CI/SfB
UDC

branz

BUILDING RESEARCH ASSOCIATION OF NEW ZEALAND

REPRINT No. 8 AUGUST 1978

HEATING ENERGY NEED IN HEAVY AND LIGHTWEIGHT HOUSES

PRESENTED AT: N.Z.I.E. ANNUAL CONFERENCE, FEBRUARY 1977.

42 Vivian St., Wellington,1 – P.O. Box 9375 – Tel. 851479 – Teleg. BRANZ

1. INTRODUCTION:

In 1974 the N.Z. Energy Research and Development Committee awarded a research contract to the Building Research Association of New Zealand, for a study into the effects of building mass on the space heating energy requirements of domestic buildings. This study was completed and the report published in 1976 (see Ref.1).

The following gives a summary of the principal results and conclusions only, and does not attempt to detail or justify the method of analysis. For that information reference must be made to the original paper. Graphs and tables which are reproduced here from the original paper, are given under their original references* (excepting Fig.1 which does not appear in Report R17 but uses data from it).

This study differed fundamentally from previously reported ones which have examined the effect of thermal mass. Those earlier studies have shown that both plant requirements and peak energy rate (power) requirements can be reduced by the addition of mass. In contrast, this study examines the long term energy requirements, and the way in which this is affected by mass.

* The tables and figures so included are:-

Tables	Figures
1	5
3	11
4	12
	17
	18
	19
	B-1
	B-2

2. Outline of Method:

2.1 Calculation Procedure:

The method used was an hour-by-hour computer analysis of a house utilizing a number of different combinations of wall and roof constructions. The best modern methods of computer analysis for this purpose have been adequately validated in overseas studies, by comparing computer predictions with observed building behaviour. One such computer program is SUSTEP, developed by the Division of Building Research CSIRO Melbourne, and this was kindly made available by the Director of DBR, and used to carry out this project.

The program requires a comprehensive file of the complete hour-by-hour weather details for an extended period. For this study, climatic data files (called CLIMDATA) were established for a 5 year period from 1969 to 1974, for 4 New Zealand urban centres, Auckland, Wellington, Christchurch and Invercargill. The files contain complete hour-by-hour records during this period of:-

Air dry bulb temperature;
Relative humidity;
Wind speed;
Wind direction;
Direct solar radiation on a horizontal surface;
Direct solar radiation normal to solar beam;
Diffuse solar radiation on a horizontal surface;
Cloud cover.

During analysis, the computer is required to calculate using this data and any stated indoor conditions, the temperatures, heat flow and heat storage in all walls, windows, roof, and floor and ventilation. The results are stored, totalled, etc., for later printout.

2.2 Buildings Examined:

The full details of buildings examined are not given here, but an indication is given in Table 1. They included both lightweight and heavy weight walls, with and without additional insulation in various quantities and locations within the walls, and both lightweight and heavy weight roofs with and without insulation. A single building plan, a single glazing plan, and slab-on-ground floor were adopted. For certain analyses the thermal capacitance of materials was varied from the normal value, in order to reveal the influence of thermal capacitance more decisively.

2.3 Heating Levels:

Three heating levels were considered, to represent the sensitivity of heating energy to a chosen level. The 3 levels were:-

a) Continuous heating to 20^{0}C;

b) Intermittent heating, evenings only.
The buildings were heated to 22^{0}C from 4-11 pm daily and unheated during the rest of the day.

c) "Unheated".
In this case the buildings were heated only by the coincidental effects of (e.g.) cooking , lights, occupants, T.V. and sunshine.

In cases (a) and (b) the heating energy required was calculated, whilst in case (c) the resulting indoor temperatures were found.

3. Results:

The principal results of this study are given in the attached tables and graphs, and discussed below:-

3.1 Year-to-Year Variation:

The year-to-year variation in heating energy requirement is approximately:-

Mangere	±	11%
Kelburn	±	8%
Christchurch	±	6%
Invercargill	±	4%

The average relative energy demand for the particular intermittent heating regime used here was 60% that for continuous heating. Other intermittent heating regimes could lead to either higher or lower demand (See Fig. 5).

The average effect of an insulation program, taking an uninsulated building as a reference, was:-

	Relative heating energy required	
Uninsulated	1.0	
Roof insulated	0.52	
Roof & walls insulated	0.35	(See Fig. B1&B2)

3.3 Effects of Thermal Capacitance:

The thermal capacitance of a building increases with its mass. The annual heating energy requirements differs according to the heating regime adopted. For continuous heating, extra mass is an advantage but for intermittent heating the mass is a disadvantage except in the northern-most climate of Mangere.

By far the greatest effective contribution to building mass is provided by the floor and ground. The walls and roof provided a further but much smaller effect. The relative savings, taking zero mass as a reference are typically:-

(See Figs 11 and 12)

	Continuous Heating		Intermittent Heating	
	FLOOR/GROUND	WALLS & ROOF	FLOOR/GROUND	WALLS & ROOF
MANGERE	35%	18%	14%	8%
CHRISTCHURCH	14%	5%	-26%	-3%

In this Table, the annual heating energy requirement for a concrete floor, concrete masonry building with normal mass in the floor, (or wall + roof) is compared with that for the same building and location but with zero mass. It is evident that the addition of mass has resulted in significant energy saving in most instances.

It must be noted that this Table compares a "heavy" building with a mass-less building, not with a "light" building. Lightweight buildings also exhibit some thermal storage. As is demonstrated in Fig 5 and Table 1, the heating energy required for both lightweight and heavyweight buildings is very much in line with their respective overall conductances. The differences in heating energy needs between "light" and "heavy" walls is equivalent to about 3-6% in building conductance (insulation or 'U' value), to the advantage of mass in continuous heating, but to the disadvantage of mass for intermittent heating (except in Mangere where the effect is neutral.

The difference is greater in the case of heavyweight roofs, but is also dependent on the location of the insulation. With an externally insulated roof, the addition of mass can reduce heating energy by 2-6% for continuous heating, but increase it by 4% in Christchurch and 16% in Mangere for intermittent heating. For internally insulated roofs the effect of mass will be smaller.

3.4 Insulation of heavyweight walls:

The effect on annual heating energy requirement, of adding various amounts of insulation to the concrete masonry walls of a house with an insulated lightweight roof, is shown in Fig. 17. Following the pattern of 3.3, the saving is greater when the insulation is external for continuous heating, and greater when the insulation is internal for intermittent heating.

Insulation Thickness	Continuous Heating	Intermittent Heating
	Average Saving	
25 mm	31%	23%
65	40%	31%
100	42%	33%

It should also be noted (from Table 1) that the reduction in heating required is rather greater than proportional to the reduction in conductance.

3.5 Effect of Sunshine:

In course of the project opportunity to examine the contribution of sunshine was taken. This was effected simply by defining solar radiation equal to zero, and will indicate the extreme difference between fully sun-exposed sites and totally shaded ones.

The effects found were great, and are illustrated in Table 3. The absence of sunshine adding to the heating requirements from 50% to 130%.

3.6 Effect of Windows:

The effect of windows was examined for Mangere and Christchurch climates, by repeating analysis and defining window area to be nearly zero. The result of so doing is shown in Table 4.

It will be seen that in Mangere the presence of windows almost always gave an energy advantage, in spite of a 30% increase in overall conductance. In Christchurch the presence of windows had virtually no effect in intermittent heating, and was a disadvantage in continuous heating. The disadvantage was however still very much smaller than suggested by the overall conductance, especially in the heavy building.

3.7 Temperatures in "Unheated" buildings:

As a means of examining the native behaviour of the various building types, the indoor temperatures of buildings subject only to climate and sunshine, and to the casual heat release of occupants by cooking, lights, etc., were examined.

The results of this are shown in histogram form in Figs 18 and 19. The average indoor temperature is typically 4°C warmer than average outdoor temperature. The buildings with windows have slight advantage over those without, and the lightweight buildings have a slight advantage over heavyweight, in the sense of being warmer more often than they are colder.

CONCLUSIONS

These results demonstrate several important conclusions on the heating energy needs of housing units in N.Z.:

- the thermal mass effects of a building do influence the space heating energy requirements, although the influence is small compared with other effects of insulation, climate, heating regimes, etc.

- the effect of mass is to reduce heating energy demand in continuous heating, but to increase it in intermittent heating.

- the effect of the mass of slab-on-ground floors far outweighs that of likely walls or roofs.

- the effects of sunshine on heating energy needs is very large.

REFERENCES

S. Leslie	Annual heating demand of heavy domestic buildings. N.Z. Energy Research & Development Committee Report No.16 Auckland (also as BRANZ Report R17). 1976
S. Leslie & H. Trethowen	A computer file of New Zealand climate. N.Z. Energy Research & Development Committee Report No.21 Auckland (also as BRANZ Report P14). 1977

TABLE 1 ANNUAL HEATING ENERGY REQUIREMENT IN GIGAJOULES.

BLDG NO. DESCRIPTION	1 Totally insulated Timber Frame		2 Uninsulated Timber Frame		3 Insulated roof Uninsulated Conc Block Wall		4 Insulated Roof Int. Ins Conc Block Wall		5 Ext. ins. precast roof. Ext. ins. Conc. block wall		6 Ins. roof Ext. ins conc block Wall.		7 Roof Insulated Timber Walls uninsulated		8 Roof uninsulated Conc blk walls uninsulated.	
HEATING REGIME	20^0C	INTER	20^0C	INTER	20^0C	INTER	20^0C	INTER	20^0C	INTER	20^0C	INTER	20^0C	INTER	20^0C	INTER
MANGERE	18.0	10.7	68.1	34.4	33.5	20.5	20.3	12.5	17.4	16.0	18.5	14.4	31.7	18.0	70.9	37.3
KELBURN	46.9	30.0	140.1	73.9	79.7	49.4	53.2	33.6	47.6	44.5	51.0	37.7	73.1	43.7	146.3	78.9
CHRIST-CHURCH	64.8	38.0	173.1	80.3	103.2	57.9	71.8	41.8	67.1	56.7	69.9	47.2	94.8	51.0	179.4	86.3
INVERCAR-GILL	78.2	46.4	200.5	94.3	124.1	70.6	86.9	51.3	83.2	70.0	85.3	57.8	112.9	61.6	210.3	102.5
AVERAGE	52.0	31.3	145.4	70.7	85.1	49.6	58.1	34.8	53.8	46.8	56.2	39.3	78.1	43.6	151.7	76.2
BLD CONDUCT IN WATT/K	513		969		698		554		561		554		642		1026	
BLDG CAPAC MJ/K	656		661		677		683		704		683		661		677	

TABLE 3 THE EFFECT OF SOLAR RADIATION ON HEATING ENERGY REQUIREMENT FOR AN UNINSULATED CONCRETE BLOCK BUILDING IN AN INTERMITTENT HEATING REGIME GJ (see page)

	MANGERE	KELBURN	CHRISTCHURCH	INVERCARGILL
RADIATION INCLUDED	20.5	49.4	57.9	70.6
RADIATION EXCLUDED	47.8	85.0	86.4	104.0
RADIATION/RADIATION EXCLUDED/INCLUDED	2.34	1.72	1.49	1.47

TABLE 4 THE EFFECT OF REMOVING WINDOWS ON ANNUAL HEATING REQUIREMENT IN GIGAJOULES.

	MANGERE				CHRISTCHURCH			
BLDG NO.	1		5		1		5	
DESCRIPT-	Roof Timber Wall Timber	Frame Insulated Frame Insulated	Roof Concrete Wall Concrete	Insulated Block Ins.	Roof Timber Wall Timber	Frame Insulated Frame Insulated	Roof Concrete Wall Concrete	Insulated Block insulat
HEATING REGIME	20°C	INTER	20°C	INTER	20°C	INTER	20°C	INTER
WINDOWS	18.0	10.7	17.4	16.0	64.8	38.0	67.1	56.7
NO WINDOWS	16.8	14.1	19.7	23.4	50.4	36.5	59.5	56.2
ADVANTAGE OF WINDOW PRESENCE	-1.2	3.4	2.3	7.4	-14.4	-1.5	-7.6	-.5
RELATIVE ADVANTAGE OF WINDOW PRESENCE	-7.1%	24.1%	11.7%	31.6%	-28.6%	-4.1%	-12.8%	-1%
NORMAL W/K BUILDING CONDUCTANCE	513		561		513		561	
NO WINDOW BUILDING CONDUCTANCE	356		405		356		405	
RELATIVE DECREASE	30.6%		27.8%		30.6%		27.8%	

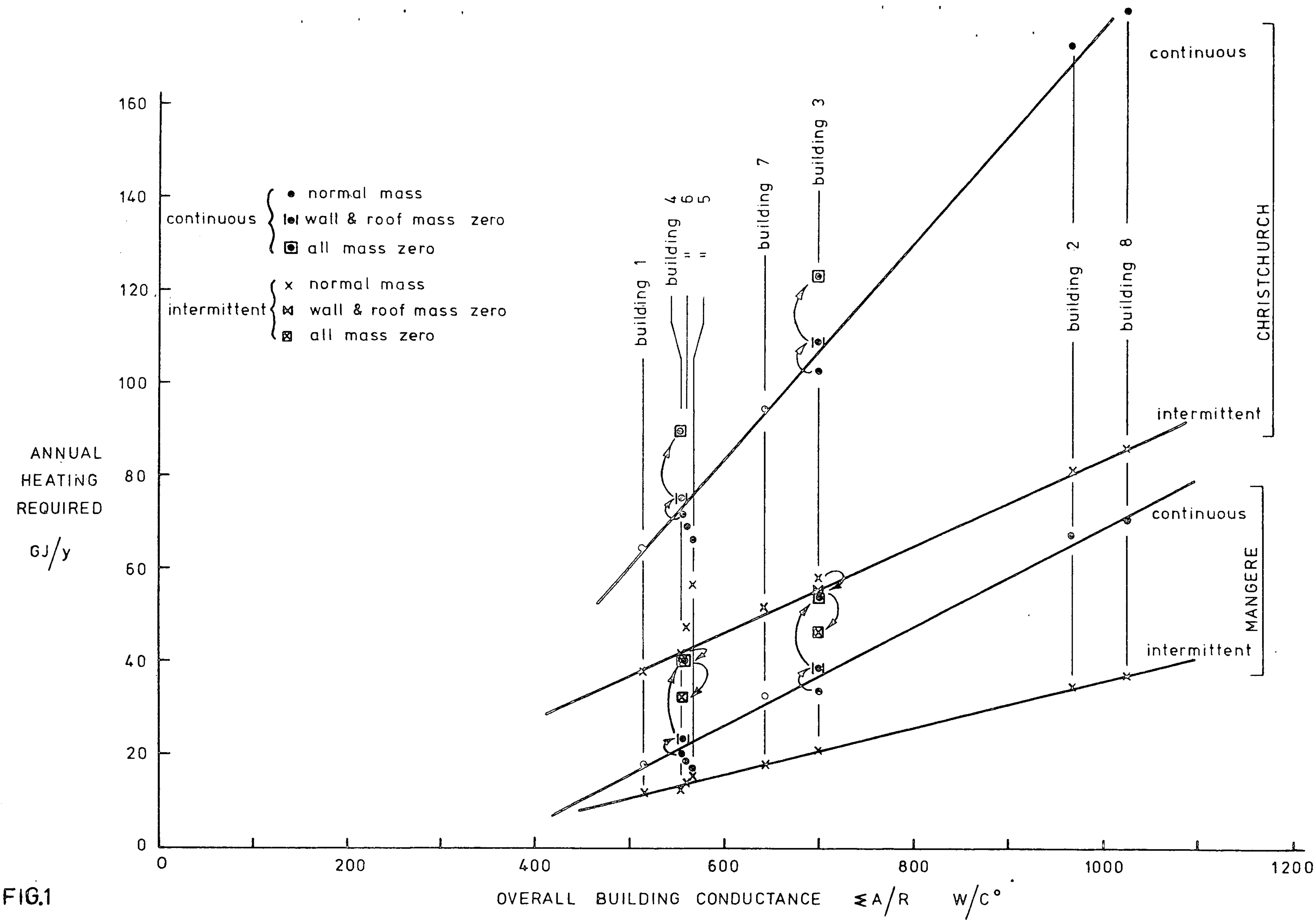
ANNUAL
HEATING
REQUIRED
GJ/y
0
20
40
60
80
100
120
140
160
0
200
400
600
800
1000
1200
OVERALL BUILDING CONDUCTANCE ΣA/R W/C°
continuous
normal mass
wall & roof mass zero
all mass zero
intermittent
normal mass
wall & roof mass zero
all mass zero
building 1
building 4
" 6
" 5
building 7
building 3
building 2
building 8
continuous
intermittent
CHRISTCHURCH
continuous
intermittent
MANGERE

FIG.1

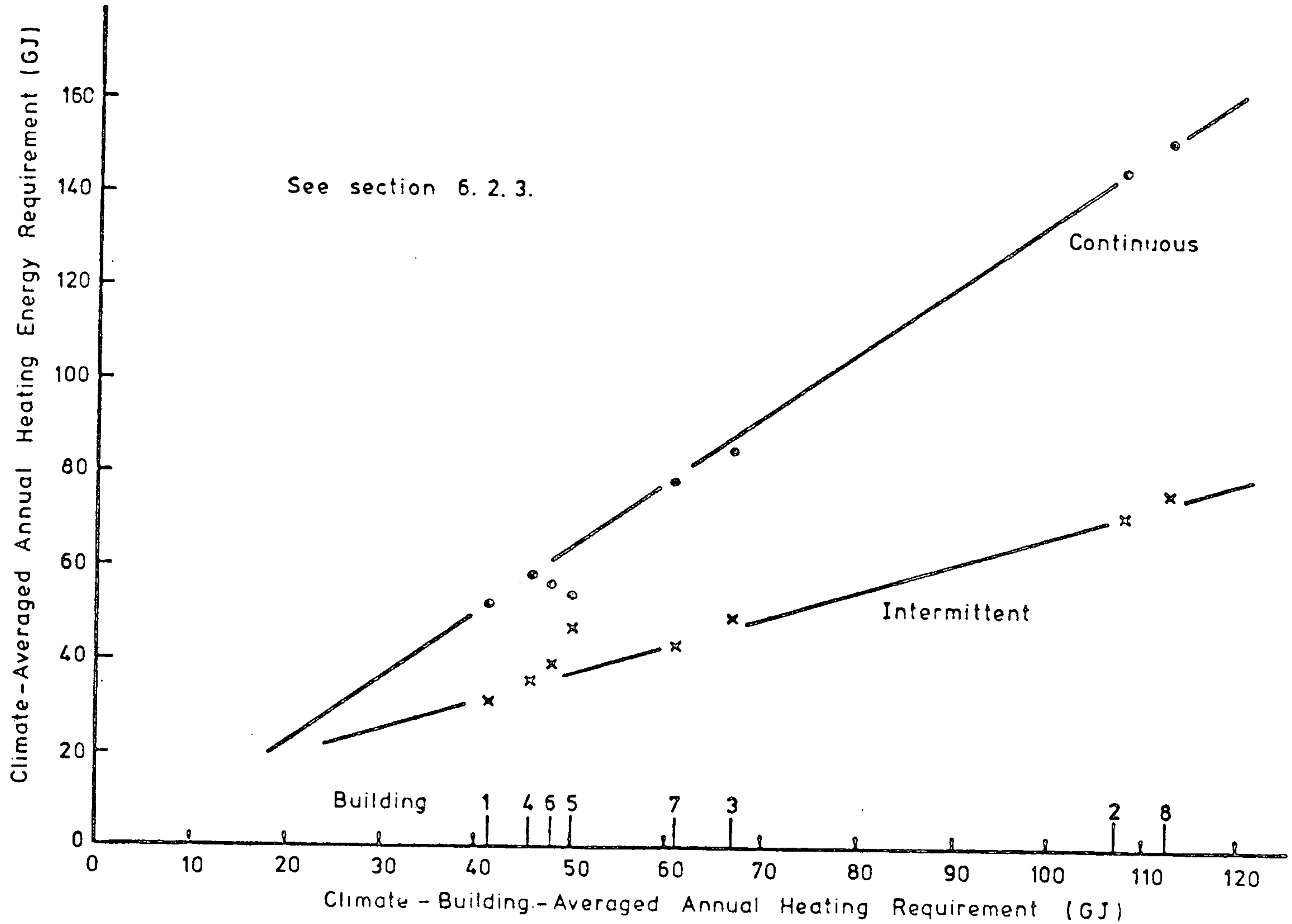

FIG. 5 EFFECT OF HEATING REGIME ON BUILDING HEATING REQUIREMENT

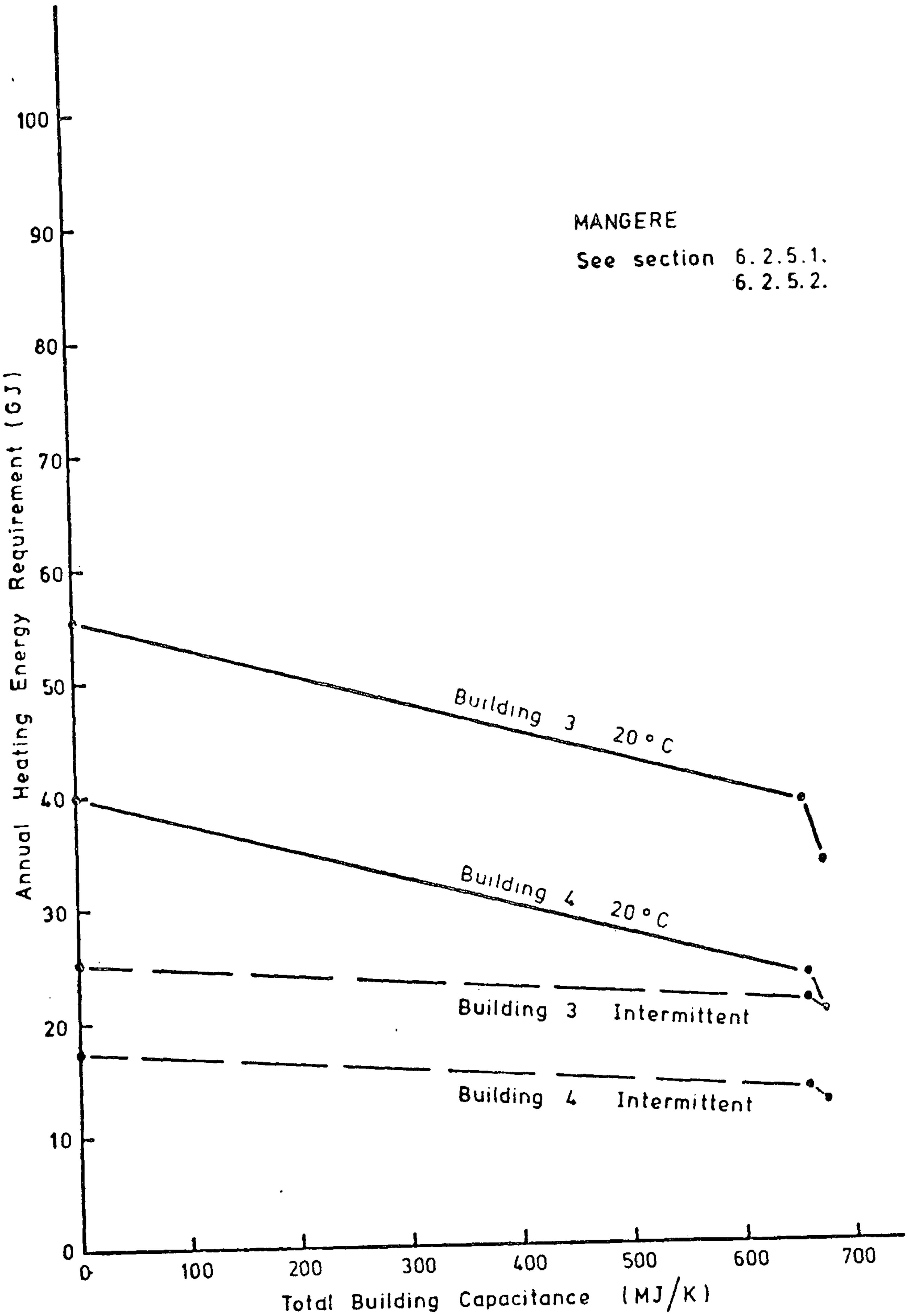

FIG. 11 EFFECT OF BUILDING CAPACITANCE ON ANNUAL HEATING ENERGY REQUIREMENT FOR MANGERE

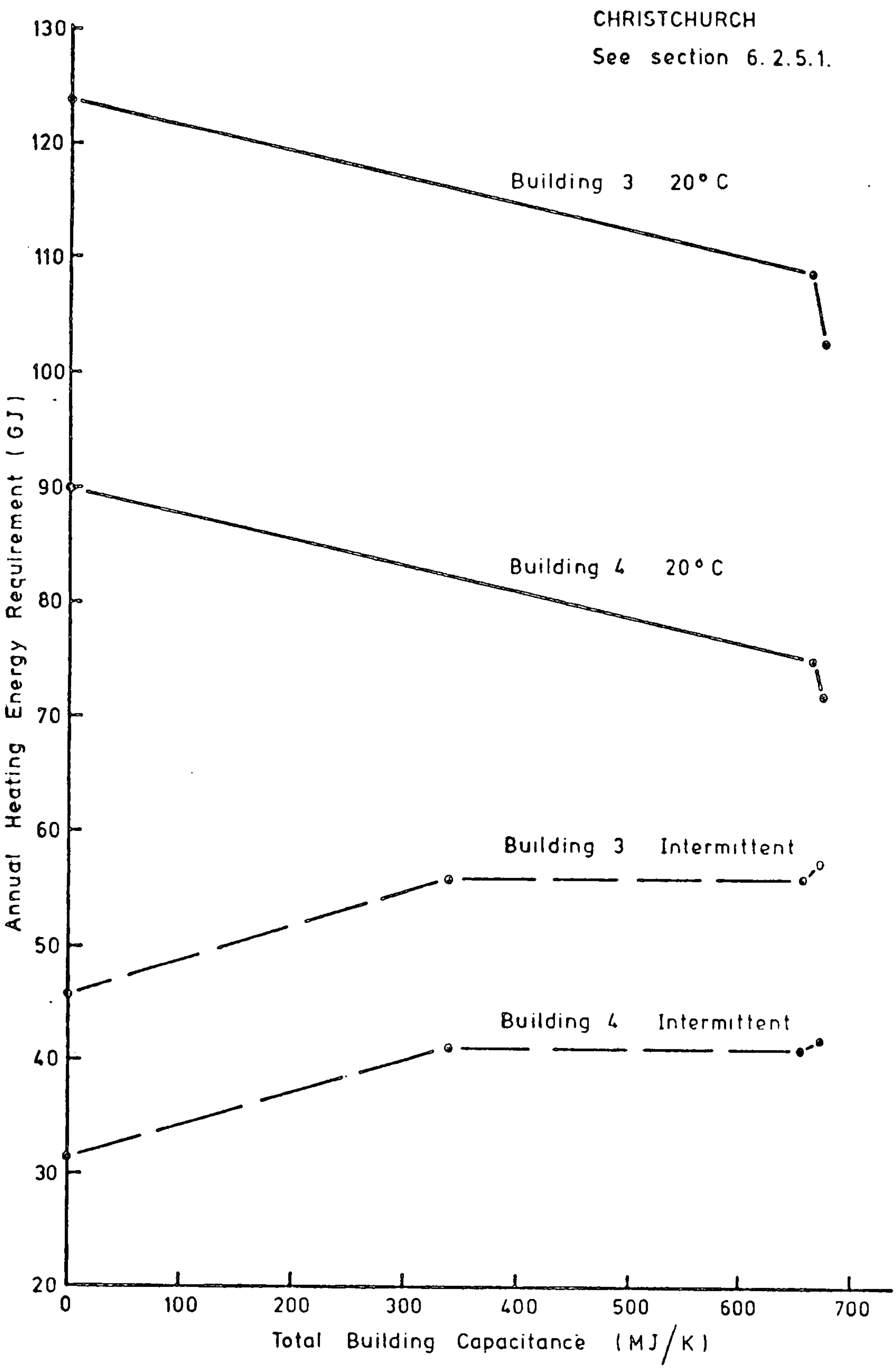

FIG. 12 . EFFECT OF BUILDING CAPACITANCE ON ANNUAL HEATING ENERGY REQUIREMENT FOR CHRISTCHURCH

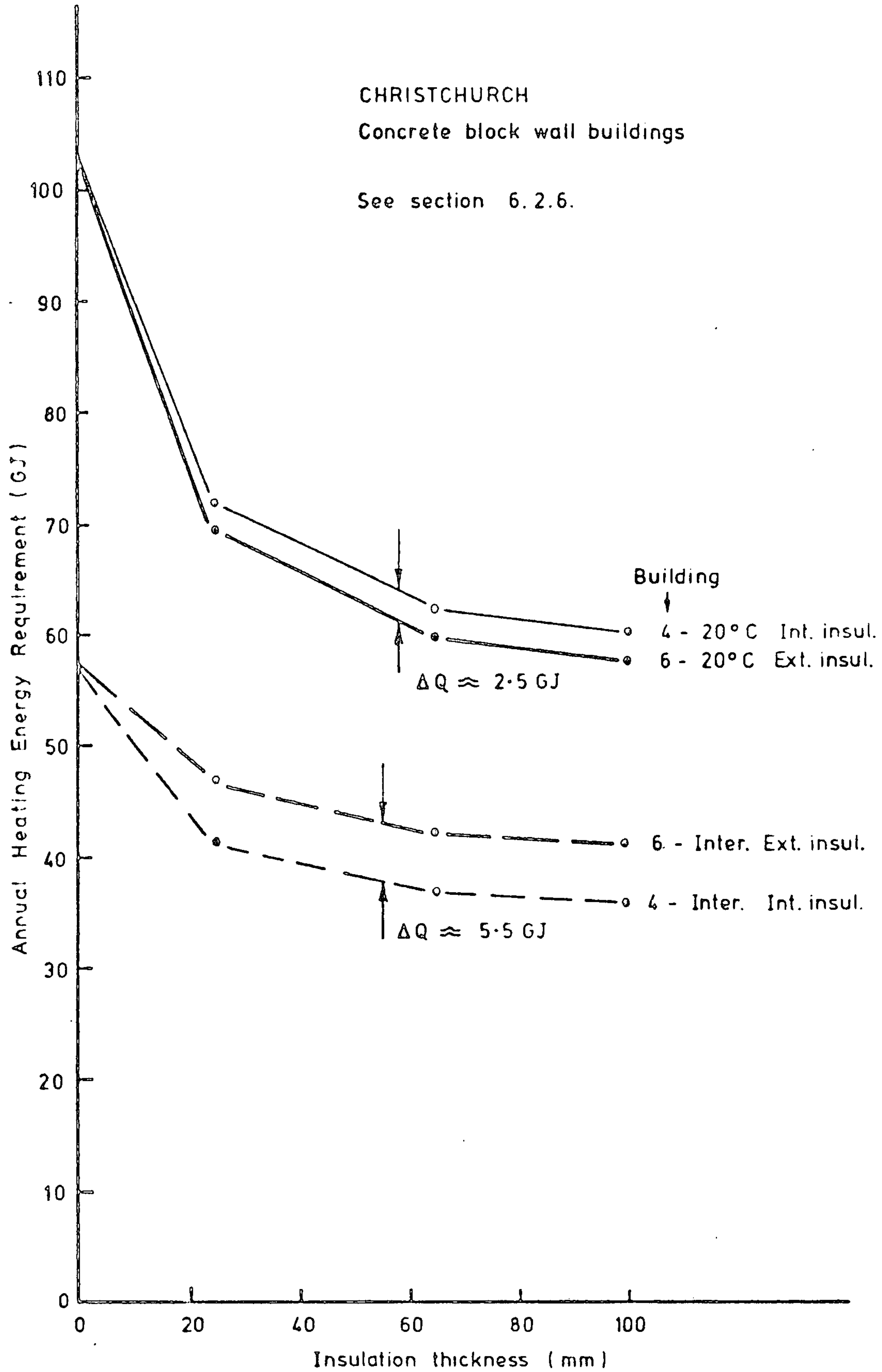

FIG. 17 EFFECT OF THERMAL INSULATION THICKNESS AND ORDER ON ANNUAL HEATING ENERGY REQUIREMENTS OF HEAVY BUILDINGS

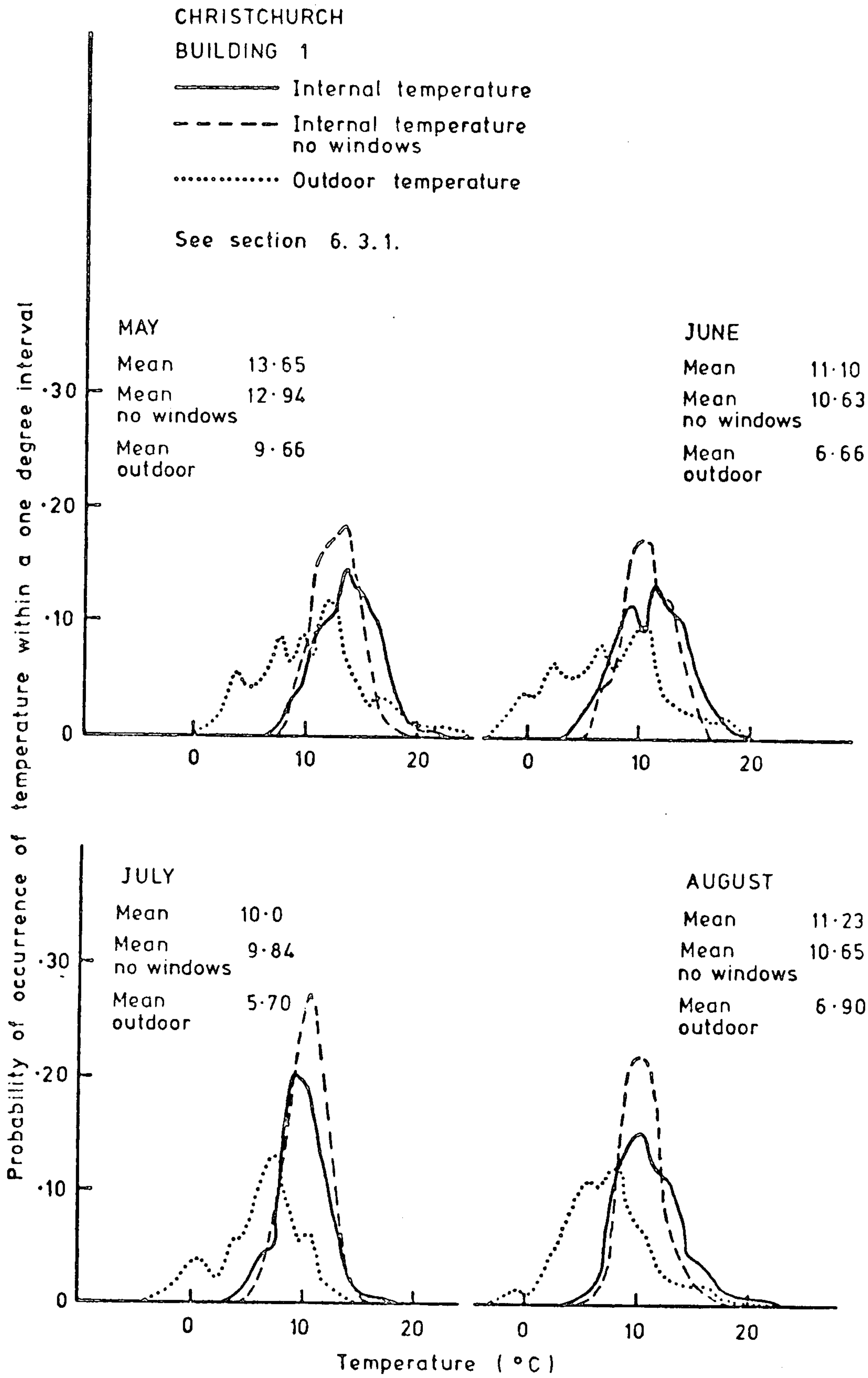

FIG. 18 MONTHLY INDOOR TEMPERATURE DISTRIBUTION FOR BUILDING 1 FOR CHRISTCHURCH

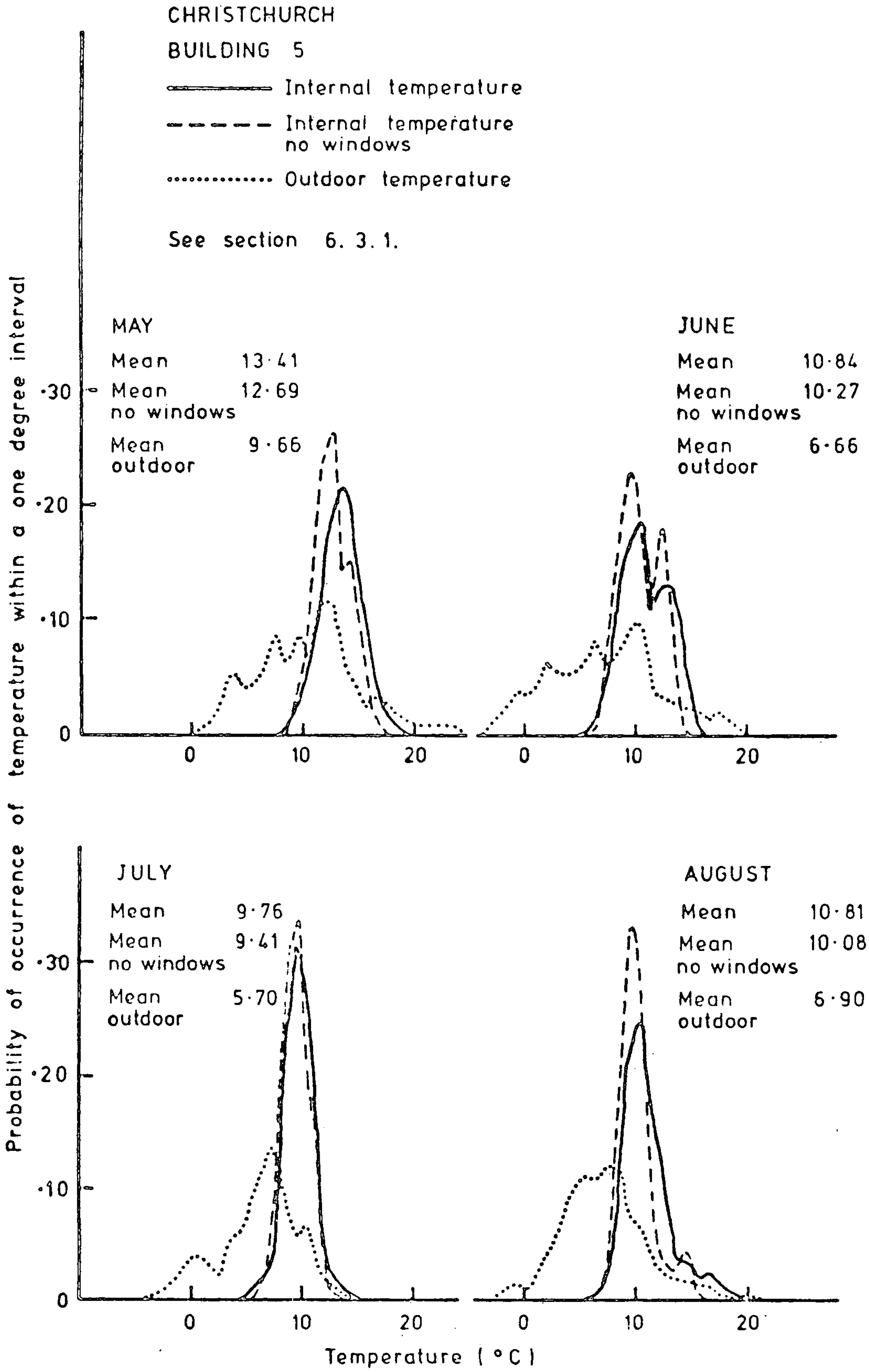

FIG. 19 MONTHLY INDOOR TEMPERATURE DISTRIBUTION FOR BUILDING 5 FOR CHRISTCHURCH

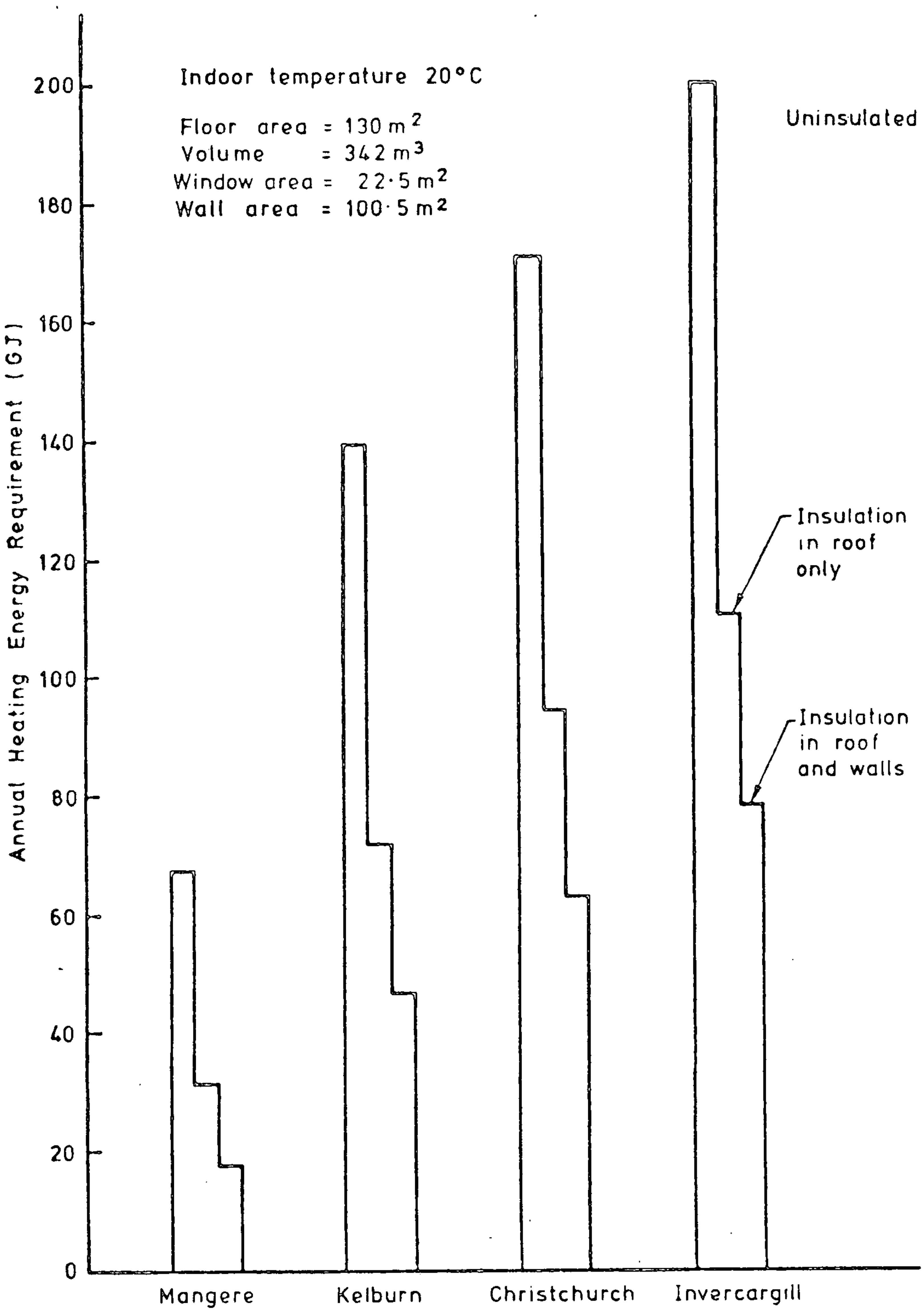

FIG. B-1 EFFECT OF ADDING 65mm OF FIBREGLASS INSULATION TO THE ROOF AND WALLS OF AN UNINSULATED TIMBER FRAME HOUSE.

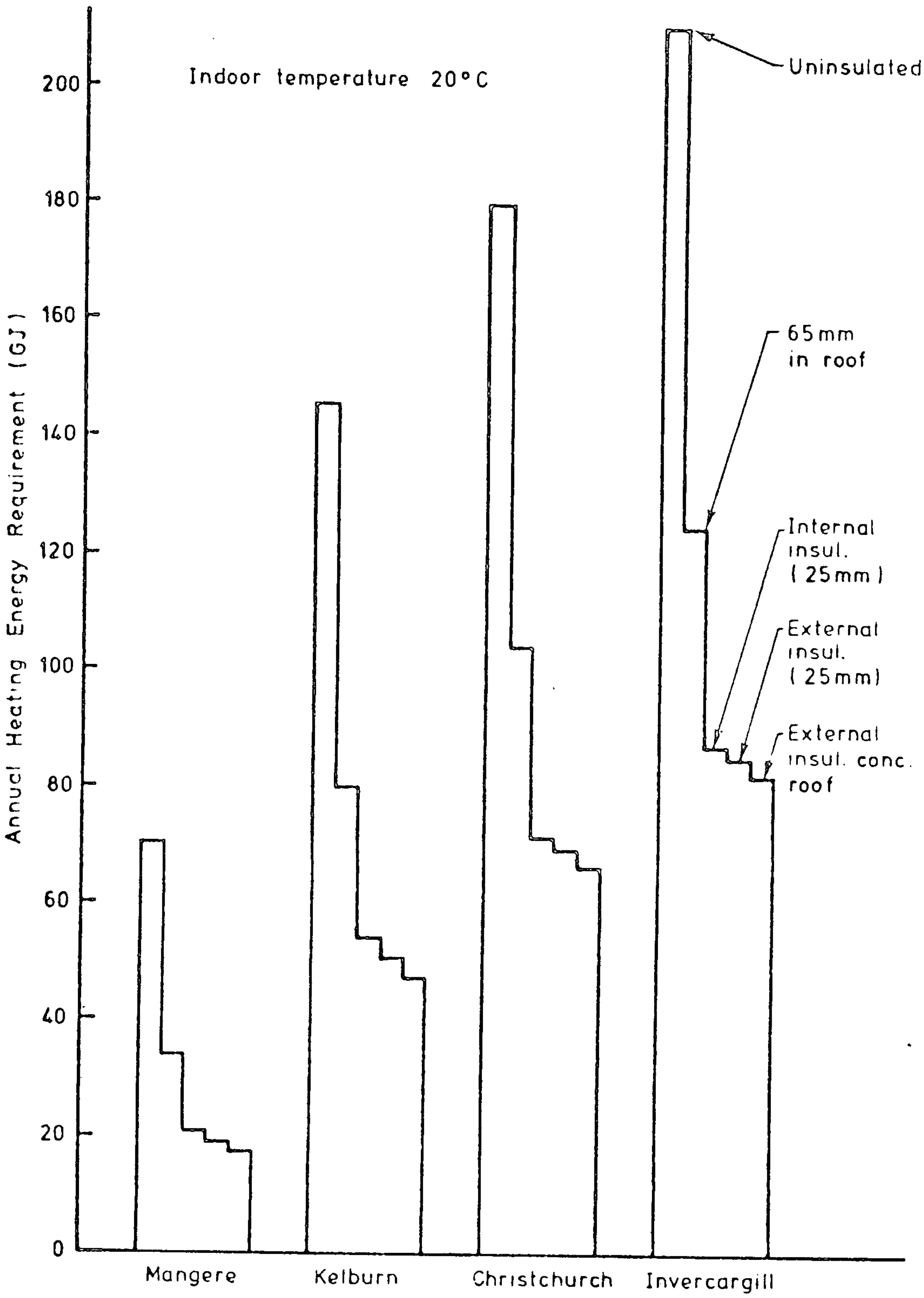

FIG. B-2 EFFECT OF ADDING INSULATION TO THE ROOF (65 mm) AND WALLS (25 mm) OF AN UNINSULATED CONCRETE BLOCK HOUSE