SEN 741

Building Technology

CSIR

REPRINT

R/BOU 538
1974

Building design for the Rhodesian climate

J F van Straaten
F J Lotz

Paper presented at Symposium: Design of
Buildings for Rhodesian Climate
October 1974

Published by the Division of Building Technology · P O Box 395 · Pretoria · South Africa · Tel. (012) 841 3871

PAPER PRESENTED AT SYMPOSIUM: DESIGN OF BUILDINGS
FOR RHODESIAN CLIMATE

October 1974

BUILDING DESIGN FOR THE RHODESIAN CLIMATE

by

VAN STRAATEN JF and LOTZ FJ

ABSTRACT

The need for conserving energy is emphasised. Recommendations are made to ensure the best thermal performance under the relevant climatic conditions. Several construction methods are discussed against a thermal comfort scale for housing.

BUILDING DESIGN FOR THE RHODESIAN CLIMATE

by
J.F. van Straaten[x] and
F.J. Lotz[xx]

SYNOPSIS

The need for conserving energy in building and the building process is emphasized.

The climate of Rhodesia is briefly reviewed and design precautions to ensure the best thermal performance under the relevant climatic conditions are highlighted.

Finally, the thermal performance characteristics of several different methods of construction currently in use in Rhodesia are compared against a thermal comfort scale for housing.

INTRODUCTION

With the ever-increasing cost of energy, the time has come for the building industry to initiate drastic conservation measures. It is a question of looking not only at initial capital layout and the energy investment in the manufacturing and handling of materials but also at the running costs required to maintain structures and acceptable indoor living environments. Although it is true that scientifically valid answers have still to be found on many aspects of energy use and conservation in buildings, it is equally true that much can already be achieved by judicious application of existing knowledge.

Conserving energy in the actual building process generally means using lighter components. The population explosion, too, means that we shall have to make wider use of industrialized building techniques and these also favour lightweight components. On the other hand, effective natural control - as compared with control by air-conditioning - of indoor environment in warm arid climates can only be achieved by using heavyweight components and by taking the utmost care in design and planning.

This paper sets out to highlight some of the design precautions and to compare the relative thermal performance of different methods of construction in the context of the climate of Rhodesia.

CLIMATE OF RHODESIA

The month-by-month average variations in temperature of five different stations are compared in Figure 1.[1] The thick black vertical columns reflect the mean daily temperature fluctuations for the different months whilst the mean annual temperature is given by the solid horizontal line. The curve through the midpoints of the columns represents the annual variation of the daily mean temperature. The extreme upper and lower curves give the highest and lowest recorded temperatures and the two curves on the inside of these indicate the mean monthly maximum and minimum temperatures for each month.

As in South Africa, there is less cloud cover during the winter months and this causes an increased daily temperature range during these months. Although the daily and annual variation of mean temperature change from station to station, October appears to be the warmest month of the year throughout Rhodesia. For

---

[x] Head, Environmental Engineering Division, National Building Research Institute, CSIR, Pretoria.

[xx] Chief Research Officer, National Building Research Institute, CSIR, Pretoria.

stations south of 23°S December/January is generally the warmest period of the year.

However, for building design purposes the weather data discussed so far are inadequate. Under conditions of relatively large daily fluctuations in air temperature and high solar radiation intensities, we require design data derived from hourly records taking account of the probabilities of occurrence of various combinations of the relevant weather elements as they actually occur. Design data of this nature have already been determined for 13 stations in Rhodesia. Some of the more pertinent design parameters extracted from this data are compared in Table 1. It appears from a study of these parameters and more detailed information that the country can be roughly divided into three climatic zones, shown in Figure 2, and described as:

a) A sub-tropical to tropical region where the summers are hot and the winters are mild to warm. This region includes the whole of the low-altitude area (i.e. below about 900 m). The main centres in this area are Kariba and Binga in the north-west and Buffalo Range in the south.

b) A relatively cool high-altitude region above about 1 500 m with Inyanga as focal point.

c) An intermediate altitude region between about 900 m and 1 500 m covering most of the central parts of the country where the summers are warm but not hot, and the winters mild.

Rhodesia generally has a favourable winter climate with warm to hot summers. It is therefore logical that the thermal design of buildings should be dictated by summer rather than winter requirements.

MAJOR THERMAL DESIGN CONSIDERATIONS

The thermal performance of a building is determined by a combination of factors including the insulating properties of the various elements comprising the structure, their ability to store heat, the heating effects of the sun and the ventilation rate.[2] For best thermal performance the following general rules will serve as a useful guide:

a) Limit the absorption of solar radiation of sunlit surfaces.
b) Limit the direct transmission of solar radiation through glazed and other openings.
c) Insulate elements, in particular elements with little mass such as roofs in order to increase their resistance to heat flow.
d) Utilize mass in the walls and/or floor to absorb and store heat during warm periods for heating during cooler periods.
e) Provide for sufficient ventilation for removal of heat during the day and for structural cooling purposes during the night.

a) Limitation of solar absorption of exposed surfaces

The absorption of solar radiation of sunlit surfaces can be greatly minimized by either shading such surfaces or painting them the lightest possible colours for maximum reflection of heat. In the case of a conventional 280 mm cavity brick dwelling in Pretoria it was found that the maximum indoor air temperature in summer could be lowered by between 3° and 4°C by painting the walls white.

b) Limitation of solar heat gains through windows

Solar heat gains through windows and other openings can best be controlled by correct orientation of such openings with respect to the sun, by limiting glass areas generally and/or by shading them externally.

The influence of orientation on indoor air temperature is brought out by measurements carried out in full-scale well-insulated timber dwellings in Pretoria.[3] On warm days the maximum indoor air temperature in the living room of a house facing east/west was on the average 5°C higher than the corresponding temperature in a similar room in a house facing north/south and also about the same amount higher than the maximum outdoor air temperature. Shading the windows of the east/west house externally brought the indoor temperatures down to more or less the same level as those in the north/south house.

There are basically four ways of controlling solar heat gains through windows. These are:

(i) the use of special glasses and glazing materials,
(ii) double-glazing techniques,
(iii) internal shading, and,
(iv) external shading.

A large variety of glazing materials and different methods of shading have already been evaluated under natural conditions of exposure in the solar calorimeter of the National Building Research Institute (NBRI) and the relative efficacies of some of the more commonly used methods are compared in Figure 3.[4]

From the diagrams it is clear that external shading, whether in the form of awnings and louvres or special reflecting glass shields, is the most effective because the solar radiation is intercepted before it reaches the glass. Heat-absorbing glass is not really effective as its temperature can be elevated to such an extent, depending on its tint or absorptivity for solar radiation, that it can become a directional longwave heat radiator itself. It is then also very often found that people working near to heat-absorbing glass - even in air-conditioned spaces - experience greater discomfort than their counterparts working some distance away from it.

Since shading is generally expensive, the first aim in design should be to limit the area of the glazing to the minimum required for daylighting and to orientate the building in such a way that the minimum amount of shading is required. In this respect the NBRI solar shadowscope[5] shown in Figure 4 can be usefully employed to make a visual study of sun and shade patterns on a building. All that is required is a model of the building, or part of it, and an adjustable table which can be tilted so that light from the sun or any other parallel beam light source casts shadows which can then be studied. The shadowscope itself can be adjusted to reproduce sunlight conditions for any pre-selected latitude, longitude, day of the year and hour of the day.

For Rhodesia it must be remembered that, as already indicated, maximum temperatures occur round about October when the sun has still not reached its highest noon altitude. Solar altitude and azimuth angles have been calculated for each month of the year for both Bulawayo and Salisbury. As an example the solar angles for June and October for the two centres are reproduced in Figures 5 and 6 respectively. Whilst the sun rises to something like 50 degrees above the horizon in mid-winter, it goes up to about 80 degrees in October. However, it is not only the noon altitudes that are important in the planning of shading but the sun angles during at least the warmest part of the day. In fact, cases have been investigated where the low northern sun in mid-winter was responsible for serious overheating. Large expanses of unprotected glass even in north-facing walls must therefore be avoided. In this respect it must be remembered that it is not always the direct rays of the sun that cause all the problems. Heat reflected from surrounding surfaces such as concrete paving in front of a window or glass door can also result in overheating.

c) Thermal insulation and shading of roofs

The importance of insulating and/or shading of roofs - and of lightweight roof elements in particular - cannot be overemphasized. On a warm summer's day roofs receive about twice as much solar energy per unit area as either an east or west wall. Roof temperatures of over 80°C are not uncommon in summer.

Roof insulation is not only required to reduce both heat gains in summer and heat losses in winter but also to eliminate the risk of discomfort associated with directional radiation from uninsulated roofs or ceilings.

The insulation can be in either mass or reflective form. The former, which should be equivalent to at least 40 mm thick mineral wool, includes such materials as glass fibre, slagwool, polyurethane and polystyrene. The plastic materials,however, have limitations when it comes to fire risk and spread of flame and noxious fumes.

In the case of conventional glavanized steel roof/ceiling combinations, insulation of this standard will reduce both downward heat gain and upward heat loss by something like 60 per cent.

Reflective insulation in the form of bright aluminium foil, if draped in such a way between the roof and ceiling that it forms two separate air spaces, with the lower air space not less than 100 mm thick, will be about equally effective as far as downward heat flow is concerned but only be about 50 per cent as effective in reducing night-time heat losses. This will be the case even if the upper surface of the foil gets covered with dust, which is inevitable in practice, provided the under-surface remains clean. Bright surfaces have the property that they are not only excellent reflectors of heat but that they are also poor emitters of heat. This makes reflective insulation eminently suitable for the warmer parts of Rhodesia where every possible means of cooling of structures at night in summer should be fully exploited to provide reasonable sleeping conditions. It is only in the high-altitude area where winter heating is required that mass insulation will be more advantageous in conserving energy. For this reason, too, lightweight roofs are preferable to heavyweight roofs practically throughout the territory.

Concrete roofs should have additional insulation. By applying the insulation on top it can serve the additional purpose of restricting thermal movements of the roof itself. The advantage of insulating concrete roofs in this way is illustrated in Figure 7.[4] The results reproduced in this figure were obtained in two similar test huts, 3 m square, built of 230 mm brick, one with an uninsulated concrete roof and the other with a concrete roof insulated with 25 mm thick compressed glass fibre. Whilst there was a continuous heat gain throughout the day from the uninsulated roof, there was a slight heat loss, at least during the warmest part of the day, through the insulated roof. Another important aspect brought out by these results is that the maximum heat gain from uninsulated heavyweight roofs of this type takes place in the late afternoon when indoor air temperatures are generally at their highest too.

Another effective way of dealing with solar heat gains through roofs is to shade them externally. The extent to which temperatures of a flat galvanized steel roof can be reduced under warm weather conditions by shading it externally with specially shaped clay tiles spanning the corrugations of the roofing sheets is illustrated by the results reproduced in Figure 8.[5] On the particular day of test the maximum roof temperature was reduced by about 33 per cent. This, resulted in a reduction in total heat gain of over 50 per cent, which compares favourably with what can be achieved with 40 mm thick mineral wool insulation on the ceiling, whilst the heat loss at night was reduced by only 18 per cent as compared with an unshaded roof. This would thus be a very effective alternative to the use of reflective insulation in the warmer areas of Rhodesia where night-time cooling is of paramount importance. All that is necessary is to ensure that free air flow between the shade and roofing skin can take place.

Many people believe that tiled roofs are cooler than galvanized steel roofs and that pitched roofs are also cooler than flat roofs. Temperatures and rates of heat flow measurements carried out on experimental structures have proved that both these beliefs are fallacies. As can be seen from Figure 9, the maximum heat gain through a galvanized steel roof after about three years' exposure was still only about two-thirds of that through a similar grey cement tile roof of the same pitch. This was the case despite the fact that the galvanized steel roof reached a peak temperature of about 25°C higher than that of the tile roof. The explanation for this lies in the different heat emissivities of the under-surfaces. Whilst relatively new galvanized steel emits only between 5 and 10 per cent of the absorbed heat, cement tiles, like most other roofing materials, can emit over 90 per cent. Similarly, it will be seen from Figure 10 that the maximum temperature attained by a flat roof on a fairly warm day in Pretoria was about 12°C lower than that of a pitched roof whilst the total heat gain from the flat roof was about 20 per cent lower than that from the pitched roof. This is explained by the difference in the mechanism of heat exchange of the upper surfaces of the two roofs. Whilst the pitched roof exchanged heat with the sky and surrounding buildings, the flat roof exchanged heat with the sky only, which has a much lower space temperature, often as low as 30°C below zero. For the same reason flat roofs cool down further during the night than pitched roofs. If suitable precautions are not taken this can give rise to serious condensation problems in the air space between the roof and ceiling in high humidity areas.

d) Utilization of mass in walls and floors

In climates where there are relatively large differences between day and night temperatures, the heat-storing capacity of the various structural elements, exercises a useful damping effect on such temperature fluctuations. This heat-storing capacity is directly related to the mass of the elements. Generally, the heavier the structure the more pronounced this damping or flywheel effect will be. The heat-storing capacity is not limited to the external walls of a building, but it can with advantage also be contained in the internal walls and/or floors. However, too much mass can be a disadvantage under certain climatic conditions. This is especially so in tropical areas where night temperatures are also high. A massive structure prevents the building from cooling down sufficiently during the night for comfortable sleeping.

The influence of mass on typical annual indoor air temperature variations is illustrated in Figure 11. The temperature ranges reproduced here were derived from actual temperature measurements on full-scale dwellings with the same floor plan and orientation but with different mass, under Pretoria climatic conditions.' The results show that temperature extremes in even a well-insulated timber house can be reduced by the introduction of mass, whether this is in the form of a solid concrete floor or a concrete floor plus brick internal walls. However, mass as found in brick veneer construction serves relatively little useful purpose because it is on the wrong side - i.e. the outside of the structure, where it is insulated from the indoor environment. It should also be noted that the moderating effect of a massive concrete floor slab can be easily neutralized in practice, particularly in the case of lightweight structures, by covering it with wall-to-wall carpeting with thick insulative underlays.

e) Ventilation

In warm climates ventilation is more than the mere provision of air to satisfy minimum health requirements. Much higher ventilation rates and rates of air movement are generally required for removal of excess heat and for body and structural cooling purposes. Here the following general rules apply:

(i) Provide openings in both external and internal walls to ensure proper cross-ventilation but avoid over-ventilation of lightweight structures and buildings in which little heat is generated during the warmest part of the day.

(ii) Provide for the control of the direction of the incoming air by means of horizontally pivoted sashes or louvred windows.

(iii) Provide for night-air cooling of the structure.

Ventilation openings can also be provided with advantage in the ceilings and roofs of single-storey buildings. The lower the pitch of the roof the more effective such openings will be. This is because roofs below about 15° pitch are always, in the case of single-storey buildings, under suction, irrespective of the wind direction, whilst parts of pitched roofs can be under a positive pressure.

One must also realize that mosquito gauze offers considerable resistance to air flow and that shading devices should be designed so that they interfere as little as possible with the free flow of air. Furthermore, there is no reason why ventilation openings should always be in the form of glazed sashes or glass louvres. More use can be made of opaque materials for sun control purposes.

It may very often be necessary to augment air movement mechanically for body cooling and in this respect much can be achieved by the use of ordinary portable free-standing fans, or, preferably, ceiling mounted fans. This particularly applies in instances, as mentioned before, where there is a danger of over-ventilation.

RELATIVE MERITS OF DIFFERENT METHODS OF CONSTRUCTION FOR THE RHODESIAN CLIMATE

Having outlined how indoor thermal conditions can in general be controlled by building procedure, attention can now be focussed on the relative merits of different methods of construction currently in use for Rhodesian climatic conditions. For this purpose seven centres were selected viz:

a) Kariba and Buffalo Range in the low altitude region,

b) Inyanga in the high altitude region, and

c) Bulawayo, Salisbury, Victoria Falls and Fort Victoria in the intermediate altitude region.

In each case assessments of the likely thermal performances under design day conditions based on the 5 per cent probability level of two plan types were made, the first with a floor plan of about 70 m^2 and the latter with a floor plan of about 40 m^2. In view of the mild winter climate, preference was given to assessment of thermal performance under summer conditions except for Inyanga and Bulawayo where winter conditions were also considered. The estimated diurnal ranges of the indoor corrected effective temperature (CET[x]) for the different centres are lined up against the thermal comfort scale adopted in South Africa for dwellings, in Figures 12 to 18. The thick black bars refer to the houses with the larger floor area and the cross-hatched bars to the houses with the smaller floor area.

Although all the designs under consideration satisfy the upper health requirement, they do not perform equally satisfactorily from a thermal comfort point of view. For the bigger type of house, conventional brick construction finished off externally in a light colour and with the roof shaded externally offers the best solution in all climatic regions except in the Inyanga area, where a darker colour for the exposed wall surfaces would be preferable for both summer and winter. Even in the Bulawayo area winter conditions call for darker surfaces. However, as mentioned before it is more important to put the emphasis on summer rather than winter design considerations. As far as the smaller and less expensive type of house is concerned, there is relatively little to choose between the three different designs although hollow clay tiles perform slightly better than either hollow concrete blocks or 115 mm solid brick. Asbestos-cement roof-sheeting allowing more effective night-air cooling than galvanized steel is quite acceptable in all regions except in the Inyanga area, where special precautions should be taken to seal all openings or gaps in the roof to prevent the houses from cooling down too much in winter.

For the warm lowveld areas the best thermal performance should be obtained with the following design:

External walls - conventional heavyweight i.e. 230 mm brick or equivalent.
Internal walls - 115 mm brick or equivalent.
Roof - lightweight shaded on top with large overhangs to shade all windows.
Floor - concrete with thermally conductive floor finish i.e. any material having a thermal conductivity greater than 0,72 W/m °C (e.g. burnt clay tiles, slate, etc.), or any material less than 3 mm thick (e.g. vinyl tiles, linoleum, cork).
Windows - relatively small but strategically placed to promote good cross-ventilation.
Colour - lightest possible colour for exposed surfaces.
General - mechanical agitation of indoor air by means of ceiling mounted fans will be desirable for body cooling purposes.

Throughout Rhodesia, with the possible exception of the Inyanga area, reflective roof insulation or external shading of roofs is preferable to mass insulation.

---

[x] The CET-scale is based on the fact that different combinations of air temperature, radiation from surrounding surfaces, humidity and rate of air movement can induce similar sensations of warmth or cold.

CONCLUSIONS

With the favourable winter climate experienced in practically the whole of Rhodesia, design considerations for summer comfort should be given preference to winter requirements. This means that:

a) Conventional heavyweight construction should be used for the walls and floor.

b) Solar heat gains through roof/ceiling combinations should be restricted as far as possible by the use of reflective insulation or by external shading of roofs.

c) Window areas should be restricted and shaded where necessary.

d) Provision should be made for good cross-ventilation and night-air cooling of structures.

e) Exposed wall surfaces should be finished off in the lightest possible colours.

REFERENCES

1. SCHULZE, B.R. Climate of South Africa, part 8, General Survey. Weather Bureau Report WB28, Pretoria, Department of Transport, January 1965.

2. VAN STRAATEN, J.F. Thermal performance of buildings. Elsevier Publishing Company, London, 1967.

3. LOTZ, F.J. Thermal performance of lightweight structures. CSIR Research Report 307, Pretoria, 1971.

4. Solar heat control through glazed openings. CSIR Technical note no. X/Bou 118, Pretoria, May 1968.

5. GOUWS, J.M. An improved solar shadowscope. Build International, Vol. 3, no. 9, September 1970.

6. LOTZ, F.J. and VAN STRAATEN, J.F. The role of roof and floor design in environmental control for S.W. African climatic conditions. Symposium, Building Research in South West Africa Today, S66, vol. 1, Windhoek, July 1972.

TABLE I

SUMMARY OF PERTINENT SUMMER AND WINTER DESIGN DATA BASED ON THE 5 PER CENT PROBABILITY LEVEL FOR DIFFERENT CENTRES IN RHODESIA

Summer						Winter					
Centre	Drybulb temperature (^{o}C)			Rel. humidity (%)		Centre	Drybulb temperature (^{o}C)			Rel. humidity (%)	
	Max	Min	Amplitude	14h00	07h00		Max	Min	Amplitude	14h00	07h00
Binga	37,1	27,3	9,3	24,2	64,5	Binga	23,8	12,9	10,9	36,3	61,9
Buffalo Range	34,1	22,0	12,1	37,5	90,6	Buffalo Range	18,3	13,0	5,3	-	89,6
Bulawayo	28,4	18,2	10,2	50,1	91,9	Bulawayo	14,9	7,5	7,4	26,0	49,1
Chipinga	26,5	17,9	8,6	54,5	95,3	Chipinga	13,6	7,9	5,7	65,8	95,6
Fort Victoria	29,6	18,6	11,0	44,8	86,4	Fort Victoria	15,2	8,7	6,5	52,5	89,0
Grand Reef	28,4	18,0	10,4	59,4	92,4	Grand Reef	16,9	-	-	34,0	-
Gwelo	28,1	17,5	10,6	44,6	86,1	Gwelo	17,3	8,4	8,9	22,3	51,5
Inyanga	24,3	15,3	9,0	33,1	72,1	Inyanga	11,3	5,0	6,3	51,7	89,0
Kariba	37,1	28,7	8,4	25,4	-	Kariba	24,1	15,6	8,5	43,5	77,3
Karoi	28,2	17,8	10,4	39,3	80,5	Karoi	18,5	10,0	8,5	45,8	91,3
Que Que	29,3	18,6	10,7	34,0	82,0	Que Que	18,1	-	-	45,5	74,0
Salisbury	27,0	16,9	10,1	65,2	98,6	Salisbury	15,9	8,4	7,5	31,3	47,0
Victoria Falls	31,4	20,7	10,7	33,8	80,0	Victoria Falls	23,3	14,1	9,2	33,7	41,0

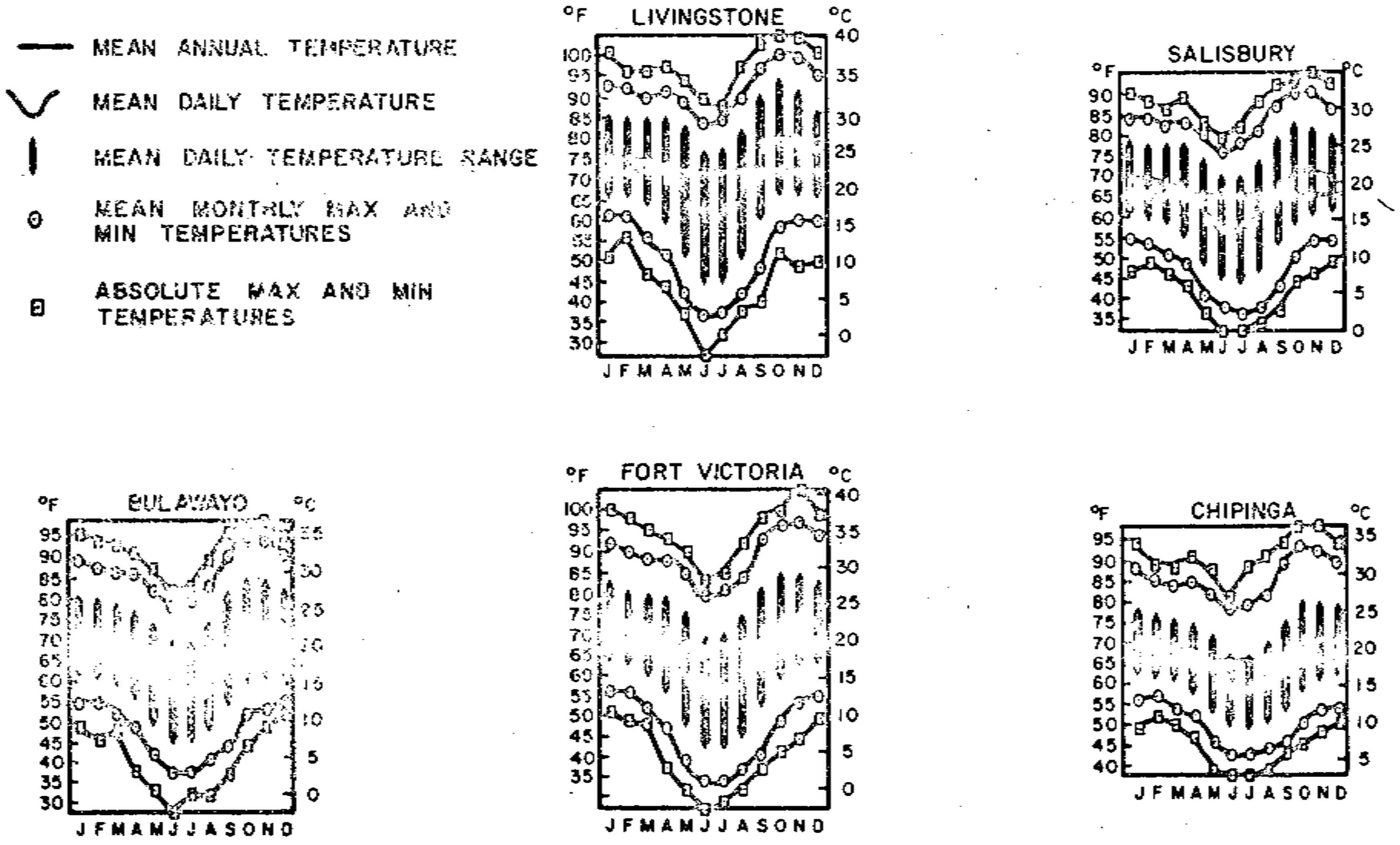


FIGURE I

Comparison of mean temperature marches by month of different centres in Rhodesia

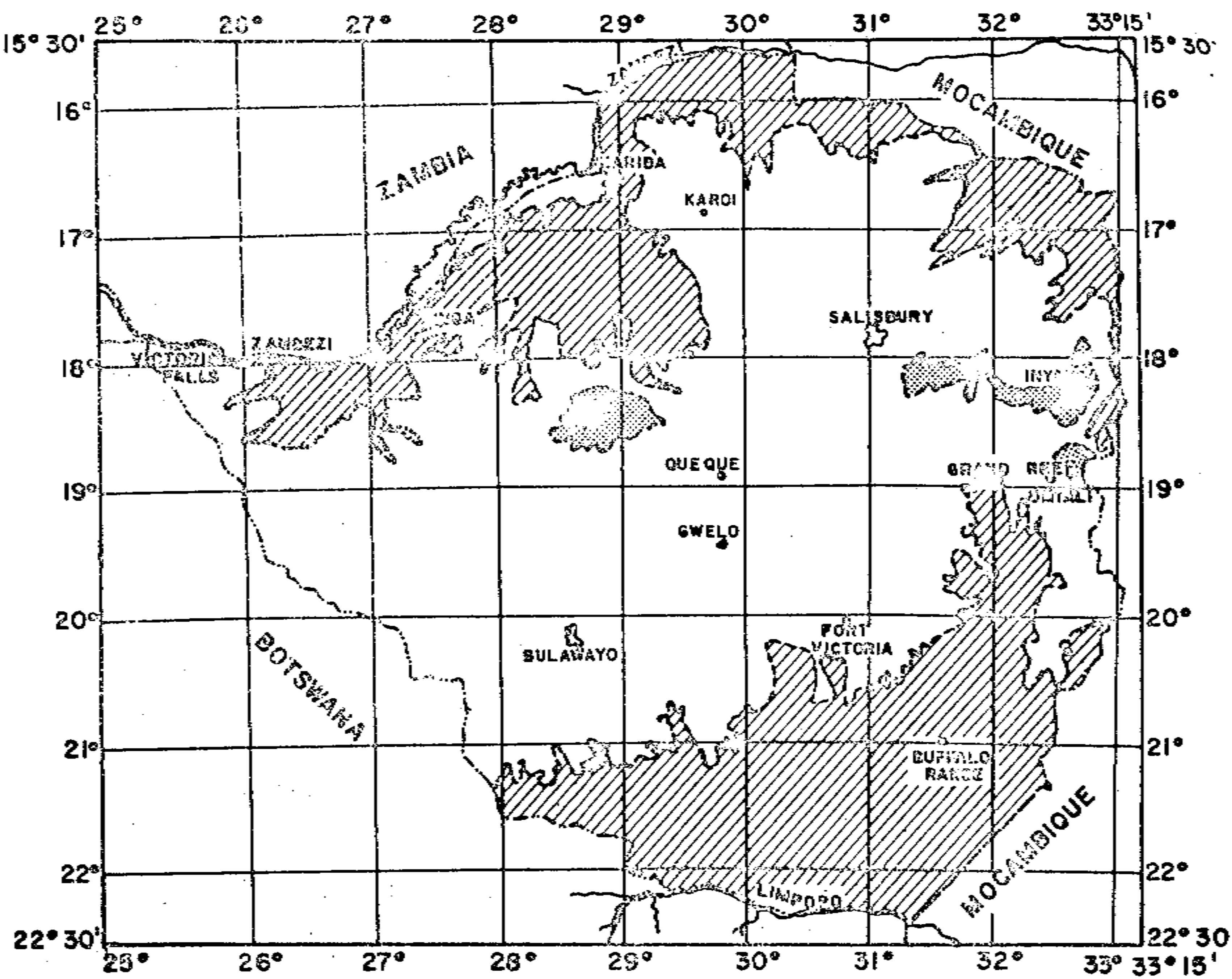
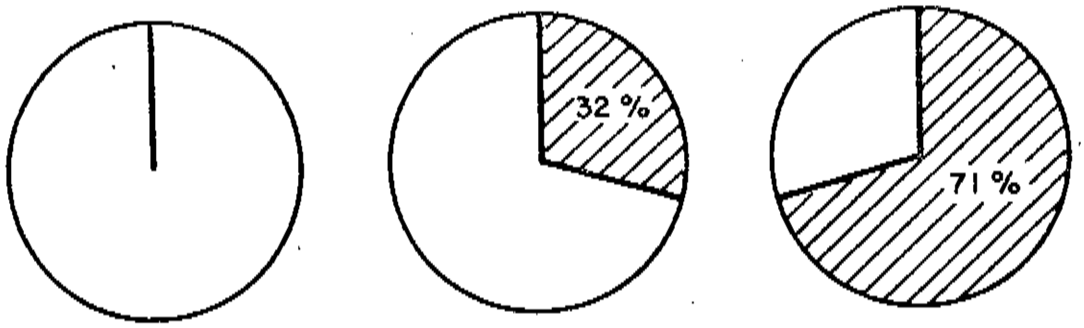


FIGURE 2

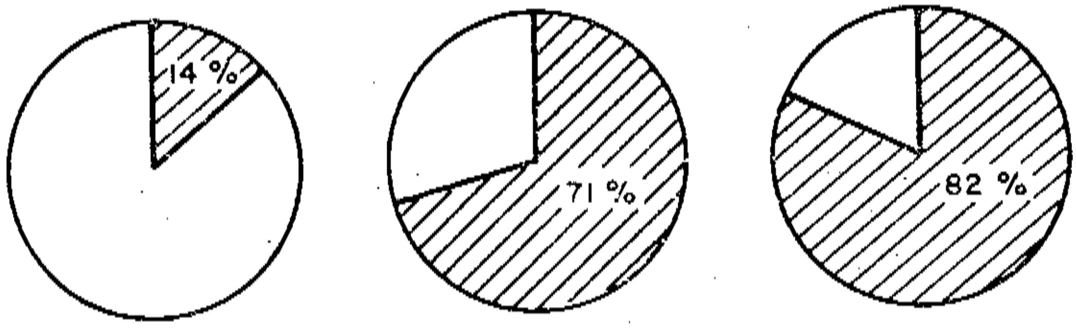
Different climatic regions in Rhodesia from the point of view of thermal design of buildings

(a) SINGLE GLAZING



CLEAR GLASS TINTED GLASS REFLECTING GLASS

(b) DOUBLE GLAZING

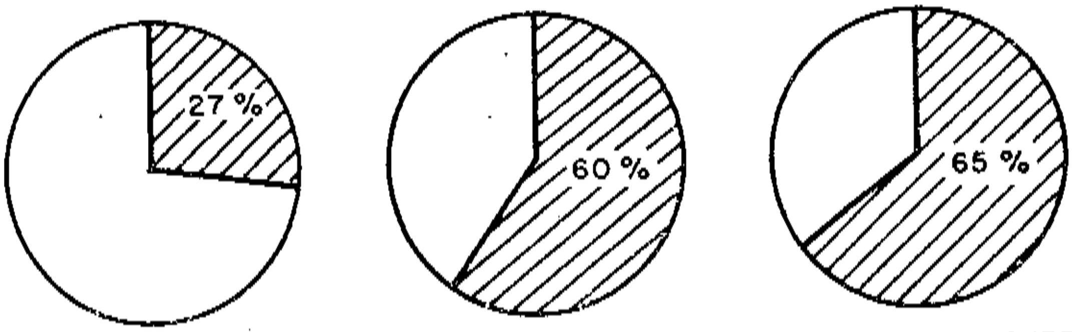


CLEAR GLASS BOTH SIDES

CLEAR GLASS BOTH SIDES WITH VENETIAN BLIND IN BETWEEN

HEAT REFLECTING GLASS OUTSIDE, ORDINARY GLASS INSIDE

(c) INDOOR SHADING



SUNFILTER CURTAIN

VENETIAN BLIND LIGHT GREEN

HEAVY LINED CURTAIN

(d) OUTDOOR SHADING

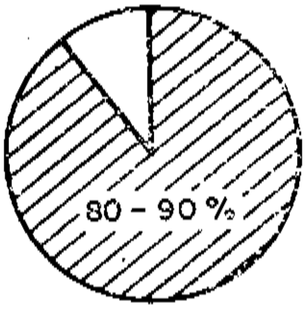


FIGURE 3

Relative efficacies of diffsrent methods of shading

FIGURE 4

NBRI Solar shadowscope with model

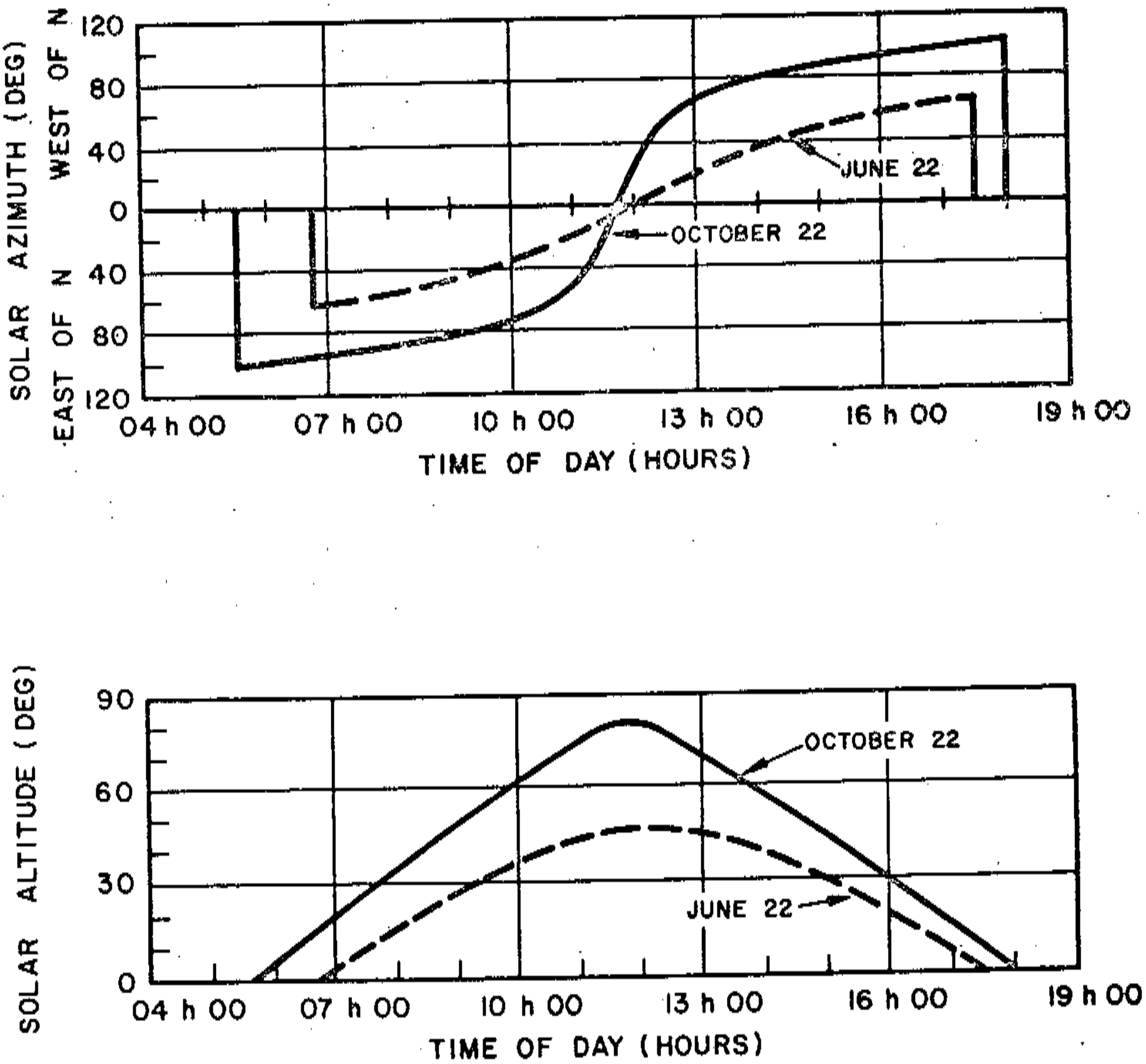
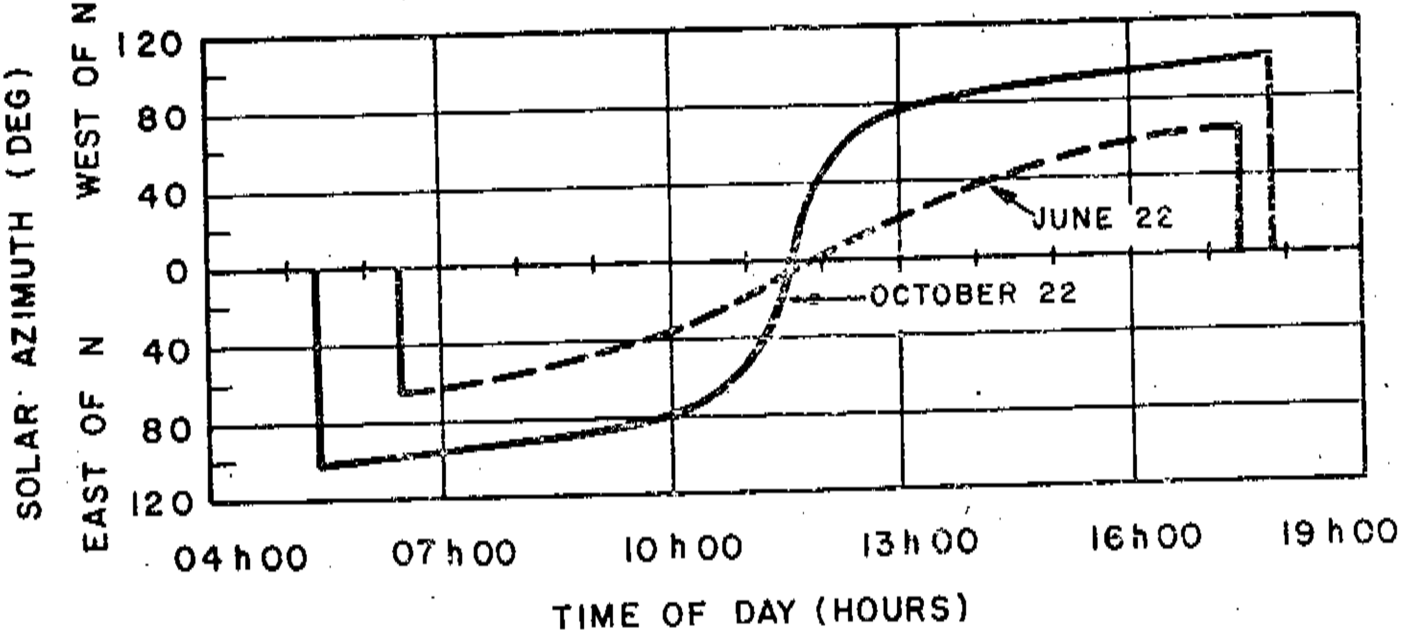


FIGURE 5

Solar azimuth and altitude angles for June 22 and October 22 for Bulawayo



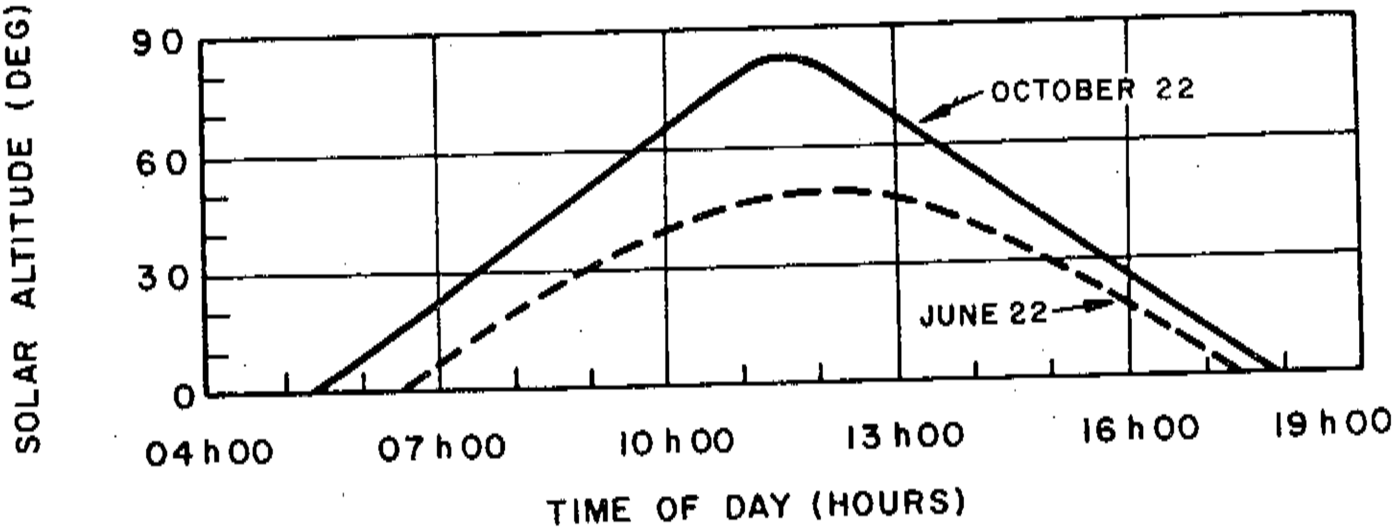


FIGURE 6

Solar azimuth and altitude angles for June 22 and October 22 for Salisbury

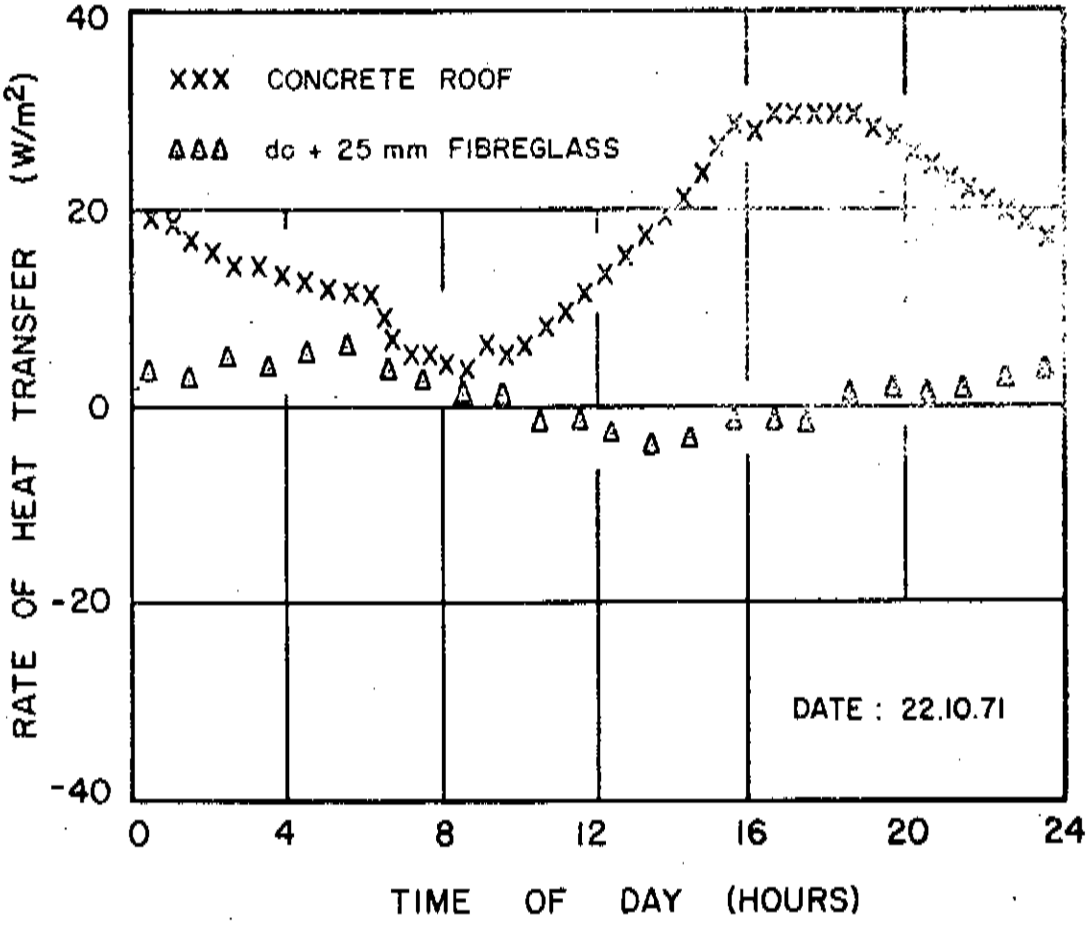


FIGURE 7

Reduction in solar heat gain through concrete roof by insulating it externally with 25 mm thick fibreglass under typical summer conditions in Pretoria

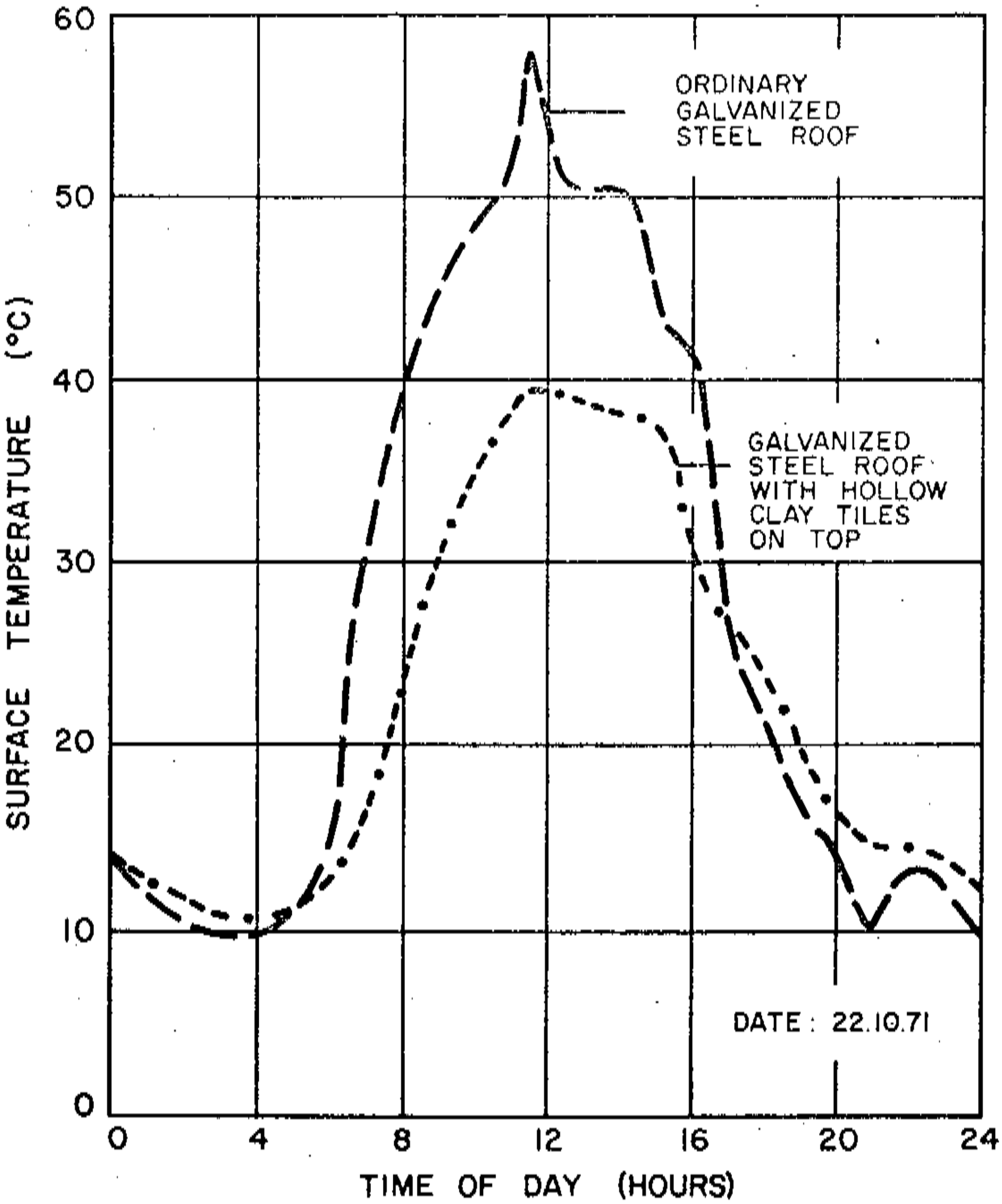


FIGURE 8

Comparison of surface temperature variations of a flat galvanized steel roof shaded on top with hollow clay tiles and a similar roof unshaded under typical summer conditions in Pretoria

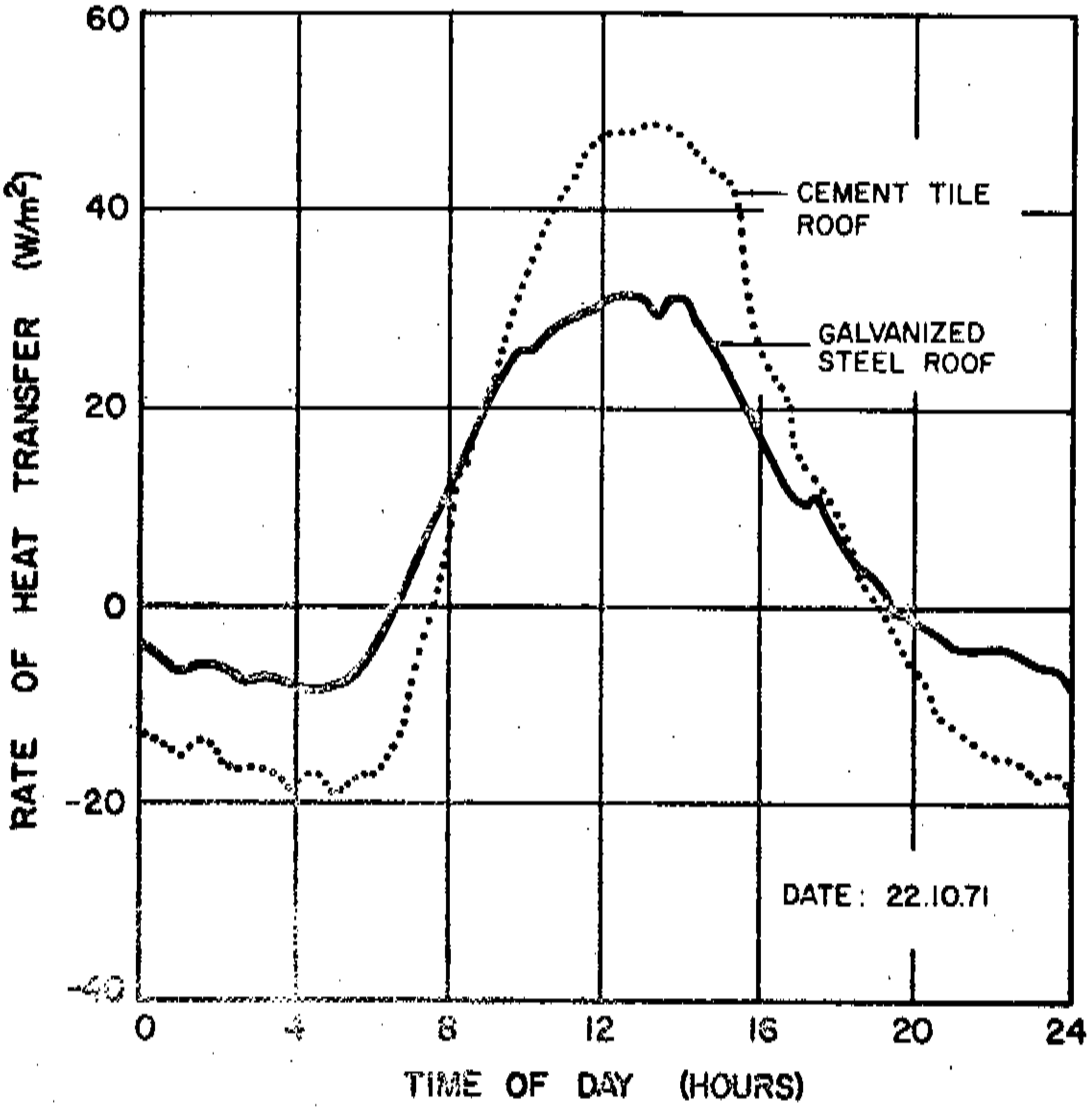


FIGURE 9

Comparison of heat transfer rates through the ceilings of two similar test huts, one with a tiled roof and the other with a galvanized steel roof under typical summer conditions in Pretoria

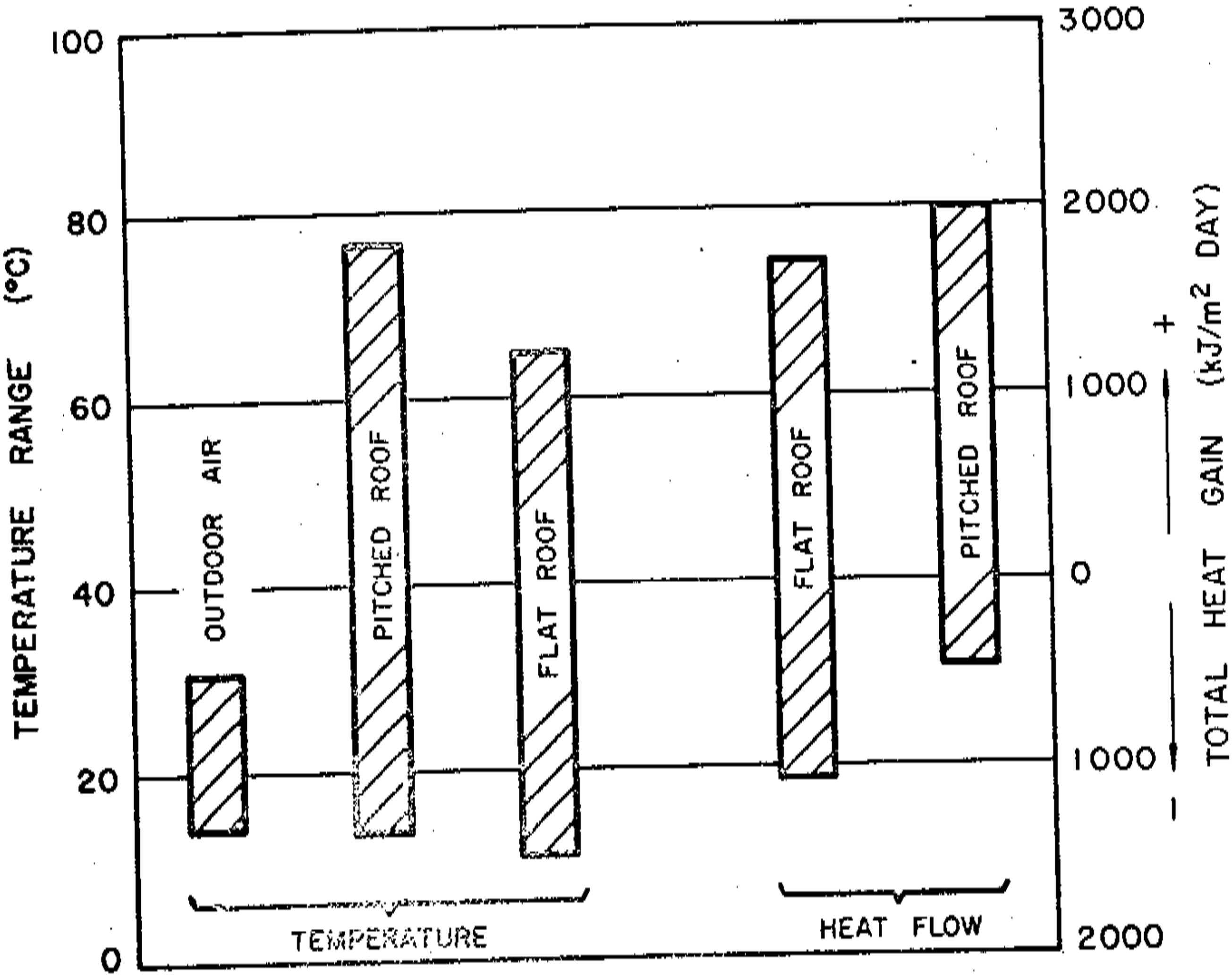


FIGURE 10

Influence of roof pitch on roof temperature and total heat gain through roof as measured on four different relatively warm days

BG4 5839

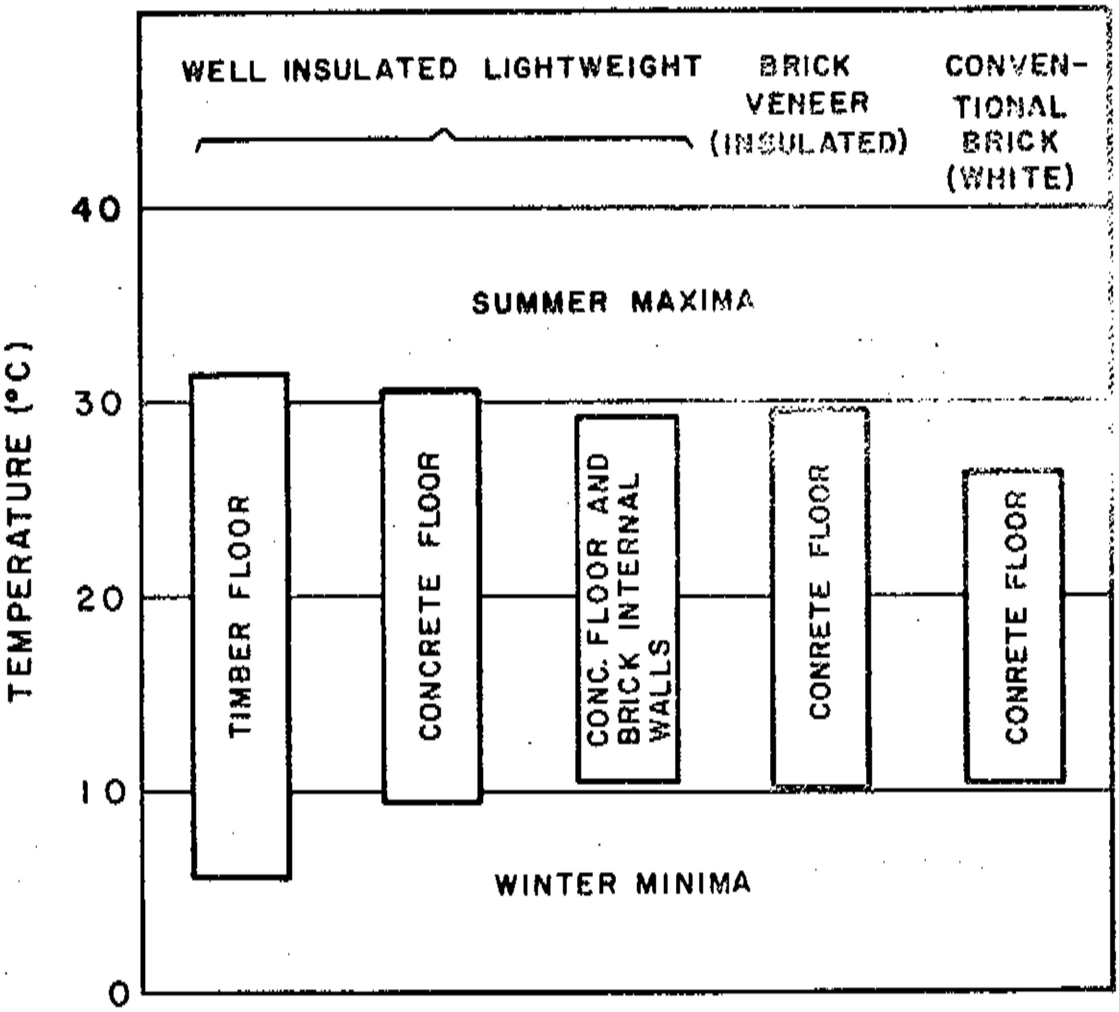


FIGURE 11

Typical annual indoor air temperature variations in houses with different mass under Pretoria design day conditions

ELEMENT AND FINISH	CONSTRUCTIONAL AND OTHER DETAILS						
FLOOR AREA	70 m²				40 m²		
EXTERNAL WALLS	LIGHTWEIGHT		230 mm BRICK		115 mm BRICK	120 mm HOLLOW CLAY	115 mm HOLLOW CONCRETE
INTERNAL WALLS	LIGHTWEIGHT		115 mm BRICK		do		
ROOF	LIGHTWEIGHT - UNSHADED			LW-SHADED	ASBESTOS CEMENT		
CEILING	3-6 mm				—	—	—
ROOF INSULATION	REFLECTIVE			—	—	—	—
FLOOR	CONDUCTIVE	INSULATIVE	CONDUCTIVE		THERMALLY CONDUCTIVE		
EXTERNAL COLOUR	NEUTRAL			WHITE	NEUTRAL		

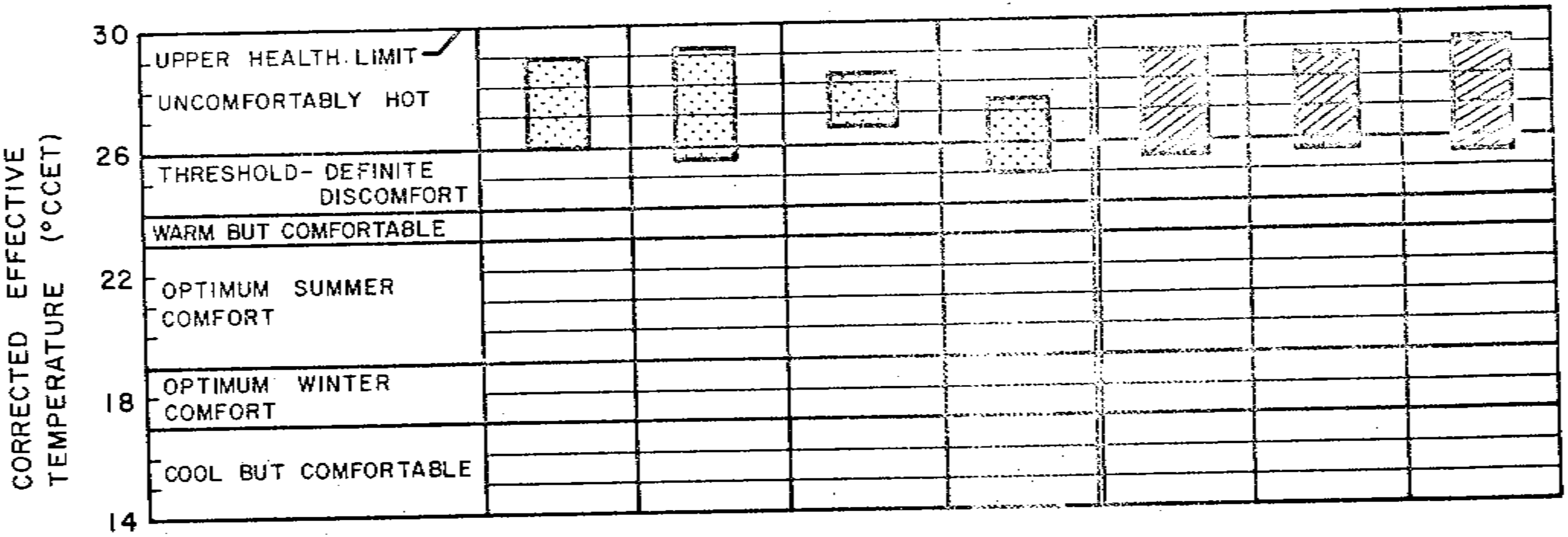


FIGURE 12

Estimated diurnal ranges of indoor corrected effective temperature for houses of different construction under typical summer conditions in the Kariba area

ELEMENT AND FINISH	CONSTRUCTIONAL AND OTHER DETAILS						
FLOOR AREA	70 m^2				40 m^2		
EXTERNAL WALLS	LIGHTWEIGHT		230 mm BRICK		115 mm BRICK	120 mm HOLLOW CLAY	115 mm HOLLOW CONCRETE
INTERNAL WALLS	LIGHTWEIGHT		115 mm BRICK		do		
ROOF	LIGHTWEIGHT – UNSHADED			LW-SHADED	ASBESTOS CEMENT		
CEILING	3 – 6 mm				—	—	—
ROOF INSULATION	REFLECTIVE			—	—	—	—
FLOOR	CONDUCTIVE	INSULATIVE	CONDUCTIVE		THERMALLY CONDUCTIVE		
EXTERNAL COLOUR	NEUTRAL			WHITE	NEUTRAL		

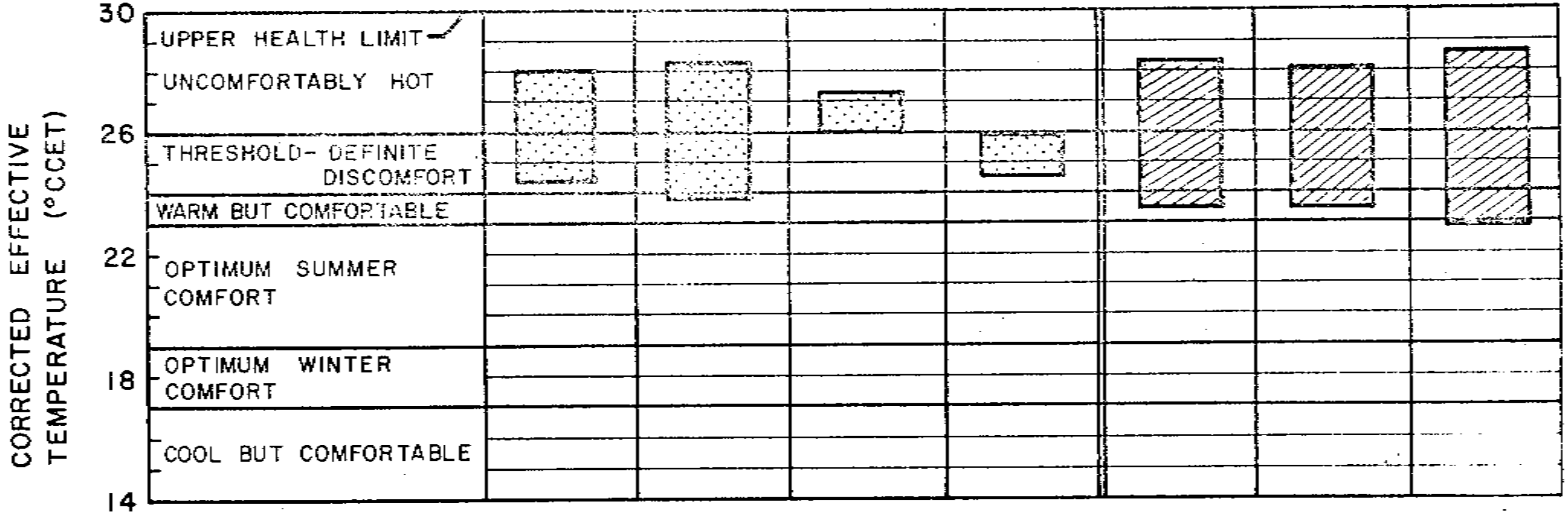


FIGURE 13

Estimated diurnal ranges of indoor corrected effective temperature for houses of different construction under typical summer conditions in the Buffalo Range area

ELEMENT AND FINISH	CONSTRUCTIONAL AND OTHER DETAILS						
FLOOR AREA	70 m^2				40 m^2		
EXTERNAL WALLS	LIGHTWEIGHT		230 mm BRICK		115 mm BRICK	120 mm HOLLOW CLAY	115 mm HOLLOW CONCRETE
INTERNAL WALLS	LIGHTWEIGHT		115 mm BRICK		do		
ROOF	LIGHTWEIGHT - UNSHADED			LW-SHADED	ASBESTOS CEMENT		
CEILING	3 – 6 mm				—	—	—
ROOF INSULATION	REFLECTIVE			—	—	—	—
FLOOR	CONDUCTIVE	INSULATIVE	CONDUCTIVE		THERMALLY CONDUCTIVE		
EXTERNAL COLOUR	NEUTRAL			WHITE	NEUTRAL		

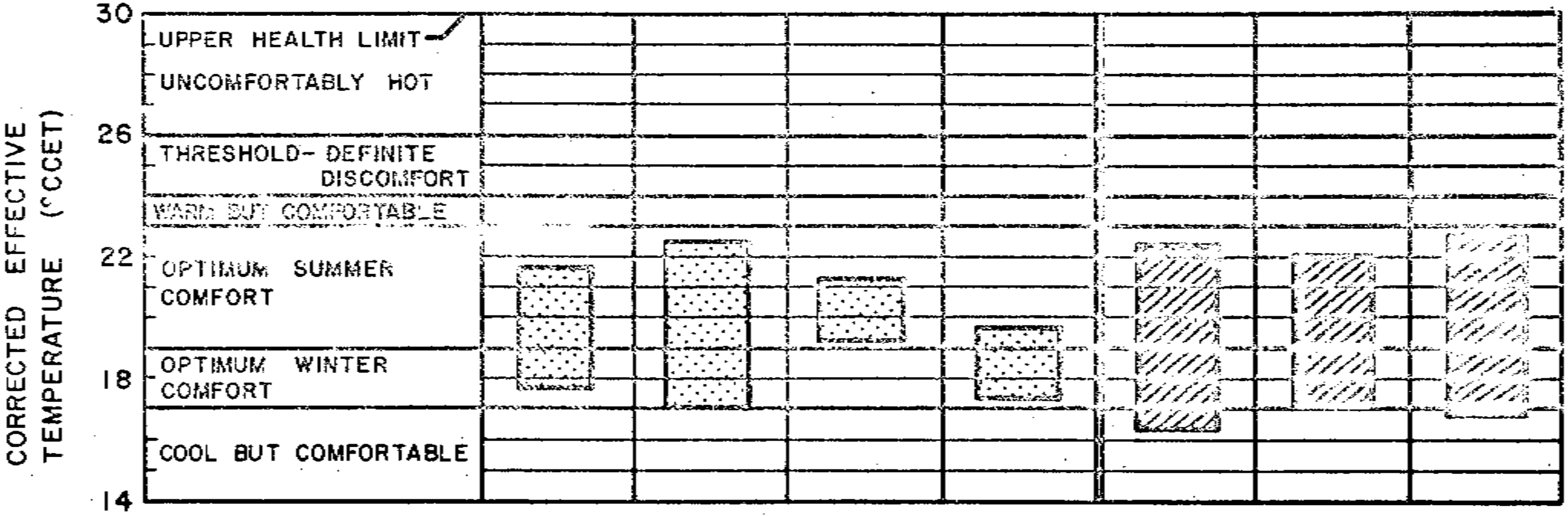


FIGURE 14(a)

Estimated diurnal ranges of indoor corrected effective temperature for houses of different construction under typical summer conditions in the Inyanga area

ELEMENT AND FINISH	CONSTRUCTIONAL AND OTHER DETAILS							
FLOOR AREA	70 m^2				40 m^2			
EXTERNAL WALLS	LIGHTWEIGHT		230 mm BRICK		115 mm BRICK	120 mm HOLLOW CLAY	115 mm HOLLOW CONCRETE	115 mm BRICK
INTERNAL WALLS	LIGHTWEIGHT		115 mm BRICK					
ROOF	LIGHTWEIGHT - UNSHADED			LW-SHADED	ASBESTOS CEMENT			AC-SEALED
CEILING	3 – 6 mm				—	—	—	—
ROOF INSULATION	REFLECTIVE			—	—	—	—	—
FLOOR	CONDUCTIVE	INSULATIVE	CONDUCTIVE		THERMALLY CONDUCTIVE			
EXTERNAL COLOUR	NEUTRAL			WHITE	NEUTRAL			

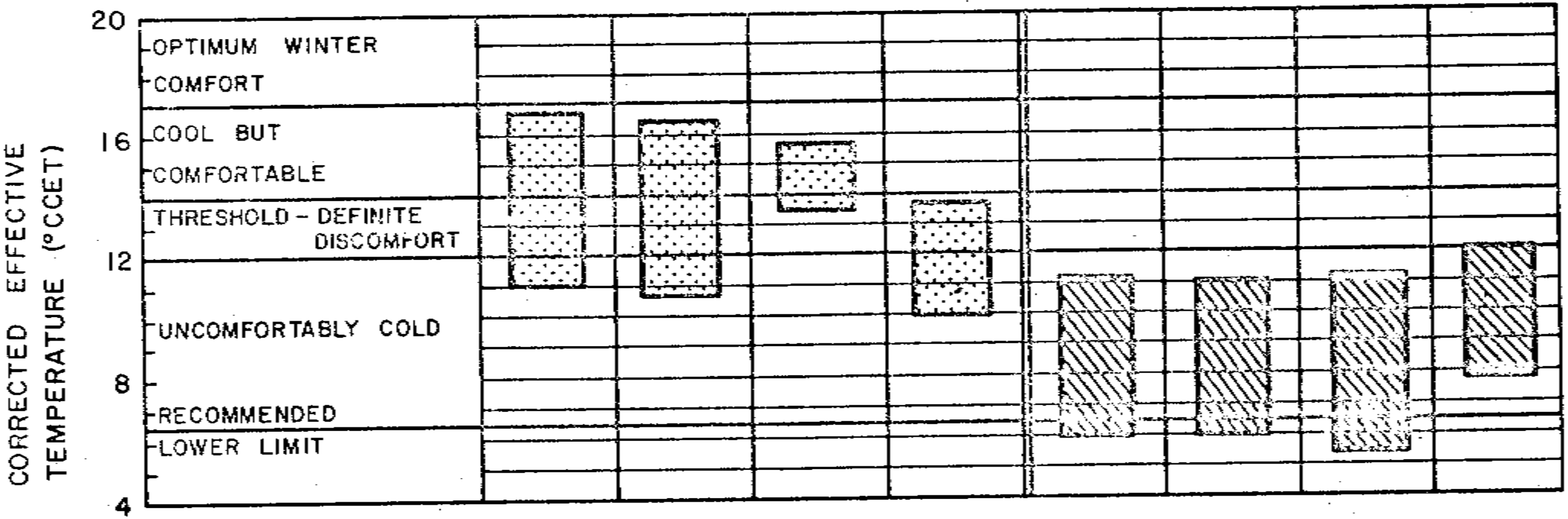


FIGURE 14 (b)

Estimated diurnal ranges of indoor corrected effective temperature for houses of different construction under typical winter conditions in the Inyanga area

ELEMENT AND FINISH	CONSTRUCTIONAL AND OTHER DETAILS						
FLOOR AREA	70 m^2				40 m^2		
EXTERNAL WALLS	LIGHTWEIGHT		230 mm BRICK		115 mm BRICK	120 mm HOLLOW CLAY	115 mm HOLLOW CONCRETE
INTERNAL WALLS	LIGHTWEIGHT		115 mm BRICK		do		
ROOF	LIGHTWEIGHT - UNSHADED			LW-SHADED	ASBESTOS CEMENT		
CEILING	3 – 6 mm				—	—	—
ROOF INSULATION	REFLECTIVE			—	—	—	—
FLOOR	CONDUCTIVE	INSULATIVE	CONDUCTIVE		THERMALLY CONDUCTIVE		
EXTERNAL COLOUR	NEUTRAL			WHITE	NEUTRAL		

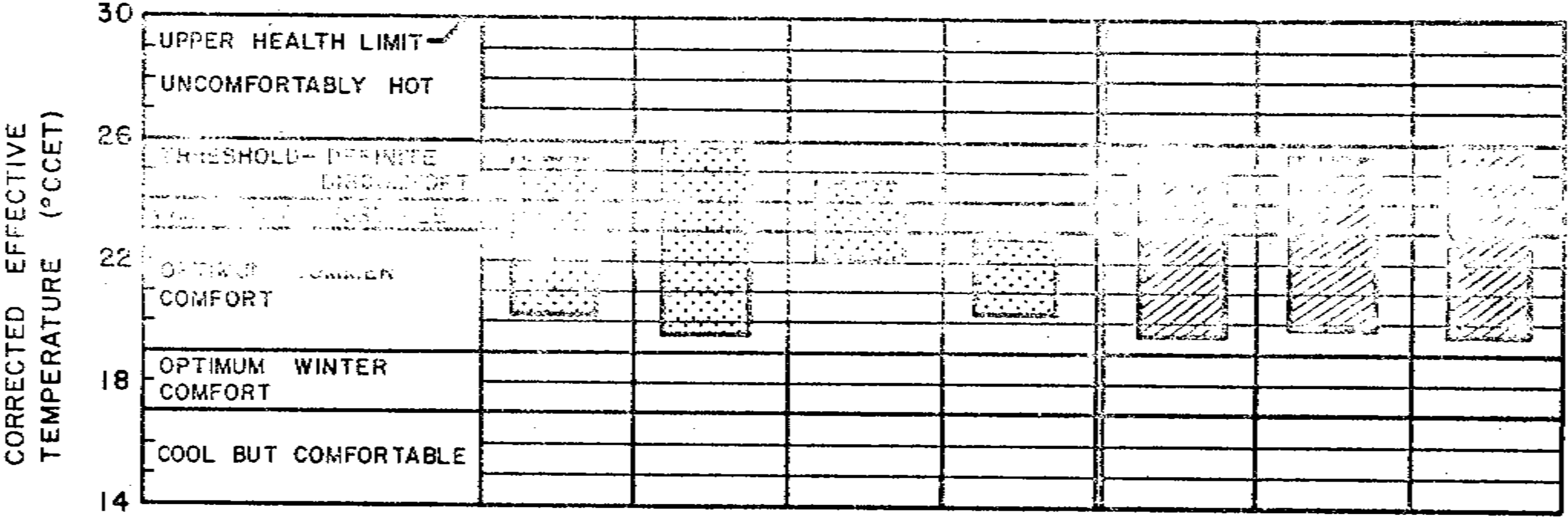


FIGURE 15(a)

Estimated diurnal ranges of indoor corrected effective temperature for houses of different construction under typical summer conditions in the Bulawayo area

ELEMENT AND FINISH	CONSTRUCTIONAL AND OTHER DETAILS							
FLOOR AREA	70 m²				40 m²			
EXTERNAL WALLS	LIGHTWEIGHT		230 mm BRICK		115 mm BRICK	120 mm HOLLOW CLAY	115 mm HOLLOW CONCRETE	115 mm BRICK
INTERNAL WALLS	LIGHTWEIGHT		115 mm BRICK					
ROOF	LIGHTWEIGHT – UNSHADED			LW-SHADED	ASBESTOS CEMENT			AC-SEALED
CEILING	3–6 mm				–	–	–	–
ROOF INSULATION	REFLECTIVE			–	–	–	–	–
FLOOR	CONDUCTIVE	INSULATIVE	CONDUCTIVE		THERMALLY CONDUCTIVE			
EXTERNAL COLOUR	NEUTRAL			WHITE	NEUTRAL			

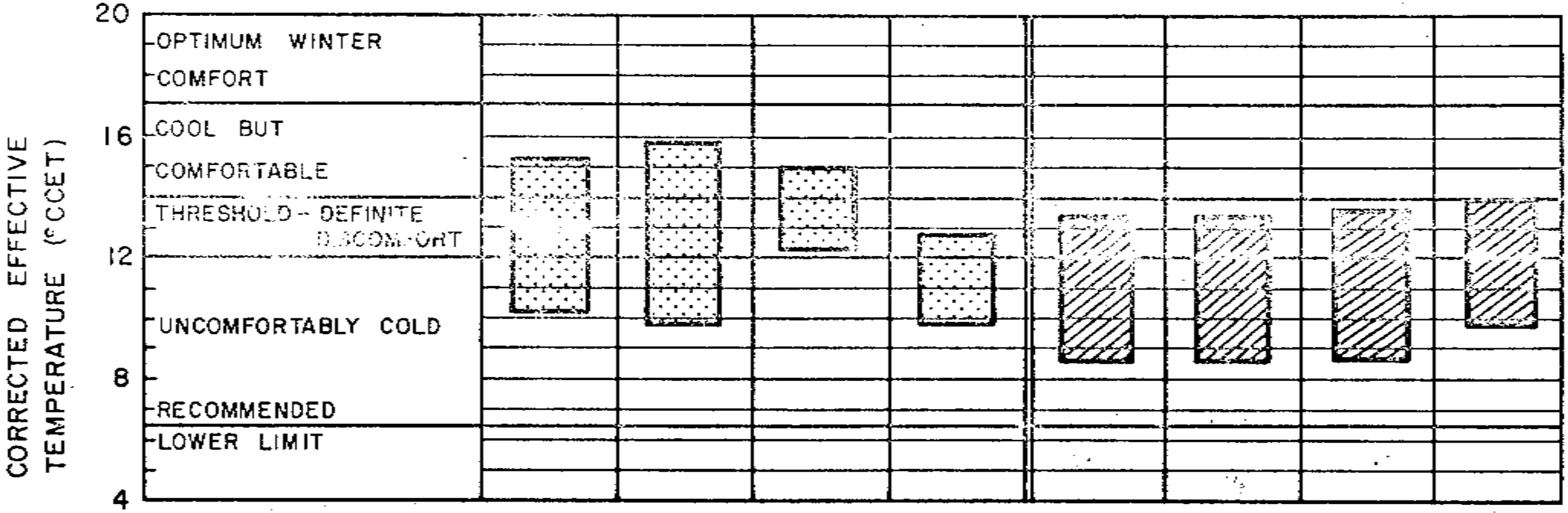


FIGURE 15(b)

Estimated diurnal ranges of indoor corrected effective temperature for houses of different construction under typical winter conditions in the Bulawayo area

ELEMENT AND FINISH	CONSTRUCTIONAL AND OTHER DETAILS						
FLOOR AREA	[illegible]0 m^2				40 m^2		
EXTERNAL WALLS	LIGHTWEIGHT		230 mm BRICK		115 mm BRICK	120 mm HOLLOW CLAY	115 mm HOLLOW CONCRETE
INTERNAL WALLS	LIGHTWEIGHT		115 mm BRICK		do		
ROOF	LIGHTWEIGHT - UNSHADED			LW-SHADED	ASBESTOS CEMENT		
CEILING	3 - 6 mm				—	—	—
ROOF INSULATION	REFLECTIVE			—	—	—	—
FLOOR	CONDUCTIVE	INSULATIVE	CONDUCTIVE		THERMALLY CONDUCTIVE		
EXTERNAL COLOUR	NEUTRAL			WHITE	NEUTRAL		

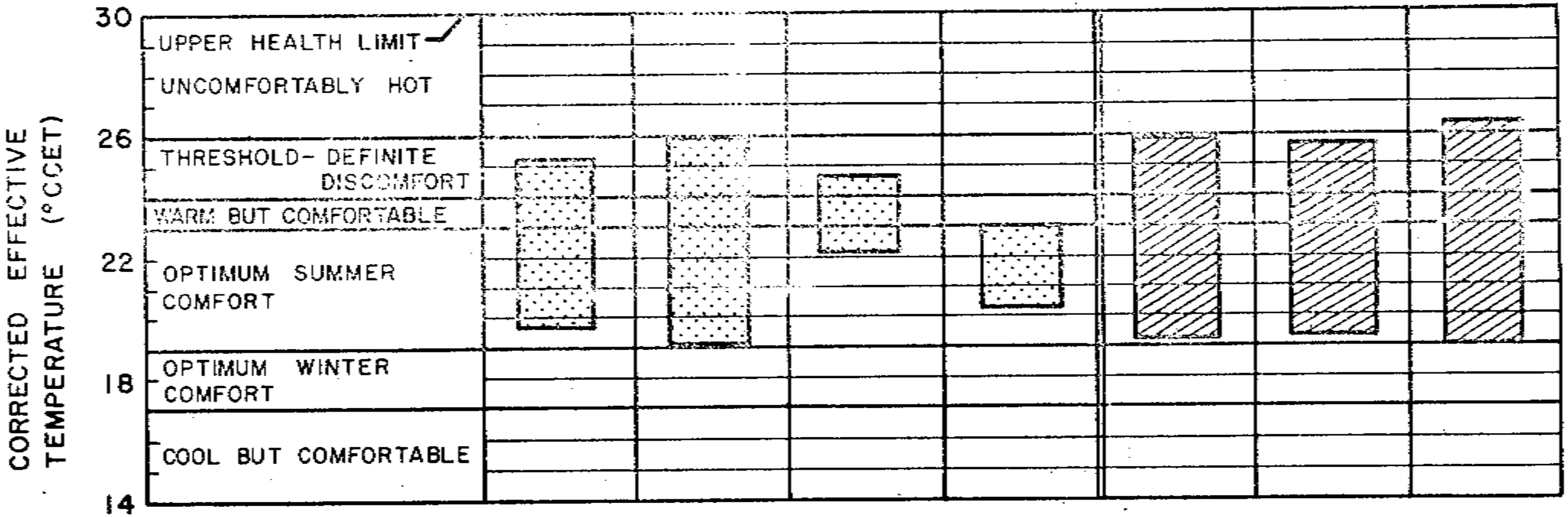


FIGURE 16

Estimated diurnal ranges of indoor corrected effective temperature for houses of different construction under typical summer conditions in the Salisbury area

ELEMENT AND FINISH	CONSTRUCTIONAL AND OTHER DETAILS						
FLOOR AREA	70 m^2				40 m^2		
EXTERNAL WALLS	LIGHTWEIGHT		230 mm BRICK		115 mm BRICK	120 mm HOLLOW CLAY	115 mm HOLLOW CONCRETE
INTERNAL WALLS	LIGHTWEIGHT		115 mm BRICK		do		
ROOF	LIGHTWEIGHT - UNSHADED			LW-SHADED	ASBESTOS CEMENT		
CEILING	3 – 6 mm				—	—	—
ROOF INSULATION	REFLECTIVE			—	—	—	—
FLOOR	CONDUCTIVE	INSULATIVE	CONDUCTIVE		THERMALLY CONDUCTIVE		
EXTERNAL COLOUR	NEUTRAL			WHITE	NEUTRAL		

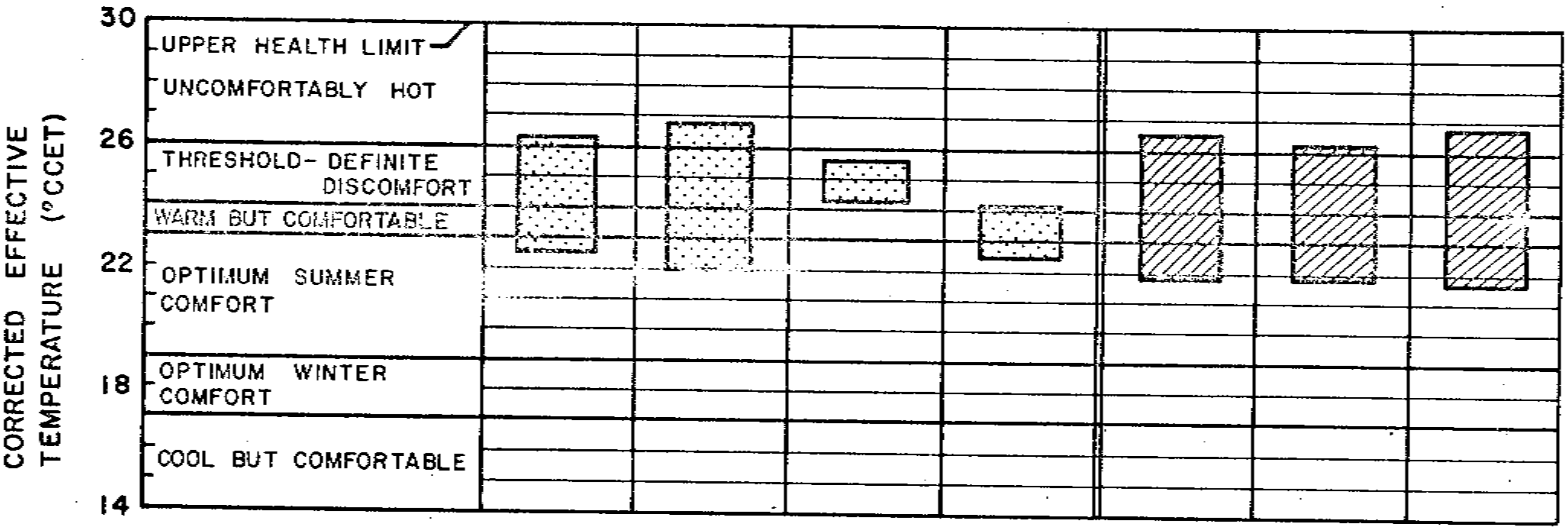


FIGURE 17

Estimated diurnal ranges of indoor corrected effective temperature for houses of different construction under typical summer conditions in the Victoria Falls area

ELEMENT AND FINISH	CONSTRUCTIONAL AND OTHER DETAILS						
FLOOR AREA	70 m²				40 m²		
EXTERNAL WALLS	LIGHTWEIGHT		230 mm BRICK		115 mm BRICK	120 mm HOLLOW CLAY	115 mm HOLLOW CONCRETE
INTERNAL WALLS	LIGHTWEIGHT		115 mm BRICK		do		
ROOF	LIGHTWEIGHT - UNSHADED			LW-SHADED	ASBESTOS CEMENT		
CEILING	3 – 6 mm				—	—	—
ROOF INSULATION	REFLECTIVE			—	—	—	—
FLOOR	CONDUCTIVE	INSULATIVE	CONDUCTIVE		THERMALLY CONDUCTIVE		
EXTERNAL COLOUR	NEUTRAL			WHITE	NEUTRAL		

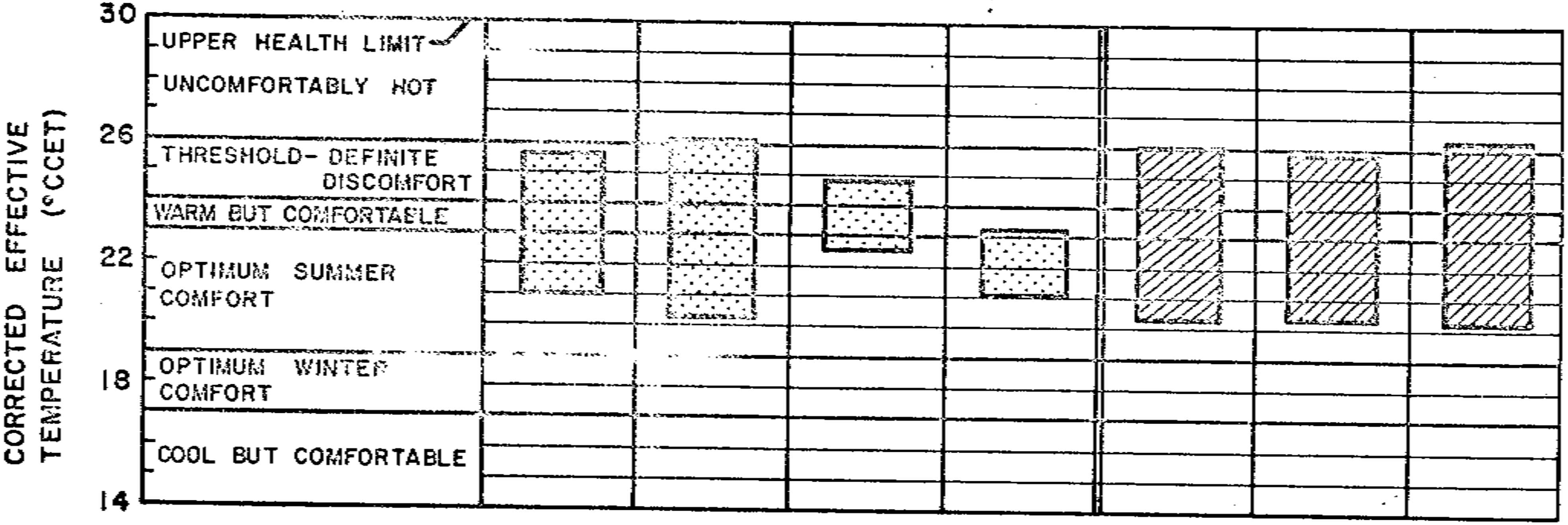


FIGURE 18

Estimated diurnal ranges of indoor corrected effective temperature for houses of different construction under typical summer conditions in the Fort Victoria area