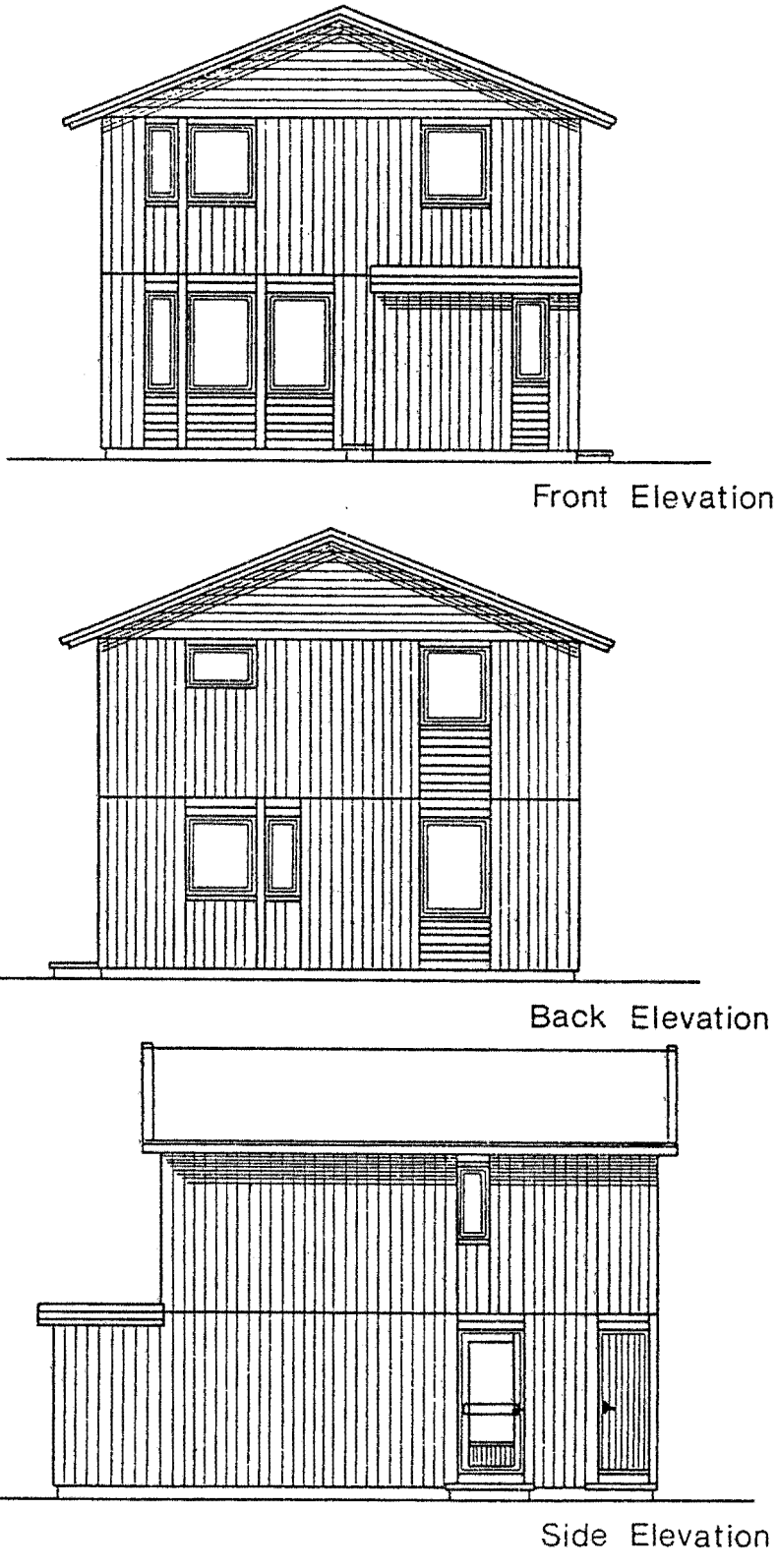
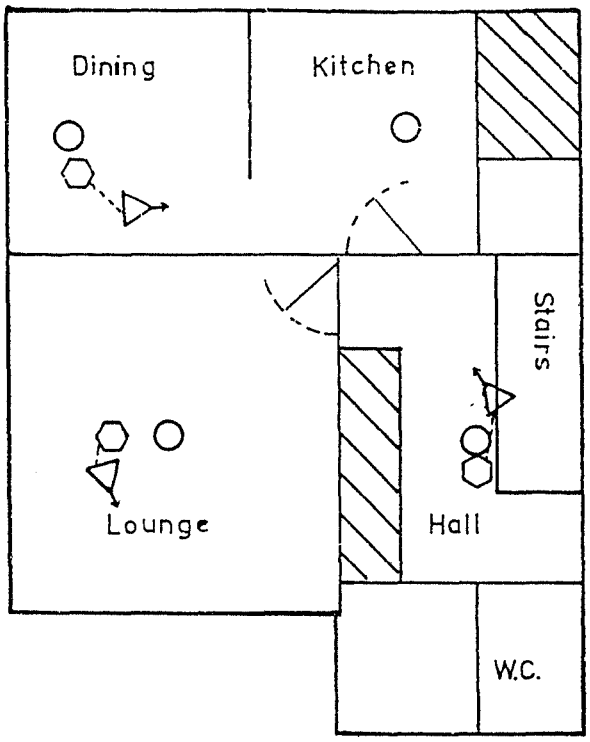
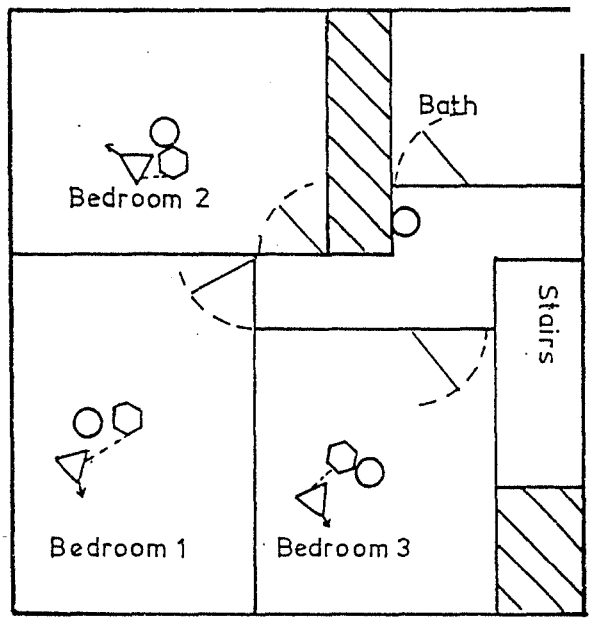


Figure 5. KENMAY – DETACHED TYPE HOUSE



Ground floor



First floor

air flow

△—Fan heater positions

⬡—Control thermostat at Ht. 0·83 m. ○—Thermograph at 1·2 m

≡—Store cupboards

GROUND & 1st. FLOOR PLAN
1, Millstone Place

FAN HEATERS

FIG.6

SCALE: 1:100

$m/s = 8A(\Delta p)^{0.66}$

$l/s = 71.8 m/s$

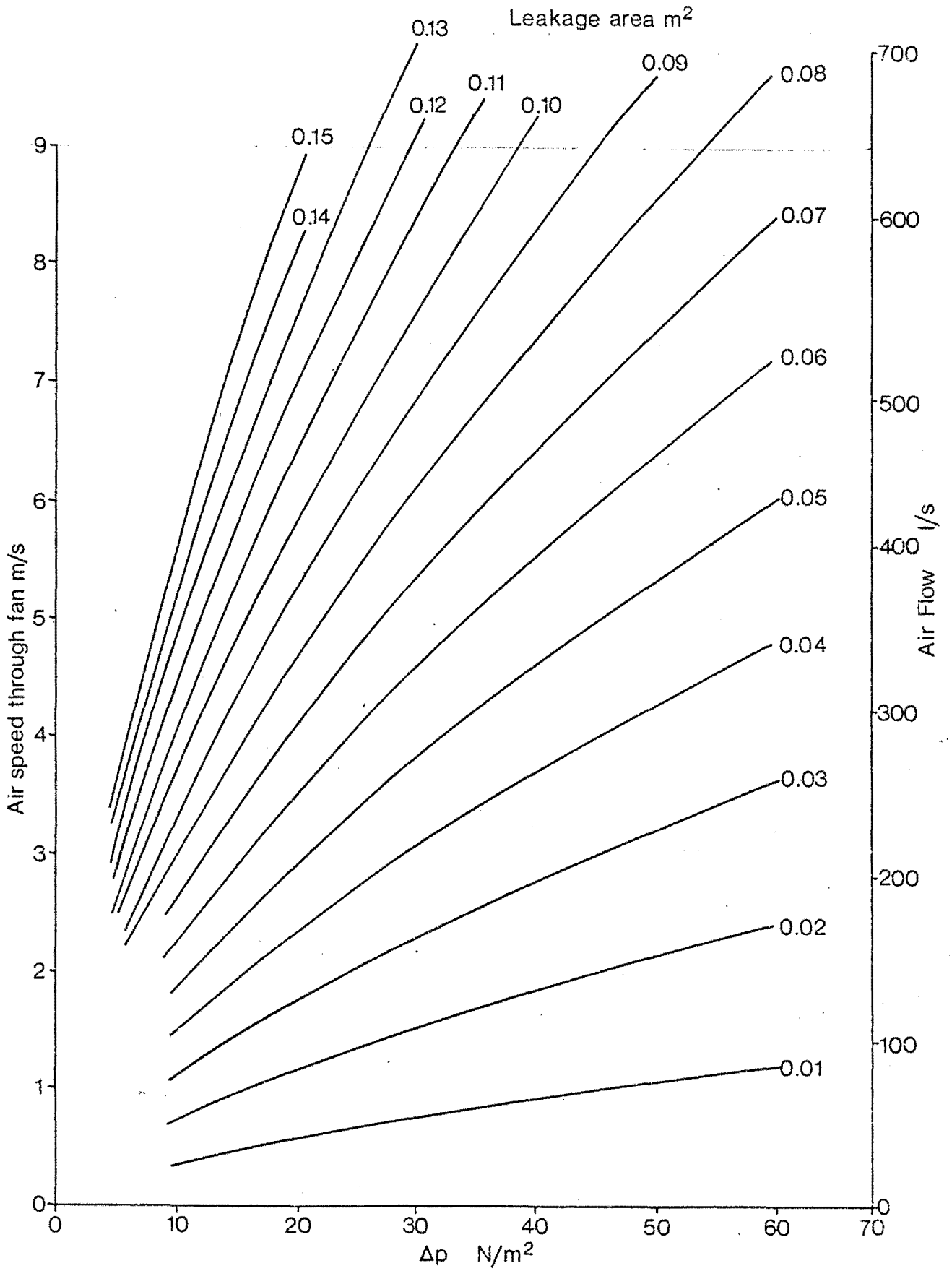


Figure 7. CALIBRATION CURVES — PRESSURISATION MEASUREMENTS.

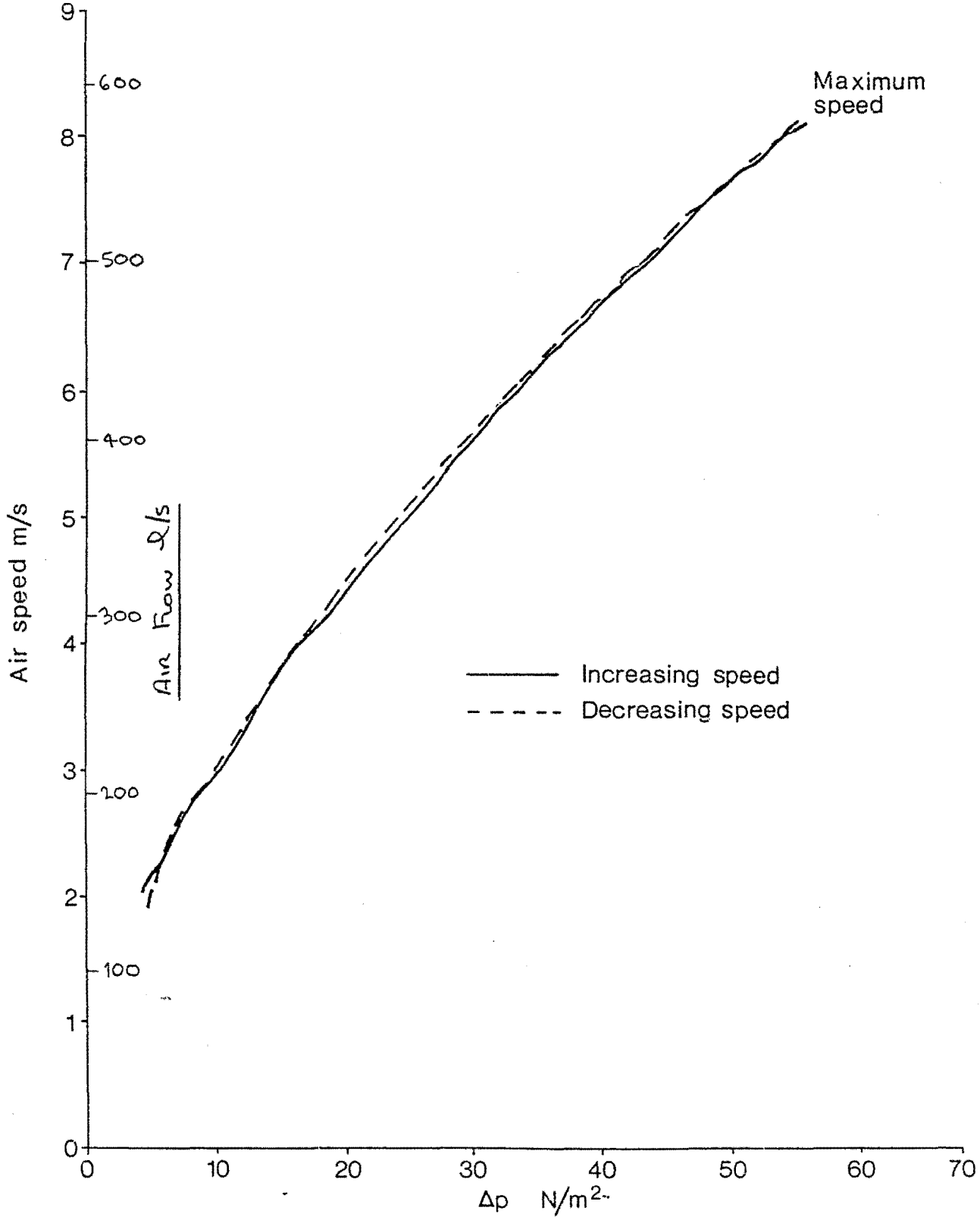


Figure 8. EQUIVALENT LEAKAGE AREA TEST HOUSE

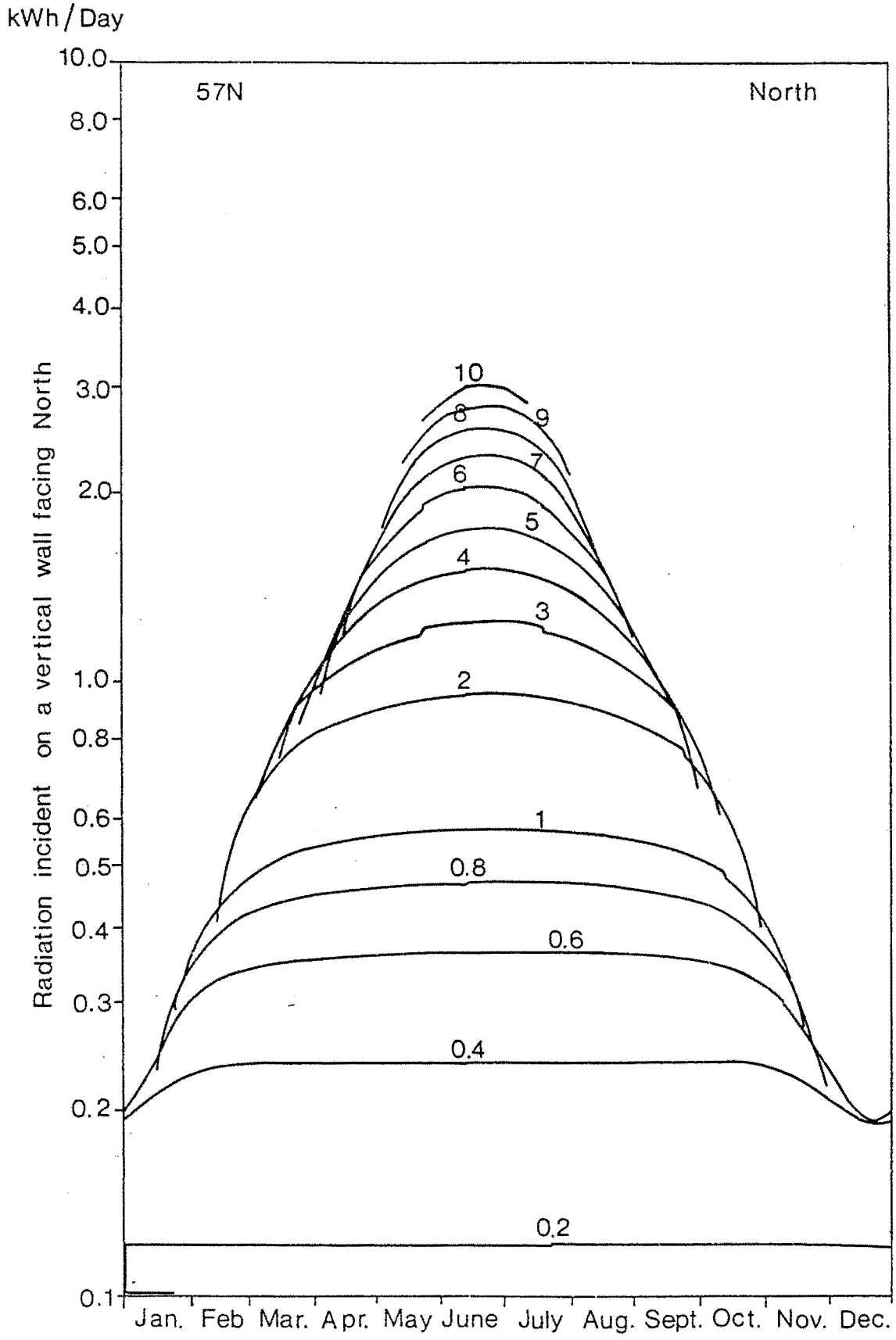


Figure 9. BASNETT'S CURVES.

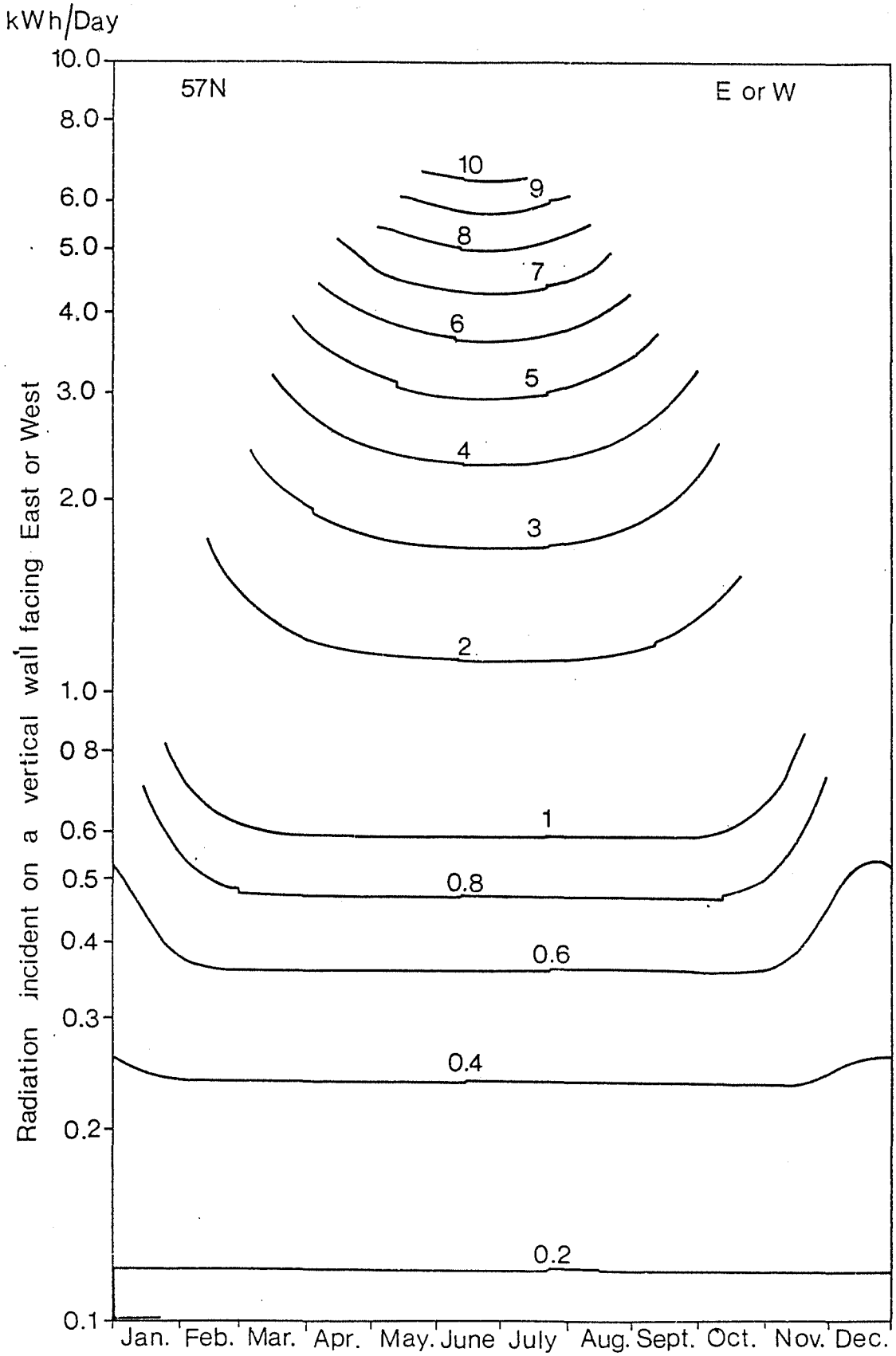


Figure 10. BASNETT'S CURVES.

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FIG. 11
Weekly Average - Energy / Δt
Fan Heaters Only

W.C. 31/10/77 to 16/1/78

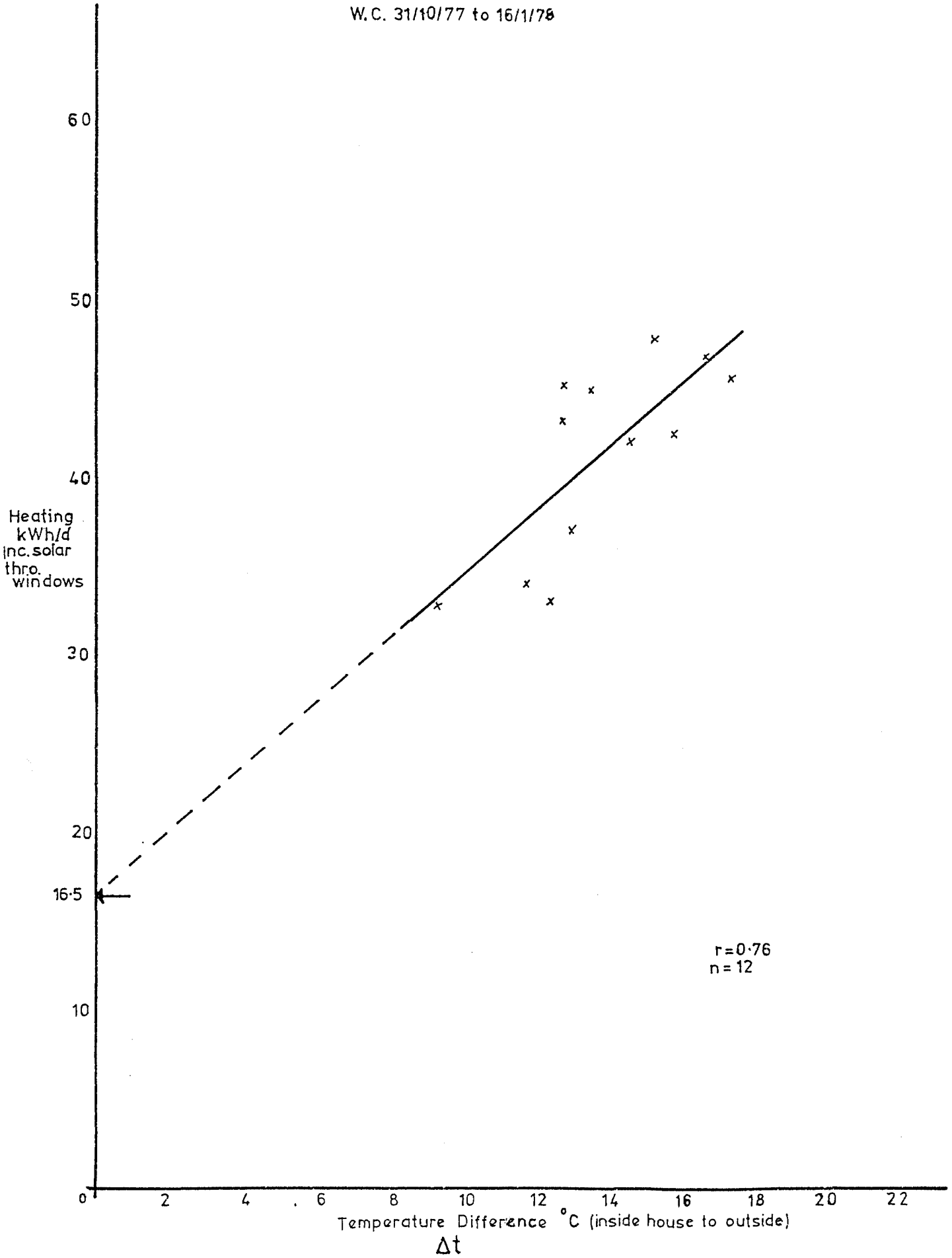

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FIG. 12
Weekly Average-Energy/Δt
Panel Heaters Only

W.C. 23/1/78 to 24/4/78 & 6 to 20/10/78

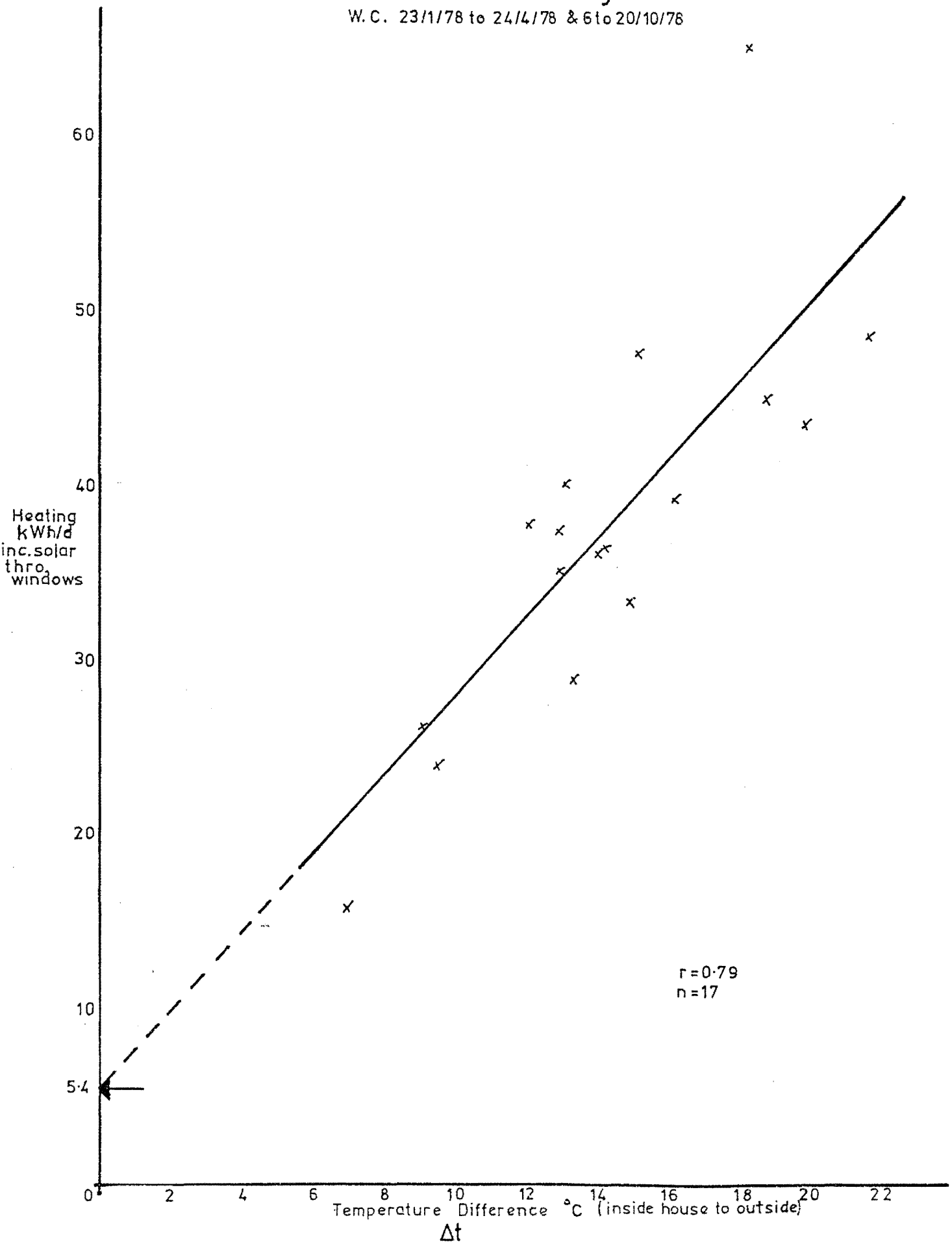

FIG.13

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Weekly Average-Energy/Δt
Panel Heaters & Fans

W.C. 30/10/78 to 21/5/79

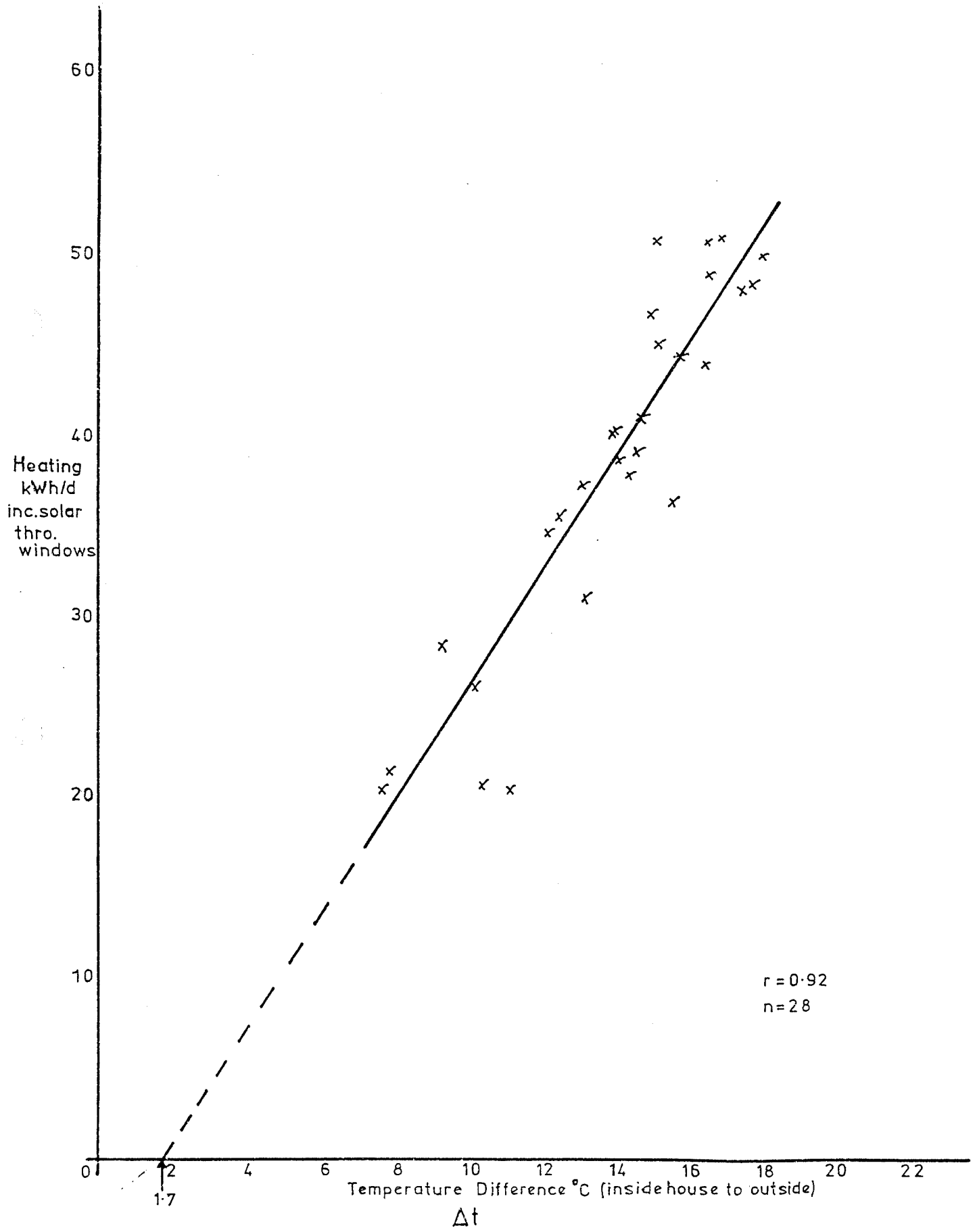

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FIG. 14

Weekly Average Net Energy

$$\frac{P - V/S}{\Delta t / \Delta t}$$

Where:
P = Input Energy
V = Ventilation Heat loss
S = Solar Heating Through Glass
Δt = Temperature Difference inside house to outside

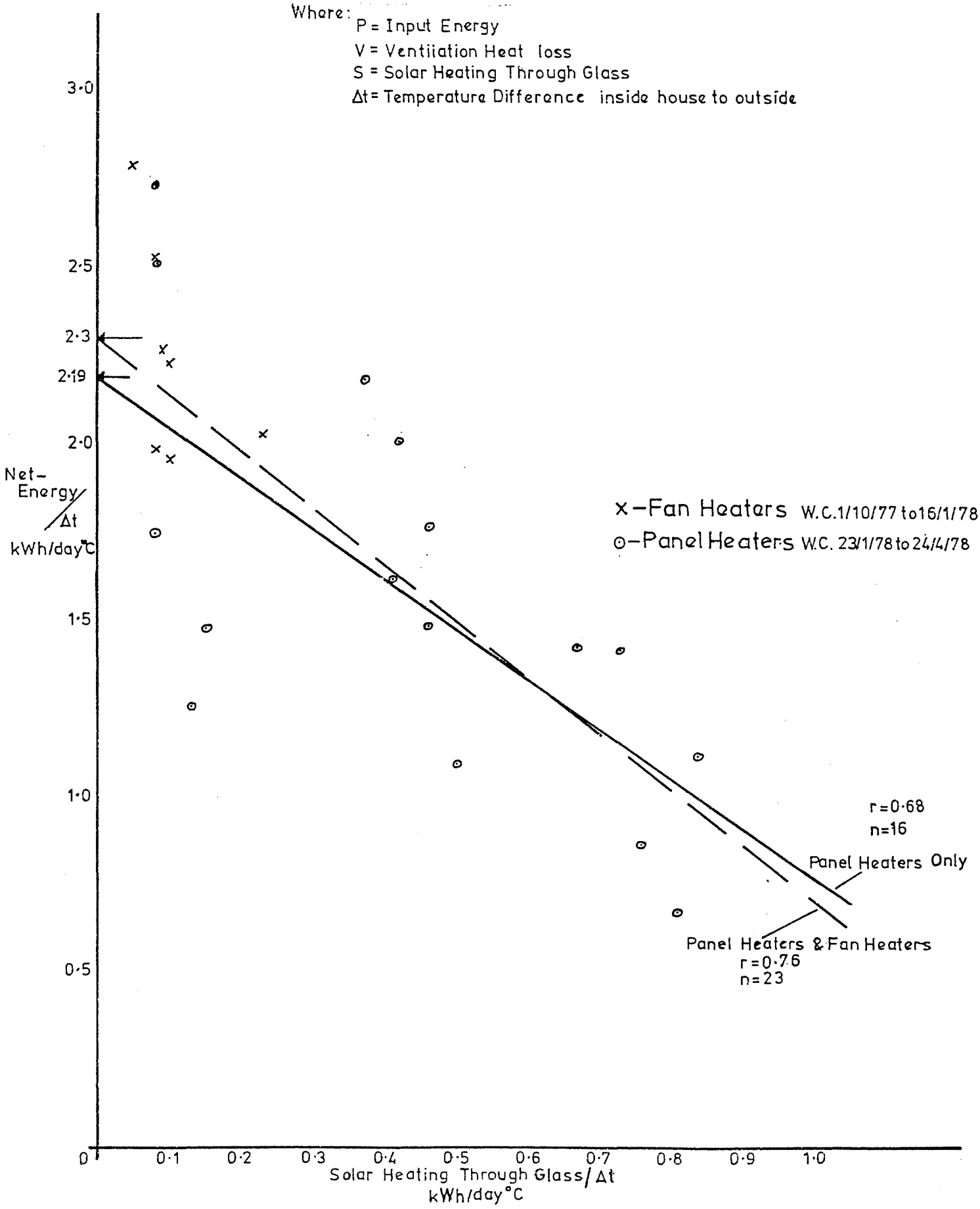


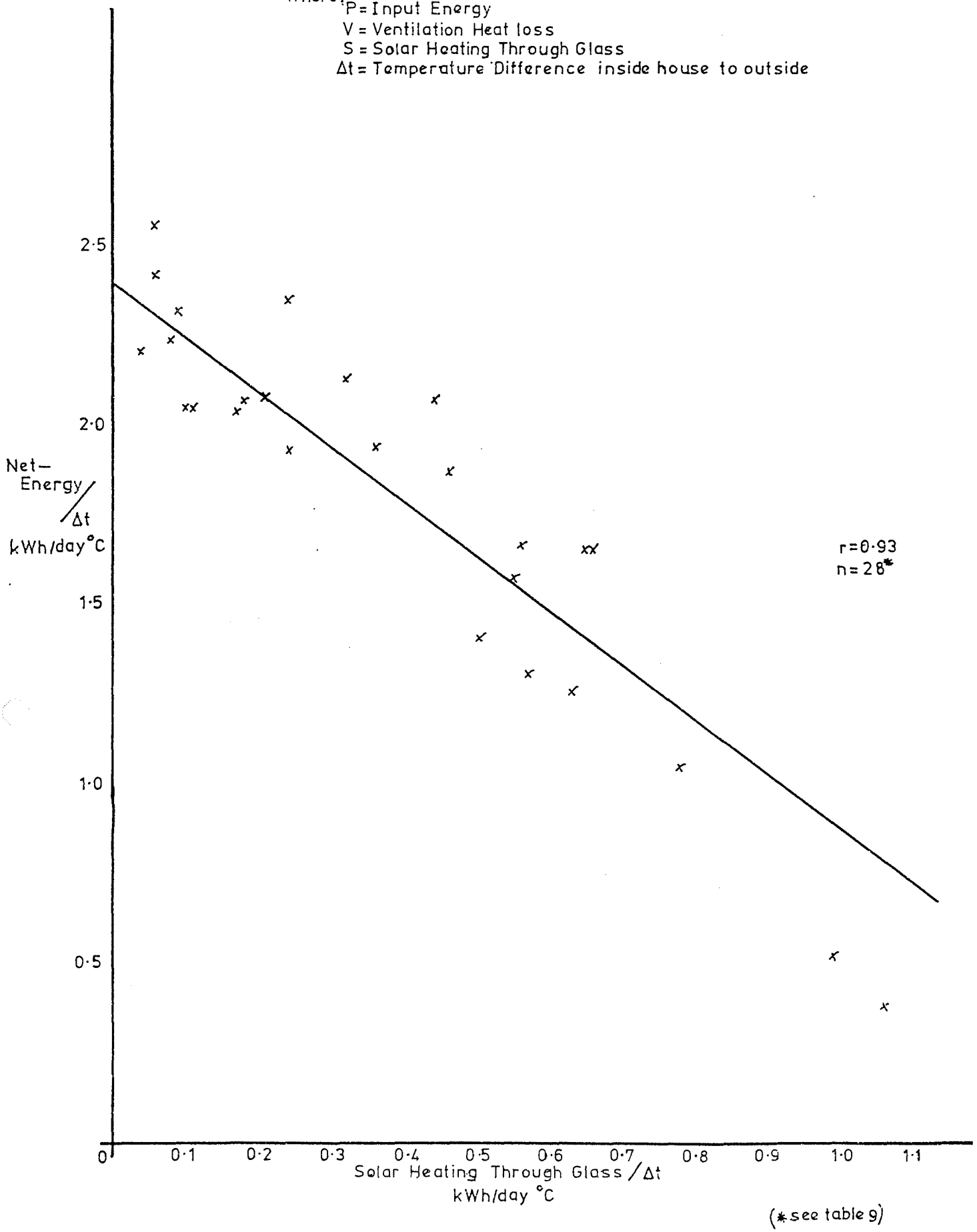
FIG.15

Weeky Averaae Net Energy - $\frac{P-V}{\Delta t} \Big/ \frac{S}{\Delta t}$

Panel Heaters with Fans

W.C. 30/10/78 to 21/5/79

Where: P = Input Energy
V = Ventilation Heat loss
S = Solar Heating Through Glass
Δt = Temperature Difference inside house to outside



(* see table 9)

FIG. 16
Variation in Δt with Time

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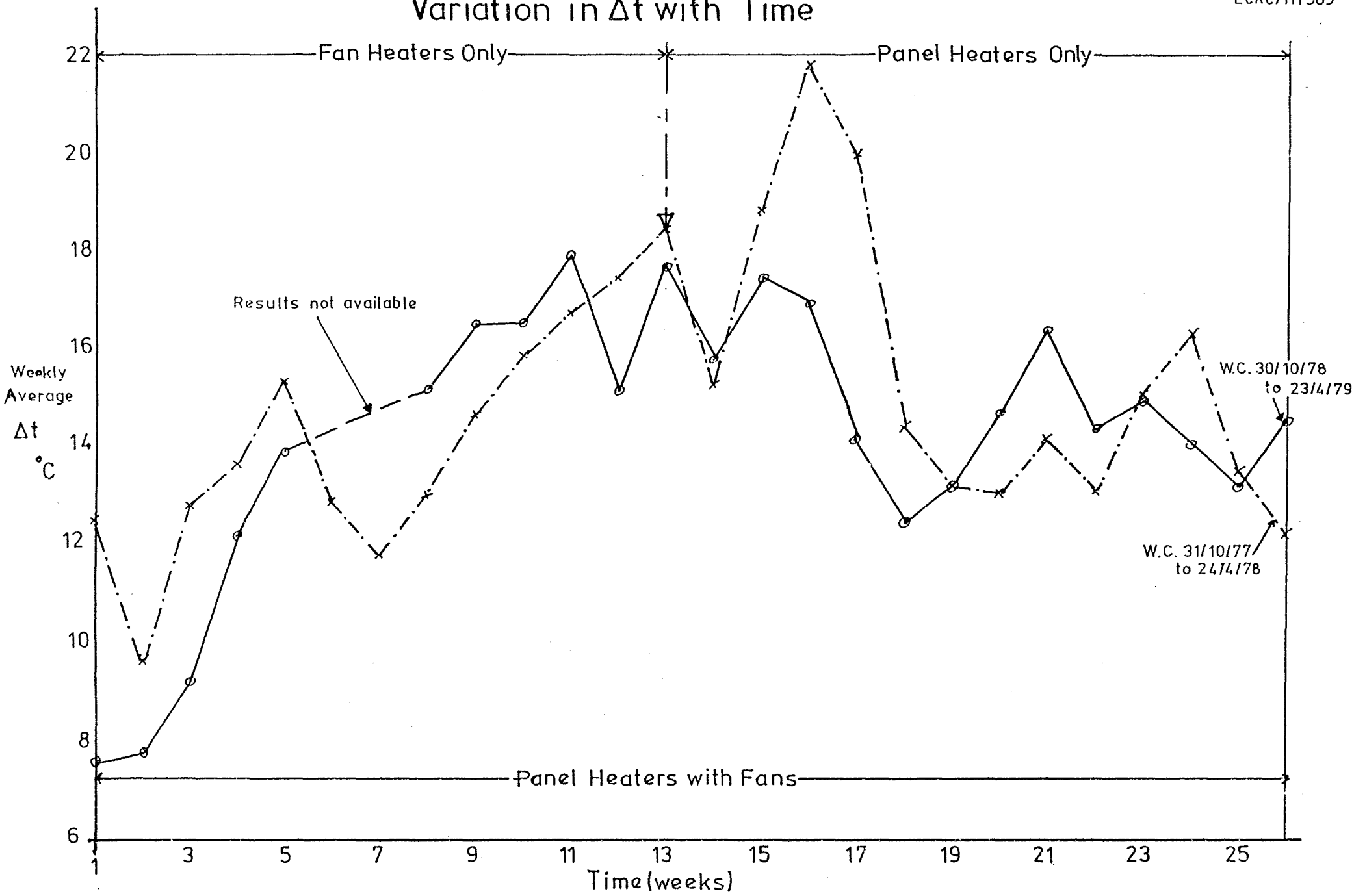

APPENDIX I

Theoretical Ventilation and Fabric Heat Loss

Ventilation Heat Loss

From 1970 IHVE Guide Book A, Section 4, Paragraph 14.

Ventilation loss $qv = 0.33\ N \quad W/m^3\ °C$ (1)

where N is rate of air change/hour

From (1) Ventilation heat loss expressed in kWh/day

$$\frac{0.33N \times \Delta T \times 24 \times Vm}{1000}$$

where Vm is house volume in m^3

simplified $\frac{N\ \Delta t\ Vm}{126}$ kWh/d

House volume (excluding front porch and w.c.) = 263 m^3

∴ Ventilation heat loss is 2.09 kWh/°C/day for 1 ac/h

Fabric Heat Loss

To determine U values

$R = \frac{L}{k}$ where R = thermal resistance $m^2\ °C/W$

L = thickness of slab m

k = thermal conductivity $W/m°C$

and thermal transmittance $U = \frac{1}{R} \quad W/m^2°C$

The wall ceiling and floors are not simple elements consisting of parallel slabs of material, but are bridged at intervals by a dissimilar material. It is therefore necessary to calculate a composite value of thermal resistance (R). The composite value is obtained by calculating a value of thermal resistance (R') for one portion of the structure and another value (R") for the other portion of the structure. The values obtained are then combined in proportion to their relative areas. The method is fully described in IHVE Guide (1970), Book A, Page A3-8 under the heading 'Heat Bridges'.

Allowing for timber occupying 12.5% of area

then $R' = 3.84$ and $R'' = 0.26$

Composite value of $R = R' + R''$

$\therefore R = 3.84 + 0.26 = 4.1\ m^2°C/W$

$\therefore U = \frac{1}{4.1} = 0.24\ W/m^2°C$

Floor

	L	k	R'	R''
Chipboard	0.021	0.15	0.14	0.14
Insulation	0.15	0.039	3.85	-
Board	0.004	0.13	0.03	0.03
Timbers	0.2	0.13	-	1.55
Air space			0.18	0.18
			4.20	1.89

Allowing for timbers occupying 12.5% of area

then $R' = 3.68$ $R'' = 0.24$

Composite $R = 3.92\ m^2°C/W$

From IHVE A3.18 Basic thermal resistance $R_B = 1.27\ m^2°C/W$

$\therefore U = \frac{1}{R + R_B}$

$U = \underline{0.19\ W/m^2°C}$

Windows

From 1970 IHVE Guide Book A Section 3 Table 22

$U = 2.5\ W/m^2°C$

Fabric Heat Loss $Q = u.A.\ \Delta t$ Watts

where A = area of respective surfaces in m^2

	U	A	
Windows	2.5	11.0	= 27.6 Δt
Walls	0.32	129.0	= 41.3 Δt
*Floor	0.19	51.4	= 9.8 Δt
Roof	0.24	52.6	= 12.8 Δt
	Total heat loss		= 91.5 Δt watts

Theoretical Fabric Heat Loss = 2.2 kWh/°C day

*excluding front porch and w.c.

APPENDIX II

Estimation of Solar Heating

The daily aggregate of insolation radiant on a horizontal surface is converted to radiation incident on a vertical surface using Basnett's curves. The daily value is located, taking time of year into consideration, on the curves and the vertical energy in kWh/day estimated. The solar heat gain through the fabric in question, in this case the glazing, is then calculated making allowances for transmission coefficients and areas. This procedure is repeated for each orientation of the vertical surfaces being examined. The solar heat gains, through each surface, are then added to provide an estimate of total solar heating through the glazing.

APPENDIX III

Statistical Analysis of Results : J.F. Waddington

Panel Heaters

Estimate of variance about regression line

$= (1 - v^2)s_o^2$

$= 0.163167$ with 13 d.f.

Estimate of variance about regression line for panel heaters and fans

$= (1 - v^2)sy^2$

$= 0.044627$ with 27 d.f.

Variance ratio $F = \frac{0.163167}{0.044627} = 3.66$ with 13 and 27 d.f.

$F_{5\%} = 2.105$

$F_{1\%} = 2.88$

$\therefore$ Variance ratio of 3.66 is highly significant

Conclusion

The variance about its regression line for the panel heaters is significantly greater than for the panel heaters and fans. It is very unlikely that the panel heater data was drawn from the same population.

Fan Heaters

Variance about regression line $= (1 - v^2)s_y^2 = 0.05598$ with 7 d.f.

$\therefore$ Variance ratio $= \frac{0.05598}{0.044627} = 1.25$ with 7 and 27 d.f.

$F_{5\%} = 2.37$

$F_{1\%} = 3.39$

$\therefore$ Variance ratio not significant

This makes further tests worthwhile

(a) significance of regression coefficient

(b) significance of mean deviation from line.

(a) Significance of Regression Coefficient

This is tested using the student statistic

$$t = (b - \beta)\frac{s_x}{sy}\sqrt{\frac{N-2}{1-v^2}}$$

$$= (0.279874 - 0.133017) \times \frac{0.663248}{0.300734}\sqrt{\frac{6}{0.619}}$$

$= 1.008$ with 6 d.f.

$t_{5\%}$ = 1.943

$t_{1\%}$ = 3.143

$\therefore$ t not significant.

(b) Mean Deviation From Line

Mean deviation of fan heater points from the line of panel heaters and fans is - 0.0843196

The standard deviation is 0.255874.

Again the test uses student t statistic

$$t = \frac{\bar{x}\sqrt{v}}{s}$$

$$= \frac{-0.0843196}{0.255874}\sqrt{7}$$

$$= 0.87 \text{ with } 7 \text{ d.f.}$$

$t_{5\%}$ = 1.895

$t_{1\%}$ = 2.998

$\therefore$Value of t not significant

Conclusion

There is no significant difference between the fan heater data and the panel heater and fans either in speed, slope or mean deviation from the line.