FIELD WORK.

project 4 egypt.

climatic study of

Climatic Study of Traditional Buildings, Cairo, Egypt

Contents

INTRODUCTION

THERE HAS BEEN A GROWING RECOGNITION OF THE SUITABILITY OF TRADITIONAL DESIGN AND PLANNING CONCEPTS TO THEIR CLIMATE. STUDIES HAVE BEEN DONE ON THIS LEVEL. WE ATTEMPTED TO APPLY A TECHNICAL OVERLAY ON THE WORK ALREADY DONE BY STUDYING VARIOUS HOUSES USING EQUIPMENT TO MEASURE THEIR CLIMATIC PERFORMANCE.

THE WORK CAN BE DIVIDED INTO TWO PARTS:

(1) STUDY OF TRADITIONAL HOUSES IN OLD CAIRO
(2) STUDY OF EXPERIMENTAL ROOMS AT THE BUILDING RESEARCH CENTRE IN CAIRO.

IN STUDYING BUILDINGS IN OLD CAIRO WE PAID CLOSE ATTENTION TO THE MICROCLIMATIC CONDITIONS BOTH WITHIN AND IN THE STREETS AROUND THE HOUSES WHICH WE SURVEYED. AIR MOVEMENT INDUCED BY THE "MALKAF" OR WINDCATCHER, AND PRESSURE AND TEMPERATURE DIFFERENCES WITHIN THE HOUSES AND COURTYARDS WAS STUDIED USING A WIND VELOCITY METER, KATA-THERMOMETER AND A WHIRLING HYGROMETER. NATURAL LIGHTING THROUGH THE MUSHRABEYA OR TRADITIONAL LATTICE WINDOWS WAS MEASURED USING A MINI-LUP METER TO RECORD ILLUMINATION LEVELS WITHIN ROOMS AND A PHOTOMETER TO DISCOVER THE ACTUAL WORKINGS WITHIN THE MUSHRABEYA ITSELF. THERMAL CONDITIONS DUE TO BOTH AIR TEMPERATURE AND RADIATION FROM SURROUNDINGS WERE STUDIED EMPLOYING DRY BULB THERMOMETERS, MAXIMUM - MINIMUM THERMOMETERS TO DISCOVER DAILY RANGES, A GLOBE THERMOMETER TO FIND RADIATION LEVELS AND AN ELECTRONIC CONTACT THERMOMETER WHICH IS USED TO MEASURE TEMPERATURES AT THE SURFACE OF A MATERIAL.

FROM THESE TESTS WE HAVE ATTEMPTED TO EVALUATE THE MICRO-CLIMATIC WORKINGS OF THE TRADITIONAL HOUSES.

THE EXPERIMENTAL ROOMS AT THE BUILDING RESEARCH CENTRE IN CAIRO WERE BUILT TO TEST PROTOTYPE BUILDING SOLUTIONS FOR POOR RURAL AREAS IN DEVELOPING COUNTRIES. AMONG THE ROOMS BUILT WAS ONE OF MUD BRICK VAULT AND DOME CONSTRUCTION AND ANOTHER OF PREFABRICATED CONCRETE SLAB CONSTRUCTION, ILLUSTRATING THE CONTRADICTORY PROPOSALS FOR RURAL DEVELOPMENT, ONE PROPOSING A REINSTATEMENT OF TRADITIONAL MODES OF CONSTRUCTION AND THE OTHER AN IMPORTATION OF IDEAS AND MATERIALS FROM OUTSIDE. WE TESTED BOTH EXAMPLES FOR THEIR PERFORMANCE IN EGYPT'S CLIMATE, BY CALCULATING HEAT FLOW THROUGH THE BUILDING MATERIALS. OTHER TEST ROOMS INCORPORATED VARIATIONS ON THE TRADITIONAL MALKAF WINDCATCH AND AIR MOVEMENT STUDIES WERE DONE THERE.

IN EFFECT, WE ARE TRYING TO SHOW ENVIRONMENTALLY THAT THE TRADITIONAL BUILDING SOLUTIONS ARE STILL TODAY THE MOST APPROPRIATE MODEL ON WHICH TO BUILD AND CONCEPTS CAN BE APPLIED TO NEW DESIGN PROBLEMS.

Definition of Terms

Part of the work in which we were involved consisted in establishing a system that we could use ourselves in evaluating the climatic performance of the buildings which we surveyed.

Our primary purpose was to make a comparison between the traditional or vernacular ways of building and new forms of building imported from Europe.

Several terms must be introduced at this point:

1. **Temperature**

   Temperature is a measurement of heat and for our purposes we are using the metric system. Heat can be transmitted by radiation, convenction or conduction. Radiation is a transfer of heat energy through space from a warm body to a cold body, i.e. the sun to the earth or an open fire to one's face. Convection is the old principle of hot air rising and cool air falling. Conduction is the transfer of heat through a solid, and in our case we are concerned with the heat transfer through the walls of a building.

2. **Relative Humidity**

   Relative humidity is simply the percentage of water vapour in the air. This is important because at a high temperature a person will tend to feel comfortable if there is a low relative humidity, but he will feel hot if there is a high percentage of water vapour in the air.

The reason for this is found in the physiological function of perspiring or letting off of water at the surface of the skin to evaporate into the air. Physically, evaporation has a cooling effect and helps to cool the body. The higher the percentage of water vapour in the air the less ready is the air to absorb evaporated water from the surface of the skin, hence the less the cooling effect. In summary, if the relative humidity is low, the body can cool itself by perspiring, but it cannot do so as readily if the relative humidity is high.

3. Air Movement

Air moves from areas of high pressures to low pressure areas. The effect of air movement on thermal comfort is related to the previous explanation. If there is no air movement the layer of air next to the skin tends to become saturated with water vapour due to perspiration. Air movement causes the air next to the skin to be continually replaced by new less saturated air. Air movement can be seen to aid evaporation from the skin's surface. Therefore, various degrees of air movement correspond to degrees of aid to evaporative cooling.

4. Thermal Comfort Condition

This may be defined as a physiological state at which an individual feels neither too warm nor too cold. There are several factors determining the limits of this zone. The air temperature, the relative humidity, the degree of air movement and finally the degree of acclimatisation or the degree to which one becomes used to ones local climate. The first three factors: temperature, humidity and wind speed can be combined by the use of graphs and tables into one value being called the "effective temperature" and relates to what one feels as a temperature on the skin due to a combination of all three factors. Therefore, if the effective temperature at a particular time falls within the range that one feels acclimatised to, it is said to fall in the comfort zone. For the Cairo climate we have calculated the comfort zone to lie between 19.7^{o}C and 24.7^{o}C (effective temperature).

If, for example, the air temperature recorded at some time is found to be higher than the maximum comfort zone temperature, comfort conditions may be maintained if the air movement is induced. In this way the effective temperature can be brought into the comfort zone.

<u>Climatic Survey of Traditional Buildings</u>

There are many ways that building can manipulate the climate within, to produce favourable conditions if they do not exist outside. We are interested here primarily in vernacular solutions, which have evolved over centuries due to continuous contact with a harsh climate.

The typical house form throughout the tropics, the courtyard house, is in itself a clear example of this vernacular response to climate. The couryard is a cool air well, where the cool night air settles, expelling the lighter warm air collected during the day. This cool air is retained during the daytime when activities are carried on, in rooms on the ground floor opening on to the courtyard. The courtyard also in some cases contains a pool of water which tends to cause evaporative cooling. Of course, in the open court and rooms opening on to it, one finds that the air moves more freely than one would find in an enclosed space.

An interesting traditional solution employed in many hot climates is the wind catch. In its simplest form it is composed of some sort of catching or funneling device oriented to trap the prevailing wind and a system to vent the escaping air. The purpose of this device is to induce air movement within an enclosed space to aid evaporative cooling.

Study of Qa'A Mohib-al-din

One of the buildings containing a wind catch which we surveyed was the Qa'a Mohib al Din in Old Cairo and shows the principle simply. This house was built in the 14th century and illustrates more clearly than any other that we studied, the design concept of the Qa'a which is discussed in another section of the report.

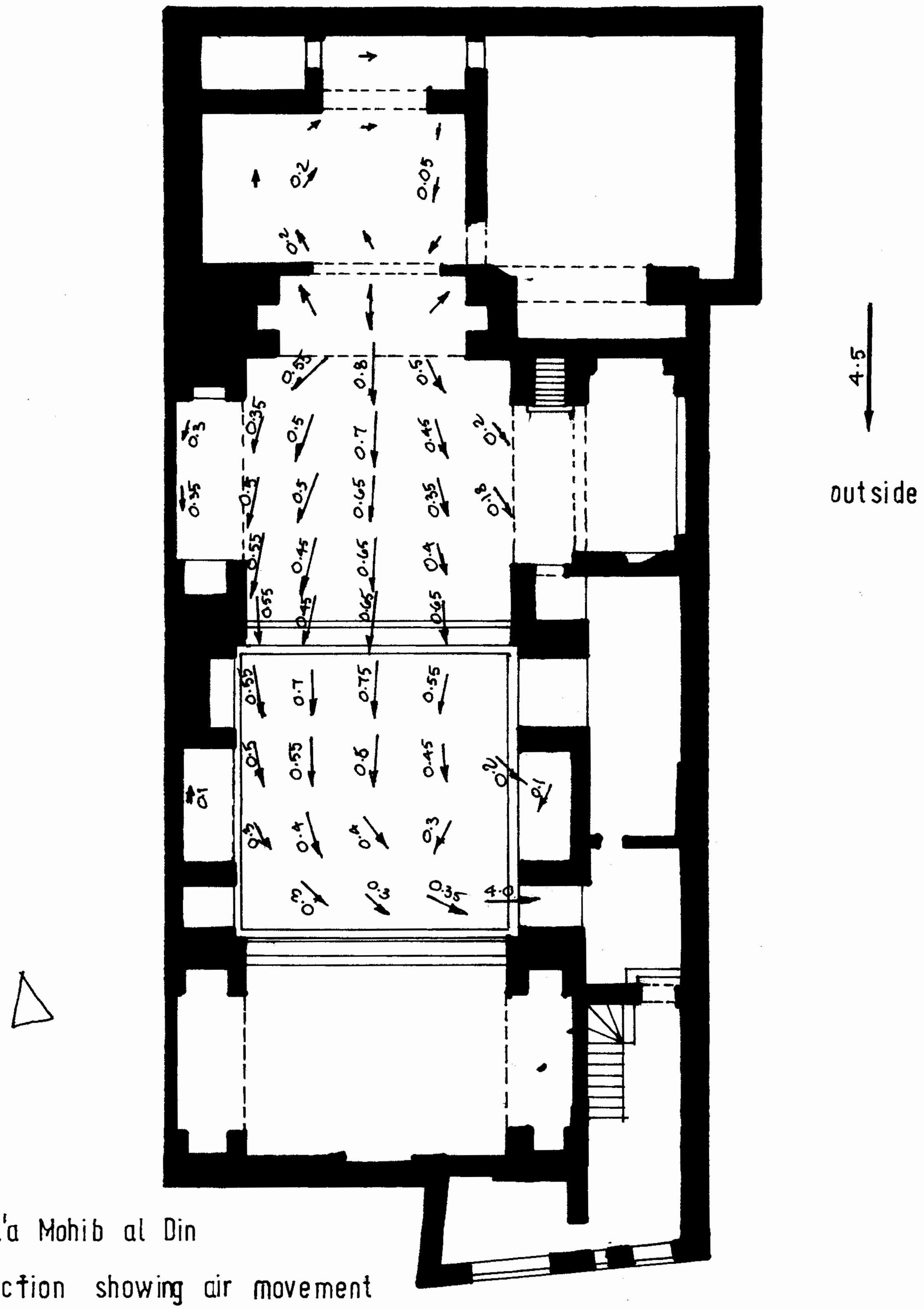
The catch itself is oriented towards the northerly prevailing winds. The air is drawn down a shaft through two gates or doors which can be opened or closed to determine the amount of air entering. The air then moves down across the floor through the useable parts of the room. The air escapes by high openings at the top of an upraised circular projection above the central Qa'a. This upper area collects hot light air by the convection principle; therefore it is a low pressure area, helping to draw the air out that way.

The high roof above the central Qa'a is of light construction and relatively flat, because of this it heats up quickly and in turn heats the air collecting here to a further degree aiding the air movement. We have noticed that even without a wind outside the convection system within this building works because of this particular design.

Air movement cannot be looked at alone as can be seen here. Localised temperature differences within a large building can modify the pattern. In the Qa'a Moheb al Din we were interested to find that during most of the day we were comfortable inside the building because our bodies were continually radiating heat to the cool walls (i.e. the walls were cooler than the air).

There are many ingenious variations on this basic model including multi-directional catch devices (persia) for areas where the wind often shifts directions. Systems for introducing porous water jars or wet materials into the mouth of the catch to encourage evaporative cooling of the air before it reaches a person within the building and many solutions for the design of the exit vent to produce a low pressure in that area and actually draw the air through the building.

The reason for the relative coolness will be explained in the next section. As the walls became warmer later in the afternoon this radiant cooling effect was lost and at this point the air movement, due to the system described above, increased dramatically. This increase may have been due to a slight change in wind direction outside and the fact that a cool breeze tends to blow from the north in the late afternoon and evening. This particular increase in air movement though may also relate to the relationship between indoor and outdoor temperature within the building is raising due to the fact that the walls are beginning to radiate warmth. The air within the building in this case being relatively warmer than the outside air has a lower density or pressure. Air always moves from high to low pressure hence air movement occurs here as a convection system is set up, through the building.

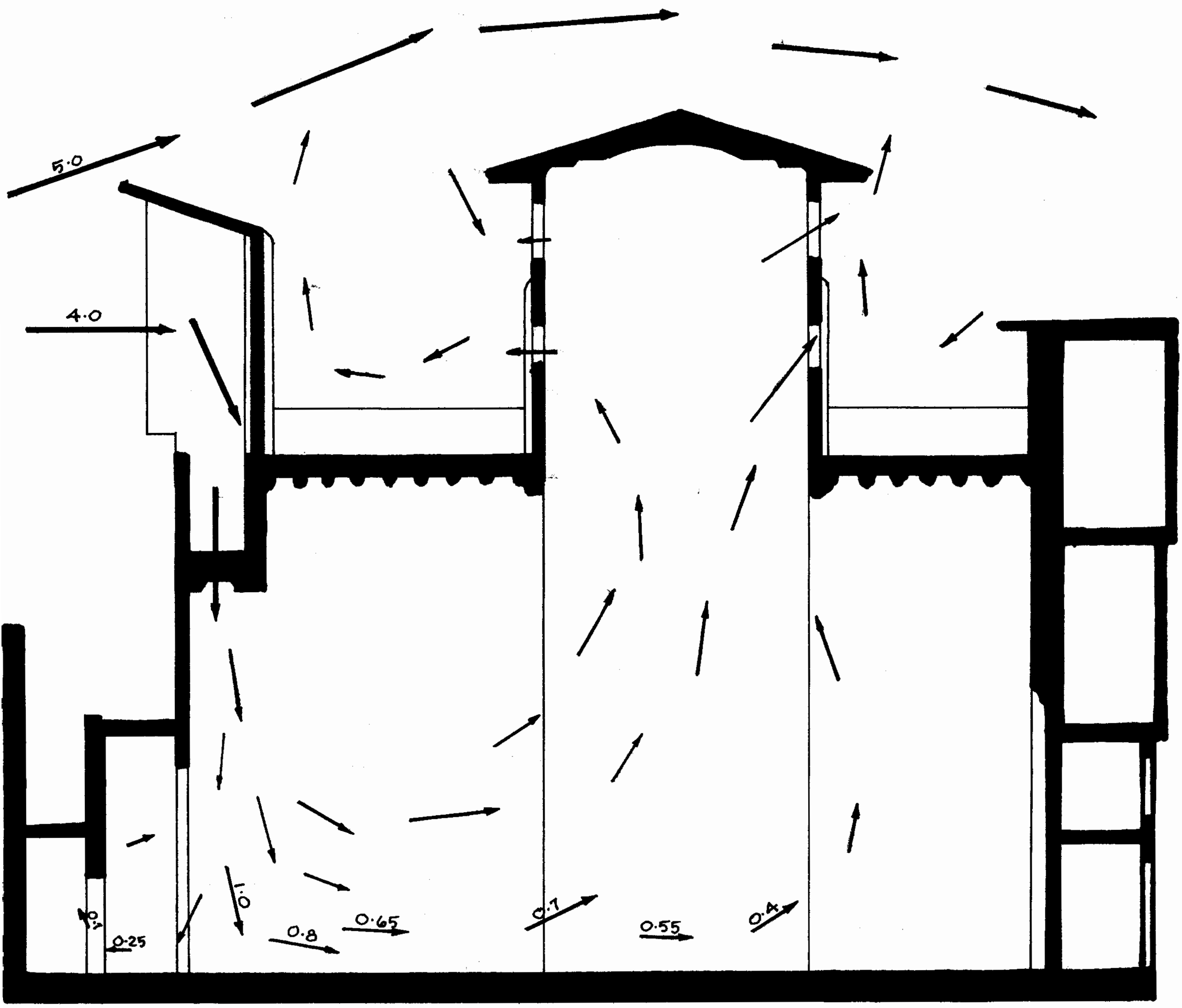


Qa'a Mohib al Din

Section showing air movement

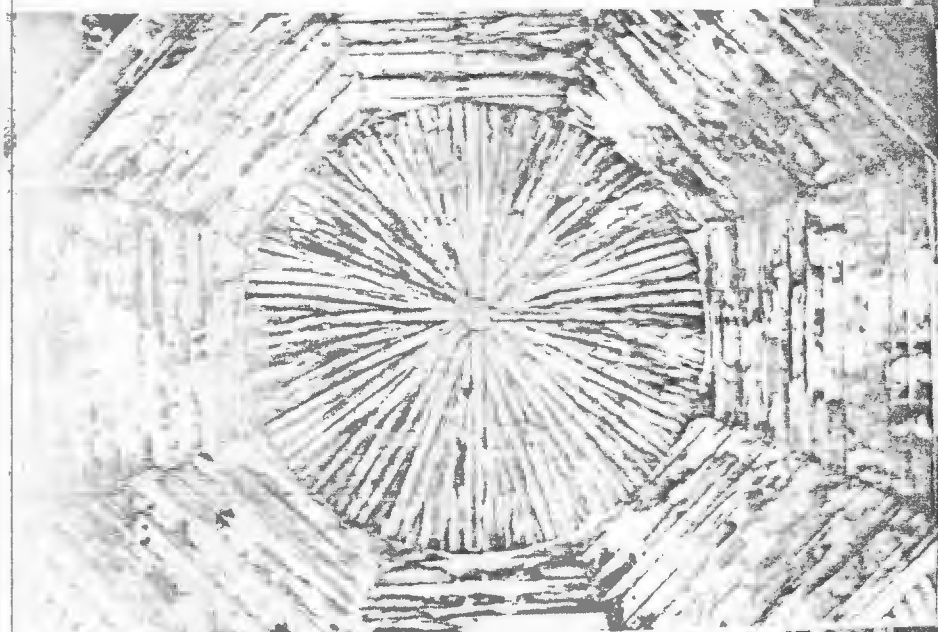
figures in m./sec.

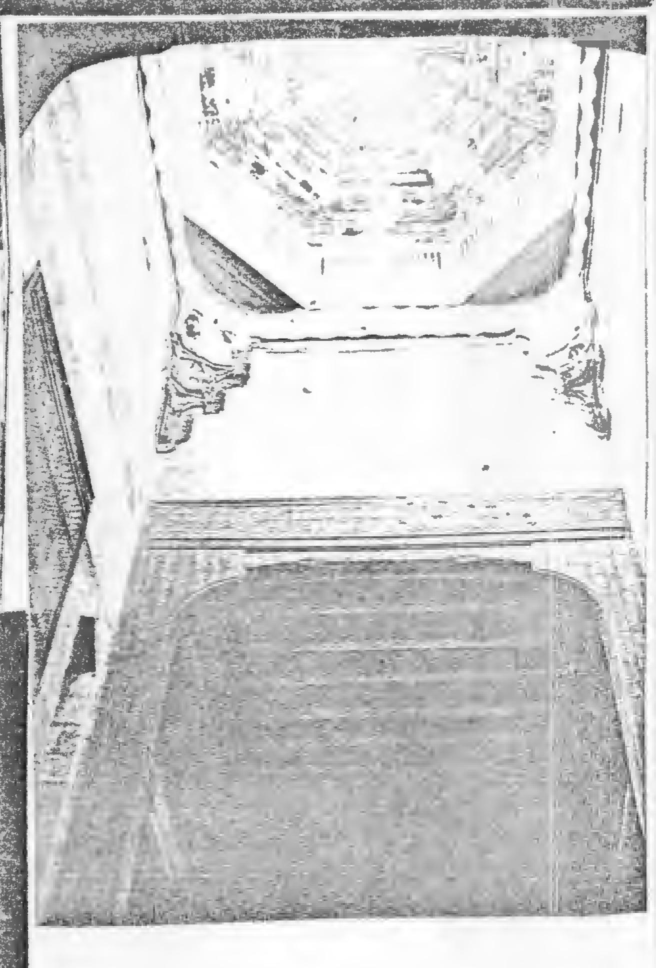
1·3 m. from floor



Qa'a Mohib al Din – section showing air movement
figures are in meters per second
arrow lengths proportional to velocity
measurements made April 2, 1973







QA'A MOHIB AL DIN.

Climatic Study of Streets and Courtyards

The street pattern of Old Cairo, complex as it may appear has an important planned control over the microclimate. The main street, the only relatively wide street, Sharia el Mu'Izz runs in a north south direction at right angles to the path of the sun. This orientation keeps the main street in shade most of the day.

The side streets on the other hand running east-west are very narrow and contain many bends, width changes and overhanging buildings. These streets by their design are also kept in shade. The only spaces in old Cairo which are open enough to receive sunshine for greater lengths of time are the points of intersection of side streets with the main street; and courtyards within the houses. These intersections tend to open up into small squares. The open spaces at the intersection not only provide a focal point or visual highlight and a community space but also serve micro-climatic functions. In the middle of the day these areas, receiving intense solar radiation, heat up to a greater extent than the shaded side streets. The hot air of the open intersection is of course less dense than the cooler air of the street. A convection system is automatically set up with cool denser air drawn down the side streets to replace the hot light air which rises. The side streets are therefore ventilated by this convection system. This theory is born out by observations recorded in our experiment. It can be seen clearly from our measurements that in areas, relatively unaffected by the prevailing wind conditions the air always moves from a cooler to a warmer area. The relationship between the courtyards and the streets of Sihaymi House in our tests also bears this out. In this example in the morning 10.30 the street is in sun, therefore is warm (31.5°C) while the courtyard is in cool shade (26.6°C). Air moves from the courtyard to the street. In the afternoon 14.30, the reverse is found when the court is in sun (31°C) and the street is in shade (30°C). Just after sunset, 18.30, though, there is no sunlight and the temperature of the street (27.°C) is close to that of the courtyard (27.3°C) and relatively little air movement is detected.

The north-south axis of the main street has other climatic implications when one notes that a north wind prevails most of the year. The main street draws air down its length ventilating this heavily used space. While moving down the length of the main street the wind tends to create low pressure areas in the wide open intersections of smaller streets off to the side. This action also induces air movement in the streets tending to draw the air up the streets to the intersection. This, combined with the convection system created by temperature differences creates a definite satisfactory air movement and ventilation system in the streets and courtyards of Old Cairo.

Climatic Study of Streets and Courtyards

Description of Experiment

A specific area of Old Cairo had to be chosen which was representative of the typical case and which contained the important elements of: a section of the main street, a side street and intesection point and a courtyard house. The area around Sihaymi House suited our purposes.

Eight test locations were chosen as representative of all the varying conditions in the immediate area. An open space on the roof of Sihaymi House allowed us to note the free air direction and velocity.

Location A gave us an indication of wind flow on the main street.

Location B was at the open space where the side street intersects with the main street.

Location C was at the entrance to the narrow side street.

Location D is at a point on the side street where a certain amount of turbulence was noted. The turbulence seems to have resulted from two special conditions, firstly the intersection of a narrow lane with the street and secondly due to the fact that the building on the south side of the street at D, not being the original building, projected several stories above the roof level of Sihaymi House across the street. The first building acted as a wind catch and deflected a current of air down at D. See the photo for the profile of this street.

Location E is a point on the side street in front of Sihaymi House.

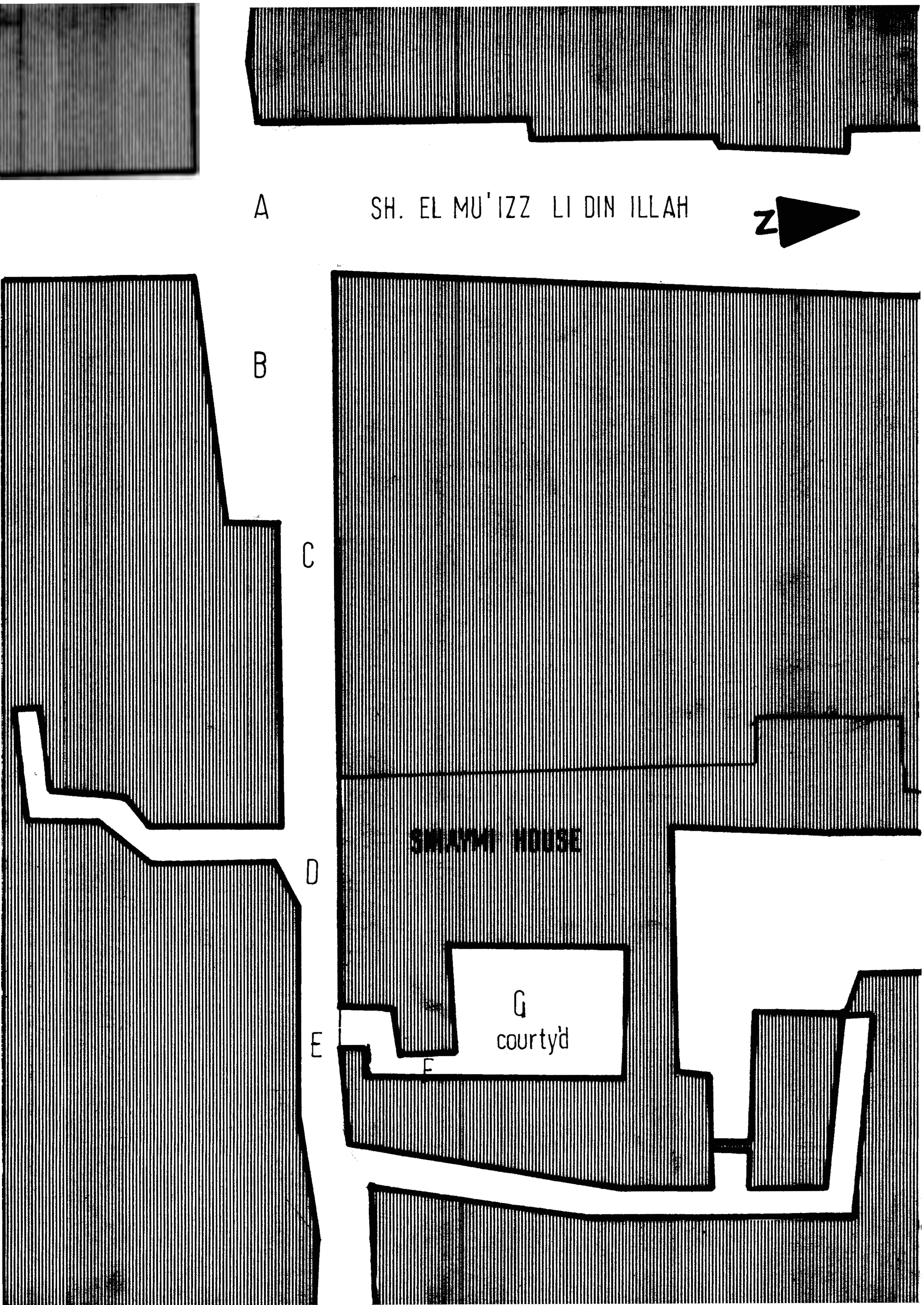
Location F is in a tunnel-like passage way which is typical of the transition space between the street and courtyard of the Islamic house.

Location G is the centre of one of the courtyards of Sihaymi House.

The apparatus used in this experiment included:- a dry bulb thermometer to record air temperature, and a velometer which records the velocity of air moving from the direction of maximum intensity.

Measurements were made at three different times of day. Firstly, at 10.30 in the morning, secondly at 14:30 in the early afternoon (hottest time of day) and thirdly at 18.30 a few minutes after sunset.

This experiment was carried out on May 1st, 1973.



A
SH. EL MU'IZZ LI DIN ILLAH
N
B
C
D
SUHAYMI HOUSE
G
courty'd
E
F

TEMPERATURE

TIME	10:30	14:30	18:30 AFTER SUN SET
ON ROOF IN OPEN	30·0 SUN	35·0 SUN	29·5
A	33·0 SUN	35·0 SUN	29·2
B	31·5 HALF SUN	34·0 SUN	29·2
C		31·5 SHADE	29
D	26·3 SHADE	31 SHADE	27·5
E	31·5 SUN	30·0 SHADE	27·0
F	27·0 SHADE	28·0 SHADE	26·0
G	26·6 SHADE	31·0 SUN	27·3

WIND VELOCITY M./SEC.

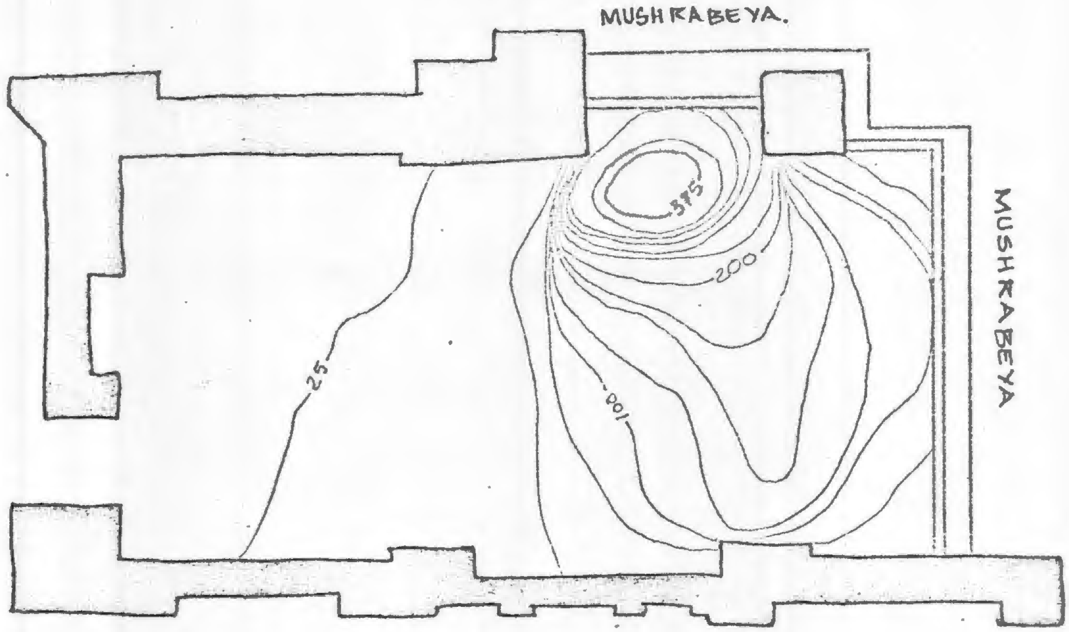
TIME	10:30	14:30	18:30
ON ROOF IN OPEN	2·5	1·5	2·0
A	0·6	1·5	0·4
B	1·5	1·5	0·4
C	1·8	1·5	0·2
D	0·8	1·0	0·6
E	1·0	2·0	0·2
F	0·2	0·5	0·175
G	0·05	0·05	0·0

WIND DIRECTION

TIME	10:30	14:30	18:30
ON ROOF IN OPEN	↖	↖	↖
A	←	←	←
B	↑	↑	↑
C	↑	↑	↑
D	↺	↺	↓
E	↑	↑	↑
F	←	→	←
G	↖	→	

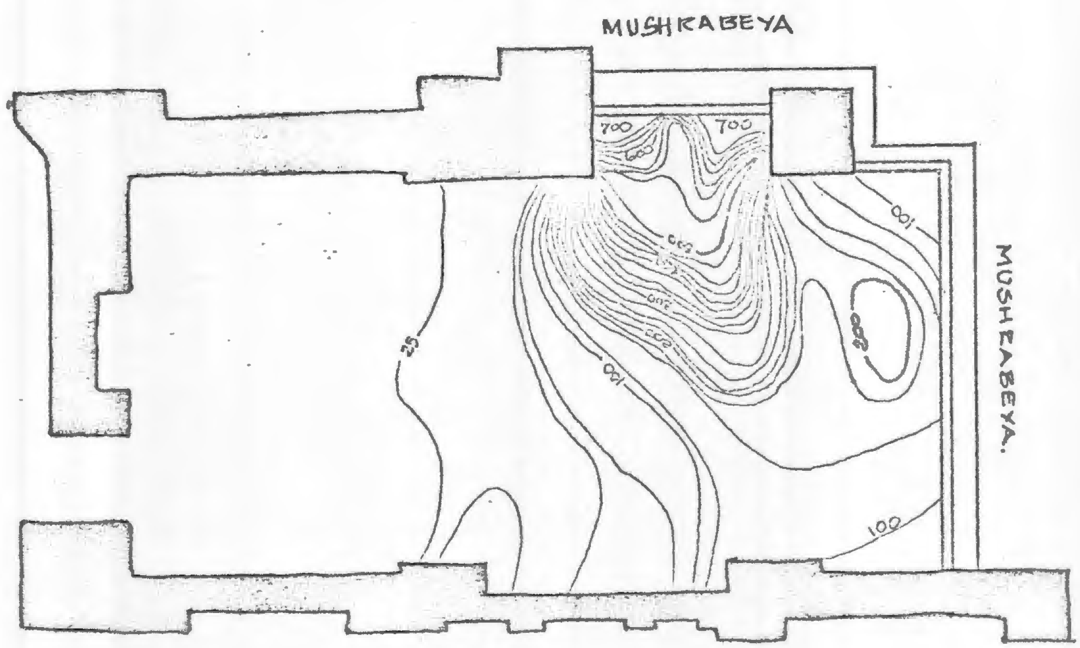
MUSHRABEYA

To reduce the glare without reducing the movement of air, the window was fitted with a latticed screen called a mushrabeya, made of small wooden bars. These bars are circular in section, and have the effect of breaking up the light that falls on them. Thus, there are no harsh edges visible, and the contrast of the bright light and dark lattice is reduced, softening the glare and not dazzling the eye. The characteristic shape of the lattice-work produces a silhouette which carries the line of sight from one bar to the next across interstices, so that a decorative pattern is superimposed upon the whole view from the window. The intensity of the lattice-work changes at different heights, thus increasing or decreasing the view through the window of the outside. Where the mushrabeya was used, the opening in the wall had to be larger than that for an ordinary window, to compensate for the dimming effect, and this was an advantage for ventilation purposes. The large openings require that the outer walls on the ground floor at the house are screen walls and not load-bearing walls.



11·30 a.m.

N ⟶



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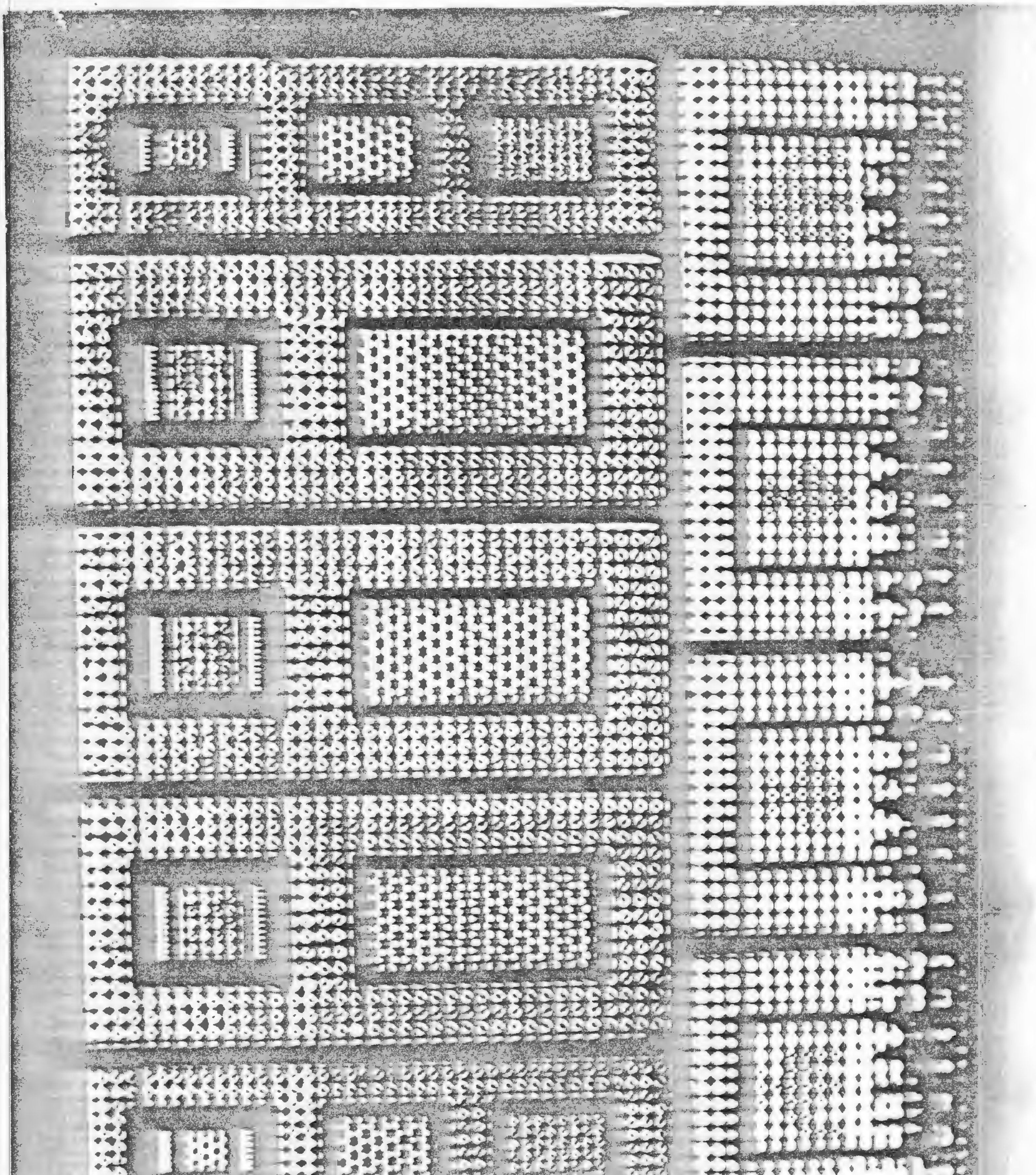
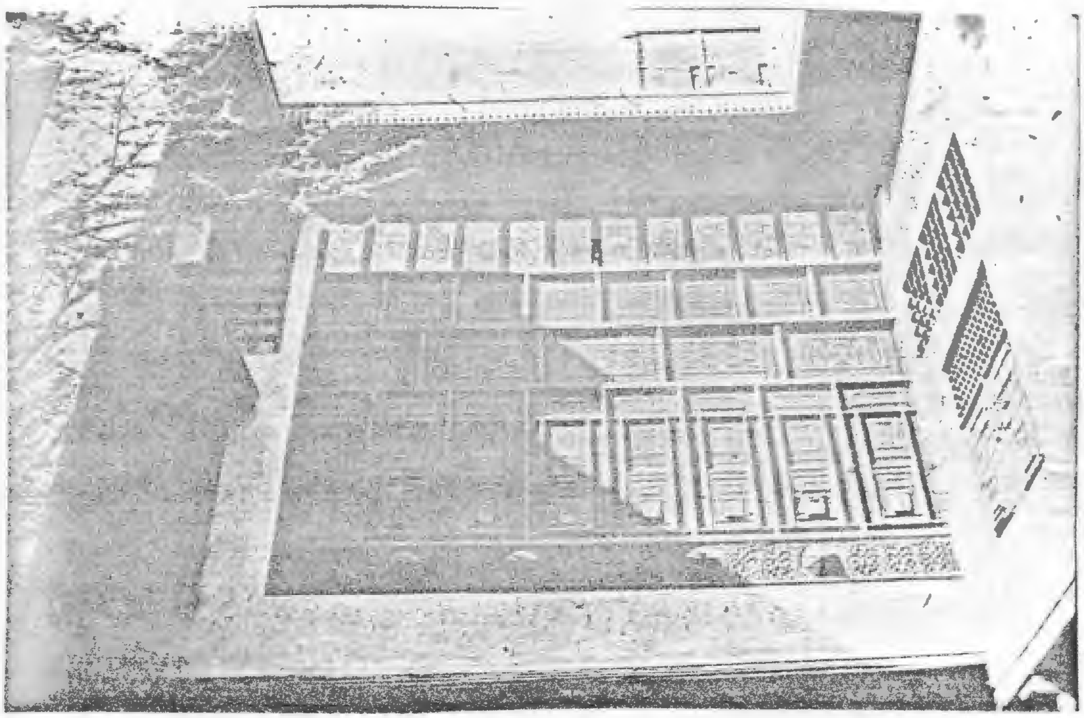
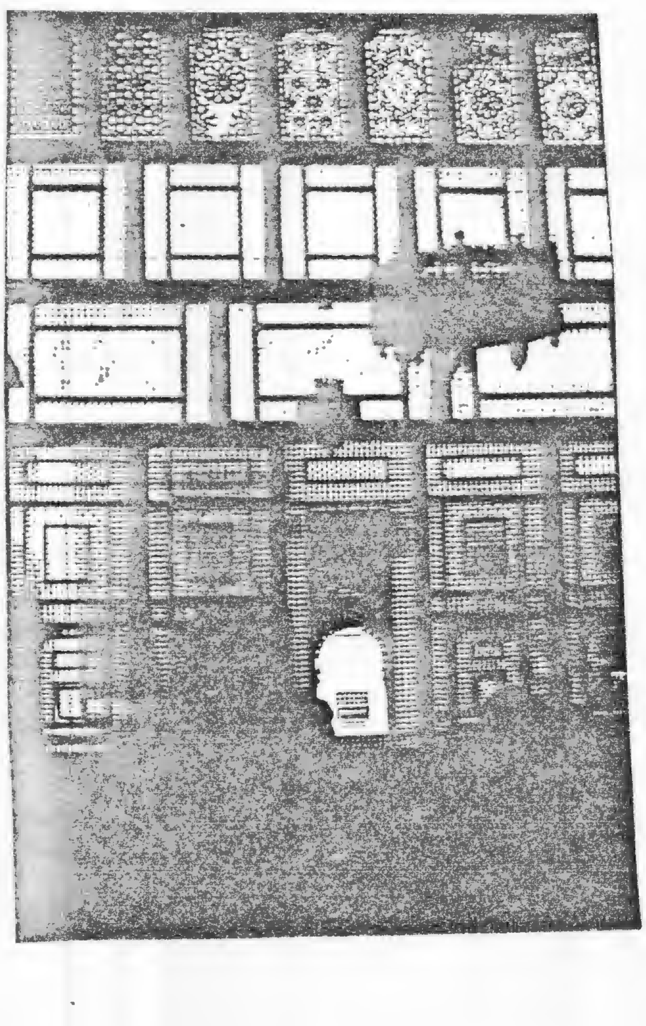
ILLUMINATION LEVELS – SUHAMI HOUSE







Climatic Study of Experimental Rooms at the Building Research Centre in Cairo

A number of years ago the Building Research Centre in Cairo invited several architects to propose ideas for housing the rural poor of Egypt. A large percentage of the non urban population did not even have the resources to roof their houses. Solutions were and still are urgently needed.

The Building Research Centre proposed the construction of a number of prototype rooms which could be tested for their suitability both economically and functionally.

Among the rooms built at the centre, were three rooms built by Hassan Fathy of mud brick with limestone foundations. Other rooms built included one of prefabricated lightweight concrete blocks and panels, one of red brick with a concrete slab roof, and another using standard concrete blocks and a light weight concrete slab roof. There were also a number of incompleted rooms which could not be studied.

Interesting though this project may be, these rooms had never been tested or compared.

We made simple tests on all six buildings. Using an electronic surface contact thermometer we measured surface temperatures of the exterior walls and roofs, in order to compare the relative heat absorbsion properties of the different materials due to solar radiation. Since each test room was built in an open space by itself, and each is orientated in the same direction they can be considered to be affected by the same climatic factors. All tests were made between 13:00 and 15:00 hours on March 28th 1973. We also measured interior wall and ceiling surface temperatures in each room to give some indication of heat transfer from exterior surfaces to interior surfaces. These later tests though cannot be considered to be accurate because the rooms had not been closed up before testing to allow the interior wall surface temperatures to stablize.

More thorough heat transfer tests were carried out on two of these rooms, and suitable precautions were taken in order to isolate this one phenomenon.

CLIMATIC EVALUATION OF TEST HOUSES AT THE BUILDING RESEARCH CENTRE - CAIRO

Firstly, it must be understood that our measurements were taken during the spring months in 1973, therefore the extremes of the Cairo climate were not experienced, and it is during the critical months of July and August and the coldest months of winter that must be designed for when considering climate.

On the other hand the measurements that we were dealing with could be considered to approach the ''average'' conditions of this area and estimates of the critical situations we have attempted to extrapolate from available data.

To begin with, we have made a comparatative study of thermal comfort conditions within specific houses at the building research centre, due to heat transfer through the building materials.

Although some measurements were made on all the test houses representing a wide range of building materials, we decided to focus our attention on two buildings which we felt represented two opposing sides to the problem of housing development in developing rural areas. Firstly, a house constructed with mud-brick using the traditional vault and dome construction and secondly, a house built using recently developed prefabricated concrete block and roof slab techniques.

Although thermal comfort comditions rely on a number of variables including air movement and individual tolerance, we have ,for this particular experiment ,assumed minimal air movement and, realizing that we have not controlled relative humidity, established our comfort zone using a method prescribed by 'C.T.Mahoney AA DIP. ARIBA' in a paper published by the PDU. London Univ.

We established the comfort zone for people used to the Cairo climate to be between <u>19.7°C to 25.7°C</u>

The two factors relating to thermal comfort discussed here will be thermal contuction and radiation i.e. conduction or the flow of heat through a building material by the transfer of energy from warmer to cooler molecules in contact with each other and the subsequent radiation of the wall surfaces to the air within the rooms.

Design of Experiment

The test rooms I to 6 were to be tested during the hottest time of the day (approx. 2pm) as to their wall surface temperatures.
Measurements to be made on (a) SSW facing outside wall(wall catching the sun at that time of the day)and the corresponding measurement on the inside surface (b) the NNE outside and inside wall and (c) the roof and the inside ceiling.Dry and wet bulb temperature readings were made throughout the period of measurement and a globe thermometer recorded the radiant temperature in a nearby open space.Colour chips were used to evaluate the reflectance value of the surfaces of the walls

The next stage in the experiment was to close or block up the doors and windows of two of the test rooms No.I and No.5 (mud brick vault and dome and prefab concrete house).The houses were to stay closed for at least 24 hours to allow the air temperature in the rooms to stabalize and not be constantly renewed by air movement and wind.Following this period a maximum-minimum thermometer was hung in each room in turn for 24 hours to establish the range of temperatures experienced inside each of the rooms on a given day.Corresponding to this,Dry Bulb,Wet Bulb and Globe Thermometer measurements were taken at the hottest time of day,2pm,and readings of the lowest outside temperatures were obtained from the Cairo weather office.
Wall surface temperatures inside and outside are to be taken at regular intervals i.e. every hour for 24 consecutive hours,for the two test rooms.Indoor and outdoor air temperatures are to be recorded at regular intervals as well.

From this information graphs can be drawn showing the heat transfer through the walls and the actual time lag for each condition can be determined.

The effect of radiation from the walls on the air temperature in the room can be observed and it should be noted whether or not comfort conditions can be maimtained.

Once the time lag is calculated it is a simple matter using published climatic data to extrapolate conditions in hte critical monthe,to discover whether or not comfort conditions are maintained.

TEST ROOM SURFACE TEMPERATURE COMPARISONS

Room One	Vault and dome mud brick
Room Two	Limestone and mud brick - vaulted with malkaf
Room Three	Limestone and mud with folded frpnd roof wind catcher (Rendered)
Room Four	Red brick with concrete slab roof
Room Five	Prefabricated concrete block and panel
Room Six	Concrete hollow block with slab roof

	Walls	Room One	Room Two	Room Three	Room Four	Room Five	Room Six
EXTERNAL SURFACES	South	40°	41°	40°	42°	43°	40°
	North	32°	32·5°	32°	33·5°	34°	33°
	Roof	43°	42°	48°	48°	49·5°	48°
INTERNAL SURFACES	South	28°	30°	31°	33°	34°	32°
	North	28°	30°	30°	29°	30°	30°
	Roof	25°	25°	26·5°	32°	34°	33·5°
Globe Thermometer		26·5°	27·5°	28°	28°	30°	29°

The globe thermometer measures air temperature combined with the temperatures radiated from walls and roof.
It was taken in the centre of each room.

Heat Transfer through Walls

The traditional materials which people were forced to use not only had implications on the structural system employment in Egypt, but also had an effect on the thermal performance of the buildings. Limestone tended to be used in the towns and mudbrick in rural areas. Both materials are useful only in compression and massive loadbearing wall systems resulted. Thick walls of these materials transmit heat very slowly. Heat absorbed in these walls is retained and emitted at a later time.

Direct Ratiation from the sun on exposed exterior walls causes the surfaces of those walls to heat up to a temperature higher than the air temperature. The transfer of this heat from the surface into the wall materials by conductance occurs. At some time later a portion of this heat will be radiated into the interior of the building from the interior wall surface. On the other hand during the night when the interior is warmer than the outside the heat flow will occur in the opposite direction. The time that it takes for heat to flow through a particular wall is called "time lag".

The effect of this heat flow through limestone walls has been briefly mentioned in relation to the Qa'a Mohib Al Din.

To make a comparison between the vernacular building and a proposed 'modern' building solution we tested two small rooms built in different ways. The first room was made of mud brick and consisted of a vault and dome roof supported on 50 cm thick load bearing walls. The second room was a similar size but was made from reinforced concrete with a prefabricated roof panel system supported on a 15 cm thick prefabricated block wall. These are examples of two different systems proposed for rural reconstruction projects in poor areas of Egypt.

We tested these rooms to see how they responded to the hot dry climate. Our tests focussed on the heat transferred through the walls of these buildings and its effect on internal air temperature.

Firstly, it must be understood that our measurements were taken during the Spring months in 1973, therefore the extremes of the Cairo climate were not experienced, and it is during the critical months of July and August and the coldest months of winter that must be designed for when considering climate.

On the other hand the measurements that we were dealing with could be considered to approach the 'average' conditions of this area and estimates of the critical situations we have attempted to extrapolate from available data.

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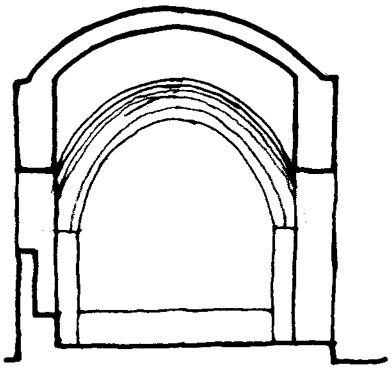
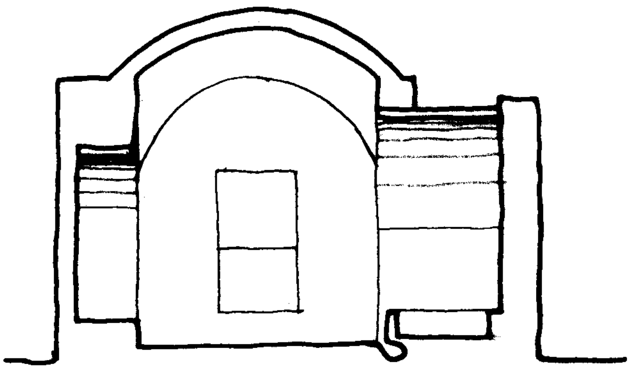


SECTION A-A



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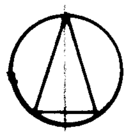

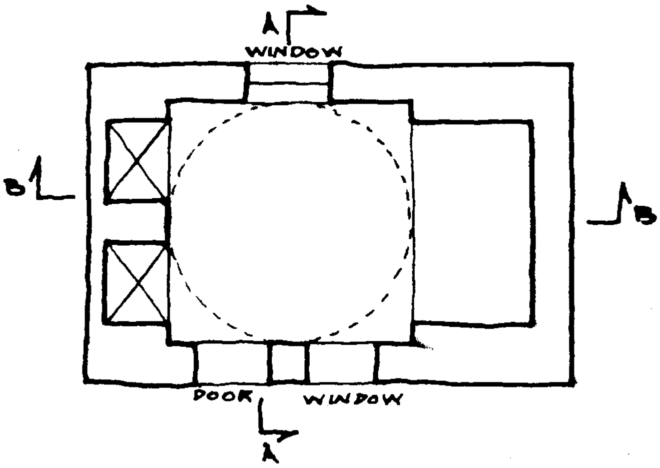

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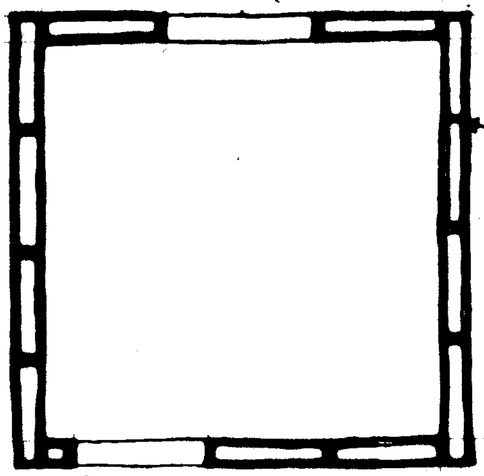
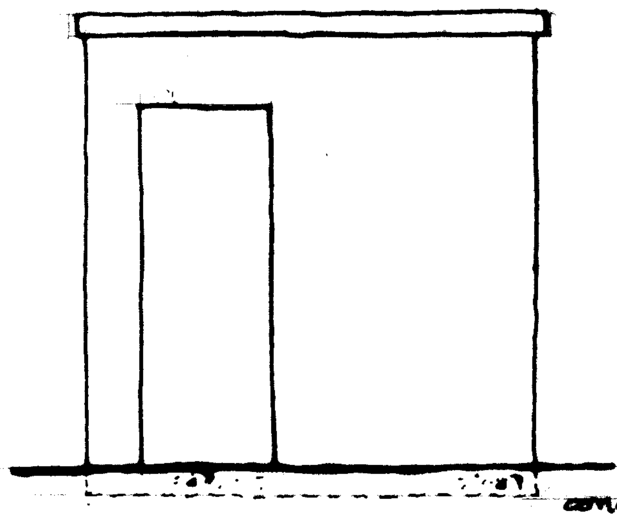
EXPERIMENTAL ROOM 1. SUN DRIED MUD BRICK UNIT.
VAULT & DOME ROOF.



PLAN.

ROOF SECTION



ELEVATION.

1:50.

EXPERIMENTAL ROOM 2.
PREFABRICATED CONCRETE UNIT.

Design of Heat Transfer Experiment

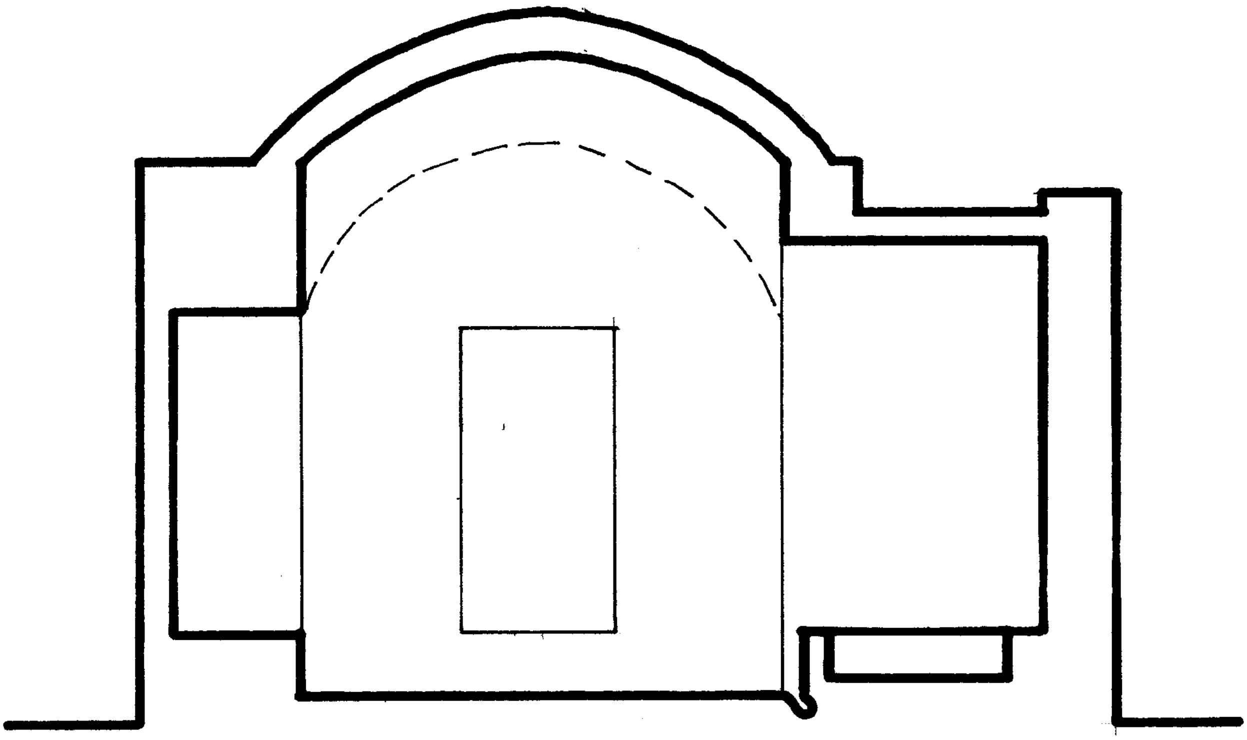
The first step in the experiment is to close or block up the doors and windows of the two test rooms (mud brick vault and dome and prefab concrete house). The houses are to stay closed for at least 24 hours to allow the air temperature in the rooms to stabalize and not be constantly renewed by air movement and wind. Following this period a maximum-minimum thermometer is hung in the centre of each room for 24 hours to establish the range of temperatures experienced inside each of the rooms on a given day. Corresponding to this, Dry Bulb, Wet Bulb and Globe Thermometer measurements are taken at the hottest time of day, 2pm, and coolest time of day, approx. 6.00 am.

Wall surface temperatures inside and outside are to be taken at regular intervals, i.e. every hour for 24 consecutive hours, for the two test rooms. Indoor and outdoor air temperatures are to be recorded at regular intervals as well.

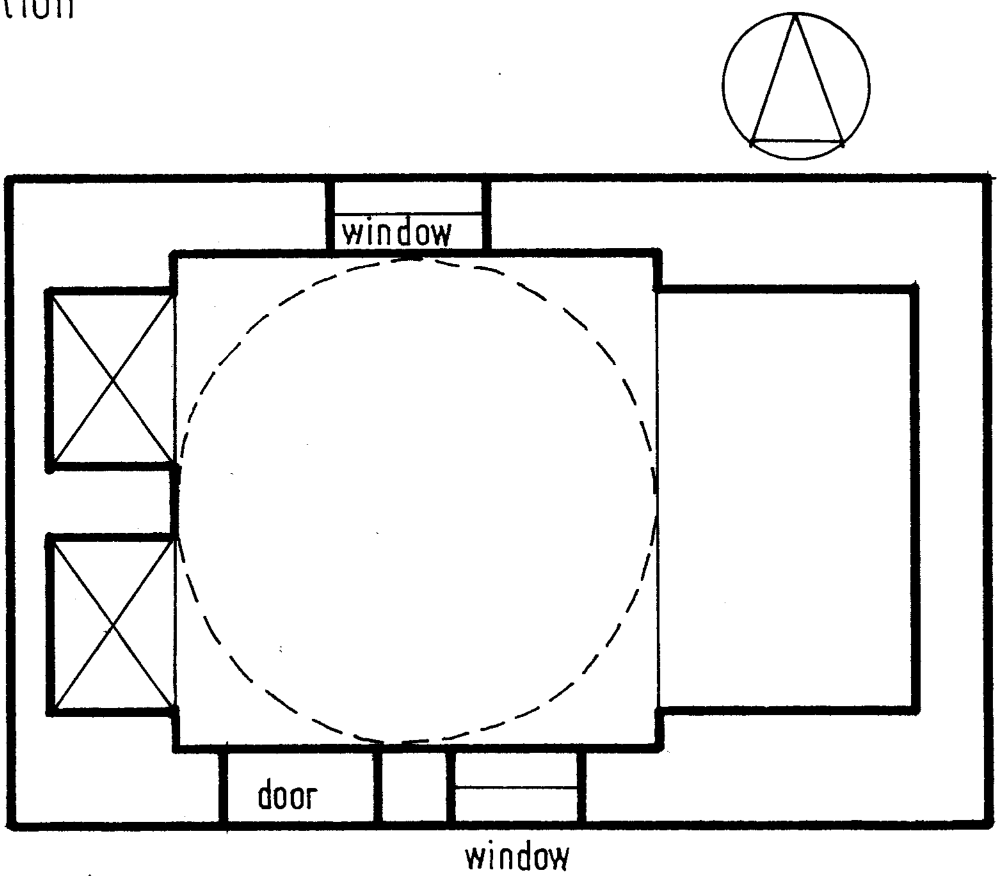
From this information graphs can be drawn showing the heat transfer through the walls and the actual time lag for each condition can be determined.

The effect of radiation from the walls on the air temperature in the room can be observed and it should be noted whether or not comfort conditions can be maintained.

Once the time lag is calculated it is a simple matter using published climatic data to extrapolate conditions in the critical months, to discover whether or not comfort conditions will be maintained.



Section



Plan

SUN DRIED MUD BRICK VAULT AND DOME TEST ROOM

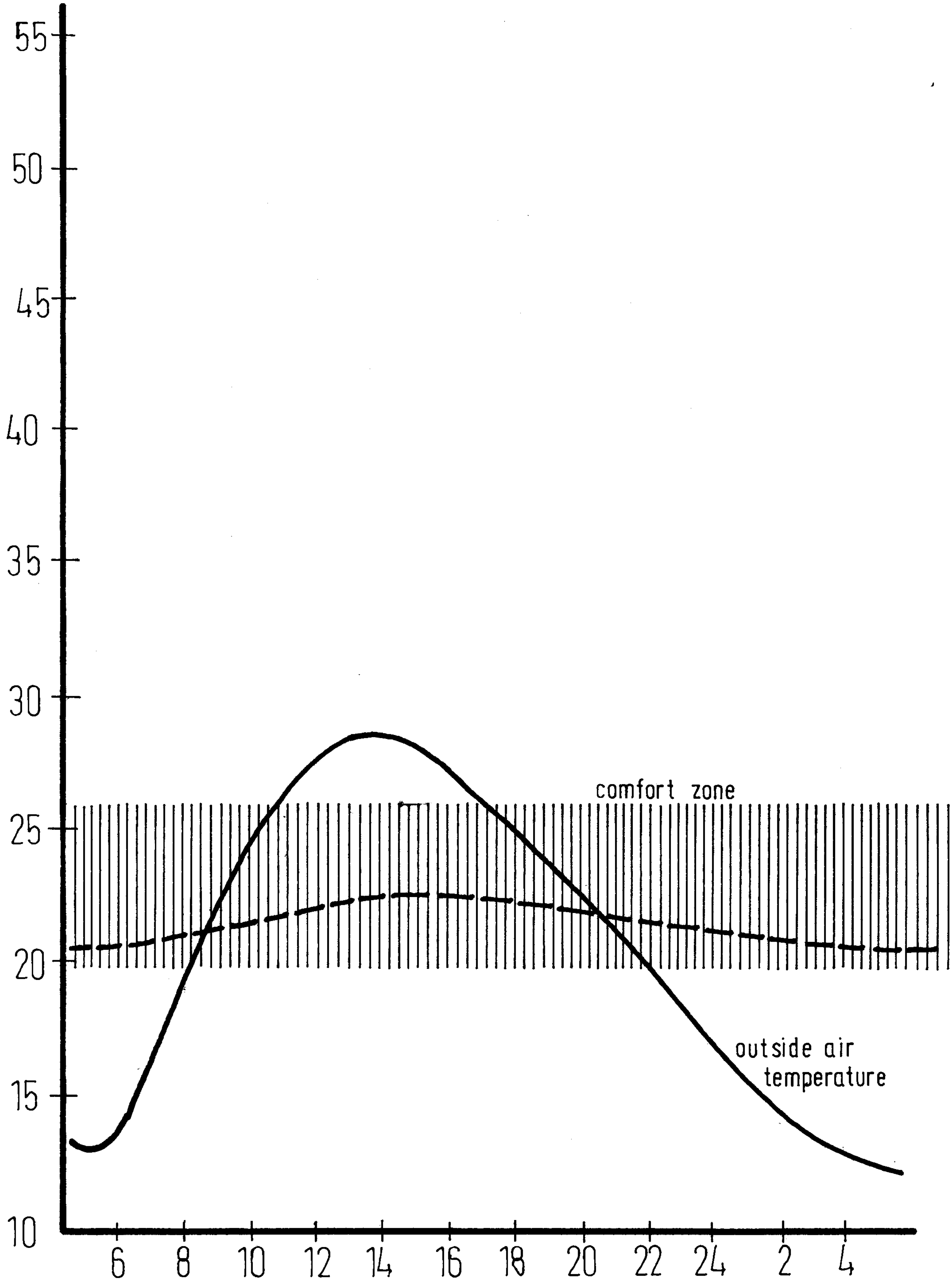
The graphs which follow show the variation of internal and external wall surface temperatures for the mud brick and prefabricated concrete test rooms over the 24 hour period of our experiment.

'Temperature' is plotted on the vertical axis and 'time' on the horizontal axis.

Both external and internal wall surface temperatures are found on the same graph.

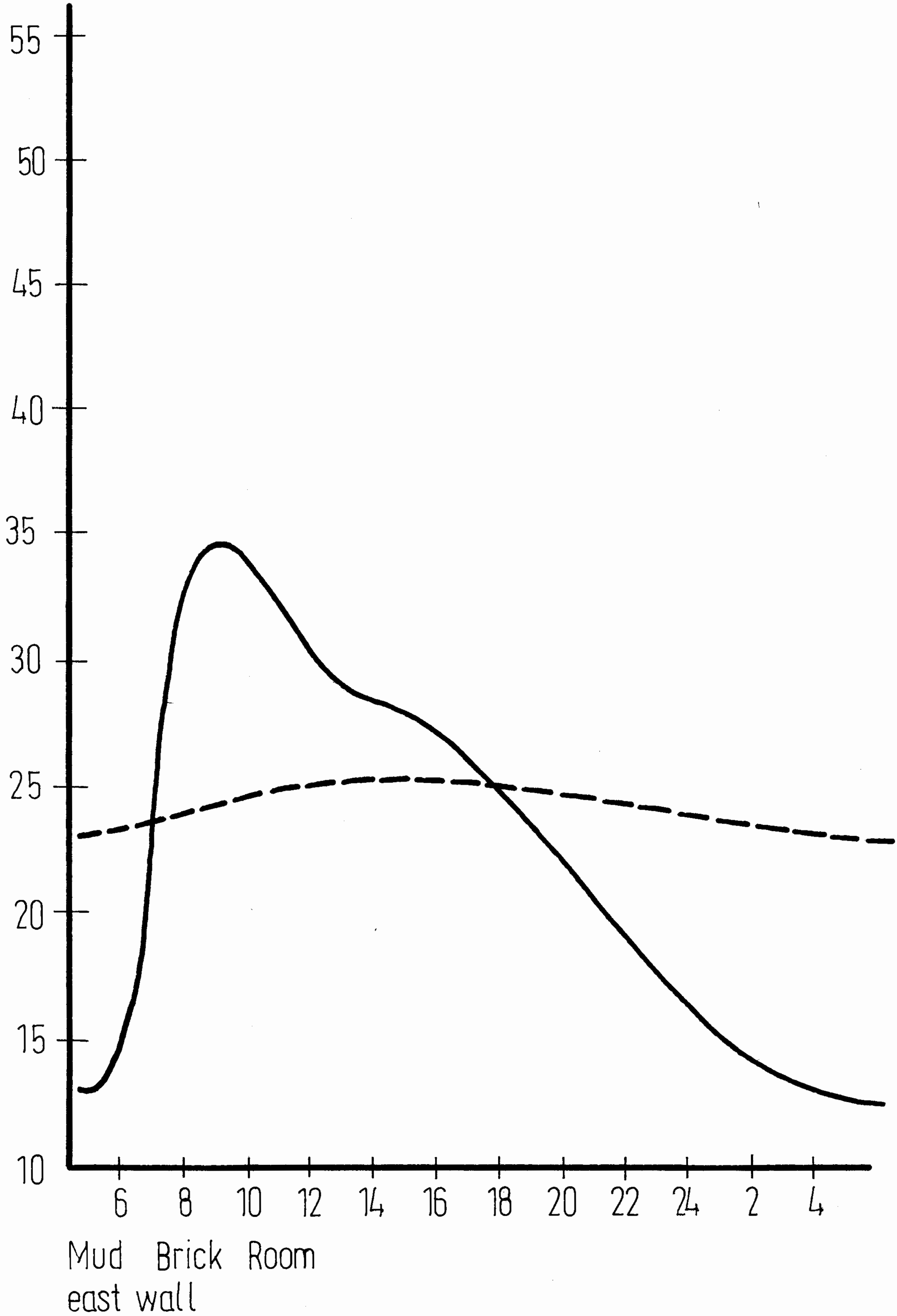
Internal — — — — — —

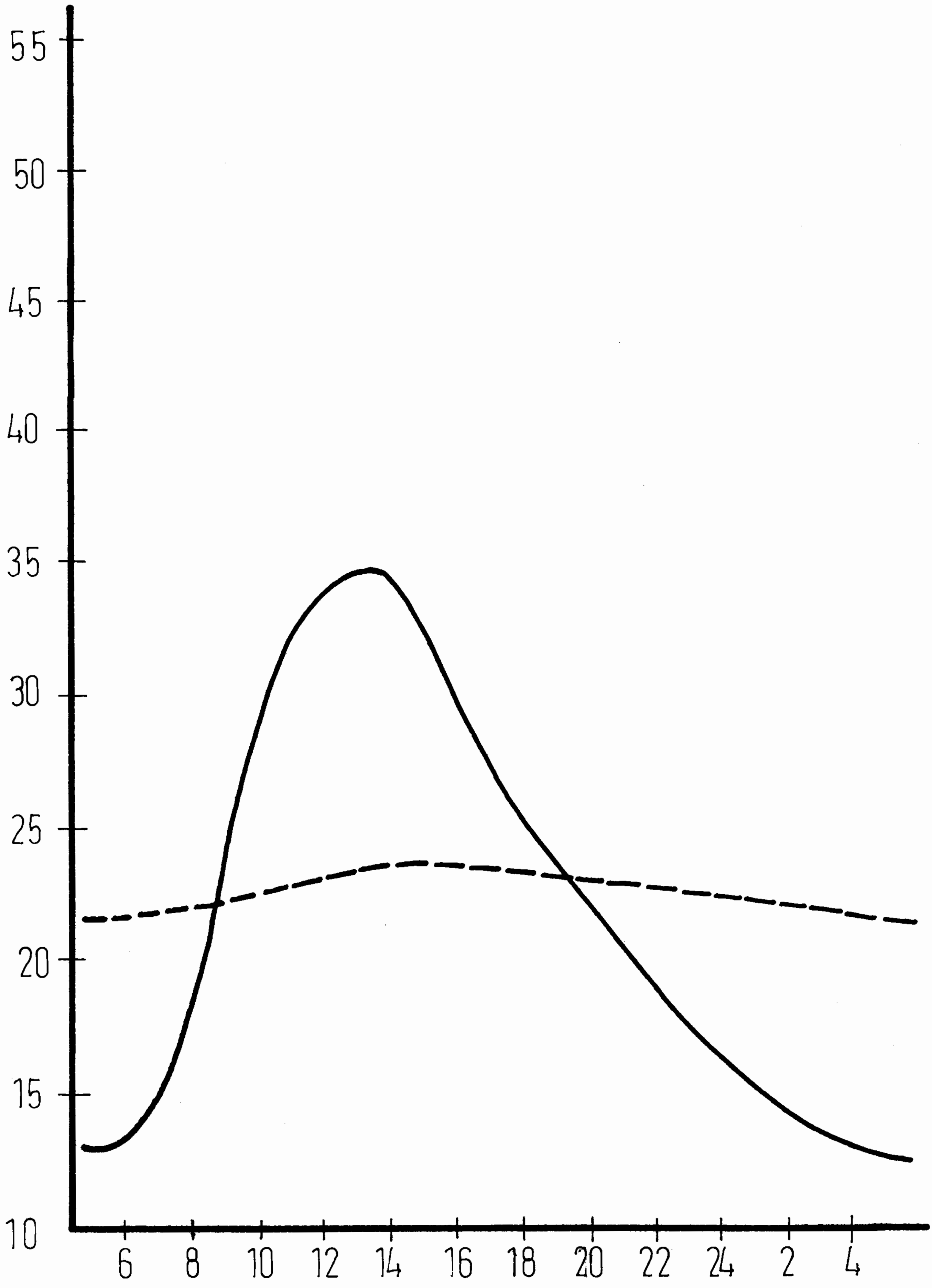
External ————————



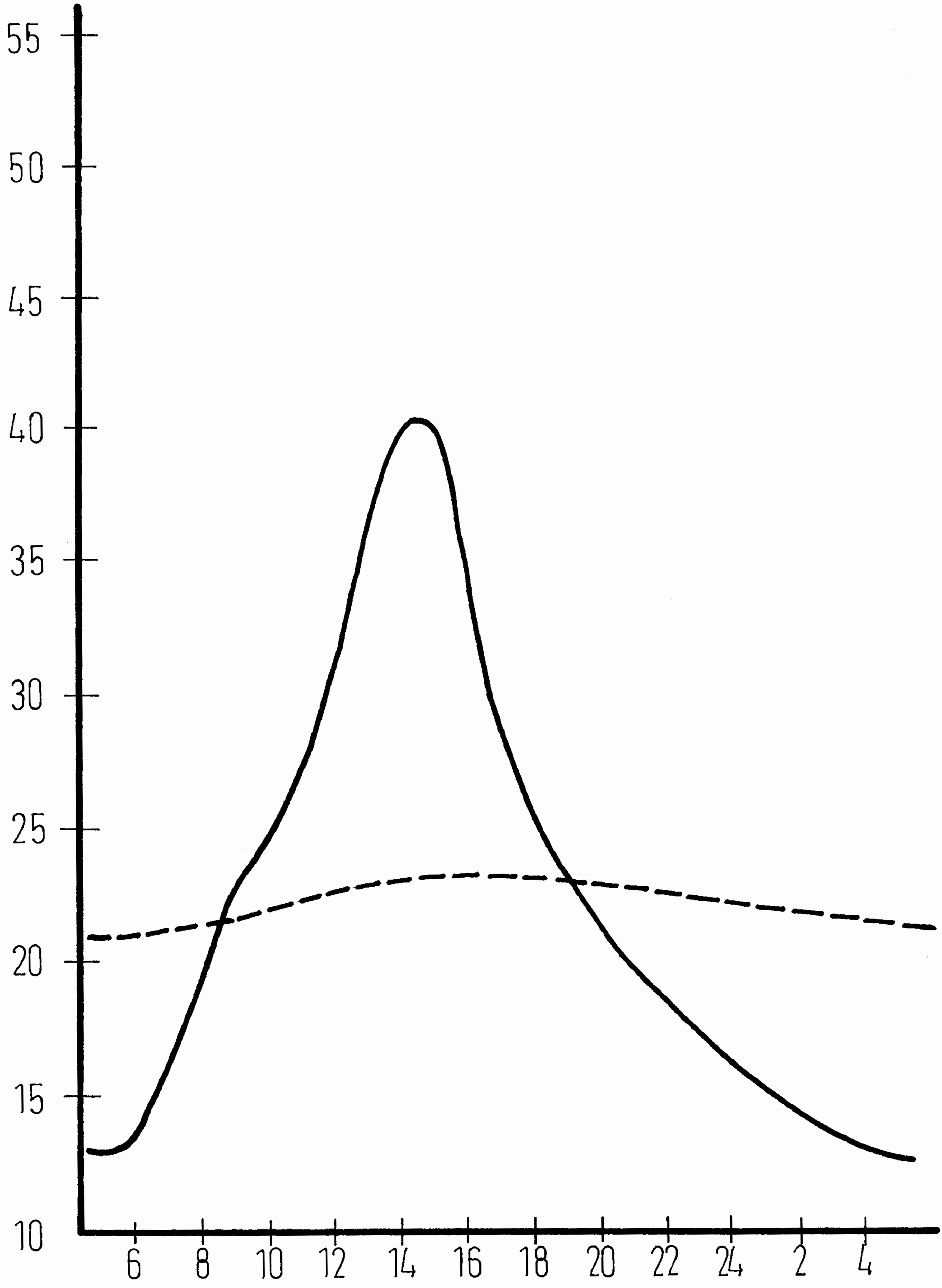
Mud Brick Room

interior air temperature - - - -

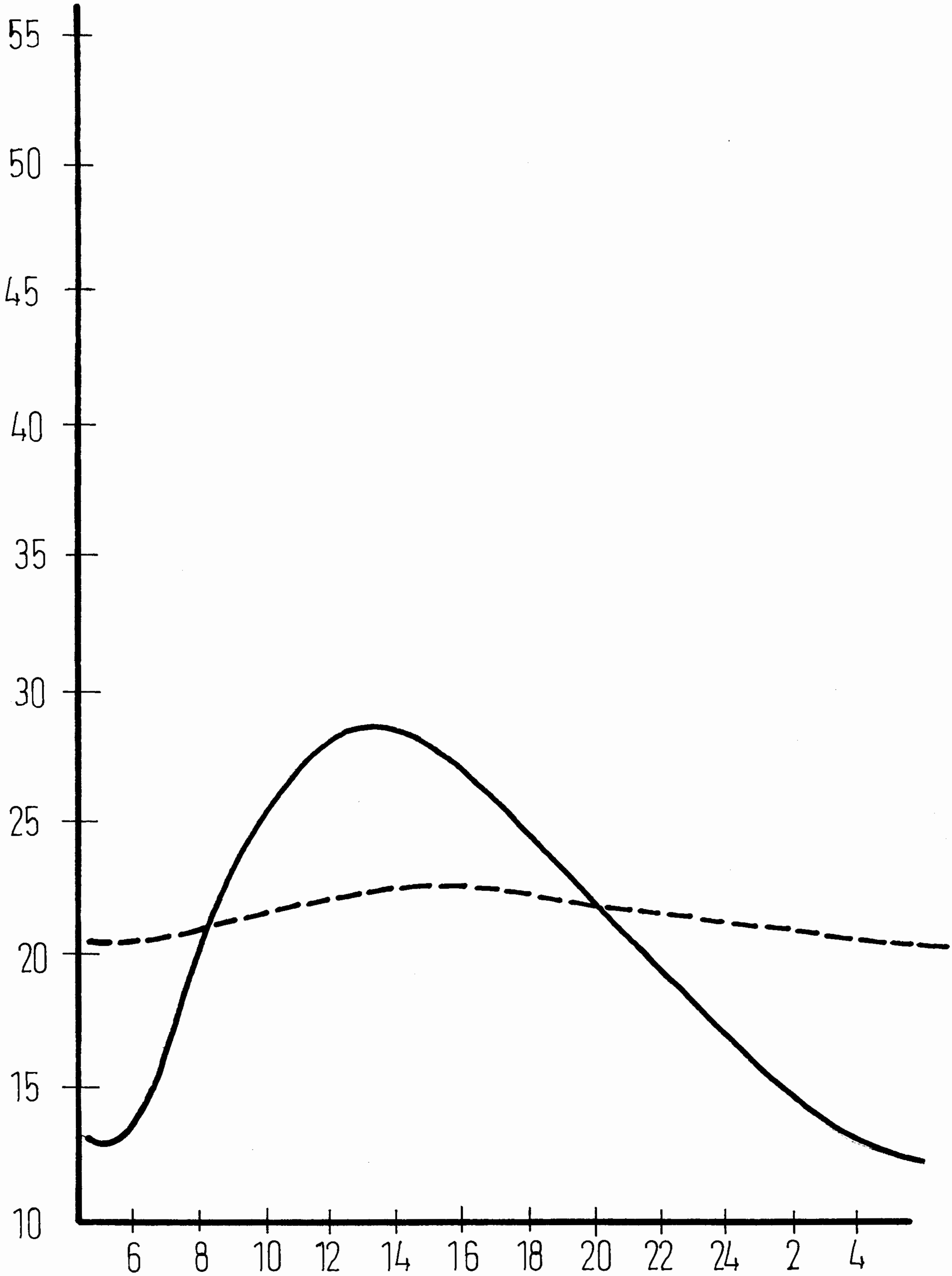

55
50
45
40
35
30
25
20
15
10
6
8
10
12
14
16
18
20
22
24
2
4
Mud Brick Room
east wall



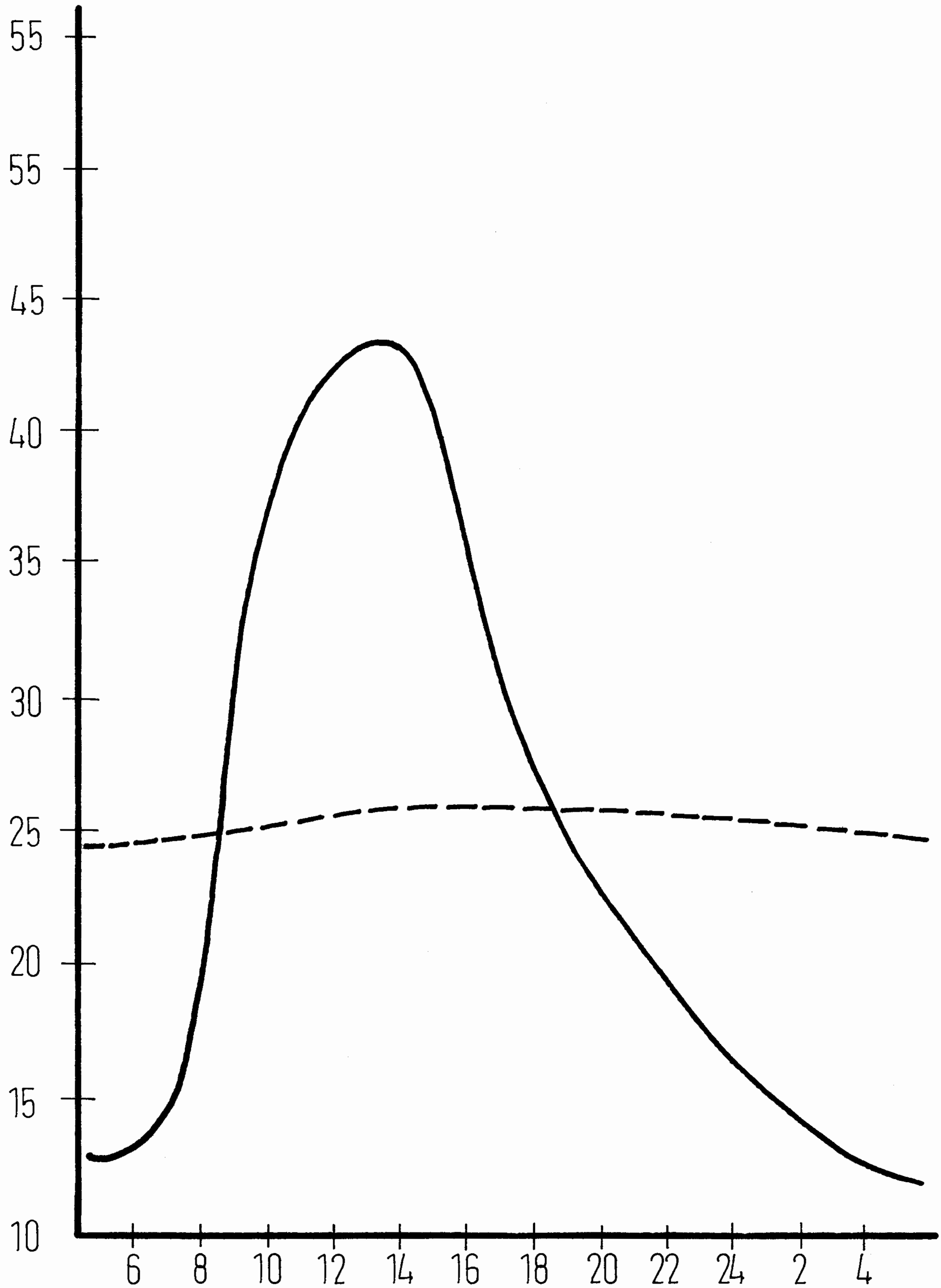
Mud Brick Room
south wall



Mud Brick Room
west wall

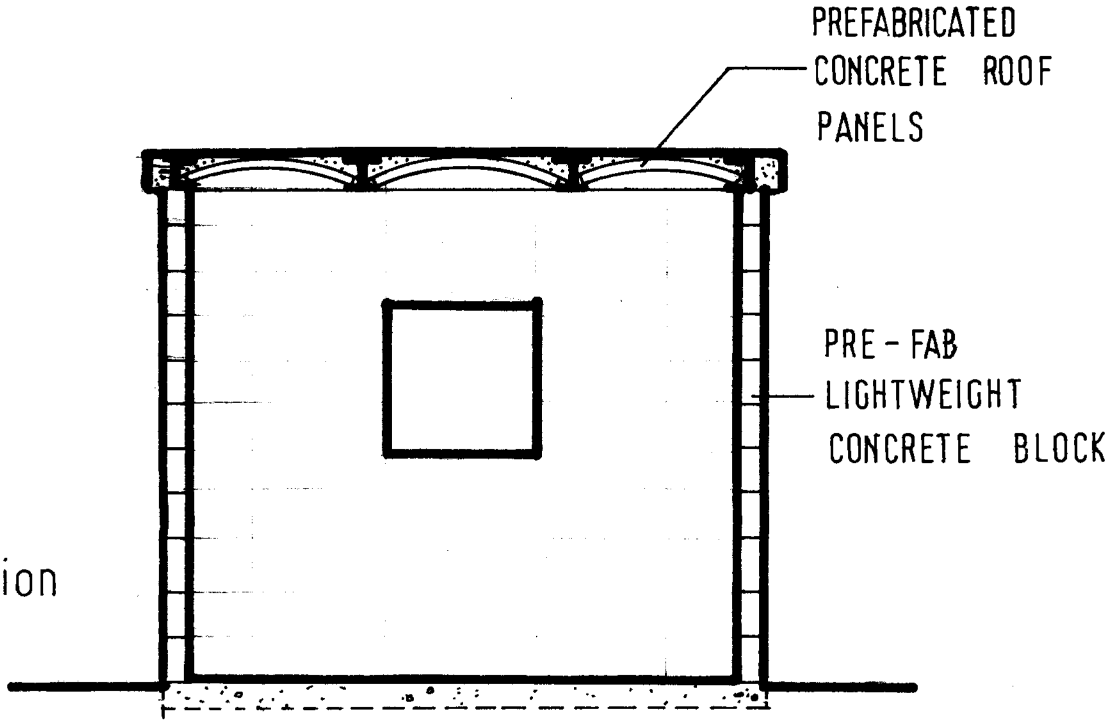


Mud Brick Room
north wall

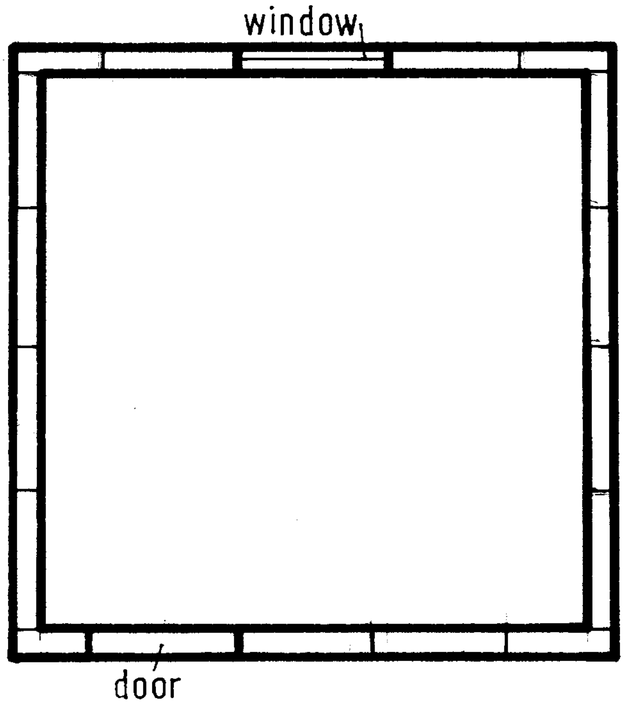


Mud Brick Room
roof

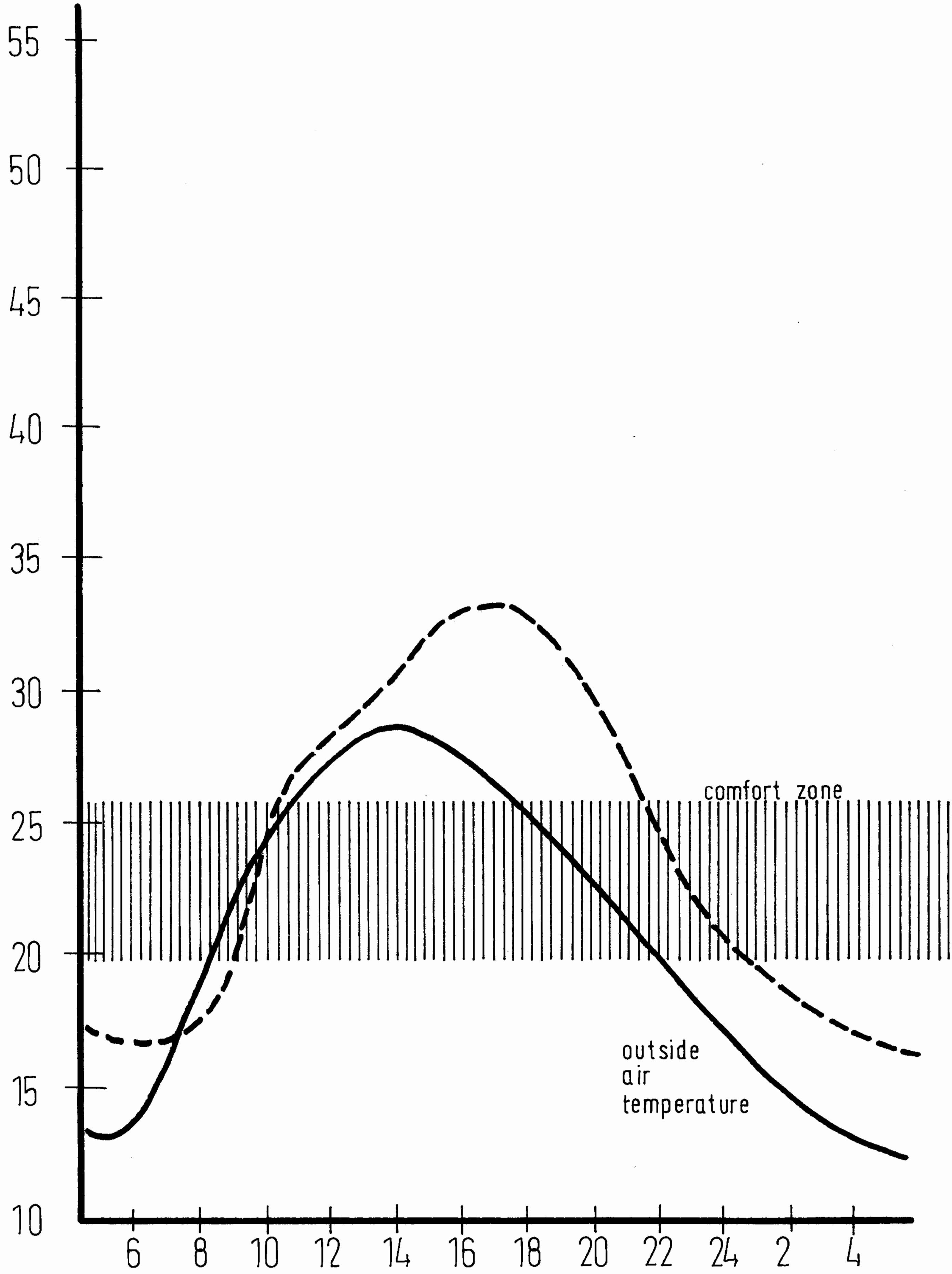
Section



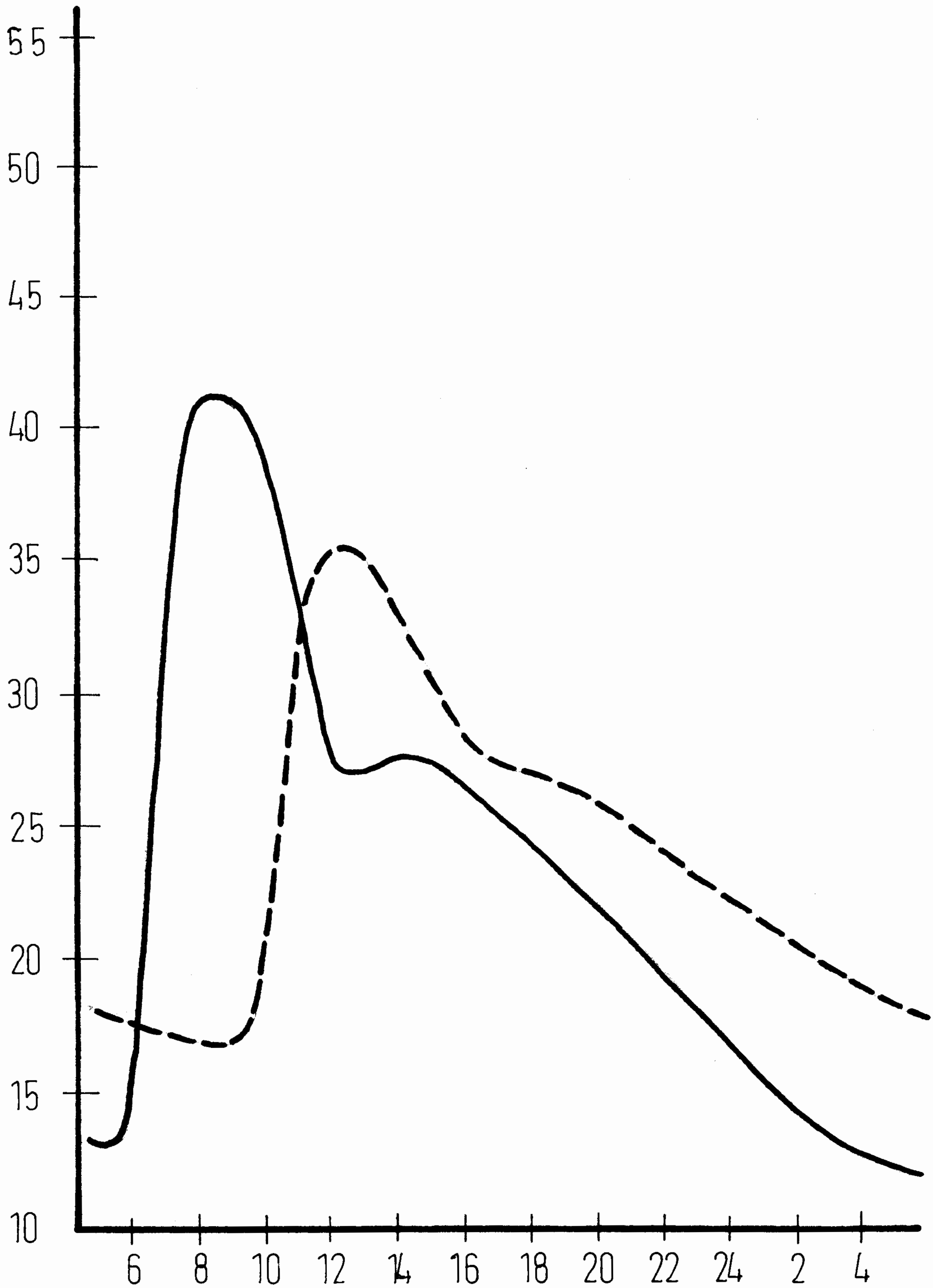
Plan



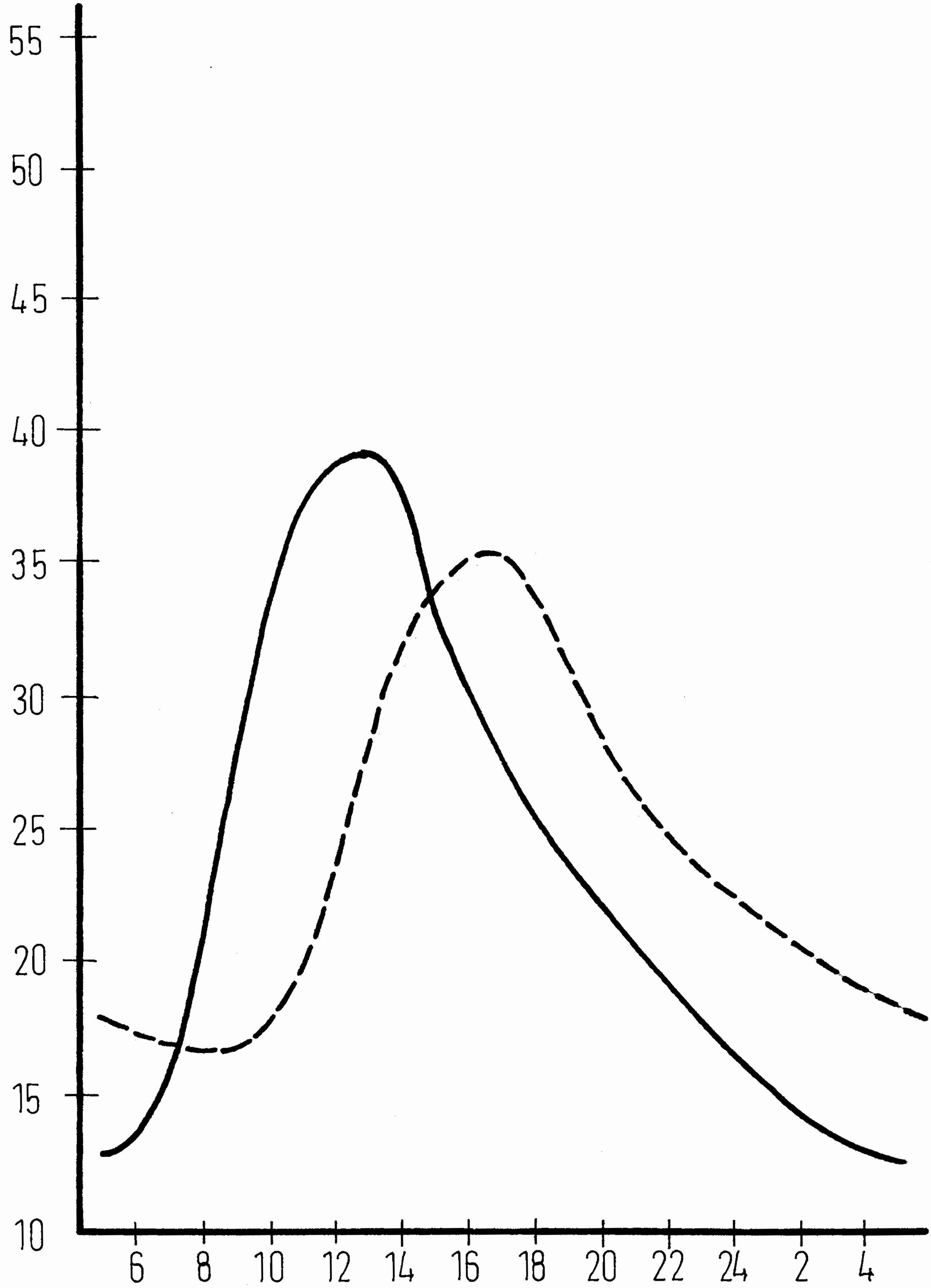
PREFABRICATED CONCRETE TEST ROOM



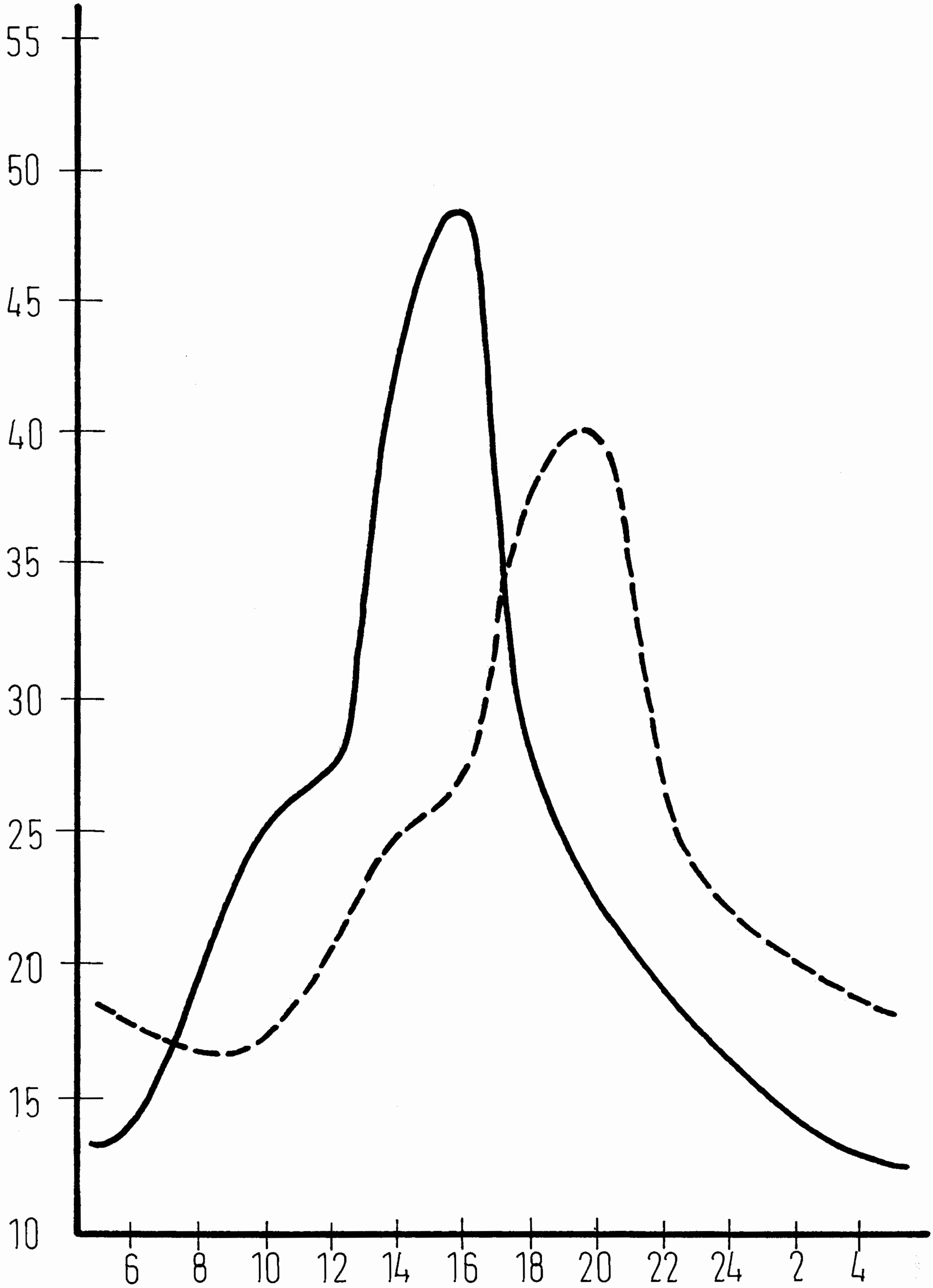
Prefabricated concrete room
interior air temperature - - - -



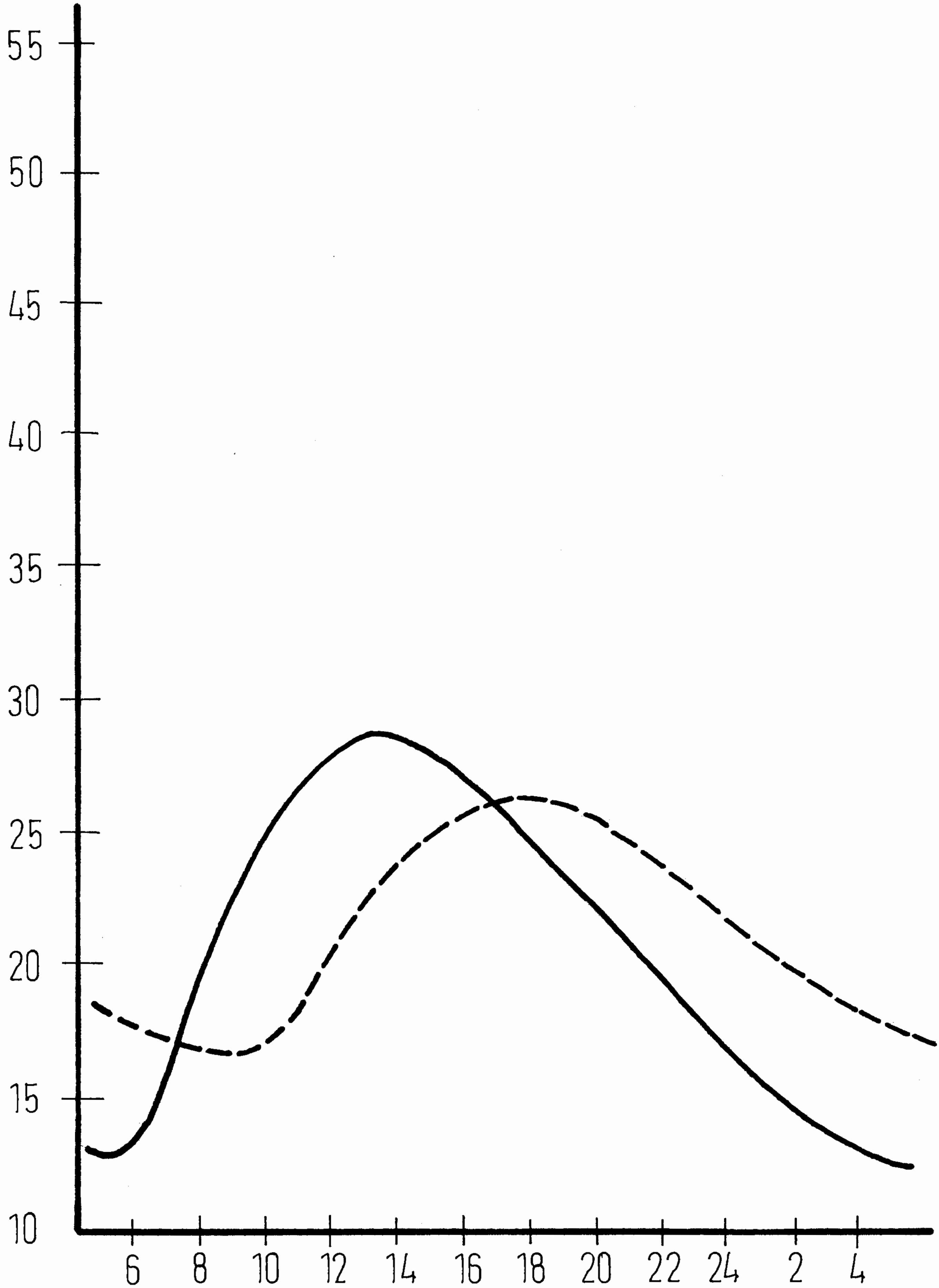
Prefabricated concrete room
east wall



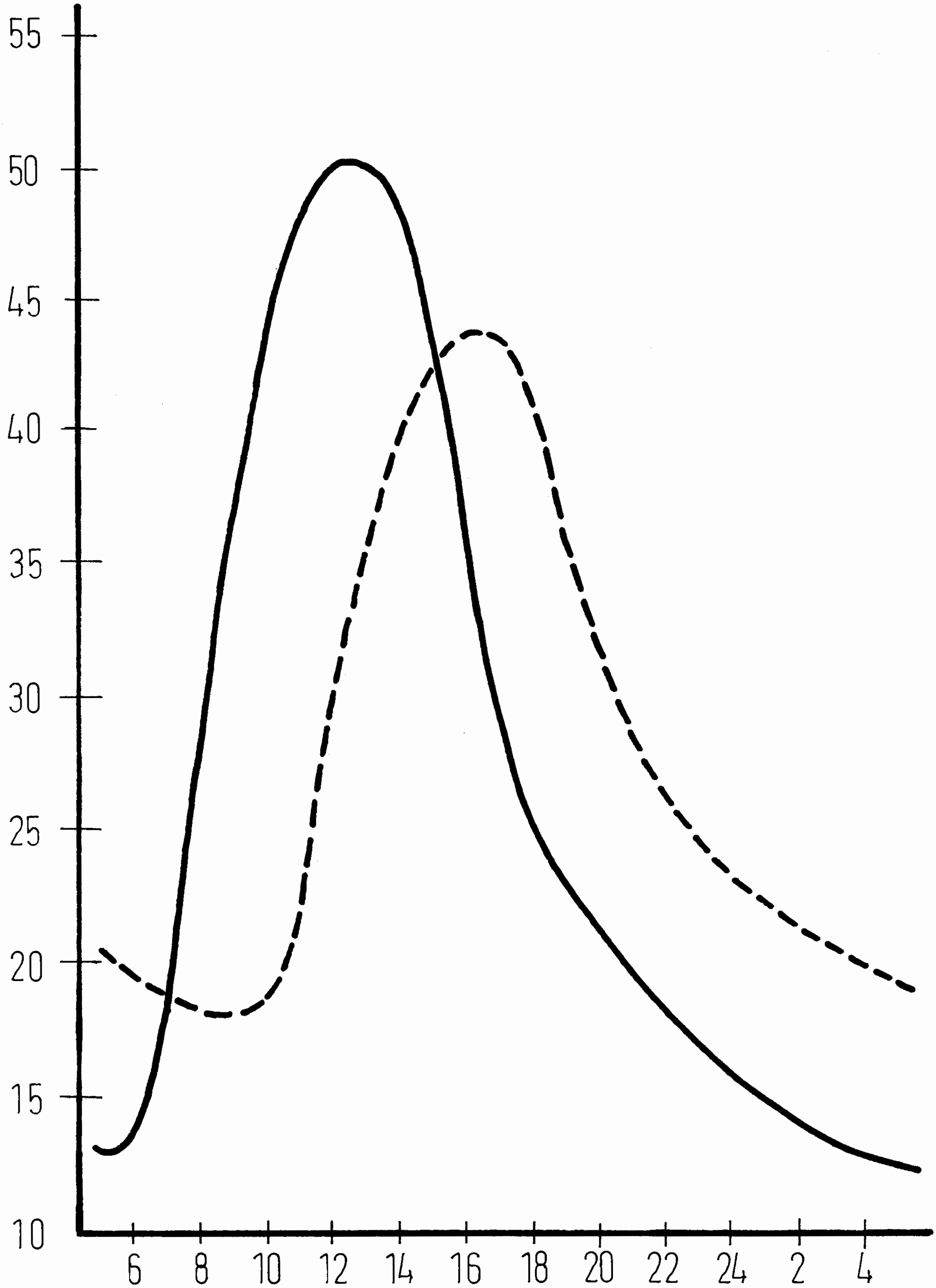
Prefabricated concrete room
south wall



Prefabricated concrete room
west wall



Prefabricated concrete room
north wall



Prefabricated concrete room
roof

Conclusions

In testing the mud brick house we found that the internal air temperature varied only one or two degrees over a complete day, averaging 21°C. This was due to the fact that even though the externally exposed surfaces heated up due to the sun and cooled at night, very little temperature fluctuation was noted on the internal surfaces. The time lag for these thick walls was very long, 20 hours or more, and very little heat energy actually penetrates.

On the other hand, the concrete construction was found to transmit heat quickly. We calculated that about 75% of the heat built up on the exterior exposed surfaces due to solar radiation was re-radiated into the room only 4 or 5 hours later. As a result the interior temperatures ranged from 34°C to 17°C over a similar 24 hour period.

It must be remembered that in this experiment we are measuring only one factor being 'heat flow through building materials' and in reality air movement will have an effect on comfort conditions as well. But this experiment does illustrate the superiority of the vernacular way of building over a recently introduced factory made European product.

The economic implications of using indigenous materials and knowledge in this example are clear, if one looks at the costs of mud brick in comparison to that of prefabricated concrete and then one looks at the earnings of the majority of the rural population.

Test Room (B.R.C.) Air Movement Study

One of the test rooms built by Hassan Fathy at the Building Research Institute in Cairo incorporates a traditional malkaf or windcatch into a simple vaulted roof design. The construction material here again is basically mud brick.

Even though the room is quite small, measuring 5 meters by 4 meters it illustrates well how an element found in vernacular architecture of urban areas of this region can be incorporated into contemporary designs such as low cost housing groupings. Although the malkaf is used often to bring air into generally inaccessable parts of the house such as rooms without windows facing the outside, it can also be employed on single story structures. In this case the windcatch stands above the rest of the building in order to draw air from above the layer of hot dusty street air. This malkaf could also protrude above the roof level of surrounding buildings in order to catch the unhindered free moving breeze. As with all wind catchers in this region the opening is fixed to catch the prevailing northerly winds.

This particular room was designed with a number of different kinds of openings. For our purposes we will classify the openings on the north wall or windward side of the building as air inlets and the openings on the south lee side as outlets. The north wall as seen from the plan and section contains the malkaf openings at the top and a window; while the south wall contains a door, a window and a large vent type opening at top.

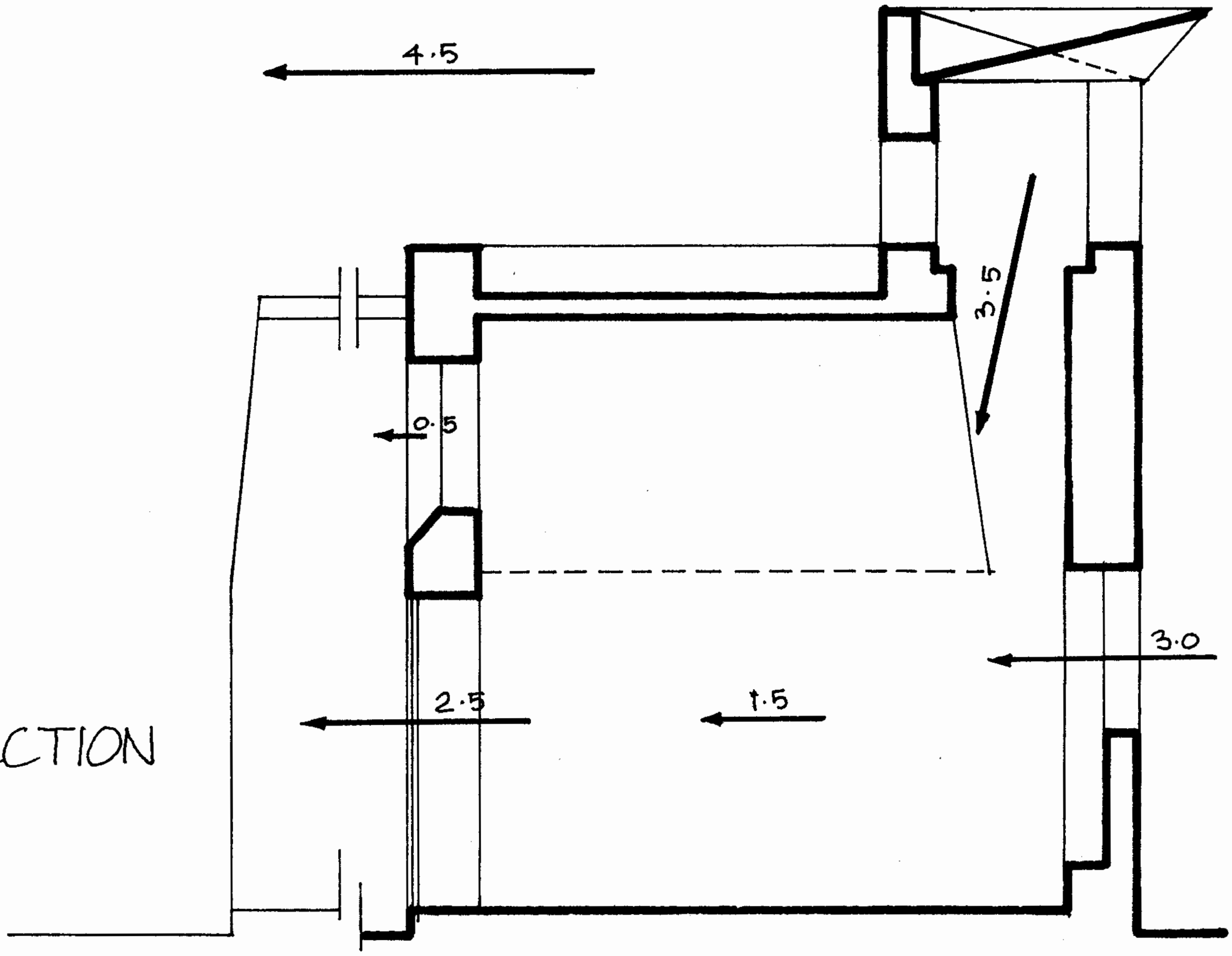
We were interested in finding the effects of opening and closing various inlets and outlets, on the air movement inside the room. We also wished to discover the relationship, if any, for the size of inlet openings and outlet openings to the air movement.

For this study we made use of a velometer which is an instrument which tells one the velocity of air moving in one given direction. The arrows and figures drawn on the plans and sections indicate the velocity of the air moving at the direction of maximum intensity.

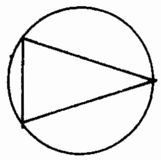
Three different combinations of openings were tested. These experiments were made between 14:00 and 15:00 hours on March 29th 1973 when the air temperature was 28.8°C (Dry Bulb) and relative humidity was 31%. The "effective temperature" in this case considering minimal air movement is 23.5°C. It has been discussed earlier although that air movement has a definite effect on the 'effective temperature'. It is given in the following chart: (Constant 28.8°C and 31% R.H.)

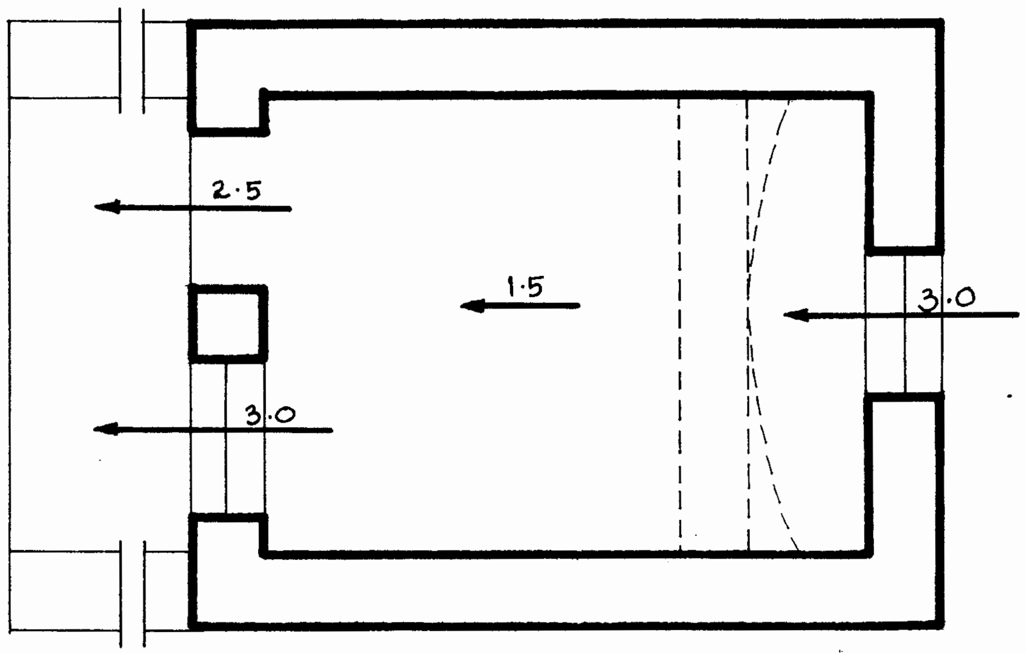
Velocities (m/sec)	.08	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
Effective Temp. (°C)	23.5	23.0	22.5	22.0	21.7	21.4	21	20.8	20.6	20.4	20.2

To calculate ratios of inlets to outlets, the area of each opening was measured and then added to find the overall area of opening on each wall. The volume of air moving through an opening in one second can be found by multiplying the area of the opening by the velocity of air moving through the opening at that particular time.



SECTION





PLAN

CASE 1

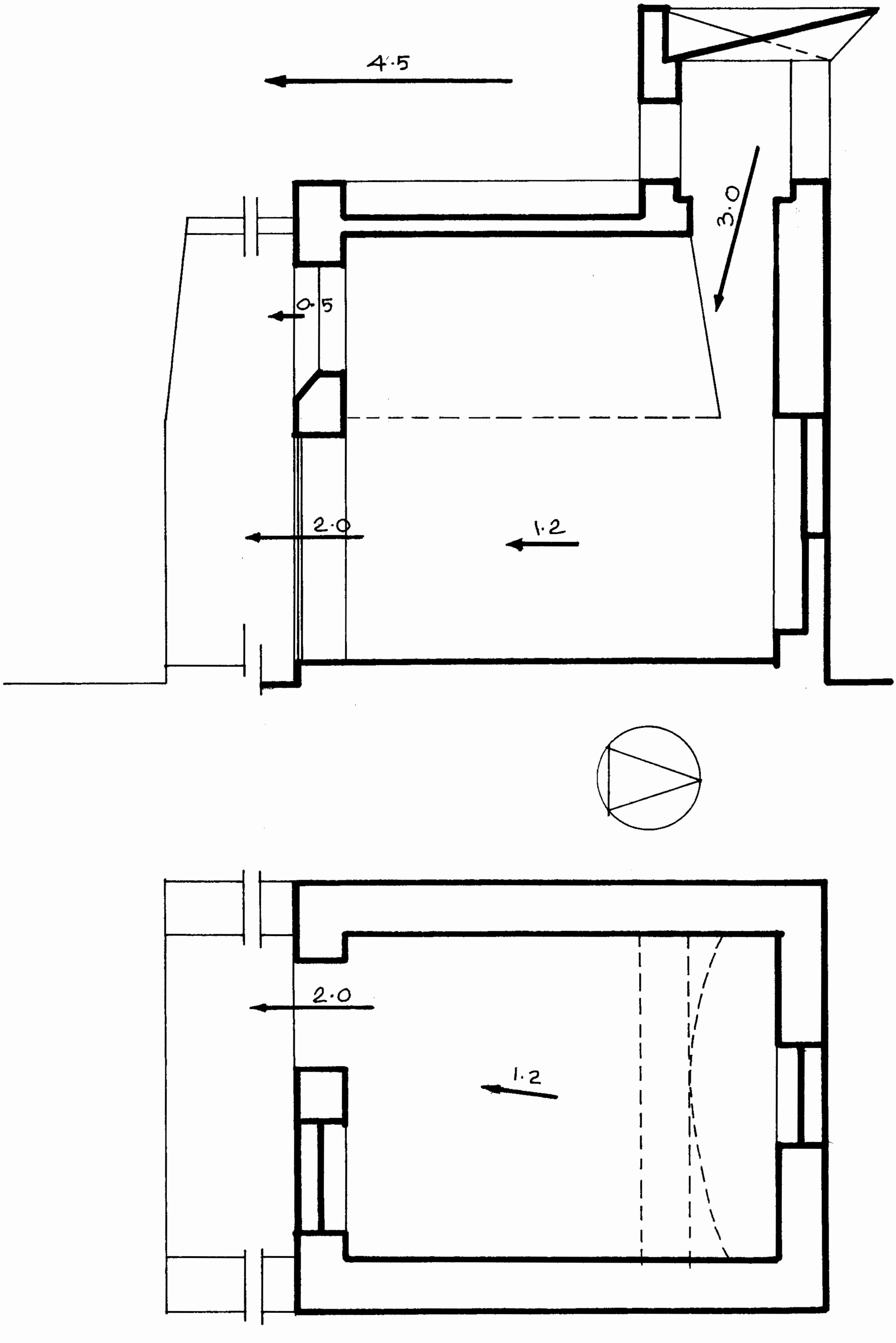
CASE 1

			AREAS	GROSS AREA	VELOCITY	VOLUME OF AIR PASSING PER SEC. THROUGH OPENING	GROSS VOLUME Cu. Meter/Sec.	AVERAGE VELOCITY THROUGH OPENINGS
INLETS	1	MALKAF	1·7	2·8	3·5	6·0	9·3	3·3
	2	NORTH WINDOW	1·1		3·0	3·3		
OUTLETS	1	DOORWAY	2·2	4·8	2·5	5·5	9·3	1·9
	2	SOUTH WINDOW	1·0		3·0	3·0		
	3	HIGH OPENING	1·6		0·5	0·8		

VELOCITY OF AIR IN ROOM CENTRE = 1·5 M./SEC.

AREA RATIO OF INLET OPENINGS TO OUTLET OPENINGS = 2·8/4·8

= 1 : 1·7



CASE 2

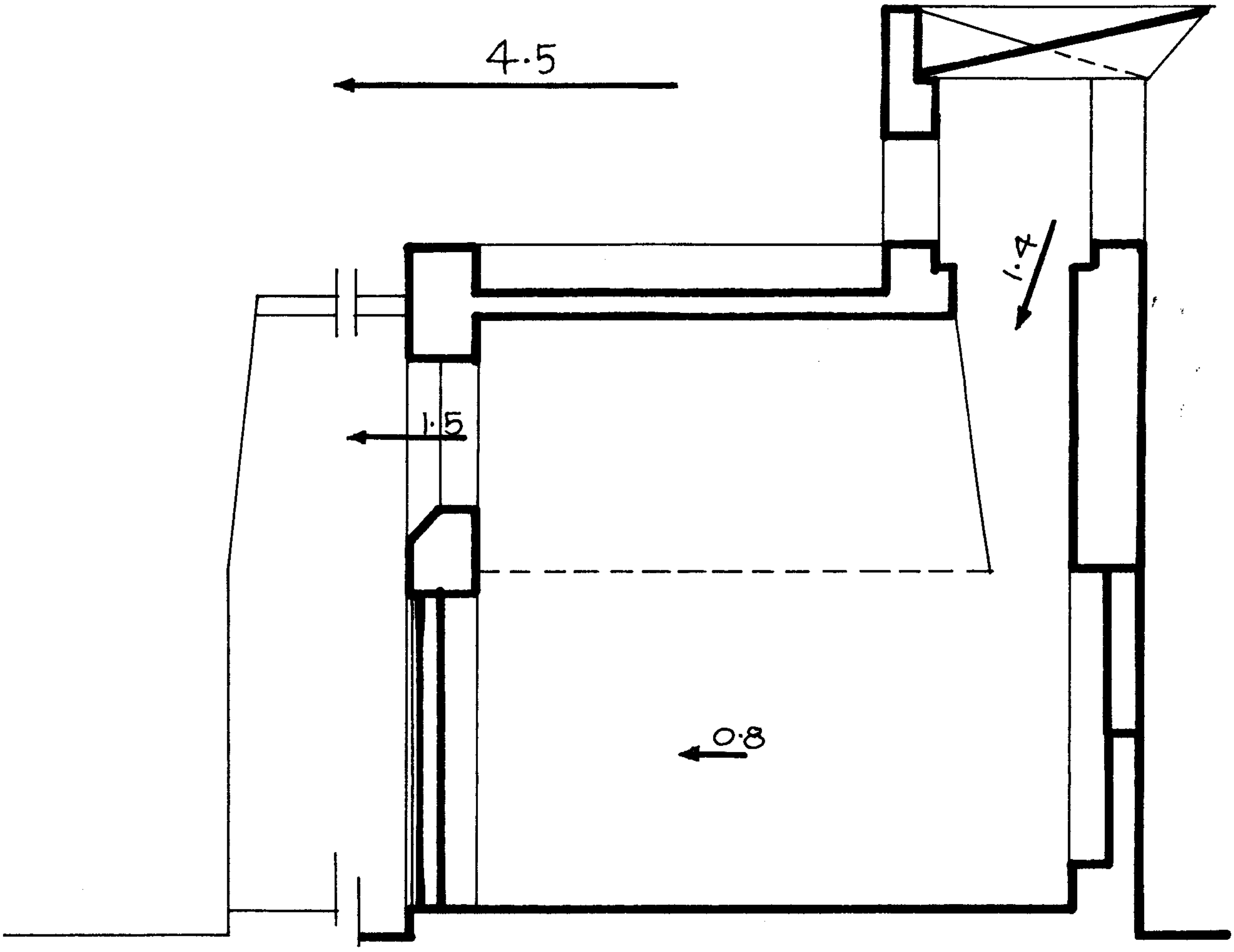
CASE 2

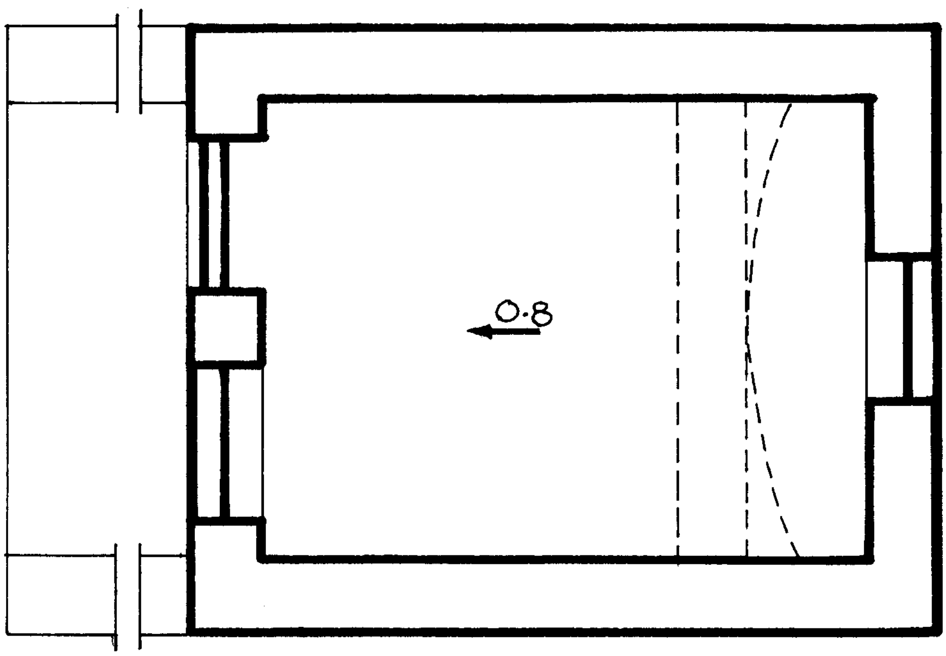
		AREAS	GROSS AREA	VELOCITY	VOLUME OF AIR PASSING PER SEC. THROUGH OPENING	GROSS VOLUME CU. Meters/Sec	AVERAGE VELOCITY THROUGH OPENINGS
INLETS	1 MALKAF	1·7	1·7	3·0	5·1	5·1	3·0
	2 NORTH WINDOW	CLOSED					
OUTLETS	1 DOORWAY	2·2	3·8	2·0	4·4	5·2	1·36
	2 SOUTH WINDOW	CLOSED					
	3 HIGH OPENING	1·6		0·5	0·8		

VELOCITY OF AIR IN ROOM CENTRE = 1·2 M/SEC

AREA RATIO OF INLET OPENINGS TO OUTLET OPENINS = 1·7 / 3·8

= 1 : 2·2





CASE 3

CASE 3

			AREAS	GROSS AREA	VELOCITY	VOLUME OF AIR PASSING PER SEC. THROUGH OPENING	GROSS VOLUME Cu.Meter/Sec.	AVERAGE VELOCITY THROUGH OPENINGS
INLETS	1	MALKAF	1·7	1·7	1·4	2·4	2·4	1·4
	2	NORTH WINDOW	CLOSED					
OUTLETS	1	DOORWAY	CLOSED	1·6			2·4	1·5
	2	SOUTH WINDOW	CLOSED					
	3	HIGH OPENING	1·6		1·5	2·4		

VELOCITY OF AIR IN ROOM CENTRE = 0·8 M/SEC

AREA RATIO OF INLET OPENINGS TO OUTLET OPENINGS = 1·7/1·6

= 1 : ·94

Conclusions

In the three cases tested here we have in each an example of a different area ratio of input openings to output openings. Case one for example is 1:1.7, case two is 1:2.2 and case three is 1:0.94.

We can see from the data obtained, that when the inlet outlet ratio is 1:1.7, as in case one, we get maximum velocity of air movement through the openings and through the room. That is when the outlet opening is 1.7 times larger than the inlet opening.

When the outlet opening is 2.2 times larger than the inlet opening as in case 2, the air movement through the openings and in the room is somewhat less.

In the 3rd case when the inlet opening is slightly larger than the outlet opening, the velocity of air movement through the openings and through the room is considerably less.

The actual optimum inlet/outlet area relationship requires many more tests with varying sized openings under a number of wind conditions. Our tests although show this relationship to be in the neighbourhood of 1:1.7, and it is clear in any case that the size of the air outlets must be greater than the air inlets.

Climate Tables and Graphs

Included in this section are a number of design aids which one would find to be useful in climaticly evaluating a particular area in relation to building.

Air Temperature and Relative Humidity

The first is simply a climatic table which one can find in World Meteorological Listings or obtain from a Meterological Office near the locality in which one is interested.

This information is then directly graphed on to the table which follows. It lists monthly averages for daily maximum and minimum temperatures and relative humidities. This sheet also lists monthly rainfall.

No. of years	15	15	16	16	15	15	9	13	15	15	15

CAIRO/HELWAN 29°52'N. 31°20'E. 381 ft.

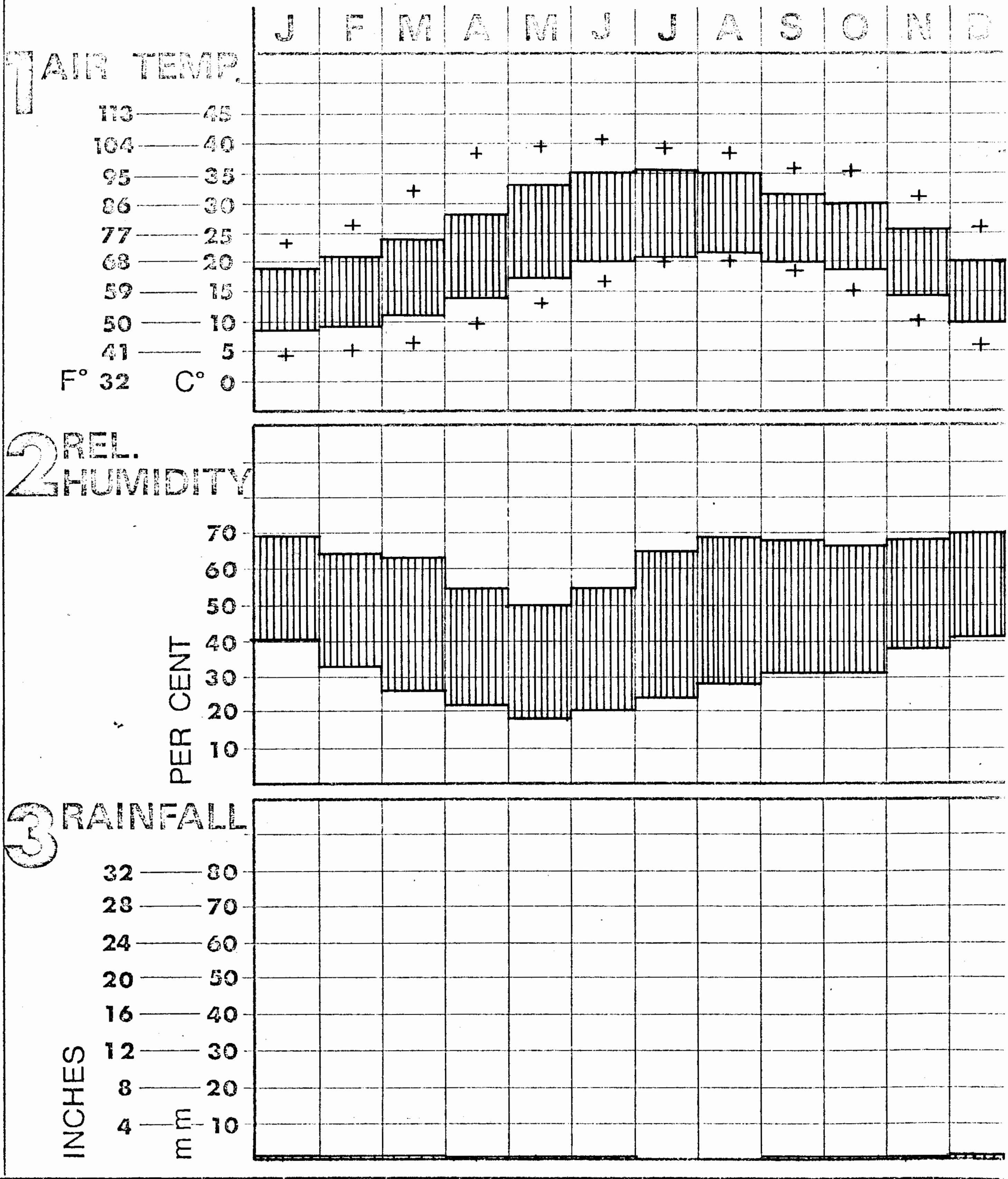
Period 1904-1945 Bibliography 28, 29	Temperature						Relative humidity		Precipitation		
	Average daily		Average of highest each month	Average of lowest each month	Absolute		Average of observations at		Average monthly fall	Maximum fall in 24 hr.	Average No. of days with 0·04 in. or more
	Max.	Min.			Max.	Min.	0800	1400			
	degrees Fahrenheit						per cent.		inches		
January	65	47	74	40	88	35	69	40	0·2	1·0	1
February	69	48	81	41	92	35	64	33	0·2	0·9	1
March	75	52	91	44	101	38	63	27	0·2	1·0	0·8
April	83	57	100	49	113	42	55	21	0·1	1·5	0·4
May	91	63	104	56	116	49	50	18	0·1	1·1	0·2
June	95	68	106	62	117	55	55	20	<0·1	0·1	<0·1
July	96	70	103	68	109	61	65	24	0·0	0·0	0
August	95	71	101	68	109	63	69	28	0·0	0·0	0
September	90	68	97	64	108	58	68	31	<0·1	<0·1	0
October	86	65	96	59	109	51	67	31	<0·1	0·9	0·3
November	78	58	89	50	100	42	68	38	0·1	0·5	0·8
December	68	50	79	43	87	34	70	41	0·2	1·1	1
Year	83	60	108*	39**	117	34	54	29	1·1	1·5	5
No. of years	42	42	15	15	42	42	9	20	42	42	42

DEVELOPMENT PLANNING UNIT U.C.L.

CASE BOOK: PROGRAMME:

CLIMATIC DATA 1

LOCATION CAIRO LONG. 31°20'E LAT. 29°52'N ALT. 381'



SOURCE: DATE:

NAME: PERIOD:

		Dry Bulb	Rel. Humid.	Wet Bulb	Efective Temp. E.T. 5 m/m
J	AM	8 ½	69	6	8 ¼
	PM	18 ½	40	11 ½	16 ½
F	AM	9	64	6 ¼	9
	PM	20 ½	33	12	17 ½
M	AM	11	65	7 ½	10 ½
	PM	24	27	13	20
A	AM	14	55	9 ½	13
	PM	28	21	14 ½	22 ½
M	AM	17 ½	50	12	16
	PM	33	18	17 ½	25
J	AM	20	55	14 ½	18
	PM	35	20	19	26
J	AM	21	65	16 ½	19 ¼
	PM	35 ½	24	20 ½	26 ½
A	AM	21 ½	69	18	20 ½
	PM	35	28	21 ½	27
S	AM	20	68	16	19 ½
	PM	32	31	20	25 ½
O	AM	18 ½	67	15	17
	PM	30	31	18	24
N	AM	14	68	11	13
	PM	25 ½	38	16 ½	22
D	AM	10	70	7 ½	9 ¼
	PM	20	41	13	17 ¾

Table of 'Air temperatures' and 'Relative humidity' and their corresponding 'Effective temperatures'.

Corrected Effective Temperature Chart and Comfort Zone

The next step, once temperatures and humidities are listed is to calculate effective temperatures corresponding to each condition of temperature and humidity. Effective temperature as previously mentioned is the thermal sensation that your skin appears to feel and relies on air temperature, relative humidity and air movement. Air movement is assumed to be negligable for the initial calculations.

To translate the information at hand into effective temperature one must make use of a Psyclometric Chart. Air temperature (dry bulb) is plotted against relative humidity and the corresponding elective temperature is read off.

Correctived Effective Temperatures are then recorded on a chart in the same way that air temperature had been recorded previously.

Following this the comfort zone limits must be calculated and plotted. The comfort zone is a concept explained earlier. A method for calculating the comfort zone for different climates was established by "C.T. Mahoney A.A. Dip. ARIBA and is presented in a paper by the D.P.U. London University. The Calculation of Cairo's comfort zone is shown here and found to range from 19.7°C to 25.7°C. People living in or near Cairo will tend to feel comfortable when the Effective Temperature is between these two extremes.

Calculation of Comfort Zone for Cairo Area

$$\text{Annual Mean Dry Bulb Temp.} = \frac{\text{mean highest D.B.T.} + \text{mean lowest D.B.T.}}{2}$$

$$= \frac{35{\cdot}5 + 8{\cdot}5}{2}$$

$$= 22{\cdot}0\ °C$$

$$\text{Centre of Comfort Zone} \simeq \frac{\text{annual mean D.B.T.}}{4} + 17{\cdot}2 \text{ (constant for tropics)}$$

$$= 22{\cdot}7\ °C$$

$$\text{Range of Annual D.B.T.} = 42{\cdot}5 - 4$$

$$= 38{\cdot}5\ C°$$

This corresponds to a Comfort Zone Range of 6·0 C°

Therefore the Comfort Zone for Cairo is between

19·7 and 25·7 °C

The extremes of the comfort zone are then plotted as an overlay on the Corrected Effective Temperature Chart. This chart is now a very useful design aid. From it we can clearly see that temperatures are uncomfortably warm for several hours of the day in July and August and uncomfortably cold for the whole of the months of January, February, March and December and parts of some of the other months. The critical times of year for which one must design are apparent.

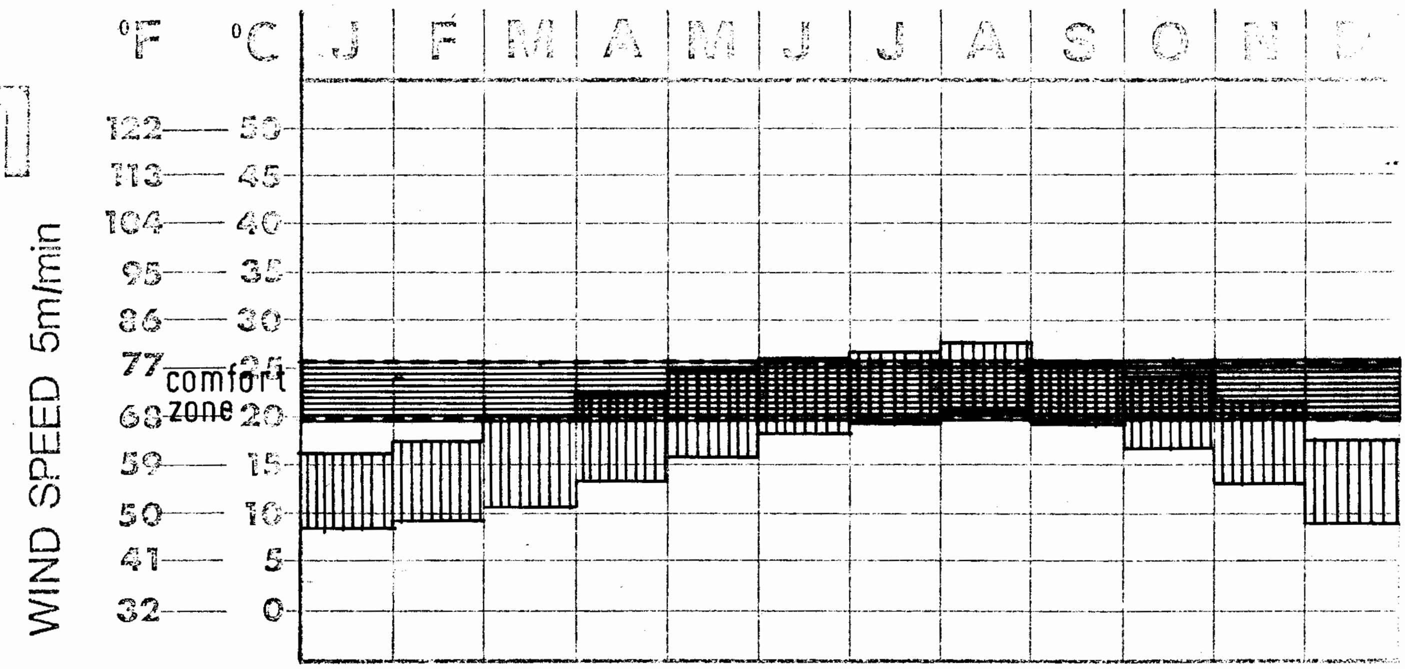
DEVELOPMENT PLANNING UNIT U.C.L.

CASE BOOK: PROGRAMME:

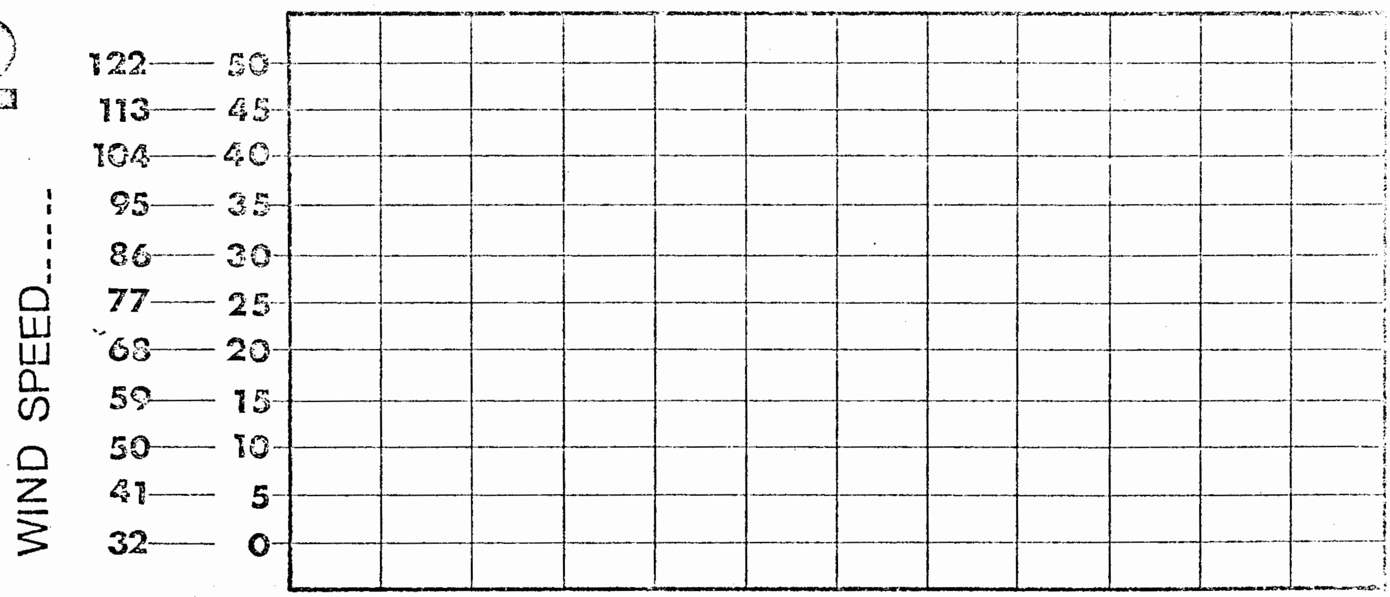
(CORRECTED) EFFECTIVE TEMPERATURE

LOCATION CAIRO LONG 31° 21' E LAT 29° 52' N ALT 381'

1



2



3 CRITICAL MONTH(S):—

SOURCE: DATE:

NAME:

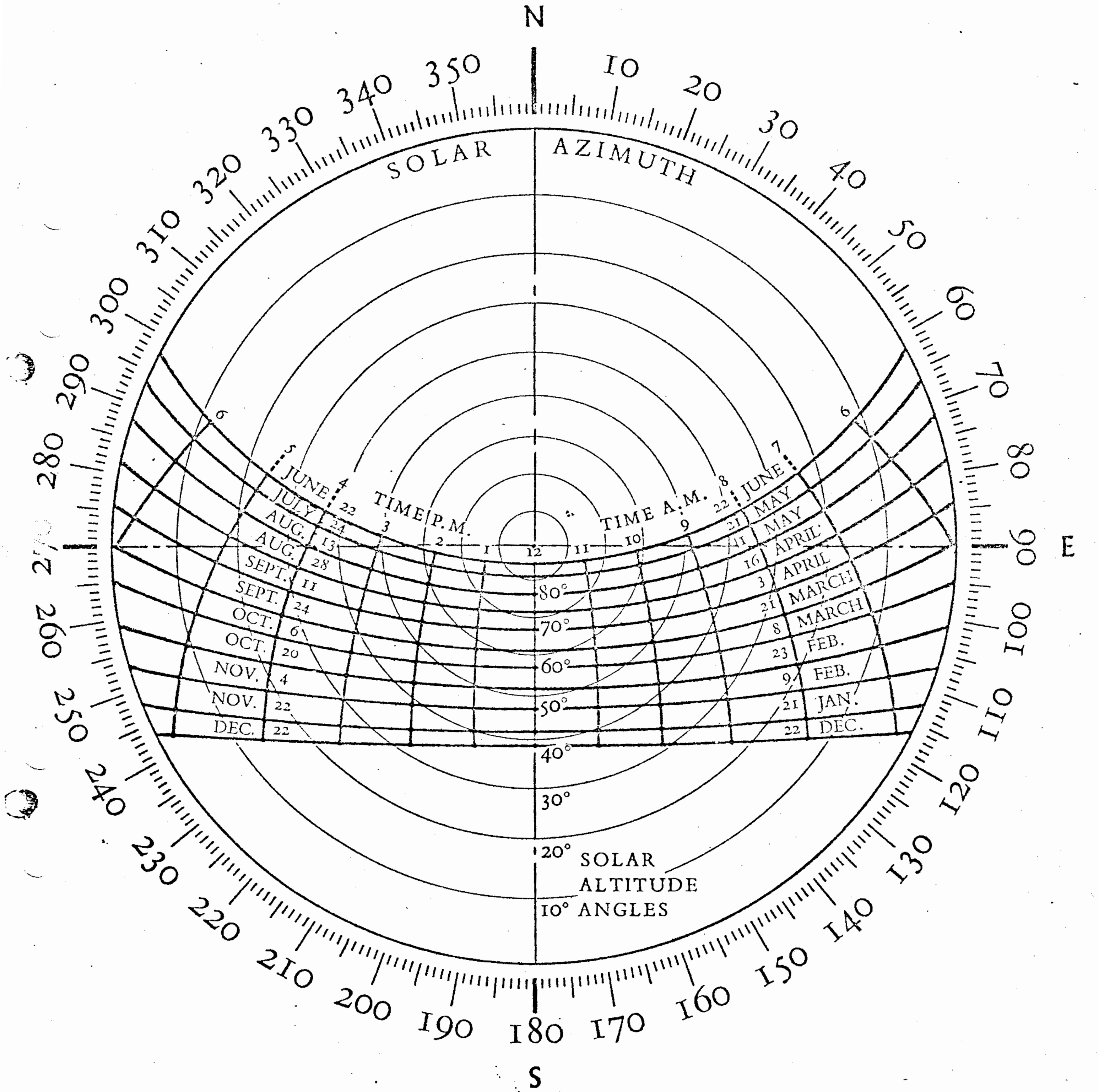
Solar Charts

Solar Charts are one of the most useful tools in climatic design but are also slightly more complex to use than the previous charts.

The simple solar chart can be seen as a map of lines traced by the sun as it travels across the sky each day, projected on a plane. The limits of the chart (circumference) can be seen as the horizon if the chart is oriented in its proper N-S alignment. The degrees from north are found around the circumferance. The concentric rings represent angles of altitude as seen from the plane of the earth's surface. (i.e. a point directly above one's head would be 90^{o}). The times of daylight hours are plotted against the sun paths for different months of the year. Therefore one can determine the precise position of the sun for a particular time for any day of the year.

Because of the seasonal shift of the earth's axis the sun retraces its path twice a year at 6 monthly intervals. Therefore to follow the sunpaths one reads the lines from bottom January to top June and then again from the top July to the bottom again with December.

SOLAR CHARTS



LATITUDE 28° NORTH

Solar Charts with Effective Temperature Overlaid

From the average daily maximum-minimum effective temperatures which we already have for each month, average hourly effective temperatures can be projected using a method proposed in the Development Planning Unit, London University, Climatic Handbook. From this data is drawn a chart of hourly effective temperatures. These effective temperatures are plotted on the solar chart corresponding to the particular hour and month which they occur. Times having similar temperatures are joined by lines and a 'contour' diagram of sorts is produced over the solar chart.

The temperatures of the high and low extremes of the comfort zone are also plotted in a similar way.

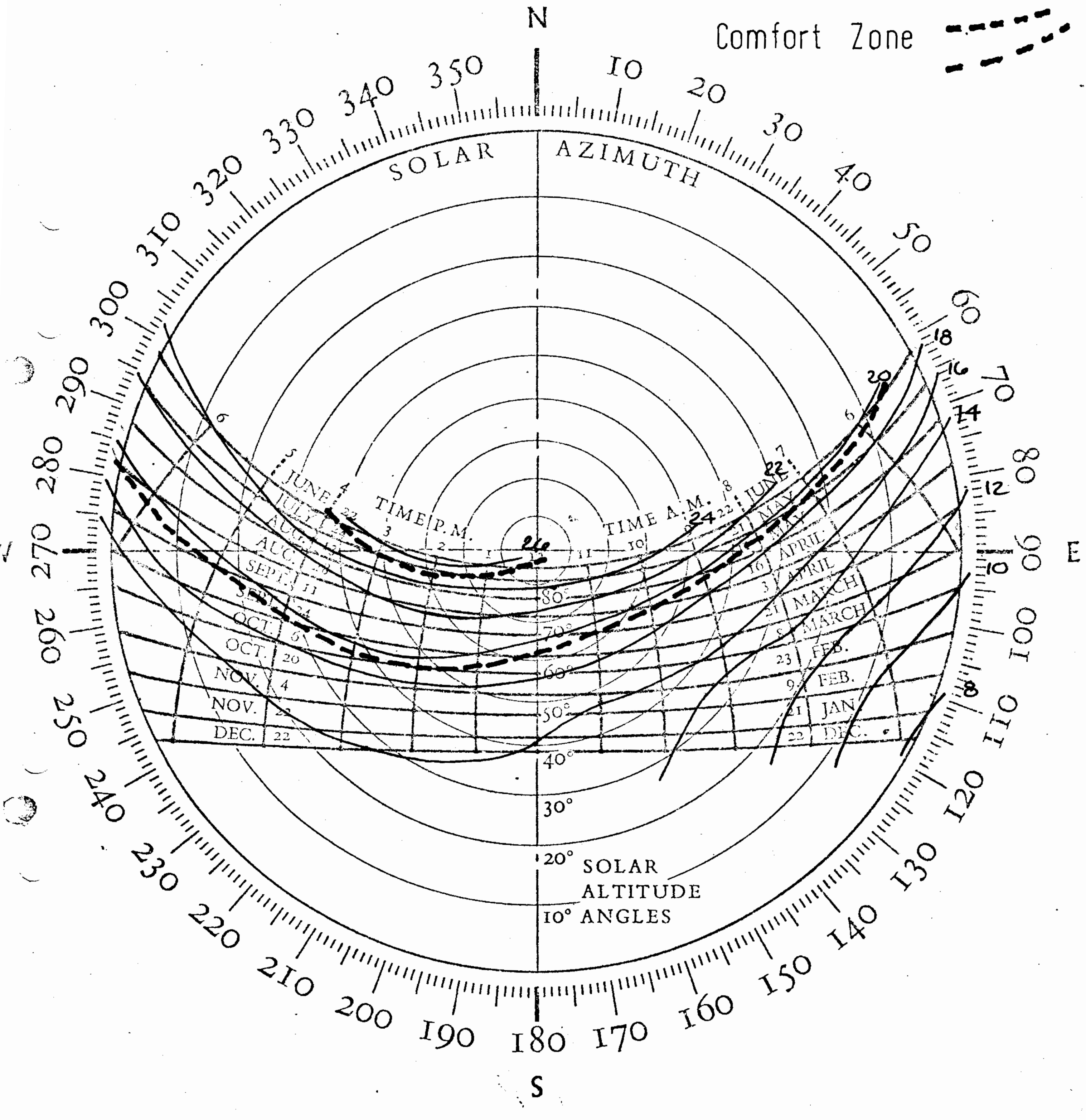
It should be noted that in this case a separate chart is needed for January to June and July to December. This chart now contains a great deal of information.

One can clearly see at which particular time of day in a given time of year the comfort zone is exceeded. In the case of spring months it can be seen that in the early morning hours the temperature is too low, since one also knows where the sun is in the sky at this time, it is a simple matter to design a building to allow the sun to penetrate rooms at this time and to exclude it at other times. The charts can similarly be used to find the optimum orientation of a building.

	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7
J			8¾	11½	13	14½	15½	16	16	16½	16¼	15¾	15		
F			10	12	13½	15	16	16½	17	17½	17	16½	15½		
M		10½	12¼	14	16	17¼	18	19	19½	20	19¾	19	18	17½	
A		13	15	17	18	19½	21	21½	22	22½	22	21½	21	20	
M		16½	18	19½	21	22½	23½	24¼	24¾	25	24¾	24	23½	22	
J	18	18¾	20½	21½	22½	24	25½	26	26	26	25¾	25½	25	23½	22½
J	19¼	19¾	21½	22½	23½	24½	25½	25¾	26	26	25¾	25½	25¼	24¼	23½
A		21	22	23	24	25	26	26	26½	26½	26½	26	25½	25	
S		19½	21	22	23	24	24½	25	25¼	25½	25¼	25	24	23	
O		17	18	19½	21½	22	23	23½	24	24	24	23¼	22¼		
N			13½	16	18	19	20	21	21¾	22	22	21	20		
D			9½	12	14	15¼	16	16½	17	17¾	17½	17	15½		

Average Hourly Effective Temperatures

SOLAR CHARTS

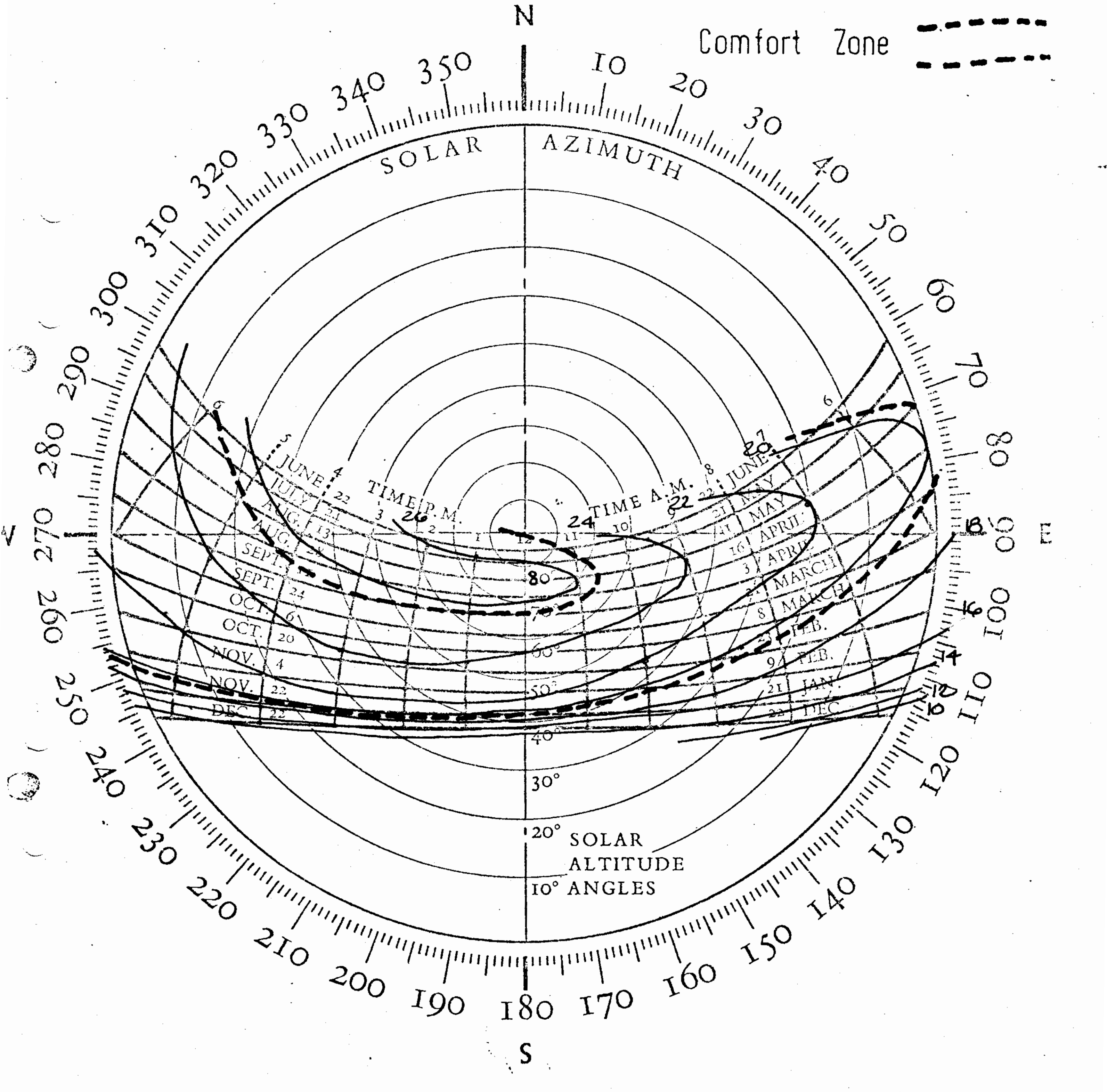


LATITUDE 28° NORTH

JANUARY – JUNE

CAIRO EGYPT

SOLAR CHARTS



LATITUDE 28° NORTH

JULY – DECEMBER