SOLAR RADIATION

IN

EXTERNAL URBAN SPACES

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ABSTRACT

There is a lack of information suitable for planners and architects to determine the distribution and intensity of solar radiation in urban spaces. New, tall buildings often reduce the quality of their immediate environment by intercepting sunlight before it reaches street level. While planners and the Local Authority recognise the necessity to rehumanise the city centre and to protect spaces with human appeal, certain squares are under threat of being overshadowed by the redevelopment of old buildings on their perimeter. This study explores an alternative to existing methods for evaluating the distribution and intensity of solar radiation. Greenmarket Square in central Cape Town was selected as a study area where radiometer readings at fifty-four points were made at one minute intervals from sunrise to sunset in midwinter. Several examples of graphical methods of depicting the readings are critically discussed and results of the field work are analysed in depth using one of the methods. An attempt is made to relate observations of solar radiation levels to human use of the Square. In addition to providing specific information necessary for a full understanding of the new procedures suggested, broadly-based background material on the subject of sun and shade in urban spaces is provided.

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NOTE OF EXPLANATION

Recent developments in the field of electronics are replacing the conventional typewriter as a tool for the production of written documents. As a result of such developments, this thesis has been produced on a microprocessor with extensive word processing facilities. The hardware used was an Apple II computer with a 32 K memory update, two disk drives, a National 14" visual display unit,and a TEC FP-1500 serial printer. The software program used is known as Applewriter, a text editing system developed by Apple Computer Incorporated, U.S.A. The considerable editing capabilities of this system have significantly reduced the difficulties involved in the drafting and redrafting of the text. As certain traditional typographic conventions, such as underlining, are not possible, the reader may occasionally find the presentation slightly unfamiliar.

CHAPTER ONE

BACKGROUND TO THE STUDY

In the centres of modern cities, old buildings are generally replaced by taller structures which change the character and quality of the spaces around them. One of the ways in which this happens is by reducing the amount of sunshine available at street level. If this occurs at a time when many people enjoy the space for its warmth, for example, during the lunch hour in the winter months, the city will have lost a valuable and probably irreplaceable amenity. Jacobs (1962) is one of the few planners to have written about this phenomenon. She describes two American examples as follows:

".....In Franklin Square, if the weather permits, a day-long reception holds sway. The benches at the center of the reception are filled, with a voluble standing overflow milling about. Conversational groups continually form and dissolve into one another. The guests behave respectfully to one another and are courteous to interlopers too. Almost imperceptibly, like the hand of a clock, this raggle-taggle reception creeps around the circular pool at the center of the square. And indeed, it is the hand of a clock, for it is following the sun, staying in the warmth. When the sun goes down the clock stops; the reception is over until tomorrow.....

Sun is part of a park's setting for people, shaded, to be sure, in summer. A high building effectively cutting the sun angle across the south side of a park can kill off a lot of it. Rittenhouse Square, for all its virtues, has this misfortune. On a good October afternoon, for example, almost a third of the square lies completely empty; the great building shadow across it from a new apartment house is a great eraser of human beings within its pall."

In Cape Town old buildings are also being replaced by new, taller ones. The town planning code loosely determines the criteria to which a new building must conform. The code does not consider the changes in sun and shade conditions which a new building will impose on its surroundings. The potential therefore exists for the reduction of sunshine in the streets and squares of Cape Town. This situation has already occurred in Queen Victoria Street, where new tall buildings on the north-western side cast long afternoon shadows across the historically-important Gardens on the opposite side of the street. The ultimate effect will probably be similar to that in the American examples, driving away of the people. Such an effect will occur at a time when planners themselves are calling for various measures, such as pedestrianisation of certain streets, to make the centre of Cape Town more attractive to a wider range of people. A similar point was made in a seminar called "Cities for the people":...."it

(Greenmarket Square) could and should be a place of quietude in the city, it should be unique in the experience that it offers, it should be respected by the changes brought about in its immediate vicinity" (Gasson, 1974).

Spaces which already have the attributes of being warm and protected from the wind, and which are currently used by people to meet, relax and enjoy an outdoor experience in an urban environment should be identified for planning purposes. These spaces should then be re-evaluated in the town planning code in a way which affords them a measure of protection from the likelihood of being destroyed in the manner described above.

Central Cape Town has several squares and other pedestrian spaces which are already of less value to the human user than they might be. Church Square is used as a car park, as are the Parade, Riebeeck Square, and Thibault Square. Greenmarket Square, at least, has retained some appeal, derived from its cobbled surface, its trees, the few benches in sunny positions, and its historic buildings. It suffers, however, from being overutilised by vehicular traffic. It has, in addition, several old, low buildings on its north-eastern side which might easily be replaced by much taller structures. As the north-east is the direction from which the morning sun shines, the Square is in potential danger of being cast into shadow. On its north-west side, an hotel, the Inn on the Square, has added a new top floor. This has had the effect of lengthening the afternoon shadow which the building casts across the square, much to the Square's detriment. The benches along the south-eastern periphery (towards Shortmarket Street), are now shaded in winter approximately an hour earlier than before.

STATEMENT OF THE PROBLEM

At present, there is no recognised system available to planners, architects, and decisionmakers for determining solar radiation in relationship to urban spaces. There is also a need to pre-determine and evaluate the possibly harmful effects of tall structures on surrounding urban spaces. Available methods for assessing the amounts of solar radiation falling at a given point have been limited to a graphic display of dark and light areas on a plan (see figure 7/15). Hours of sunlight received at a point are represented, with no distinction between weak morning sun and warm noon sun. As a result, it has been impossible to determine which parts of an urban square will be comfortable for human activities, or which parts could be successfully landscaped with various species of plants and trees. Far greater insight into the problem would be derived from an empirically-based system for evaluating the amount of sun received at points across an urban space. Measurements can be made at certain times or throughout the day, and annual or seasonal averages can be obtained. With such information, optimum use could be made of extremely valuable urban spaces, while simultaneously deriving maximum benefit from the effects of sun and shade for human users. Such an approach might go part of the way towards the determination of what Jacobs (1958) calls "that almost indefinable quality" of places in Baltimore, San Francisco and Pittsburgh, U.S.A. She states:...."In most cities there is a spot, hardly ever marked on a map, which has that almost indefinable quality of intimacy, comfort, and protection. I think of the landings on the steps leading southward down Washington Place south of Mount Vernon Place in Baltimore - sun-catchers, warm on cold days, and somewhat protected from the full impact of traffic noises by berms of earth on either side; certain benches in Union Square, San Francisco; and Mellon Square, Pittsburgh, which are nicely protected from wind currents."

CAUSES OF THE PROBLEM

A study of the literature (Chapter Four) from a number of different disciplines shows a surprising lack of information suitable for use by planners and architects for accurately predetermining the effects of sun and shade on urban spaces. Most of the reference material is concerned with more general considerations of urban climate, or the specialised aspects of buildings and their interiors with respect to the heating effect of the sun. Since man has been exposed to the sun and has been forced to adapt to it throughout his history, it might be asked why this has occurred. If the sun's effects have been so well known and understood through the centuries that they have not warranted proper documentation, why is it that we now make errors of judgement that are causing the destruction of urban quality through apparent ignorance of the effects of excessive shade on public squares and parks? The answer is to be found partly in the examination of man's relationship to nature over time. An examination of man's changing attitudes to natural environmental factors over time (Chapter Three), shows that early man had to acknowledge and co-operate with the forces of nature. In some inhospitable areas, survival itself depended on effective communal action. In time, technological advance allowed some independence and freedom from the constraints imposed by nature. Later still, advanced technological development encouraged complete disregard for natural environmental factors. This technology at the same time made possible the tall buildings which today contribute to the problem of sun and shade under consideration in this study.

Another contributing factor to the problem may be the fact that the available literature and methods for evaluating the effects of solar radiation are widely dispersed and are not in a form which planners and architects may readily assimilate and apply. These professionals seldom seek the assistance of outside specialists for a number of reasons. One of these reasons is the difficulty of communication between professions.

The problem might also have arisen from the essentially crude methods previously available for measuring the sun's intensity in relation to solar height and azimuth. Until recently, there has been no suitable method for quantifying the sun's intensity in relation to urban spaces. Neither has the amount of solar radiation in an external space been adequately related to the level of comfort experienced by the human occupant of that space. There are, therefore, many significant technological omissions which have prevented a more detailed appreciation of the problem of sun and shade.

The problem is further complicated by the fact that the commissioning authority, that is, the person or organisation that employs the planner or architect , has certain objectives. One of the most important objectives is usually to obtain the maximum economic benefit from the development of a piece of urban land, ignoring the impact on the city as a place for people (Speed, 1975). Considerations of surrounding urban quality are usually low on the list of priorities because maximum utilisation generally requires the development of a site with as much usable floor area as is allowed by regulations. This means that a taller building than the existing one will invariably be required in order to achieve full beneficial development. Considerations of urban quality which necessitate the reduction of that height imply a less beneficial development, and would therefore be unacceptable, as current business trends demand the maximisation of profits.

AIMS OF THE STUDY

This study will explore an alternative to existing methods for evaluating the distribution of sun and shade in urban spaces. Since the method is intended to be adopted by a wide range of users, it is necessary for it to be presented in fairly straightforward terms. In addition to providing the specific information necessary for a full understanding of the new procedures suggested, this study aims to provide broadly-based background material on the subject of sun and shade in urban spaces. This material has been drawn from widely-dispersed sources for use by architects, planners, and decisionmakers working in the urban context.

In relating the proposals to a specific urban site in Cape Town, it is hoped that public and official interest might be sufficiently aroused to prevent a local re-occurrence of the American experience in which Franklin Square was overshadowed and thereby lost its human appeal. To this end, an attempt will be made to relate observations on solar radiation levels to human use of Greenmarket Square.

BACKGROUND MATERIAL

Background material describes in historical perspective some of the reasons for our present-day attitudes to natural environmental factors such as sun and shade. Recent official statements on the situation in Cape Town are included.

A review of the literature reveals that the subject of sun and shade has been neglected, in that very few references were found which further the understanding of sun and shade in the urban situation. Nevertheless, many authors, including Sert (1944), Jacobs (1962), Thomas (1971), and Knowles (1974), recognise the need to design buildings and the spaces around them to achieve maximum benefit from the available sunshine.

The section on theoretical considerations of sun and shade (Chapter Five) covers topics such as solar radiation, urban climate, the implications of urban geometry, the methods currently available for making observations of the sun as well as periodicity, aesthetics, and the built environment.

FIELD MEASUREMENTS

The practical fieldwork undertaken in Greenmarket Square in central Cape Town provides numerical values of solar radiation received at 54 points along 6 traverse lines in the Square.

These values are plotted to give graphical representations of solar radiation, superimposed on three-quarter views of the surface of the Square from a point above the southern corner. The drawings show the buildings on the north-east and north-west boundaries of the Square, as it is these buildings that cause the shadows falling acrosss the Square in winter. Shadows are shown in the customary way on another drawing (figure 7/15) for comparison with the new method of analysis. (The new method shows far greater detail than was available previously, and would be of use to planners in enabling them to accurately determine areas suitable, for instance, for outdoor restaurants or various forms of landscaping). A discussion of results is followed by conclusions and recommendations. These highlight ways in which the method might be applied to Cape Town by planners, architects, and decisionmakers.

CHAPTER TWO

CHOICE OF SITE AND SITE DESCRIPTION

WHY AN URBAN STUDY AREA?

Natural environmental elements tend to predominate everywhere except in the city. In the city, the artificial built environment is dominant, often excluding natural factors almost entirely. Large economic incentives tend to mitigate against the serious consideration of natural environmental factors in urban development. Economic incentives justify to developers the creation of tall buildings in place of old, smaller ones to ensure a maximum return on investment (Speed, 1975). At the present time, there are no building regulations which cover in any detail the rights and obligations of a property owner with respect to his immediate neighbour. In addition, there is no incentive for the building owner to provide comfort or shelter for the public passing through and around his building. As a consequence, there is a tendency for the property owner to acquire as much of the view, or light and air, as possible, often to the detriment of his neighbour.

An example of this may be seen in Cape Town, in Adderley Street, where a new tower block is turned at 45 degrees to the street grid. Here, the mirror glass of the tower's windows reflects the sunshine and heat onto the neighbouring unprotected windows in the afternoon, while in the morning the tower casts a shadow across the same neighbouring building. Such effects are partly caused by failure to see the building in its broader urban context in the early stages of planning. The argument that the neighbour could have bought the adjacent piece of land to protect his initial investment, and that by not doing so exposed himself to risk, serves to illustrate a weakness in the legal provisions.

When the property under threat is not privately-owned, but is instead a public space such as a square, corrective measures are difficult to implement. Funds are generally not available to concerned public bodies to buy expensive properties or to use the appropriate legal channels to prevent potentially damaging development. In cases such as these, it would appear that the Local Authority, as the owner of urban parks and squares, should protect the rights of the members of the public who use these spaces by becoming aware of all the implications of central city development. It would be realistic to achieve such protection in Cape Town in terms of the City Council's own town planning scheme, in which "protection of those things which contribute to the city's unique character" (Morris, 1974) is implied, as well as in terms of the internationally-recognised 'ecological movement' in planning. In the meantime, potential problem areas in the city need to be identified and suitable baseline measurements made, such as those carried out in this study, prior to further more detailed research.

STREET OR SQUARE?

The streets and pavements of central Cape Town are generally narrow and fully committed to the needs of heavy traffic and pedestrian flows at many times of the day. They are set out on a strictly rectangular grid pattern, where the street intersections are significant both to cognitive mapping and to the regulation of traffic and pedestrians who would come into conflict at this point without strict control.

On the pavements, the pedestrian is part of a moving queue. Human proximity is accepted, and bumping and jostling results from the large numbers of people using a relatively narrow corridor. Discomfort is increased by the tendency of individual building owners to neglect the provision of shelter over the pavements from wind, rain, and summer sun. With few exceptions, streets are fully utilised and cannot accommodate trees and planting.

"The squares of Cape Town are ideally suited for development as places for human relaxation, yet they are presently used as car parks" (Speed, 1975). They do, however, offer the pedestrian an opportunity to step out of the mainstream of pedestrian flows. In the case of Greenmarket Square, there is also the option of taking diagonal routes, which is unusual in a rectangular grid layout of streets.

In the squares there is place for trees to be planted. In addition, surfaces can be varied to make the spaces more interesting, as has been done in Greenmarket Square, since usage by traffic, although heavy, is not of paramount importance. The cobbles in Greenmarket Square, recently introduced, are in keeping with the historical buildings, and distinguish the surface from that of the adjacent roads.

Traffic noise is less intense in the squares than in the streets, partly because users are able to put some distance between themselves and the moving cars, which is not possible on most pavements. Further, the traffic on the square has to regulate itself to some degree as a result of the mixed usage, which does not occur on the streets.

Both streets and squares are potentially at risk from the sorts of development forces discussed in a previous section. The decision to locate the practical aspects of this study in an urban square, rather than a street, is based on the following considerations:

In order to study the effects of sun and shade related to buildings on both the NE/SW and NW/SE orientated streets, two separate streets at right angles to each other would have had, to be studied. This would reduce the possibility of important interactions of the sun on the buildings along the two streets being observed. This problem was overcome in studying a square, where a single space is subjected to the effects of the sun on all the buildings around its periphery. While a square has been chosen instead of a street for the above reason, the techniques for the measurement of solar radiation can be applied to the planning of all external urban spaces, including streets and squares.

As the streets in central Cape Town are relatively narrow, the adverse effects of a new, tall building, whether from shading or the reflection of sunlight, would be felt as much at the adjacent street level, as on the buildings opposite. As the intention is to consider the space used on a voluntary basis by the public, as opposed to the inhabitants of buildings, a square was seen as more suitable for the study.

The study attempts to show how areas suitable for landscaping or for certain specialised human activities, may be more accurately selected in terms of solar radiation received than at present. Since the potential for landscaping a street or developing it for specialised human activities is less than in a square, the latter is more appropriate as a study area.

CHOICE OF SQUARE

The seminar, 'Cities for People', held in Cape Town in 1975, discussed the City Council's report on the pedestrianisation of parts of the city. That there was a great need for such a move in order to improve the human environment of the city, was established by speakers such as Prinsloo, Speed and Gasson (South African Institute of Town and Regional Planners, 1975).

Squares singled out by the report for attention under the heading, 'Squares for the people', included Greenmarket Square, Church Square, and Riebeeck Square. Plans depicting pedestrian flows through the city showed that Greenmarket Square forms part of the area exposed to intense pedestrian movement, while Riebeeck and Church Squares are not used for this purpose to any large degree. In fact the scheme, through measures such as the closure of sections of Church Street, and restriction of traffic movement at certain times, attempts to increase the usefulness of Church Square to the pedestrian.

In choosing the study area, it was necessary to establish whether the square under consideration had buildings on its north-west and north-east boundaries which were likely to be redeveloped and intercept the sunshine to the square. Since

Church Square is bounded on its north-west side by an historical building, the Groote Kerk, the Square does not appear in imminent danger of being overshadowed from this quarter. On the other hand, Greenmarket Square has low buildings on its north-east boundary. On its north-western side the Inn on the Square, previously Shell House, has recently had a new floor of accommodation added which has increased the length of the afternoon shadow across the square. Greenmarket Square, as an external urban space for the people, therefore seems to be under threat from these quarters.

In addition, two buildings of historical importance, the Old Town House and the Metropolitan Methodist Church, are situated on the south-western side of Greenmarket Square. Being central to the business district, the Square is used by a great variety of people and serves many functions.

All these reasons taken in combination have led to the choice of Greenmarket Square as the study area. It must be noted, however, that while the methods used for this study can be applied elsewhere, the measurements of solar radiation are site-specific and cannot be extrapolated to other squares.

DESCRIPTION OF GREENMARKET SQUARE

Greenmarket Square is bounded on the northeast and southwest by

Shortmarket and Longmarket Streets respectively, and is bisected perpendicularly by Burg Street. This part of Cape Town is laid out on a fairly strict grid of streets, forming rectangular blocks of buildings. The Square is formed by two adjacent half-blocks, as opposed to one single block, due to the unfortunate bisection by Burg Street.

HUMAN USAGE OF THE SQUARE DURING WINTER

Before sunrise the newspaper publishers in upper Burg Street are active, their lorries being loaded with bundles of newspapers. Street lights and advertising signs illuminate the Square. The street lights are extinguished block by block as the sun rises, while the advertising signs are switched off individually. The sun does not bring immediate relief from the pre-dawn cold, as the buildings cast long shadows, and the streets remain cold for several hours, a 'cold island' effect. Dawn is observed overhead by a lightening and colouring of the sky, rather than by the appearance of the sun itself.

Because of its size, the Square receives sunshine before the narrower streets. With the sunshine come the vagrants from nearby doorways, derelict buildings and parking areas. Between eight o'clock and nine o'clock, pedestrians on their way to work enter the Square at the eastern corner from Shortmarket Street. They fan out across the Square diagonally to Burg and

Longmarket Streets. Vehicular traffic is busiest from 08h20 to 09h00 with the available parking around the Square soon occupied. After nine o'clock, the pedestrian activity decreases sharply. Elderly people tend to visit the city after the morning rush of workers, and move about at a leisurely pace. The tranquility is shattered periodically by messengers on delivery motorcycles.

At twelve o'clock, signalled by the noonday gun, the Square begins to attract lunchtime shoppers and office workers enjoying the pale winter sunlight. With the exception of the Longmarket Street side, trees line the streets which border and bisect the square. Benches are placed under these lines of trees, and receive sunlight and warmth from the low winter sun as it moves around the Square. The cobbles underfoot are barely warm, and are cooler than the tar roads nearby. The trees, being evergreen, tend to shade much of the square, but introduce an attractive, natural element to an otherwise stark scene.

The volume of pedestrians drops abruptly to its pre-noon state at two o'clock as people return to work in surrounding shops and office buildings. Beggars and layabouts re-establish themselves on the benches to the south-east which are now receiving sunlight. Pedestrian traffic increases again after 16h30, when workers stream across the Square towards the railway station, converging onto Shortmarket Street, which funnels through into St. George's Street.

The temperature drops quickly as the sun sets, and the wind blows in gusts and eddies about the Square. The homeless ones move off as if some internal bodily signal has registered the limit to which they are prepared to perservere, and because the people from whom they beg have left the Square. Within a few minutes the Square is deserted, with advertising signs lighting up and steetlights flickering on. Some shop windows are illuminated and others remain dark. The difference between day and night usage of the Square suggests that human presence is determined partially by sunlight and the associated solar radiation levels.

CONTROLS ON LAND USE AROUND THE SQUARE

Management of the Square rests on various branches of the City Engineer's Department. The surface of the Square and rights to the space above it belong to the city, but the enveloping fabric, which defines the physical extent of the place, and determines its character to a large degree, is made up of individual peripheral buildings under private ownership. For completeness, details of locality, size, shape, and ownership of the indivual properties are included in the Appendix, as the owners of these properties in reality control the future character of the Square.

The City's control on the size and shape of the peripheral buildings is exercised through the zoning regulations. These restrictions may be summarised as follows:

There is a bulk factor of nine. This means that the floor area of a building may be nine times the site area. Thus a nine-storey building which covers the whole site, or an eighteen-storey building covering half the site, and other possible variations (such as full cover for three storeys, then reduced cover in the form of a tower), might be permitted. However, in addition to bulk factors there are set-back regulations. If the street is less than 12,5 metres wide, the maximum permitted height on the street boundary is 25 metres. Where the street is between 12,5 and 18 metres wide, the maximum building height is twice the width of the street. As the streets forming Greenmarket Square do not appear to be demarcated in width, some negotiations with respect to permitted maximum building height on these streets can be anticipated between the owners and the City Council. Above the maximum building height allowed on the street boundary, the building must set back one metre for every two metres of height, with a maximum height of sixty metres. This results in a stepped building, which is both difficult and expensive to construct, and unattractive visually. The tendency is therefore to build a tower where the maximum height would be one hundred metres. In practice, this maximum height is open to negotiation, with a 120 metre tower being recently approved on a nearby block.

Justification for the choice of Greenmarket Square as a study area is strong, in view of the call from urban planners for an improvement in the attractiveness of the external urban environment of Cape Town by pedestrianisation, rehumanisation, and protection of unique characteristics. It is against the background provided above that the chosen methodology was applied.

MAP 2/1

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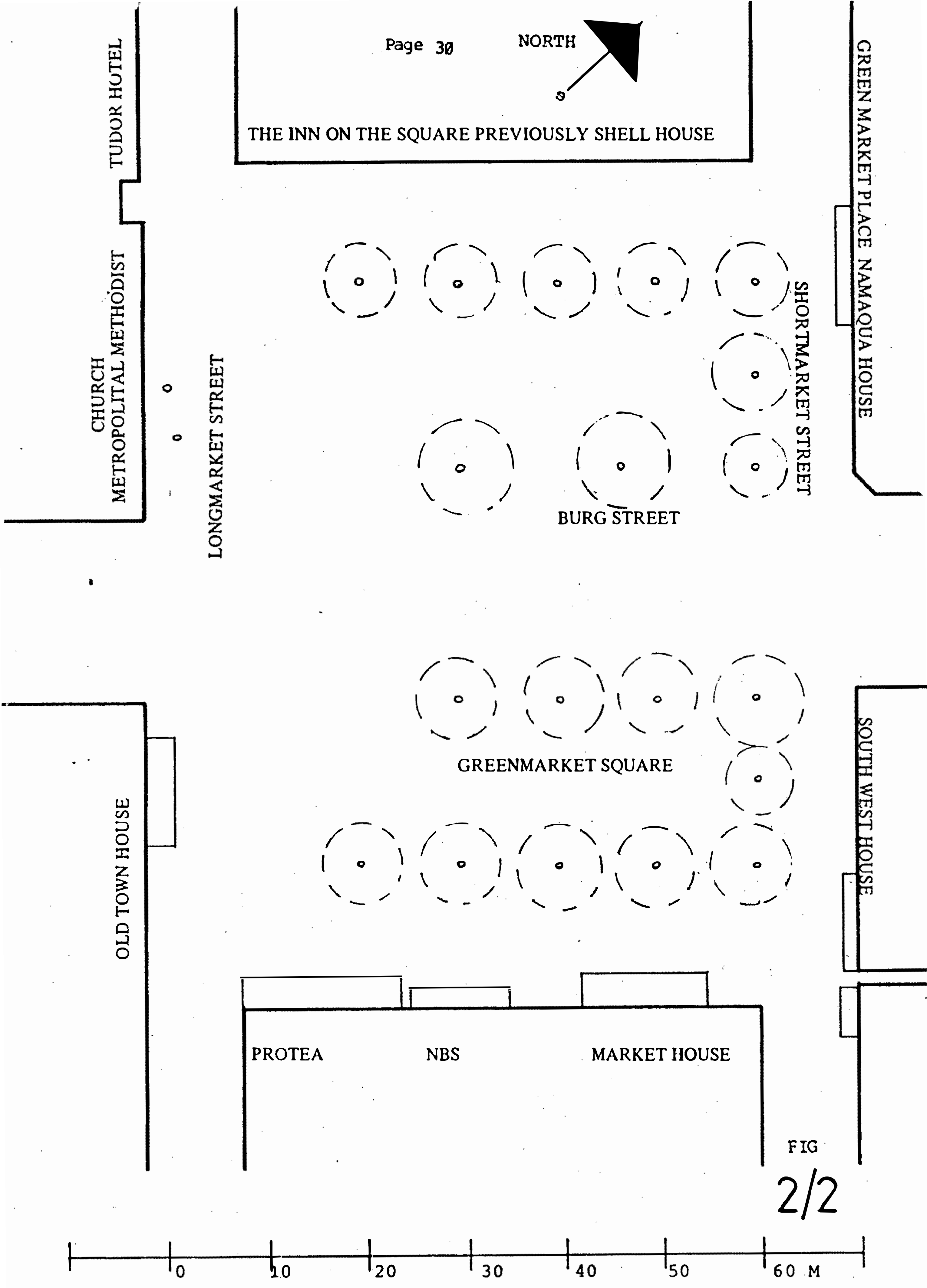
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METROPOLITAL METHODIST CHURCH
LONGMARKET STREET
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NAMAQUA HOUSE
SHORTMARKET STREET
BURG STREET
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FIG 2/2

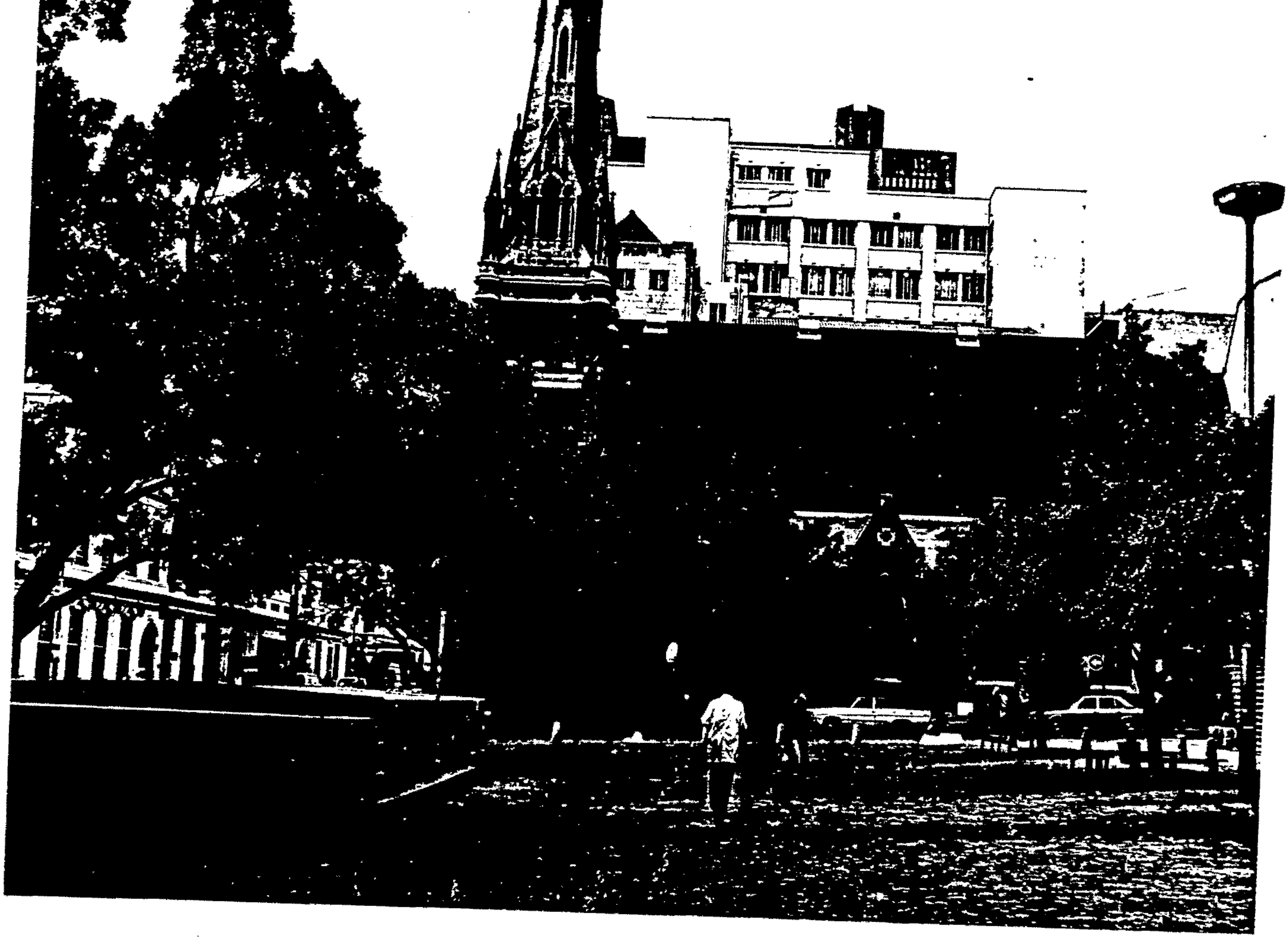


PLATE I. METROPOLITAN METHODIST CHURCH

PLATE 2. THE INN ON THE SQUARE.

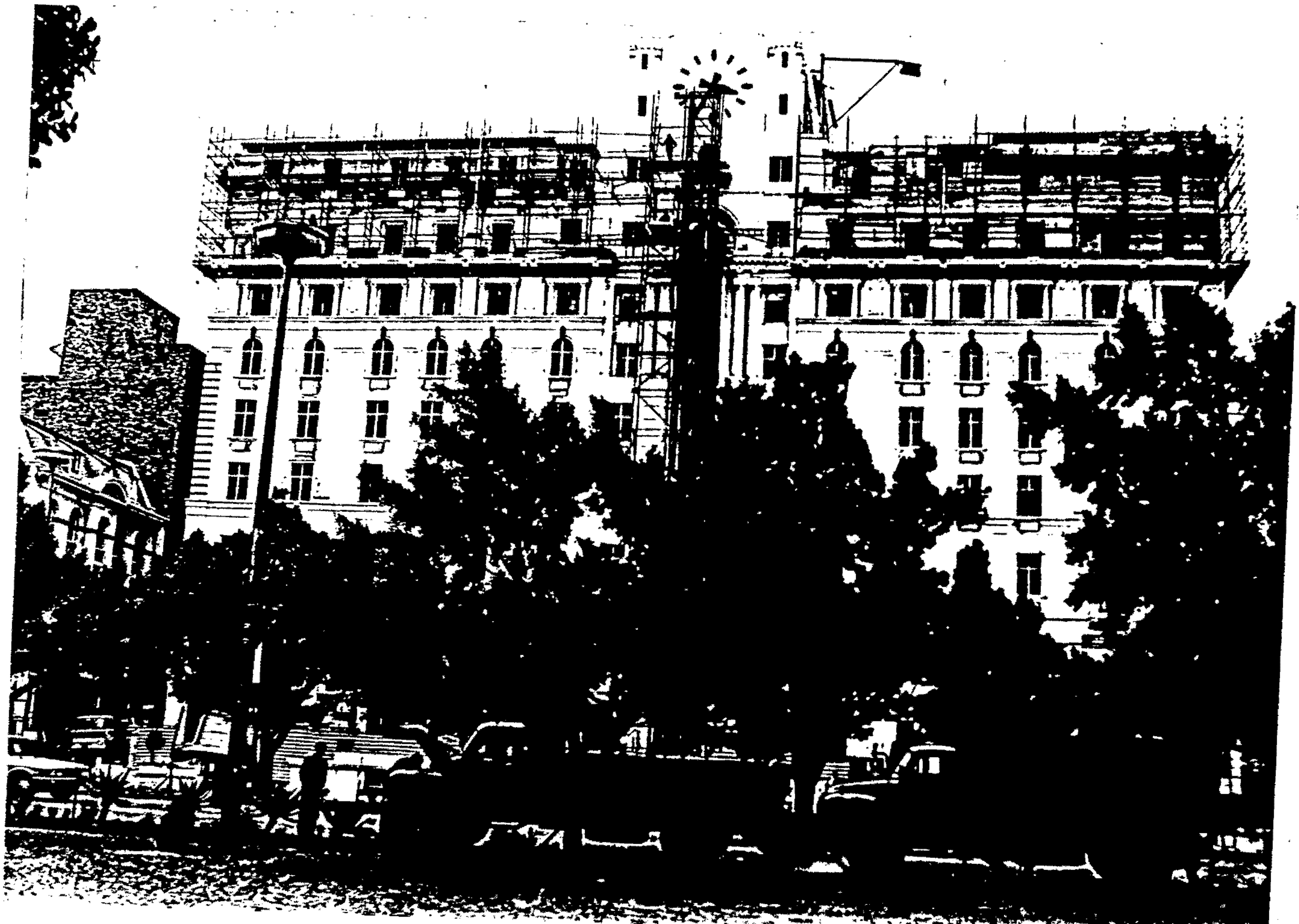
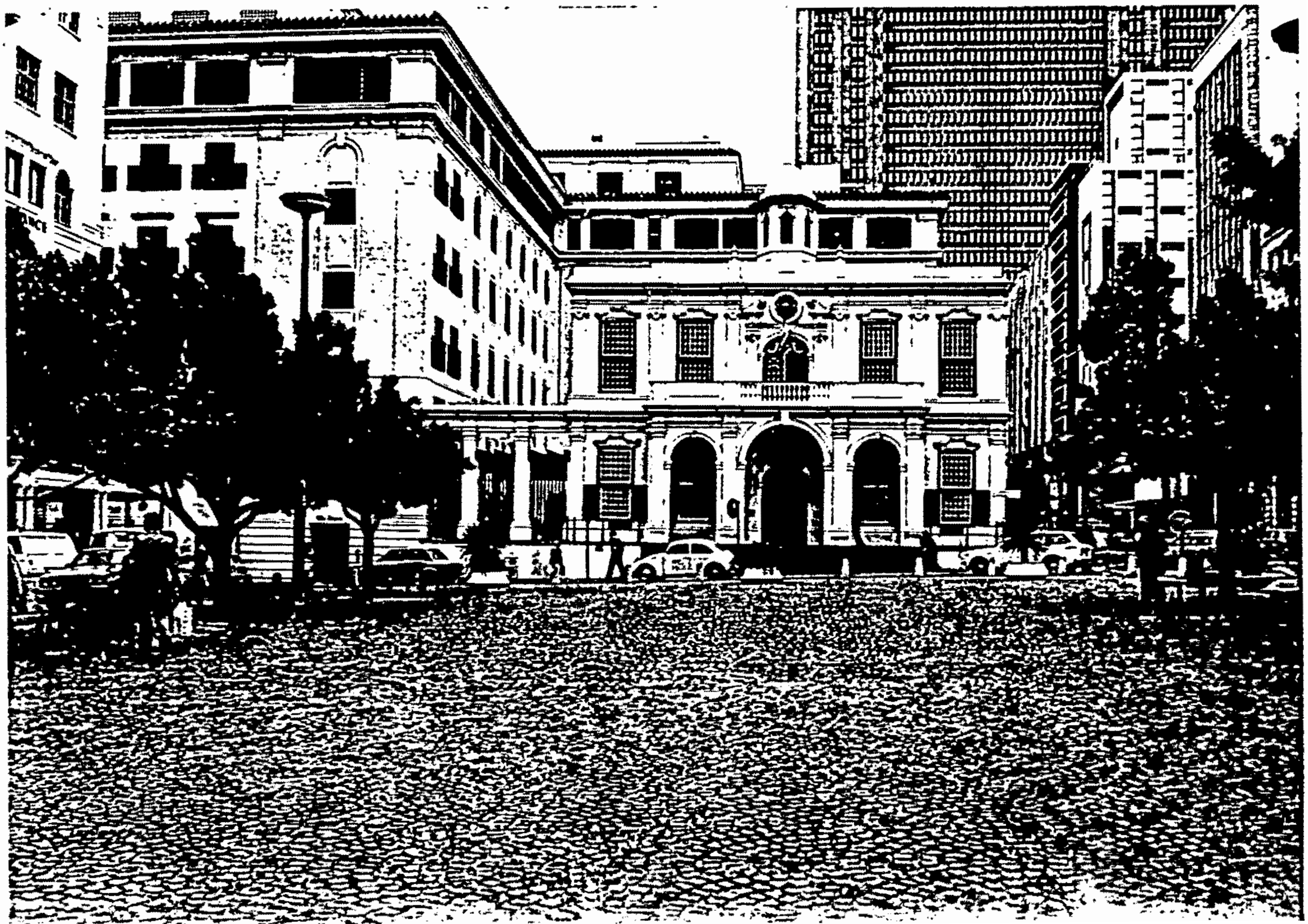


PLATE 3. GREENMARKET PLACE AND NAMAQUA HOUSE

PLATE 4. SOUTH- WEST HOUSE

PLATE 5. MARKET HOUSE, NBS, PROTEA ASSURANCE

PLATE 6. OLD TOWN HOUSE



CHAPTER THREE

MAN'S CHANGING ATTITUDES TOWARDS THE FORCES OF NATURE

A study of the relationship of man, the builder, to the natural environment, reveals that some of the causes of inhospitable urban conditions can be traced to a denial of the importance of natural environmental factors in planning. This trend developed during the Industrial Revolution and has persisted to the present time. Urban man's changing attitudes to natural phenomena are documented chronologically in this chapter, and it becomes apparent that the 'ecological' movement gaining prominence in planning is leading logically towards a multi-disciplinary approach. This approach recognises the interrelationship of many factors, both naturally-occurring and man-induced, as well as the need to measure and monitor these in a way which aids the planning process.

Early man saw the natural environment as a threat, and responded by attempting to subdue it. Banz (1970) observes: "One recurrent theme of all history is man's assumption of control over his natural environment. Only when nature was extremely hostile, as in the tropics, the deserts, or the Arctic, has eventual human control ever been in doubt. If the basic outcome of man's fight for survival varied little, there were, however, great differences in the forms human control over nature took with different peoples in different regions of the globe, and at different times in history."

The need for communal action was a common factor in man's attempt to adapt existing systems to suit his changing requirements. This need for combined human effort was recognised by Aristotle, who said: "Men come together in the city for security and they stay together for the good life" (Blumenfeld, 1979). In the cultivation of food, for example, a measure of communal co-operation towards environmental control was essential. It was simultaneously necessary to understand and work with those factors which were not subject to manipulation, such as seasonal changes.

"Nature threatening the early city was untamed. The weapons with which the individual could fight back were entirely inadequate even though man had mastered fire by this time and had learned to domesticate animals and plants. But mastery over nature could only be achieved through communal effort, and the early city was a primitive tool to control the natural environment." (Banz, 1970).

The Egyptians recognised the sun as source of energy, light and dark, heat and cold, and of the seasons and cycles which these in turn generate. Major development was restricted to the banks of the Nile, a reliable source of fresh water, where trees offered some relief from the heat of the sun. Life in the surrounding desert was perilous, and unrewarding, despite adaptations of dress, transportation, and lifestyle to suit the environmental extremes encountered by day and at night. Gallion's statement, "Society has been forged in the crucible of natural forces" (1975), is particularly true of the Egyptian response to the natural environment.

Medieval man appears to have tried to live in harmony with nature, understanding the effect but not the cause of environmental pressures. It was the lack of a simple explanation for natural events which caused these to be seen as omens. The natural surroundings gave rise to a superstitious response, and threatened evil consequences if opposed. Cities which developed at this time, and which have escaped modern redevelopment programmes, retain vestiges of the small town scale, unspoilt by long-term planning concepts.

Renaissance man, in attempting to understand both cause and effect, applied himself to a closer interpretation of natural systems in the broadest sense. A reawakening intellect acquired new knowledge and abilities, which enabled it to confront natural forces, and to attempt to harness them for its own ends. Explorers expanded the physical boundaries of the known world, bringing back hitherto unknown birds and animals, as well as spices, herbs, and other plants. The Renaissance influence on cities was typified by formal urban parks, ponds and fountains, and the rudiments of landscaping linking buildings to their surroundings with geometric patterns.

The Industrial Revolution was the culmination of a period of environmental shortcomings, supplemented by primarily mechanical corrective measures. The attraction of being independent of nature, erroneously seen as the advantage of technology, is understandable in view of the fact that not long before, the forces of nature had been seen as omnipotent. Under these new circumstances, the resilience of natural systems was overestimated, while the impact of technology was of far greater scope and complexity than previously anticipated. The steel manufacturing process in England, for example, required timber for making charcoal. Forests were cut at a faster rate than they could be replaced, resulting in the loss of major wooded areas. Fumes were discharged into the atmosphere faster than the natural processes could disperse them, while mining activities created blighted landscapes and unhealthy living conditions. When the full potential of mass transportation systems was recognised by industrial man, he installed facilities with disregard for the existing urban character. Blumenfeld (1967) observes: "The rails were located in the street and the terminals in the squares, and the yards were established wherever they could insert themselves into the growing urban tissue".

The impact of technology on the city at the beginning of the twentieth century was increased considerably by the implementation of a new theoretical approach in the mechanical and electrical engineering fields. Elevators were introduced, which made high-rise construction acceptable, and brought about an increase in urban population densities. Electricity, being clean and convenient, soon replaced gas, oil and solid fuels for heating and lighting. The artificial environment had been made possible.

"At first these new technologies were applied to the lighting and heating of buildings as we then had them but it soon became apparent that, simply because it was now possible to provide an artificial environment, there was no longer any reason why buildings should not undergo a radical change. If we could light artifically, then why have windows; they are major sources of heat loss and draughts, they let in the traffic noise and if they are no longer providing the working light, then their only function is to provide a view and this is not really necessary. Once rid of the windows, buildings need no longer be limited in depth, spine corridors are no longer necessary, rooms can be shaped and sized to their operational function, rather than by the need for daylight penetration. Industrial processes need no longer be restricted to single storey buildings in order that the roof might be glazed. So the arguments ran, and to the service engineer and the property developer they were very attractive......Curiously enough, this period of technological development in the artificial environment, the 1950's, was also the great period for the development of daylighting technology" (Hopkinson, 1970).

The effects of electrical lighting on the city as a whole were far-reaching. Where communal life in the streets and squares had previously only been feasible during daylight hours, with the advent of street lighting, areas of cities remained viable well into the night. The tempo of urban life was again changed radically by improved technology when radio, television, and telephone communications allowed people to exchange ideas and become informed without personal contact.

After the first World War, which again effectively demonstrated the destructive power of modern technology, an ecological approach was directed towards social and spatial problem-solving. Berry (1977) sees as a benchmark of this movement a paper published by Park in 1916 entitled, "The city: suggestions for the investigation of human behaviour in an urban environment". Subsequent literature placed the ecological approach in the mainstream of sociological research. The movement developed by Park was shortlived, however, and by 1950 was no longer recognised as appropriate.

In 1950, Hawley reformulated an ecological approach with his work, Human ecology: a theory of community structure, thereby initiating its revival over the last thirty years. Willhelm (1962) sees the urban predicament in broadly-structured concepts, logically linking land-use theories and zoning practices, and recognises these interrelationships as being "ecological" in nature. He advocates the inclusion of social values as essential components of ecological thought, trying to formulate a systematic, holistic viewpoint. The formulation of this viewpoint in practice has defied theorists to the present time.

"....the planners and theorists who endeavour to design our cities of tomorrow proceed without an adequate understanding of the manner in which man relates to his environment." (Willhelm, 1962).

The need for a more ecologically-oriented approach to urban planning is recognised by other writers, such as Banz (1970), Milgram(1971), and Clawson (1973). The following statement by Dubos (1968) is representative of this recognition: "The view that man must learn to collaborate with natural forces instead of conquering them must appear unrealistically romantic and, in any case, incompatible with the aggressive genius of Western civilization. Yet there are reasons to believe that it is the crude philosophy of the conquest of nature that is unrealistic and will soon prove antiquated as well".

Perloff (1971) sees the need for ecologically-orientated planning as being met by education, advocating the teaching of environmental design to young people. He states: "The education of architects and planners is, with few exceptions, extraordinarily limited. Conspicuously absent from their curricula are the social sciences and humanities, to say nothing of ecology. Training in even rudimentary research procedures is rare...I can think of nothing more important than teaching young people about environmental design, using data from such disciplines as ecology, psychology, and anthropology."

In South Africa, the ecological movement is recognised by Morris (1974 A): "We have entered the Ecological Era". He points out a noticeable shift in middle and upper class values towards new areas of social concern, including environmental issues.

Certain trends emerge when the relationship between man and the natural environment is seen in historical perspective. The state of technology at the time largely determines the extent to which planners need to recognise and implement the effects of natural phenomena as design criteria in the planning process. Appropriate planning solutions for contemporary problems require a detailed study of environmental conditions, amongst many other design criteria, in far greater detail than before.

Dependence on technology alone has resulted in urban and environmental degradation. In a new spirit of co-operation with natural forces, and using the technology available for understanding and measuring the operation of those forces, increased quality of the urban condition may be achieved. This pilot study is an attempt to implement the new approach by using modern equipment to measure and depict the effects of an environmental factor on an urban square in detail, and by relating the data so obtained to the human usage of the study area. In this way a deeper insight of environmental factors in urban spaces may be achieved, as well as an understanding of the interaction of those factors with the human occupant.

CHAPTER FOUR

DESIGN CRITERIA, ZONING, AND CONTRASTING APPROACHES TO SUN AND SHADE

During the past twenty years, with a growing interest in urban ecology, the need has been expressed for man to collaborate with nature, to teach young people about environmental design, and to utilise science for achieving an equilibrium with nature. In the light of these developments, one would expect to find a wide range of material on this subject in the literature, but this is not the case. Technological advances, which have allowed man to act independently of natural factors, have simultaneously provided the instrumentation and experimental techniques which could have been used for a closer understanding of those natural factors. It is paradoxical, therefore, that a search through planning and architectural literature for recent work on the sun, the driving force of all natural systems, reveals a lack of good, empirical data. While reasons for this are suggested, relevant material has had to be drawn from many widely-scattered sources in order to consider design criteria, and the regulation of land use through zoning, as they relate to the planning of urban spaces.

The material available on environmental factors as design criteria is superficial to the point of giving the impression that man might do without the sun altogether and survive. Considerations of land use and zoning policy with respect to the exposure of buildings to sunlight, tend to be handled cautiously. This reflects a conservative approach on the part of local authorities who have formulated the policy.

The balance of the relevant literature consists of heartfelt, intuitive reference to sunshine, with little constructive argument or supporting scientific observations. This criticism can be applied to the writings of Jacobs (1962), Banz (1970), and Alexander (1977). On the other hand, Knowles (1974), and Thomas (1971), attempt to advance our knowledge of the interaction between buildings and the sun in a scientific way, but overlook some crucial aspects, making their work limited in its practical application.

ENVIRONMENTAL FACTORS AS DESIGN CRITERIA

The problem facing most designers, including architects and planners, is that of identifying and satisfying an appropriate set of design criteria or determinants. A range of solutions which satisfy the prime objectives of the commissioning authority is generally easily achieved, as is fulfilment of the designer's personal standards. To decide finally on the optimum solution, it is necessary to subject the range of alternatives to a process of evaluation according to a set of predetermined criteria which have been agreed upon early in the design process by the designer and his client. These criteria tend to reflect the social, economic and political attitudes prevalent at the time. The socio-political-economic prerequisites and constraints are further complicated by local land use and zoning regulations and by building restrictions generally.

Environmental factors such as sun and shade have been included amongst design criteria considerations, but not on a scientific basis. In proposing design criteria for the pedestrianisation of certain areas of central Cape Town, Prinsloo (1975) recognises the importance of natural environmental factors: "....adequate shelter from sun, rain and wind are essential to ....successful humanization."

While this statement incorporates natural factors in principle, the implementation of the principle is not covered in practical detail in the literature. The problem is compounded by the fact that the attitudes of society towards considerations of sun and shade in urban spaces have not been investigated.

A notable attempt to come to terms with the problem is the work of Barac (1974), using the 'step-down' principle to focus from the general level to the particular. The results of his survey in Cape Town identify twenty criteria regarded as the most significant, of which hours of sunlight is only one. Perloff

(1971) proposes seven items for inclusion in the "environmental rubric for metropolitan areas". Sunlight is one of the seven, the others being airshed, watershed, open space, quiet-and-noise zones, olfactory zones, and micro-climate. Unfortunately, he does not reognise the importance of the sun to the spaces around buildings, only to the buildings themselves.

In reading through the literature, the impression is gained that each author is confronting the problem afresh, and therefore not penetrating the topic as thoroughly as would be achieved by building upon an existing body of work.

ZONING CONTROLS ON BUILDING HEIGHT

With few exceptions, today's local authorities apply zoning regulations to properties. These regulations, amongst other functions, determine the use to which buildings can be put, and restrict the shape and size of the building envelope to allow sunlight to penetrate to streets and adjacent buildings. The concept has its origins in the Daylight Code, developed in London at the beginning of this century. The Code protects the rights of existing properties against new, larger structures which could potentially reduce the amount of light available to existing windows. Since the Daylight Code is concerned primarily with light penetration into buildings, as opposed to public urban spaces, it will not be considered in great detail, although it has largely determined the London skyline and been adapted by other cities as the basis of their own zoning codes (Hopkinson,1970).

Blumenfeld (1979), in tracing some of the earlier influences on today's zoning practices, observes that:...."ancient Greek and Chinese city planning was far ahead of contemporary practice in paying attention to sunshine, wind, and humidity in the selection of sites".

Writing before the advantages and disadvantages of land use planning and control through zoning had been generally appreciated, Sert (1944) observes the paradox in all modern city development. He then offers his solution to the problem, based on increasing space around buildings as they increase in height:

"The haphazard growth of cities has given place to the following paradox: The height of buildings is as a general rule greater near the central areas, where the streets are narrower and traffic congestion and the nuisances resulting from overcrowding are greater. ....If a city is to be designed that will take into consideration the elementary requirements of good living, a relationship must be established between the height of buildings (dwellings or others) and their spacing.

The higher the buildings, the greater the space required between them. This statement can be taken as a general principle, though spacing will vary according to the functions of the buildings themselves and according to the climatological characteristics of the city in which they are built. Sunshine and orientation problems, in general, are more important in residential areas than in business districts. The requirements of community services, recreation, and parking also vary, but good lighting conditions, open spaces, and parking areas are necessary no matter where. High structures for residential purposes should be permitted only if open spaces around these buildings are secured so as to guarantee good lighting and view, sufficient exposure to the sun, ventilation, and isolation, together with the necessary open spaces that community services require."

Zoning has become a widely-used urban management tool. It is an interface between the local authority, the official representatives of a city, and the private sector. At this interface, major issues of importance to the entire city develop and come under review from time to time as the city grows and changes. As the re-zoning of land involves a change in the monetary value of land, it is handled with care and circumspection by both local authority and individual land owner.

In certain parts of Cape Town, the zoning regulations have been particularly restrictive, to the detriment of an area. An example is the Foreshore, where limitations to the permissible shapes of buildings have resulted in conformity. Floyd (1968) records an additional requirement which is unusual in zoning conditions, an obligation to build up to a certain predetermined height: "This, coupled with regulations governing daylight admission, inevitably results in a building consisting of double-banked accommodation distributed around a light well. Any other form of building is virtually precluded."

Zoning determines the shape and size of buildings such as those which form Greenmarket Square and other urban spaces in the centre of Cape Town. Any change in zoning limitations would bring about changes in the shape and size of the surrounding buildings, and consequently in the character and geometry of the Square. For example, if height restrictions were relaxed, the buildings would respond to market pressures, requiring maximum utilisation of valuable land, and could rise to a height that would transform the Square into a light well. Conversely, the character of the Square could be protected by the proclamation of the new Inn on the Square hotel as a National Monument. This proclamation precludes any further additions to the height of the building, and consequent effects on the Square.

In interpreting the influence of zoning on the heights of buildings in the central business district of Cape Town, Davies (1965) applies both the disciplines of geography and planning. He also argues for an interdisciplinary approach to central area problems. In the present project, it has been necessary to extend the search for relevant material far beyond the boundaries of any one discipline in order to develop the theoretical background on which the study is based.

CONTRASTING APPROACHES TO THE STUDY OF SUN AND SHADE

The importance of sun and shade in urban spaces has been recognised intuitively by a few writers, amongst them Alexander et. al. (1977):

"People use open space if it is sunny, and do not use it if it isn't, in all but desert climates....This is perhaps the most important single fact about a building. If the building is placed right, the building and its gardens will be happy places full of activity and laughter. If it is done wrong, then all the attention in the world, and the most beautiful details, will not prevent it from being a silent gloomy place. Thousands of acres of open space in every city are wasted because they are north of buildings and never get the sun. This is true for public buildings, and it is true for private houses. The recently built Bank of America building in San

Francisco, a giant building built by a major firm of architects, has its plaza on the north side. At lunchtime, the plaza is empty, and the people eat their sandwiches in the street, on the south side where the sun is....People are by nature phototropic, they move toward light, and, when stationary, they orient themselves toward the light."

Two writers have appreciated the shortcomings of the intuitive response, and have attempted to introduce a more reasoned, scientific approach to the problem. Thomas (1971) relates non-finite realities such as time and movement to solar radiation to aid the design of buildings and their surroundings. He suggests a technical procedure, with methods and media suited to its practice. He falls short of advancing known methodology by failing to see the weakness in the approach. This weakness derives from the fact that he relies on line-of-sight, or more precisely, on geometric projections representing solar radiation. Such projections, at best, give only a crude indication of the sun's movement and intensity. He provides a simple planning aid which does not lend itself to refinement.

Knowles (1974), on the other hand, attempted to "improve the quality of the urban environment by designing buildings that offered clues to orientation". His work is concerned with energy conservation through design, its scope being the form of our built environment. The emphasis is therefore on the shape and structure of buildings under stress of multiple cyclic forces in nature. His study of solar radiation, for example, uses a natural setting, and considers the effects of solar radiation on ambient air temperatures, incident energy, geology, precipitation, surface water, ground water, topography, and winds, together with the composite effects. A detailed study of the sun's movements is used to generate 'surfaces' which could represent facets of buildings, and the seasonal implications on these are thoroughly documented. While advancing the understanding of the effects of insolation on a building, and the resultant forms that a buiding can take if it is to achieve maximum utility, the study is severely limited in its application to external spaces.

As has been shown, there is a shortage of empirical data relating to the problem of sun and shade in urban spaces that would be of use to planners, decisionmakers and architects. There are several possible reasons for this shortage. In the first place, man has been subject to the effects of sun and shade for so long that a modern viewpoint has never been adopted in planning (Thomas, 1971). Further, while the technological means has been available for some time, the same technology has allowed disregard for the natural environment. There was, therefore, no necessity to further understanding of natural factors by empirical measurement. There is also no economic incentive to encourage research in this field.

Although there is a shortage of empirical data derived from architects or planners , a study of the literature from a wide variety of other disciplines has provided the theoretical basis for a pilot study on a more practical level.

CHAPTER FIVE

THEORETICAL CONSIDERATIONS OF SUN AND SHADE

There is sufficient material in the literature to be able to present a thorough description of solar radiation in general, and its relationship to urban climates in particular. Works on the design of tropical architecture deal at length with the problems of shading buildings, ventilating them to prevent heat accumulation, and of human physiological response to thermal stress. Another viewpoint considers the sun as a source of energy for the heating of buildings in cool climates. The most objective information is to be found in works on applied climatology where the urban climate is treated as a laboratory in which the effects of man's activities can be monitored. The extent to which this information has been studied by planners and architects is impossible to determine. The previous chapters have shown, however, that despite the need for a greater understanding of natural phenomena in planning, the question of sun and shade has hardly been considered. A contributing factor might be an unwillingness to cross professional boundaries, professional insularity, or denial of the growing need for inter-disciplinary action in planning. Another factor might be the more practical one of language, where information is available but not in a form which is readily assimilated from one discipline to another. This chapter attempts to set out theoretical considerations of sun and shade as background material to the practical work which follows. As this material has been assembled from several different fields, it could also provide a useful source of reference for further study of sun and shade.

SOLAR RADIATION

The earth receives almost all its energy from the sun in the form of radiation. The total radiation reaching the upper surface of the atmosphere is known as the solar constant, being 1395 watts/square metre. The spectrum of solar radiation extends from 290 to 2300 nanometres, visible light falling in the range 380 to 700 nm.(Koenigsberger, 1973).

The amount of radiation which falls at a point on the earth's surface is determined by three factors:

1. The angle of the reception surface, according to the Cosine Law, which states that the intensity of radiation on a tilted surface equals the normal intensity times the cosine of the angle of incidence.

2. Atmospheric depletion, being absorbtion by ozone, water vapours, and dust particles in the atmosphere. This factor ranges from 0,2 to 0,7.

3. Duration of sunlight.

Of the amount (100 %) of solar radiation arriving at the atmosphere approximately 50% is received at the ground. This depletion occurs in the proportions indicated on figure 5/1. Radiation is experienced as heat and light, but there is no constant relationship between radiation intensity and its lighting effect. As a general guide, the value of 100 lumens/watt can be used for solar radiation, which gives an illumination of 100 lux for every watt/square metre intensity (Koenigsberger 1973). The annual cycle of air temperature is closely related to solar radiation but with a time lag of about one month (figure 5/3). The schematic relationship between daily variations in temperature and radiation, for clear and dull days, is shown in figure 5/4.

Measurements of the heating effect of solar radiation may be made using a globe (black bulb) thermometer, instead of a dry bulb thermometer, to give the mean radiant temperature. This can be defined as follows: "If all surfaces in an environment were uniformly at this temperature, it would produce the same net radiant heat balance as the given environment with its various surface temperatures" (Koenigsberger, 1973). Globe thermometer readings, therefore, reflect both the effect of any received or emitted radiation and the air temperature in combination. Koenigsberger continues: "If the globe thermometer temperature is not available, but the dry bulb temperature is known, in many cases it can be assumed that the surface temperatures are the same as the air temperatures....If there is a strong radiation source, with a known intensity, the globe thermometer value can be roughly estimated as one degree higher than the air temperature for every 90 watts/square metre radiation intensity."

URBAN CLIMATE

Solar radiation must simultaneously be seen as the source of energy which drives the whole climatic system, and one of many climatic factors that determine local climatic parameters, such as temperature and temperature change, air movement, and glare.

Individual buildings are the means whereby these conditions are adapted to provide an equitable and stable internal environment for the intended occupants. In an urban situation, size, shape, surface material, orientation, and spacing of buildings are determined by many criteria, amongst which inadvertent external climatic modification has not hitherto been highly ranked. Oliver (1973) sees this as being related to a lack of predictive models:

"While the climatic environment is often considered as a variable in siting new buildings and building clusters (Landsberg, 1970), little attention has been paid to the modified climate that will result. Perhaps the reason for this relates to the lack of predictive models allowing the evaluation of such changes. It has become a prime task of climatologists to examine the changes that occur and to attempt to assess quantitatively the nature of the variables involved."

The changes relevant to sun and shade referred to by Oliver may be summarised as follows:

Temperature

A city can be one degree centigrade warmer by day and two degrees centigrade warmer by night than the surounding open countryside. Koenigsberger (1973) reports differences of up to eleven degrees centigrade. Some of this heat is imported as power for lighting, heating, and cooling of buildings, and for transportation. By far the greatest proportion of heat derives from solar radiation, partially absorbed by buildings and streets, and converted into heat. Dark surfaces such as tarmacadam tend to absorb, and light surfaces tend to reflect, solar radiation. This capacity is known as albedo or reflectivity. In a city such as Cape Town, approximately one-third of the central area is tarmac surface, including pavements, roads, parking and loading bays. Building surfaces vary from highly reflective 'solar shield' mirror glass to black aggregate terrazzo.

At night long-wave radiation to space occurs, resulting in rapid cooling of the earth's surface. The layer of air immediately above the surface is also cooled, leading to a reversal of the normal condition in which atmospheric temperature decreases with altitude. This inversion condition may cause pollutants to be trapped in a concentrated form, rather than being diluted with freshly circulated air and dispersed.

Chandler (1978) observes that the heat island effect is also greatest at night as a result of strong rural cooling. Later in the night, urban cooling rates often slightly exceed those in rural areas, and the urban-rural temperature difference decreases. After dawn, the vegetation-covered soils of rural areas, with a relatively low thermal capacity, and fully exposed to solar radiation, warm faster than air in city streets, so that the urban-rural temperature difference further decreases or even reverses to form an urban cold island.

It should be mentioned that above a certain critical windspeed, heat island conditions can not occur. Chandler goes on to explain the daytime cold island phenomenon as a result of thermal lag, that is, the delay in heating a city centre with high thermal capacity. He mentions as important in this respect shading of city streets, gardens, and courtyards by tall buildings. He continues: "Others have studied the effects of parks and squares, noting the lower temperatures that are usually found in open spaces within cities, a feature of some importance in urban planning."

Air movement

Increased friction caused by urban development results in reduced average wind speeds in cities compared with rural areas. Nevertheless, tunnelling effects of streets cause localised areas of gustiness, which reduce rapidly with height. In the boundary layer between and immediately above the buildings, wind speed and direction are influenced by the size, shape, and orientation of buildings, and the surface on which they are built.

Glare

Reflections from buildings and streets, as well as from cloud cover, create conditions of highly contrasting light and shade. This is particularly noticeable in Cape Town, when the sun shines from the north-east or north-west. Since the road-grid is orientated in a similar direction, a situation results where one set of roads is bathed in light, while the roads at right-angles are in full shade. This situation is particlarly apparent in winter, when the sun is at a low angle above the horizon.

The above climatic factors are not experienced in isolation but rather act and react with each other, causing a changing sequence of climatic conditions. It is not sufficient, however, to identify and describe the local climatic factors. The design of an appropriate building or place at a particular location requires detailed data on each climatic factor which fixes both the extreme high and low conditions which can be expected, as well as the average conditions. A design approach must then be adopted which places these considerations in the correct perspective with relation to all the other operative design criteria applied to the particular project.

The average climatic condition in South Africa is temperate with short periods of extreme heat, cold, and rainfall. Until very recently the design approach towards buildings and cities has recognised the average conditions but not the extremes. This attitude is now becoming unacceptable, and people expect to go about their business in a city like Cape Town without getting drenched by the winter thunderstorms, or buffeted by the south-east wind in summer. Increasing living and working standards require, for example, efficient air conditioning, air being cooled in summer and warmed in winter. Oliver (1973) sees the climatic aspect becoming increasingly significant to planning, with the ecological planning proposed by Mc Harg in 1969 becoming a necessity.

THE BUILT ENVIRONMENT AS AN AID TO ADAPTATION

If the founders of modern cities could have anticipated the future extent of their influence on the surroundings, and conversely the constraints imposed on convenient growth by topographic limitations, more careful consideration might have been given to siting of the nucleic elements of towns. At city scale, environmental factors such as radiation, wind, and rain, are generally not considered. Convenience and economic considerations primarily determine the zoning of areas. The topography and geology of an area also have economic ramifications which determine land use. At a more local scale, the siting and orientation of buildings can have important consequences for the surrounding spaces which they help to define. It is not intended to refer to the role of single buildings in adapting internal space to human use, as this study is concerned with the quality of external spaces. The interdependence of buildings and the spaces around them should nevertheless be recognised in zoning regulations, which influence the shape of buildings, and consequently their effect on external spaces.

The careful selection and placing of trees within a city has a beneficial influence on the external spaces, not only in reducing wind velocities, but in cooling the air and shading the ground surfaces. These functions contribute to human adaptation to the environment, providing a variety of opportunities for adaptive behaviour, and reducing the wide fluctuations of wind, humidity, and temperature which might otherwise have occurred.

METHODS AND MEDIA FOR MAKING OBSERVATIONS OF THE SUN

Two approaches are commonly available for making natural observations of the sun. The first depends on detailed knowledge of the sun's position in the sky at a given time above a known point on the earth's surface. With simple geometric procedures and drawing instruments, conclusions may be made, for example, regarding the sun's effects on buildings and the spaces about buildings, in terms of the angle of sunshine and the shading measures which might be necessary for protection against excessive sunlight penetration.

In the first approach methods such as sunpath diagrams, Burnett diagrams, cotangent diagrams, cartoids, and sunlight indicators are available.

The second approach requires instrumentation which may be grouped as follows:

A. Simulation of sun and topographical objective where the 'sun' moves about a fixed model of the structure under consideration. The Heliodon is a machine of this type.

B. Simulation of sun and topography where the model is tilted under a fixed light source to represent realities of light and shade at a given point in time. Here the sun's light may be used with certain initial adjustments to the alignment of the model to provide a truly parallel light source, which aids photographic recording of the procedures. The Shellidon family of instruments operate in this way.

The methods listed thus far give fairly gross results insofar as sunlight is treated as positive or negative, that is, a certain point is noted to be in sunlight for a certain length of time, after which it is in shadow. No indication is given of the intensity of the sunlight, early morning sun ranking equally with midday sun. Techniques which attempt to depict the amount of sunlight falling on a given topography, in terms of hours of sunlight only, ignore the question of intensity completely.

C. Instrumentation is available to measure the intensity of different aspects of radiation and sunlight. These observations are naturally made from the real sun. Consequently, the method is suited only to approaches which include on-site observations of real sun conditions and are not compatible with those approaches which require a simulated sun to represent reality. Sensors of this sort are known as pyranometers and radiometers.

The solar heights and azimuths for the time and location under consideration are listed in N.B.R.I. Reseach report number 262, by Van Deventer (1968). These tables are organised in such a way that the relevant material is directly available in a useful form. Many of the systems available, for example, those which assist architects to determine the amount of shading a window requires to prevent excessive penetration of sunlight, are not adaptable to other uses and have been refined to a stage where the basic principles are obscured by the technology of the procedure.

IMPLICATIONS OF URBAN GEOMETRY

There are fundamental differences in the consideration of the effects of sun and shade in urban squares as opposed to their effects on single buildings. An example of this is that in the southern hemisphere, the north-facing elevation of a building is expected to receive the midday sun, the south face being shaded. In a square surrounded by buildings, however, it is the south side which receives the sunlight, the north side being in shadow.

Architects are aware of the advantages of roof-overhangs on buildings where the hot summer sun, shining from a high solar angle, is prevented from penetrating a building, but where the winter sun, at a low solar angle, is able to reach the windows and to provide welcome heating for the interior of the building. In urban squares the situation is reversed. The summer sun is able to reach a large proportion of the square's surface, uninterrupted by the surrounding buildings. Additional shading measures are, therefore, essential to provide relief. These measures may be in the form of trees, umbrellas as in some Continental piazzas, sun awnings, or covered connecting ways. In winter, when the sunlight would be appreciated in the square, the surrounding buildings interrupt the sun, shining at a low solar angle, and cast long shadows over a large proportion of the surface for the greater part of the day. Figure 5/5 shows this phenomenon.

Figure 5/6 shows the importance of the positioning of evergreen trees. In summer trees in most parts of the Square will provide shade as they will be exposed to the high solar approach. In the winter, however, many trees will already be in shade and will not reduce the available sunlight. Trees in the southern part of the square will interrupt what little winter sun reaches the space and create more shadow.

In Cape Town, historically-significant buildings such as the Old Town House and the Metropolitan Methodist Church on Greenmarket Square are two or three storeys high. If these had been placed on the northern perimeter of the square they would have had the effect of allowing far more winter sun to reach the square than the modern buildings in those positions now allow. An argument in favour of the present arrangement is that the elevations of the historical buildings which face the square receive sunlight for the greater part of the day. The sculptural qualities of the buildings are therefore revealed, which would not occur if these were on the shaded side of the square.

Streets provide a pathway for the sunlight to reach Greenmarket Square uninterrupted by buildings. In a normal grid situation where one whole block is used as the square, sunlight reaches the square's surface along the perimeter only, as this is where the adjacent road system connects to it. Greenmarket Square, being made up of two half blocks with a central road (Burg Street), receives sunlight at its centre from the north-east by this means. (The disadvantages of the bisection of Greenmarket Square by Burg Street from a pedestrian point of view are currently under review by the Cape Town City Council, and the section crossing Greenmarket Square might eventually be closed to vehicular traffic).

The orientation of the Square also has a considerable effect on the penetration of sunlight (figure 5/7). Being set at forty-five degrees from the north-south axis, the Square receives direct winter sunlight by way of the road system at mid-morning and mid-afternoon only, from the north-east and north-west. If the grid had been arranged on the north-south axis, sunlight would have penetrated obliquely from the east and west by way of Shortmarket and Longmarket Streets, and directly down Burg Street from the North, that is, from three directions instead of two.

It is apparent that the penetration of sunlight to urban squares, particularly in winter, is determined largely by the geometry of the urban forms that contain those squares. The provision of additional sunlight to an urban surface would involve fundamental changes in the shape and positioning of surrounding buildings. Seen against the comparative ease with which shading can be provided in an urban square when too much sunlight is present, it would seem that town planners should err on the side of excessive sunlight penetration. This could be adjusted over time through use and experience of the actual situation, rather than permitting large buildings to permanently overshadow urban spaces with no potential for adjustment during the life of the buildings.

PERIODICITY

The subdivision of time into large units is adequate for the simple requirements of primitive, independent communities. To function efficiently, interdependent societies require finer time gradations and the conventional recognition of time-spans devoted to certain activities on a regular basis. This was particularly true before electric lighting made night-time hours available for work or recreation. Despite this technological advance, the diurnal cycle remains customarily and habitually entrenched in our behaviour, largely determining when we eat, sleep, work, or relax. As communal action in cities provides advantages to the single individual that he would otherwise not enjoy, he must confine himself to the traditional rhythms of that society in order to contribute efficiently.

The parallel in species other than man is described by Hawley (1950), who discusses the adaptation of species to rhythms of the physical world, to the changing seasons, and to the oscillations of temperature and humidity. He continues: "The timing of physiological rhythms is fundamental to the establishment of symbiosis among species. In order that diverse organisms may live together, their respective routines must fit into a pattern which is congenial to the needs of all.

Thus the pulse of life in a given species is often a determining factor in its attaining a niche in a given community."

Periodic human needs must be adapted to the rhythms of the natural physical surroundings, but, wherever possible, man relies on technology to reduce this constraint. The ability to freeze and store food has reduced man's dependency on the weekly market. The importance of the weekly cycle has changed in time and been adapted to suit contemporary human needs of work and recreation. The effect on many cities, and certainly in central Cape Town, is to create periods of hectic activity during working days and desolation after working hours. Attempts to change people's habitual patterns are met with considerable resistance. The introduction of flexitime has not had a marked effect in making more efficient use of facilities such as eating places, and parking areas, nor has it reduced the peak-hour traffic jam of vehicles leaving town in the evenings. Freeways are ,therefore, provided to cater for near-peak loads and are under-utilised for the remainder of the day. A similar condition pertains to the whole macro-structure, from the mass transportation system, power supply, water demand, and sewerage, down to the requirements of lunchtime shopping and eating. Costly, but "non-essential", non-productive areas such as parks and squares are also underutilised. An analysis of these places in terms of utility related to cost shows them to be extremely expensive , if utility is defined as person /hours spent occupying the space because of its intrinsic attractions. More often than not, Greenmarket Square is used as a convenient pedestrian passage across that part of the town. This is particularly true between o8h00 and 09h00 on weekday mornings when people fan out across the Square from the east on their way to work. Between 16h30 and 17h00 the reverse occurs, and people funnel down Shortmarket Street towards the railway station. It is only during the lunch hour that the Square is enjoyed by any significant number of people for its sun, shade, or fresh air. The mid-morning and mid-afternoon periods attract comparatively few people to the Square.

Human use of Greenmarket Square is predictably related to seasonal climatic conditions. Sunny spells in winter attract people to the Square, but simultaneous cold winds prevent them sitting still for any length of time. By far the more important factor, however, which influences human use of the Square is the periodic nature of human urban activity.

AESTHETIC QUALITY

Aesthetic quality of urban spaces is determined by its physical characteristics and its non-physical qualities such as mood and atmosphere. A feeling of well-being, for example, is difficult to evaluate. It is also difficult to establish the factors which contribute to that feeling. Consequently, the potential exists for the unwitting reduction of aesthetic quality by the removal or adaptation of important contributing factors, simply because these have not previously been identified as such.

Greenmarket Square may be seen as a space defined by its surrounding surfaces, which include not only the facades of the buildings, but also the cobbled floor and the sky. As has been shown, this provides a backdrop to the dramatic events of each day and is subjected in addition to the vagaries of climatic elements. Human perception of the space is largely dependent on the quality of light which falls on the surfaces. Bright direct sunlight throws into sharp relief the sculptured or modelled surfaces, found on the Metropolitan Methodist Church, where the three dimensional-qualities of the surfaces are particularly apparent. With the sun's movement these patterns change. At a certain moment of the day, an oblique light amplifies the hand-made qualities of the surfaces of the Town House. At other times these walls are a brilliant, but featureless, white.

Shadows cast throughout the day make changing textures on the cobbles, from full sunlight, through a range of mottled light caused by overhanging branches, to deep shade. This changing quality of light determines the way in which colours are perceived. Objects seen in full sunlight possess deep, full colours which turn insipid when the sun is obscured or when the object is silhouetted against the sun.

References in planning literature to the human need to be exposed to natural elements within a city or, at least, not to be totally denied that opportunity, are motivated by both aesthetic and psychological considerations. Attempts to obtain empirical data on the human need for open spaces, even in a rural setting, have thus far not been successful. Planners of the pre-war school justified open urban spaces, calling them the lungs of the city, where the combination of sunlight, plants, air, and water, produced a beneficial increase in the oxygen content of the air through photosynthesis. It was later shown that this increase is far too small to justify the dedication of urban blocks to that purpose alone, but planners still intuitively sense and recognise that need without being able to explain it in detail. The answer has probably to do with a very wide combination of factors acting in different ways on different people.

On some aspects there appears to be mutual agreement. Urban spaces are seen as places where people have an opportunity to become themselves again, to normalise after hours of hard work or after the fantasy experience of contemporary shopping centres where they are removed from the realities of the outside world and their aspirations and expectations are manipulated. In the shopping centres, air-conditioning removes the need to adapt to the cold wind or hot sun which makes the streets uncomfortable. Bright lights deny the shopper an awareness of the passage of time occasioned by the moving sun outside, and loud popular music prevents the normal auditory messages of the city from spoiling his reverie. A necessary contrast to this transient world is provided by open urban spaces where the familiar qualities of sun, wind, and rain are available.

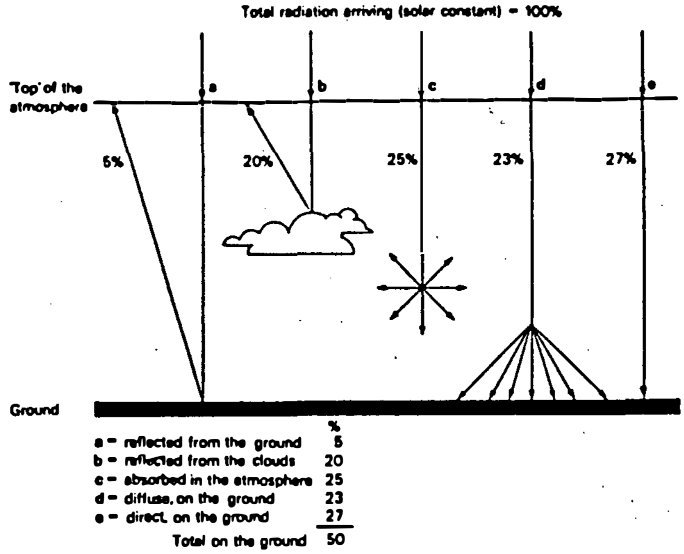
Another aspect which must be considered is the secondary use of a square. People do not only occupy the space physically, but also surround it at many levels, generally in office buildings from which they look down onto the square. A view onto trees and gardens is highly-sought after in the urban situation, and offices bordering these areas are seldom vacant.

The conditions in which people work are controlled by the Department of Manpower Utilization, with regulations existing to protect office workers in windowless areas. The question for the future, however, should not be whether buildings need windows or not, but what it is we need to experience when we look out of them.

Passage of radiation through the atmosphere

FIG

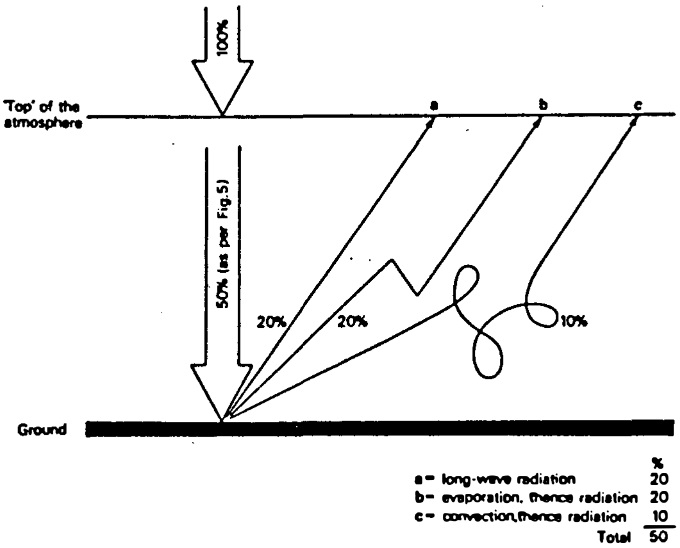
5/1



Heat release from the ground and the atmosphere

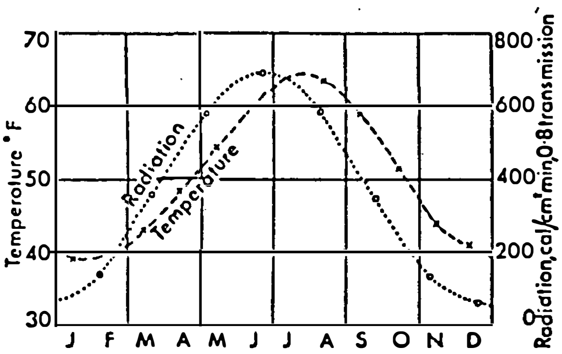
FIG

5/2

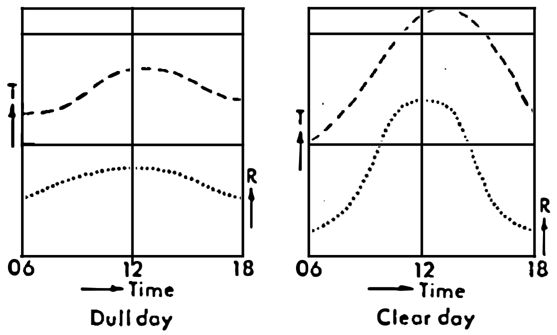


FIGURES 5/I AND 5/2 FROM KOENIGSBERGER 1973

FIGURES 5/3 AND 5/4 FROM GRIFFITHS 1966



Relationship between temperature and direct solar radiation on a horizontal plane, London



Schematic relationship between daily variations of temperature, *T*, and radiation, *R*

FIG

5/3

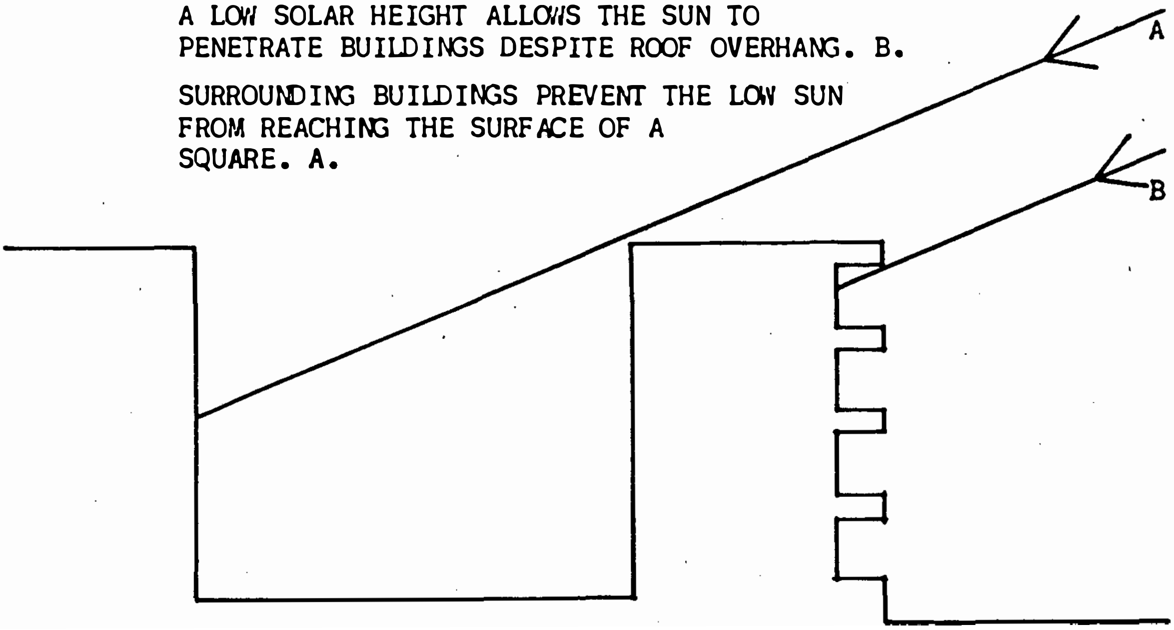
FIG

5/4

WINTER.

A LOW SOLAR HEIGHT ALLOWS THE SUN TO PENETRATE BUILDINGS DESPITE ROOF OVERHANG. B.

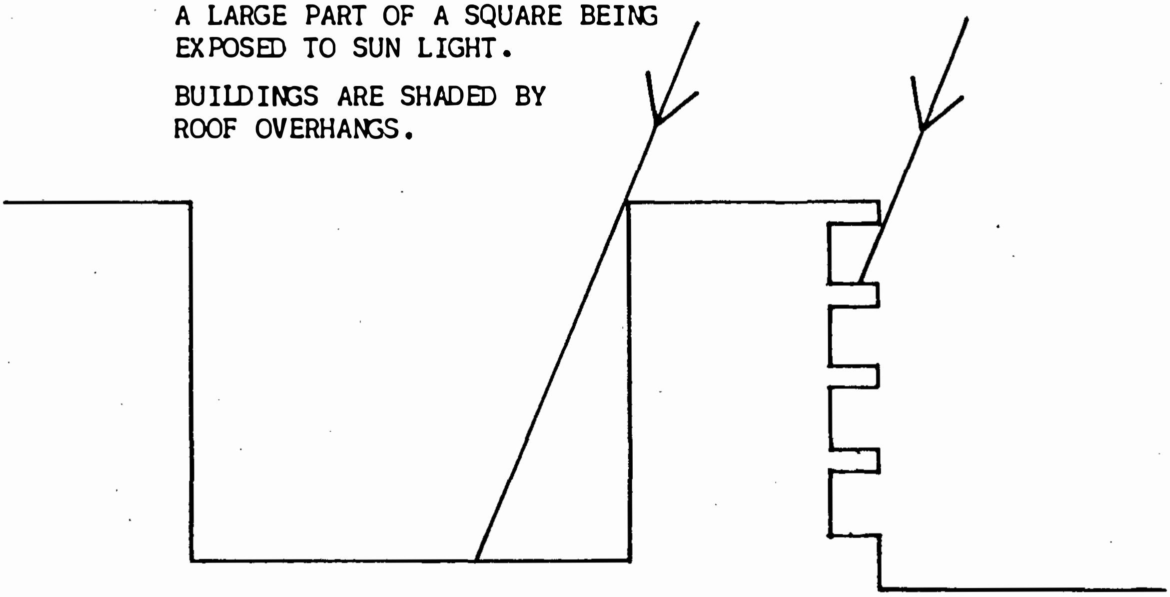
SURROUNDING BUILDINGS PREVENT THE LOW SUN FROM REACHING THE SURFACE OF A SQUARE. A.



SUMMER.

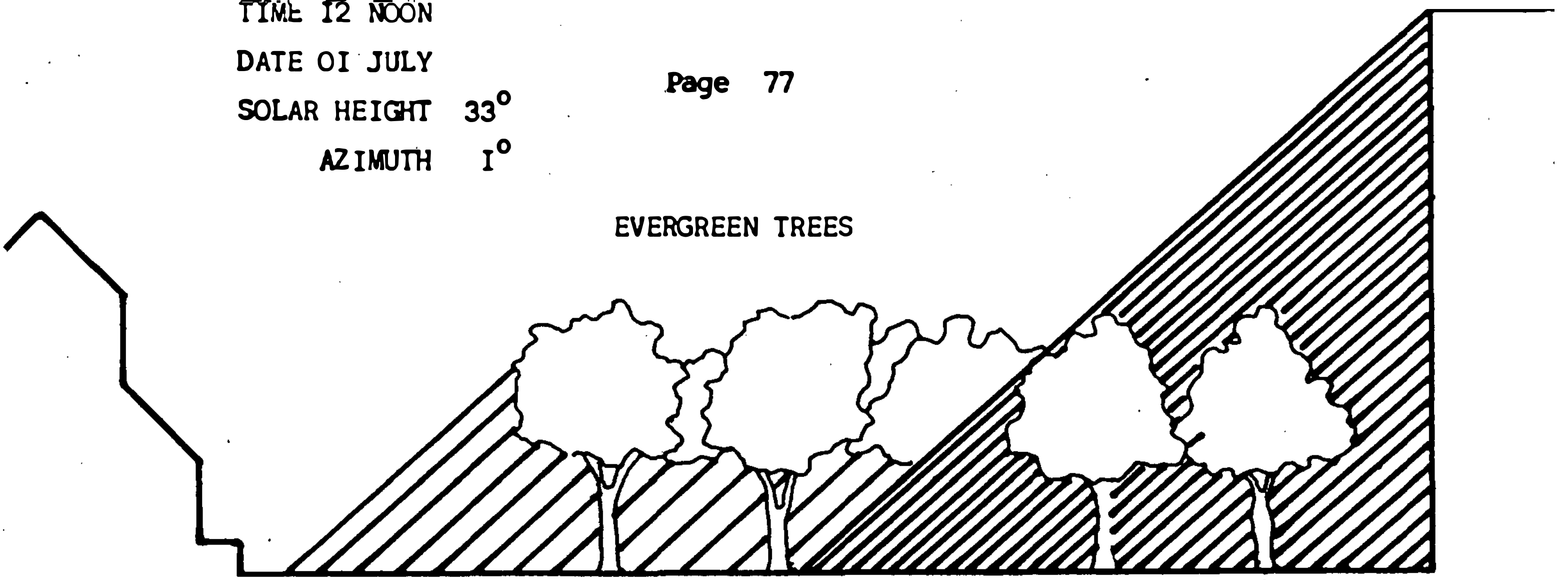
AN INCREASED SOLAR HEIGHT RESULTS IN A LARGE PART OF A SQUARE BEING EXPOSED TO SUN LIGHT.

BUILDINGS ARE SHADED BY ROOF OVERHANGS.

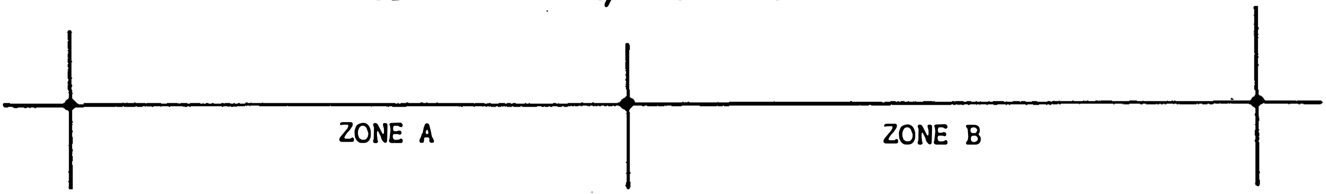


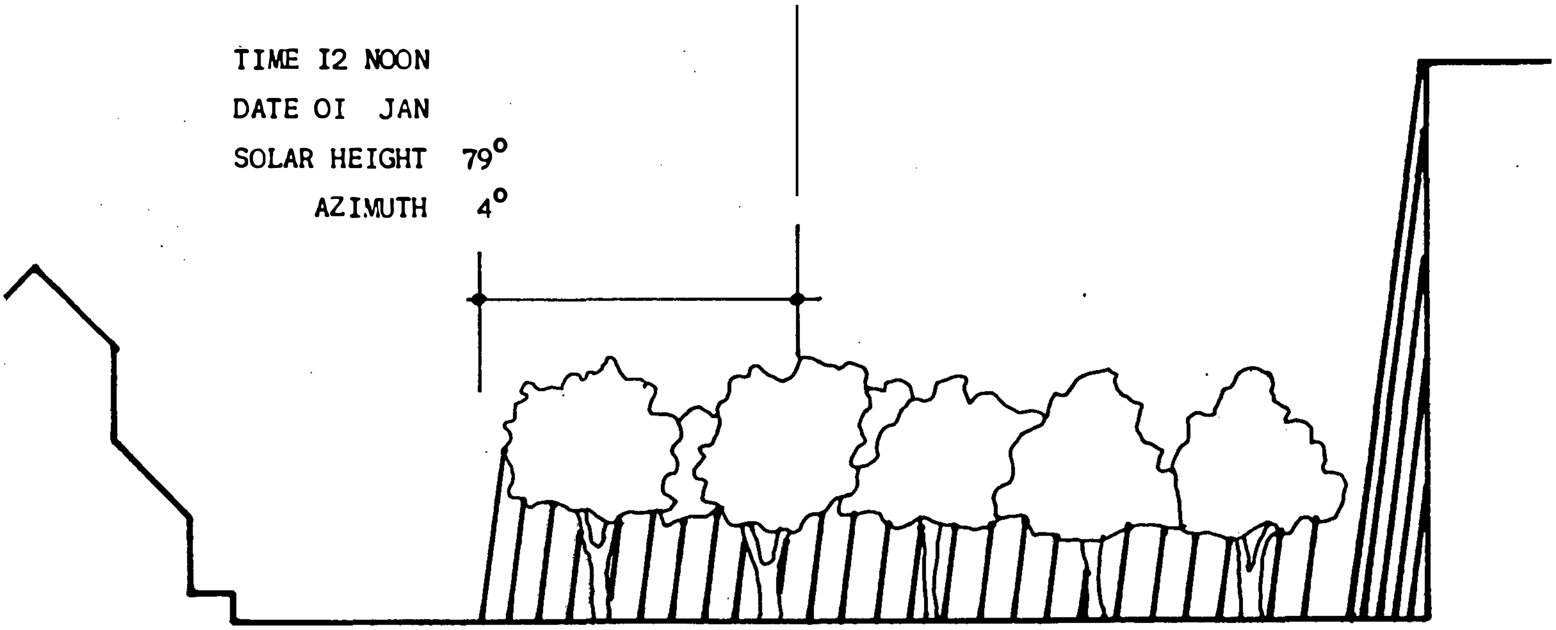
FIG

5/5



CROSS SECTION NORTH-EAST/SOUTH-WEST





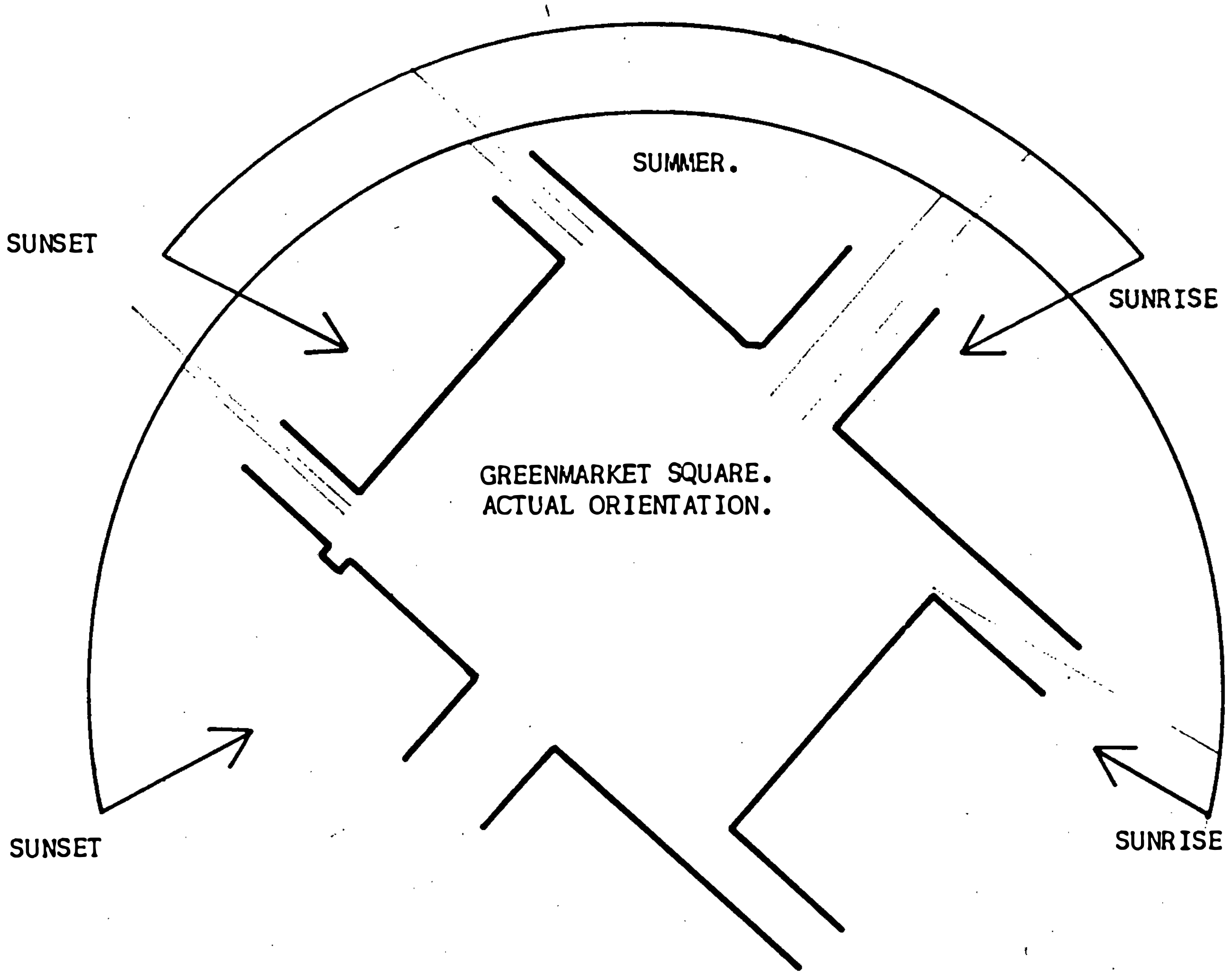
CROSS SECTION NORTH-EAST/SOUTH-WEST

TREES IN ZONE A IN WINTER REDUCE AMOUNT OF SUN AVAILABLE AT GROUND LEVEL. TREES IN ZONE B IN WINTER ARE SHADED BY BUILDINGS AND THEREFORE DO NOT REDUCE THE AMOUNT OF SUN AVAILABLE AT GROUND LEVEL.
IN SUMMER TREES IN ZONE A CONTRIBUTE RELATIVELY LITTLE TO THE TOTAL AMOUNT OF SHADE AVAILABLE.

THIS OBSERVATION ASSUMES THAT SUN IS REQUIRED IN WINTER AND SHADE IN SUMMER FOR HUMAN COMFORT.

FIG
5/6

SOLAR PATH IN WINTER



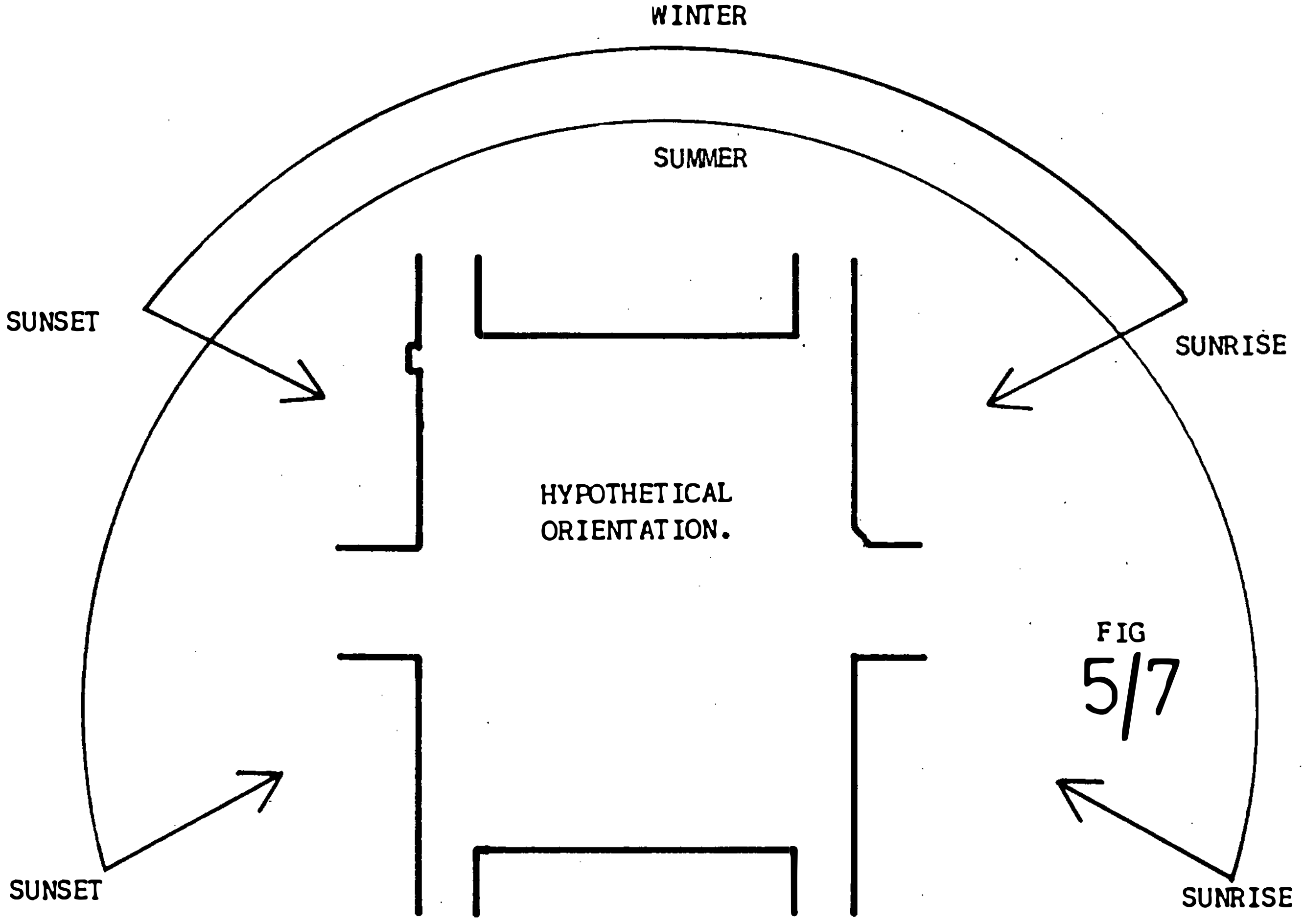


FIG 5/7

CHAPTER SIX

MEASUREMENTS IN GREENMARKET SQUARE

Measurements of solar radiation in Greenmarket Square were made at regular intervals over a period of 11 hours from dawn to sunset, between the 1st and 4th of July, 1980. Radiometer readings were taken at the points of intersection of a superimposed grid which divides the Square into zones, as shown on the accompanying drawing (figure 7/2). Radiation values were recorded and observations made of the movement of people into or away from the square. Subsequently, black bulb thermometer readings, ambient temperature readings, and radiation readings, were recorded simultaneously at a single measuring point, together with details of human use of the Square.

Aims and objectives of the site work

In formulating a new approach to the representation of the distribution of solar radiation in urban spaces, one of the requirements was that numerical data, which could be manipulated arithmetically, should be collected to provide, for example, daily totals of solar radiation received at a given point. Also the data should be such as to make possible a graphical representation in a form which renders areas of maximum and minimum solar radiation immediately apparent. Another requirement was that the measurements should indicate the amount of solar radiation at any point in the study area at any time throughout the day. In this pilot study, continuous monitoring over many points was not possible owing to logistic considerations. Measurements were therefore made at intervals to demonstrate that the approach and methods employed could produce results with far greater detail and resolution than is normal for studies of urban sun and shade.

The secondary objectives of the site work were to establish the suitability of the instrumentation chosen and of the methods employed in collecting the data. In order to ensure that unanticipated practical implications did not impede the smooth progression of measurements throughout the day, a precautionary time margin of 6 minutes was incorporated between sets of radiometer readings. During this time, observations of a practical nature concerning the instrumentation and method of use were to be recorded.

In addition to the collection of data by radiometer and black bulb thermometer, observations were to be made of the movement of people within the square to establish patterns of human response to the conditions of sun and shade prevailing at a given point at a certain time. These observations were used to establish whether any consistent behaviour could be determined which would demonstrate a definite link between the amount of solar radiation falling on a given point and the extent to which that point was seen as an attractive place to sit.

INSTRUMENTATION

Radiometer

The instrument used to measure solar radiation was a Ll-170 Quantum/radiometer/photometer manufactured by Lambda Instruments Corporation (LI-CO), of Lincoln, Nebraska. It was used in radiometer mode, in conjunction with a pyranometer sensor which measures global radiation from sun and sky received on a horizontal surface. The measurement is in watts per square metre. The instrument was attached to a platform with a level surface approximate 800 mm above the ground. The platform supported the sensor in its holder, which provides a levelling bubble and three adjusting screws.

Operating procedure

Before any readings were made, the instrument's zero adjustment was checked. This should be done with the instrument switched off. The instrument should read zero, failing which, a mechanical zero control adjustment should be made. This adjustment was not usually required during any one measuring period.

The equipment was placed at the required measuring point, and an appropriate range selected depending on the amount of radiation being received. 2000 watts per square metre was the required position for strong radiation, and 200 for weak radiation.

Since the proximity of a human body screened sufficient radiation to affect the reading, a distance of 1 metre was maintained between the operator and the instrument while taking measurements. Care was also taken not to shade or reflect radiation onto the sensor. When the needle had stabilised, the result was recorded and the equipment advanced to the next measuring point.

Calibration

On the 9 August 1978, the LI-170 instrument, Serial No. PQR 1079-7209, was calibrated to the LI-200S pyranometer sensor, Serial No PY 1326-7809. The calibration was done in air under direct sunlight.

Black bulb thermometer

The instrument used consisted of a 150 mm. hollow copper sphere painted black. A 25mm. opening in the sphere was fitted with a rubber collar through which a 7mm. glass thermometed protruded to allow the thermometer bulb to be positioned at the centre of the copper sphere. The thermometer scale, reading from 0 to 200 degrees fahrenheit, extended above the copper sphere. The instrument, on loan from the Department of Manpower Utilisation, was marked LAB 17/6. This Department uses the instrument to measure mean radiant temperature, as required for calculations of the Corrected Effective Temperature Comfort Index, to determine human comfort levels in existing work spaces.

The globe thermometer reading gives a combination of air temperature and the effect of any received or emitted radiation. If the air is warm, but the opposing surfaces such as walls are cold, some radiation will be emitted from the globe and the reading will be below the air temperature. If radiation is received as occurs when direct sunlight falls on the globe, the reading will be higher than the air temperature.

Operating procedure

The instrument was placed at position C7 (figure 7/2) on a level platform 800mm. above the ground. It was decided to raise the instrument to this level to make measurements at a level approximating that of the human torso in a seated position. The instrument was placed in position 30 minutes before dawn, to allow it to stabilise to the local conditions. Readings were taken every fifteen minutes, as a response time of over ten minutes was required.

As the readings were made at a single point, it was possible to take ambient temperature readings as well as radiation readings, and to make a note of the number of people seated in the western quarter of the Square. The results were tabulated (table 7/22) and graphed (figure 7/23).

PROCEDURE

The study area was measured, and an accurate drawing made, showing the positions of Greenmarket Square's buildings and roads. In addition, the positions of projecting canopies and trees were plotted. The building heights were recorded and cross-sectional drawings produced, as a basis for figures 7/15 and 5/6.

Radiometer readings

A superimposed grid of 6 lines, three in each direction, was devised, along which radiometer readings were taken at intervals of 10 minutes. As there were 6 lines, (A, B, C, D, E, and F) a complete set of readings covering the Square was taken every hour. At points where two grid lines crossed, readings were taken twice an hour as a natural consequence of the lines sharing a measuring point. These points are marked E/B, A/B, D/B, E/F, A/F, D/F, and E/C, A/C, D/C, on the site plan (figure 7/2). While it is advantageous to have additional readings at these points for cross-checking and giving greater definition to the results in this sector, care must be exercised in creating cumulative totals for these points, as double values will otherwise result. Each point was thus registered only once every hour when totals were determined.

Not more than four minutes were required to measure each string of readings, leaving 6 minutes to check the written notes, to make observations of a practical nature concerning the instrumentation, and to proceed to the starting point of the next string of readings. During the four-minute reading period, conditions of solar radiation changed so slightly that compensation for this was not warranted. To verify this, an additional reading was taken at the starting point after the first string had been recorded, to determine whether any appreciable difference could be observed between the first measurement of point 1 and the second measurement at the same point four minutes later. When differences were observed, these could be attributed to changing conditions of overcast sky, rather than to the slightly different position of the sun within the four-minute period.

A decision had to be made as to whether a particular sky condition was acceptable for the site readings or not. At times, overcast conditions prevented accumulation of a reliable data set. As a result, the data used were collected over a period of four days, during which an acceptably uniform sky condition was available for the readings. The criterion adopted for acceptable light conditions was that a sharp shadow line should be apparent on the ground during the entire observation period. During clear, blue sky conditions, sharp shadows were present. As the sky lost its colour owing to haze or mist, well-defined shadows would initially be apparent, and radiation readings remained high. As radiation levels dropped, well-defined shadows were no longer present. When this occurred, readings were discontinued until acceptable conditions were re-established, and the preset programme could be continued. Missed readings were made good on the nearest following day on which conditions were acceptable according to the standard. Minor errors introduced in this way are within experimental error, as during the time of observations solar altitude changed by less than one degree per week.

As people moved into the square and occupied the benches which line its borders, a plus sign was entered adjacent to the radiation reading being made at that time. Similarly, as people left a point a minus sign was entered adjacent to the radiation reading being made. This was done in an attempt to relate human use of the Square to radiation levels.

Black bulb thermometer readings

Subsequently, black bulb thermometer, radiometer, and ambient temperature readings were made simultaneously with recordings of the number of people using the benches in the western quarter of the Square. This was done under varying degrees of solar radiation during the four-hour period after dawn, to establish the local relationship between radiation and net radiant temperature. On the basis of the previous radiometer readings, a single measuring point C7 was chosen in the area which would receive the first direct solar radiation of the day.

The readings generally satisfied the aims and objectives outlined at the beginning of this chapter. Numerical data was collected over a full day along points on a grid which covered the whole square. The data recorded the intensity of the solar radiation at the measuring points, allowing daily totals to be collected and areas of maximum and minimum radiation values to be identified and represented graphically.

The instruments used and the methods employed were suitble for the collection of data in the form required. Some difficulty was initially experienced in determining the units in which the radiometer readings were expressed. This difficulty did not, however, affect the accuracy of the readings and was soon resolved.

The observations of human use of the square were satisfactorily correlated with the radiometer and black bulb thermometer readings in the form in which the data was collected. It was apparent at the time of making these readings, however, that many other factors not considered in the limited scope of this study significantly influenced the human use of the space.

CHAPTER SEVEN

RESULTS OBTAINED FROM THE MEASUREMENT OF SOLAR RADIATION IN GREENMARKET SQUARE

Radiometer readings were made between the first and fourth of July 1980. On the first of July the sun rose at 07h11 and set at 16h56. Readings were started at 07h00 and were stopped at 18h30. The results of these measurements are shown on tables 7/16 to 7/21, and are depicted graphically in figures 7/3 to 7/12.

Black bulb thermometer readings were made and compared with simultaneous ambient temperature and radiation readings. Human use of benches in the study area was recorded at the same time. The results of these readings are shown on table 7/22 and figure 7/23.

REPRESENTATION OF RESULTS

Radiometer results

The data lends itself to many forms of representation. The first method chosen employed the Dataplot computer program by Apple Computer Inc., to produce bar-graphs of radiation at a single given point at hourly intervals. Figure 7/1 shows an example of the results achieved. As the program was not readily adaptable, because of inherent limitations, the graphs are all plotted using the same vertical axis height to represent different ranges of readings. At point D2 the highest reading was 160 watts/sq.m., while at point D5 the highest reading was 400 watts/sq.m. The vertical distances between zero and the tops of the graphs are equal. The results are, therefore, not easily compared visually.

The Dataplot bar-graph shown in figure 7/1 provides detailed information at a single monitoring point at hourly intervals. This technique could also be used to show radiation values at a single time, but at ten different points along a measurement line. In this way the time factor would be brought into prominence. While the bar-graph method has the advantage of speed, the main objections to this method of representation are that it requires the use of a computer and produces results that are not readily comparable visually.

To overcome these objections it was decided to present the data by three-dimensional graphic techniques as shown on figures 7/3 to 7/12.

The radiation levels are depicted to a vertical scale of 10 millimetres to 100 watts/sq.m. To clarify the sequence in which the readings were made, that is from point A1 to A2 to

A3, these readings are connected by a solid line. Where readings taken along line B coincide with readings taken along line A at point A/B, the graphic method employed highlights the difference in radiation due to the elapsed period of ten minutes between the readings. This is clarified on figure 7/5.

Figure 7/13 shows the total radiation received at all the measurement points over the period of eleven hours. Due to the vertical height, shown here to the same scale as figures 7/3 to 7/12, the viewpoint has had to be changed to prevent the high values from obscuring the low values. On figure 7/13 the Square is viewed from the north looking south, while figures 7/3 to 7/12 view the Square from the southern corner. Viewpoints from the east or west might have been an equally suitable compromise solution to avoid this problem.

Figures 7/24, 7/25 and 7/26 show isopleths at 100 watts/sq.m. intervals for the hours 10h00 to 11h00, 12h00 to 13h00, and 14h00 to 15h00, derived from the radiation values on tables 7/16 to 7/21. Where two values were available for a given point, averaged values were used. (For this reason, there are slight differences between the isopleths under discussion here, and the example in figure 7/14, where maximum values were used).

Plus and minus signs from tables 7/16 to 7/21 also appear, showing points at which people either sat down or left benches or other resting-places around the Square.

Black bulb thermometer results

The results of the black bulb thermometer readings were plotted on a graph (figure 7/23), which simultaneously shows the ambient temperature and the radiation values obtained. Since it is regarded as important to relate human usage of the Square to the temperature and radiation conditions, numbers of people sitting in the black bulb study area are plotted on the same graph. This method of representation allows certain correlations to be observed as discussed under 'Black bulb thermometer observations'.

Radiometer observations

Dawn in Greenmarket Square on the first of July was at 07h11. At that time a mean radiation value of 1,5 watts/square metre was measured along line E. The solar radiation increased slowly with a comparatively even distribution over the whole Square until 08h10, when the mean radiation value on line E had increased to 15,25 watts/sq.m. This level distribution may be seen on line D (08h00) and line E (08h10) on figure 7/3. At that time the surrounding buildings prevented direct sunlight from reaching the surface of the square. The light which reached the square was therefore a diffused light from the sky and upper surfaces of the surrounding buildings, such as the Inn on the Square. As the sun continued to rise after 08h10, the increased radiation values became more apparent. By 08h20 the mean radiation value along line F was 29,6 watts/sq.m. The steady and evenly distributed increase may be seen by comparing readings on line F (08h20) with the readings on line B twenty minutes later (figure 7/3). The increases were relatively small however, when compared with those along the same lines one hour later. At 09h20 a peak of 200 watts/sq.m. may be seen at point F1 (figure 7/4). This peak is caused by the sun shining at an azimuth of 40 degrees, which approximately corresponds with the north-east south-west orientation of Burg Street. In comparison with this reading, the radiation value at B1 twenty minutes later was only 35 watts/sq.m., and at 09h50 a value of 45 watts/sq.m. was recorded at point C1. These comparatively low values were caused by the shadows of Namaqua House and South West House.

At 10h00 the peak of comparatively high radiation first seen at point F1 at 09h20 was recorded again, at point D/F, when the reading was 150 watts/sq.m. By 10h20, however, the reading at D/F had dropped to 30 watts/sq.m. It may be seen from figure 7/5 that this value is typical along line F at 10h20. These low values are caused by a distant tall building which blocks the sun for approximately twenty minutes.

By 10h30 the first strong rays of sunlight reached the surface of the Square, causing values as high as 400 watts/sq.m. at point A/B, and 300 watts/sq.m. at point A/F (figure 7/5). By 10h40 the whole of the south-western part of the square was in sunlight, with shade in the north-eastern and north-western parts. Low values at E10, A10, and D10 were caused by the developing shadow of the Inn on the Square, as shown on figure 7/15.

An interesting difference in radiation readings over a thirty minute period may be seen at point E/B at 10h10 (figure 7/5), and at the same point at 10h40, where values of 120 and 500 watts/sq.m. respectively were recorded. Similar differences caused by the counter-clockwise movement of the point of maximum intensity of solar radiation may be seen on figure 7/5.

The depression of the radiation values by a tall building along line F at 10h20 prevents an accurate depiction of the expected radiation distribution pattern over the period from 10h00 to 11h00, when concentration of sunlight on the south-western part of the Square, including points F8, F7, E/F, and A/F would be expected.

The continuing anti-clockwise motion of the area of maximum radiation intensity around the Square may be seen on figures 7/6 and 7/7. At points E1 and A1, values increased from 35 to 400 and from 60 to 250 watts/sq.m. between 10h10 and 11h10 and between 10h30 and 11h30 respectively. Between points E7 and E10, values reduced between 11h10 and 12h10 as well as at points E/F, F7, and F8 between 11h20 and 12h20. The depression of solar radiation values along line F, between F2 and F/A, at 11h20 was caused by the shadow of Namaqua House.

The comparatively low values of 100 and 65 watts/sq.m. at E2 and E3 at 11h10 (figure 7/6) were caused by overshadowing trees. Another example of overshadowing by trees may be seen at point A2 and A3, where readings were affected by shade throughout the day. These examples were, however, exceptional, the rest of the readings being unaffected by shading due to trees.

Increasing radiation values along line B were recorded at 12h40, with lowering values in the north-western part of the square due to the encroachment of the shadow of the Inn on the Square (figure 7/7).

As Greenmarket Square is in fact a rectangle, high radiation values were present on the south-eastern side for a longer time than on the south-western side. This may be seen by comparing the pre-noon period (figures 7/6, 7/5, 7/4, and 7/3) with the afternoon period (figures 7/7, 7/8, 7/9, and 7/10), where figure 7/3 shows the period four hours before noon and figure 7/10 the period four hours after noon. Between 08h00 and 08h50 radiation values are low in the south-western side, while between 15h00 and 15h50 peaks of 400 watts/sq.m. were recorded at the south-eastern side.

Strong values of up to 550 watts/sq.m. are to be seen at points A/B, A5, A/F, and A7 at 13h00 (figure 7/8). These high values were caused by the afternoon sun, at a solar angle of 31 degrees above the horizon, shining down the narrow space between the Inn on the Square and Greenmarket Place formed by Shortmarket Street. The continuous anti-clockwise movement of the area of maximum intensity of solar radiation resulted in a further reduction of radiation values along line E from E7 to E10 (figure 7/8). Figure 7/9 shows the continuing reduction in the south-western part of the Square, along lines F and A from A/F to A10 and from A/F to F8. The peak of high radiation at AB at 13h30 of 550 watts/sq.m.(figure 7/8) reduced to 475 watts/sq.m. at 14h30 (figure 7/9), while the high values at A/F and A7 at 13h30 reduced to a low mean value of 93 watts/sq.m. at 14h30 (figure 7/9).

The ray of sunlight down Shortmarket Street can be seen to have moved to D/F at 14h20 where a peak of 200 watts/sq.m. developed. Note that this peak was not present at D/F at 14h00 (figure 7/9), while at the same point at 13h00 the radiation reading was 70 watts/sq.m.

The depressed radiation reading at B7 at 14h40 was caused by the central tower of the Inn of the Square. An hour later at 15h40 (figure 7/10), the radiation values at E/B, B7, and B/8 reduced to a mean of 65 watts/sq.m, as the shadow of the Inn on the Square lengthened and moved towards the east.

From 15h00 onwards, the irregular sky-line caused by the surrounding buildings played an increasingly significant role, causing short periods of high and low intensity as the long afternoon shadows moved anti-clockwise towards the eastern side of the Square. An example of this may be seen at D/F at 15h00 (figure 7/10) where a value of 50 watts/sq.m. was recorded, but at 15h20 a peak of 400 watts/sq.m. can be seen.

The effect of the sun at a low solar angle moving behind the Tudor Hotel at the north-west corner of the Square may be seen on figure 7/11. Fast-lengthening shadows obliterated the peaks of high radiation shown on figure 7/10, leaving a small area of sunlight shining down Shortmarket Street. This causes a radiation value of 300 watts/sq.m. at F7 at 16h20.

Figure 7/12 shows a band of relatively weak radiation along line D, and a low peak of 72,5 watts/sq.m. at point A/C. This was caused by the setting sun reflecting off the buildings on the north-eastern side of the Square.

HUMAN RESPONSES TO SOLAR RADIATION

While the readings of solar radiation were being made, the arrival and departure of people to the benches in the vicinity of the readings was noted. The plus and minus signs on tables 7/16 to 7/21 denote the arrival of bench-users, while a minus sign denotes the departure of a bench-user, from the study area. It should be noted that there are no benches on the Longmarket Street side of the Square, while there are sufficient benches on the other three sides to accommodate the numbers of people sitting in the Square. The lack of benches along Longmarket Street restricts the bench-user's choice of location, and prevents a close correlation between radiation levels and numbers of bench-users. Certain trends can, however, be determined when the plus and minus signs are drawn onto a site plan which simultaneously shows areas of high and low radiation. These areas of high radiation are shown by means of isopleths on figures 7/24 to 7/26.

Figure 7/24 shows that most arrivals and departures for the time period 10h00 to 11h00 took place in the south-western half of the Square, that is, on the Longmarket Street side of the measuring line A, where the higher radiation levels were present. Four plus signs and two minus signs are noted in this area, while one plus and one minus sign appear on the centre line, and one plus sign appears on the Shortmarket Street side. The plus signs denotes the arrival of a bench-user, while the minus sign denotes the departure of a bench-user, from the study area.

Figure 7/25 shows the area of higher radiation to be situated on the south-eastern side of the Square during the time period 12h00 to 13h00, when seven plus and three minus signs are shown. In the other half of the Square, four plus signs appear.

Figure 7/26, for the time period 14h00 to 15h00, shows eight plus and four minus signs in the half of the Square south-east of Burg Street, where the higher radiation levels were received. Two plus and three minus signs are shown in the other half of the Square.

In interpreting the meaning of the plus and minus signs, the signs should not be arithmetically manipulated, for example, by cancelling a plus sign against a minus sign. While a plus sign could be interpreted as a person regarding the point hnquestion as an attractive place to sit, a minus sign, meaning that a person stood up and left, does not necessarily indicate that the point had become unattractive. The reasons for his leaving could have been ascertained by questioning him, but this was not within the scope of the study.

A minus sign indicates that at some previous time, a person had found that place attractive, but now had to leave. In assessing the distribution of bench users, it would therefore be reasonable to recognise both plus and minus signs as indicators of interest. In the following analysis, a plus sign is allocated a value of two, and a minus sign the value of one.

In figures 7/24, 7/25, and 7/26, the Square has been bisected either horizontally or vertically into approximately equal areas of higher and lower radiation.

Figure 7/24

Area of high radiation: 10 points

Area of low radiation : 2 points

Figure 7/25

Area of high radiation: 17 points

Area of low radiation : 8 points

Figure 7/26

Area of high radiation: 20 points

Area of low radiation : 7 points

In all three cases, the area of higher radiation received more than double the interest shown in the area of low radiation. It is not possible to determine whether people sitting in the zone of higher radiation were seeking direct sunlight or simply the resulting warmth, while perhaps using a local patch of shade to avoid excessive glare. It is also not possible, at this stage, to state whether the decision to sit in the warmer zone was a conscious or sub-conscious one.

It must be recognised that many other factors influence human use of the Square. Further, in order to more closely relate solar radiation to human use of urban spaces, many other methods and techniques from several disciplines might simultaneously be employed.

Black bulb thermometer observations

From a study of the literature it appears that there is a shortage of material on comfort indices for human occupation of external spaces, while there is a considerable amount of reference material on comfort indices for internal spaces. See Appendix One. One of the more recently devised and widely used comfort indices is the Corrected Effective Temperature index. This index requires the measurement of mean radiant temperature, as given by a black bulb thermometer, for its calculation.

For the first two-and-a-half hours after dawn, a steady increase in ambient temperatures, black bulb temperatures, and radiation levels may be seen (figure 7/23). During this period, the ambient temperature rose from 14,4 degrees to 17,2 degrees centigrade, black bulb temperatures rose from 14,4 to 15,5 degrees centigrade, and radiation levels rose from 0 to 45 watts/sq.m. Although no other trends are apparent from the readings durings this time period, the numbers of people may be seen to fluctuate between one and twelve. This is because the initial human activity in the Square is related to the half-hour period immediately after dawn, where relatively minor temperature and radiation changes are seen, but large changes in the light level occur. The subsequent decrease in the number of people sitting in the Square between 08h00 and 09h00 can possibly be related to the starting times of their employment.

At approximately 09h15, the first direct rays of sun fell on the instruments and caused a relatively fast increase in both black-bulb thermometer readings and in radiation readings. Ambient temperatures, being measured in shade, rose less quickly. By 09h45, the radiation level had risen to 525 watts/sq.m., and the black bulb thermometer temperature had risen to 34,4 degrees centigrade. At this time, ambient temperature was 20,0 degrees centigrade. The numbers of people rose from four at 09h00 to nine at 09h45 and to fifteen at 10h00.

The initial increase in numbers of people using the Square may be seen to correspond to the thirty minute period after dawn, where there is no significant temperature rise but there is a considerable increase in the light level. The second increase in numbers of people occurs during the forty-five minute period after the first rays of sun start to warm the Square.

The readings made with the black bulb thermometer closely follow those made with a radiometer. Before a recommendation could be made with regard to the suitability of radiometer readings being adapted for inclusion in calculations of human comfort, many other readings would have to be made to determine the effect of different conditions of ambient temperature, humidity, and air movement.

CONCLUSIONS AND RECOMMENDATIONS.

Conclusions.

In this study the evaluation of the distribution of sun and shade in urban spaces was done in three stages; data collection, the representation of results, and the analysis of the findings.

The use of a radiometer allowed solar radiation readings to be made within the limitations of this research, and provided data in a form which lends itself to arithmetical manipulation. In addition, the speed at which radiometer readings may be taken allows the effect of changing conditions of sun and shade to be noted over a space as large as Greenmarket Square. The simultaneous use of a black bulb thermometer provides data which takes into account both the ambient temperature and the effects of direct solar radiation. The readings are in the form used in calculations of comfort standards, but this does not add to the appreciation of the distribution of solar radiation. One of the main drawbacks of the black bulb thermometer was its slow response time, which mitigates against its use for taking many measurements over a large area.

Figure 7/23 shows a strong correlation between radiometer and black bulb thermometer readings. The relationship between ambient temperature and black bulb temperature suggested by Koenigsberger (Chapter Five), would appear to be inapplicable under the conditions of changing radiation experienced at the time of the measurements shown in figure 7/23.

The level of detail of the results achieved is dependent on the horizontal distance between the parallel lines of measurements. While it would be advantageous to measure along all the lines simultaneously with several radiometers, in order to determine precisely the effects of sun and shade at a specific time, there is no great disadvantage in a time gap between sets of measurements. The differences in readings which result from a time gap lend themselves to explanation, (figure 7/5) of the length of time for which a particular condition existed.

The method would appear to be suited to the measurement of solar radiation and its definition in terms of sun and shade for all other seasons of the year. In addition, it could be used in all urban spaces whether street or square.

The tabulation of results as shown on tables 7/16 to 7/22 does not highlight trends, neither does it give an overall view of the distribution of maximum and minimum values. Apart from the program limitations experienced in the Dataplot program, the representation of data by means of graphs is inclined to be two-dimensional. This was not seen as appropriate for the consideration and depiction of fluctuating values in three-dimensional spaces. The method chosen, as shown in figures 7/3 to 7/13, satisfies the requirement for an overall view of the distribution of solar radiation. The method also allows isopleths to be accurately drawn by the method outlined in figure 7/14.

The method chosen for the analysis of results depends on the final objectives. In this study, it was necessary to test the method of measurement and representation in some depth. The detailed explanation of results in the first part of this chapter shows that far greater insight into the distribution of solar radiation over time may be gained by the methods used when compared with one of the previous methods shown in figure 7/15. [illegible] to determine whether [illegible] conditions of solar radiation will be acceptable or not in the new [illegible]

In order to have a basis for comparison between the previous method of recording and representing sun and shade, and the new method explored in this pilot study, figure 7/15 is included. This shows the traditional method of depicting sun and shade around buildings. The method requires tables showing the solar height and solar azimuth for the day and time of day under consideration. These tables are readily available (Van Deventer, 1968). The method also requires a knowlege of the height of the surrounding buildings. Given this information, the shadows which a building casts on its surrounding surfaces can be plotted by elementary drafting procedures. The previous method is not superseded by the new. Instead the two are complementary and may be used together to advantage. For example, the extent of the shadow line of a building which is likely to be extended in height may be plotted by the traditional method. Detailed radiometer readings may then be made of the solar radiation for a certain distance on both sides of the shadow line. The anticipated position of the new shadow line may be plotted by simple drafting techniques. It would then be reasonable to assume that conditions of solar radiation around the new shadow line will be similar to those around the original shadow line, if other factors such as reflected radiation remain constant.

In order to determine whether these new conditions of solar radiation will be acceptable or not in the new position, certain considerations must be borne in mind, such as the extent to which previously unshaded parts of the area are likely to become shaded, and the new micro-climatic conditions that this will create in the shaded area. Considerations such as these may be more accurately depicted by the new method under review, than by the previous method.

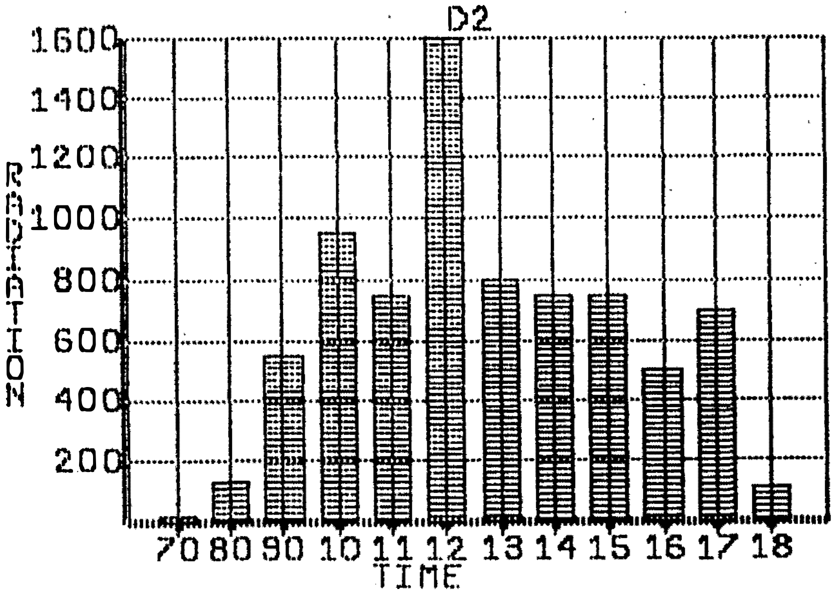
This study in addition sought to establish a definite relationship between the solar radiation distribution patterns and human use of the spaces in question. Although the relationship was tentatively established, the study did not explore other possible explanations, as this was not one of the aims or objectives of the research.

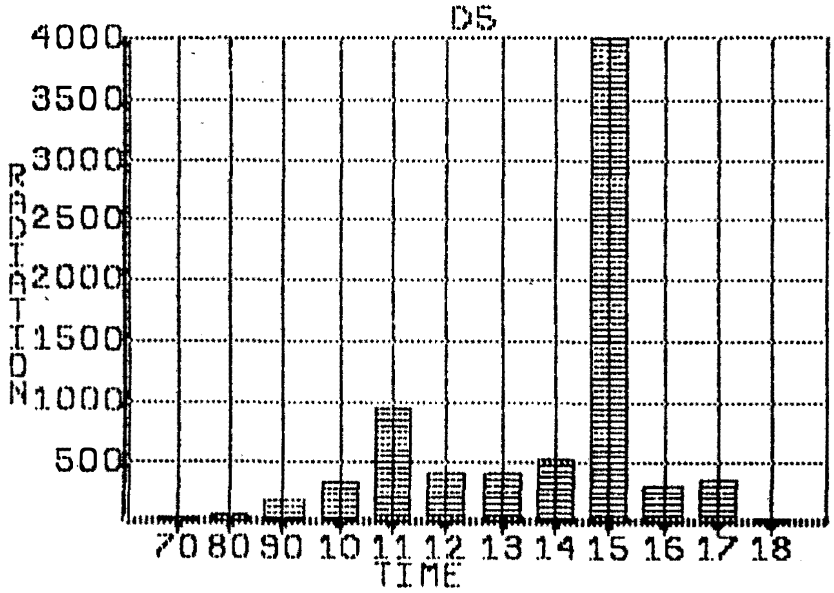
Recommendations.

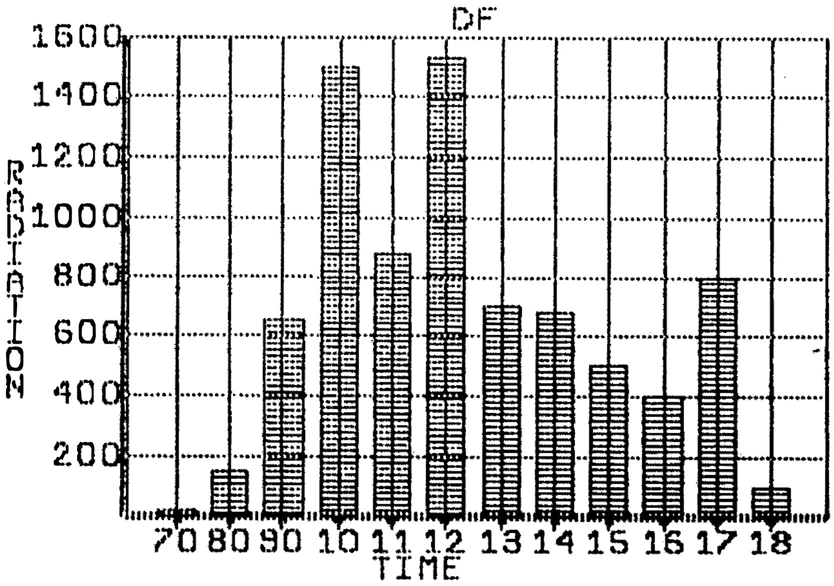
The comparative success of the pilot study in terms of its objectives suggests that further environmental monitoring of the sort described above may provide material which will assist planners and architects to design external urban spaces. There is a need to provide suitable material to allow environmental factors to be considered on a rational basis as design criteria in the planning process. This material should cover factors such as wind and rain, as well as sun and shade.

The insight to be gained, by the use of the method described into the distribution of solar radiation in urban spaces, and the fact that numerical values are now made available instead of dark and light areas on a drawing, suggest that solar radiation maps could now be made for public open spaces. These maps could be read in conjunction with an analysis of the stages of development of surrounding buildings. In this way, areas may be defined which already suffer from too little or excessive solar radiation. This will lead to certain logical conclusions concerning the height to which the surrounding buildings should be developed.

In the final analysis perhaps, the greatest need is to establish the relationship between environmental factors, such as solar radiation, and levels of human comfort in external spaces. To this time, as has been shown above, sun and shade has typically been represented by dark and light areas on a site plan. Numerical values can now replace the older method in this area. This should facilitate the incorporation of solar radiation data into comfort standard formulae. While human comfort standards, as is shown in Appendix One, have been adequately defined for internal spaces, little work has been done in the field of external comfort requirements. To achieve this, measurements of environmental factors such as those described in this study are essential.

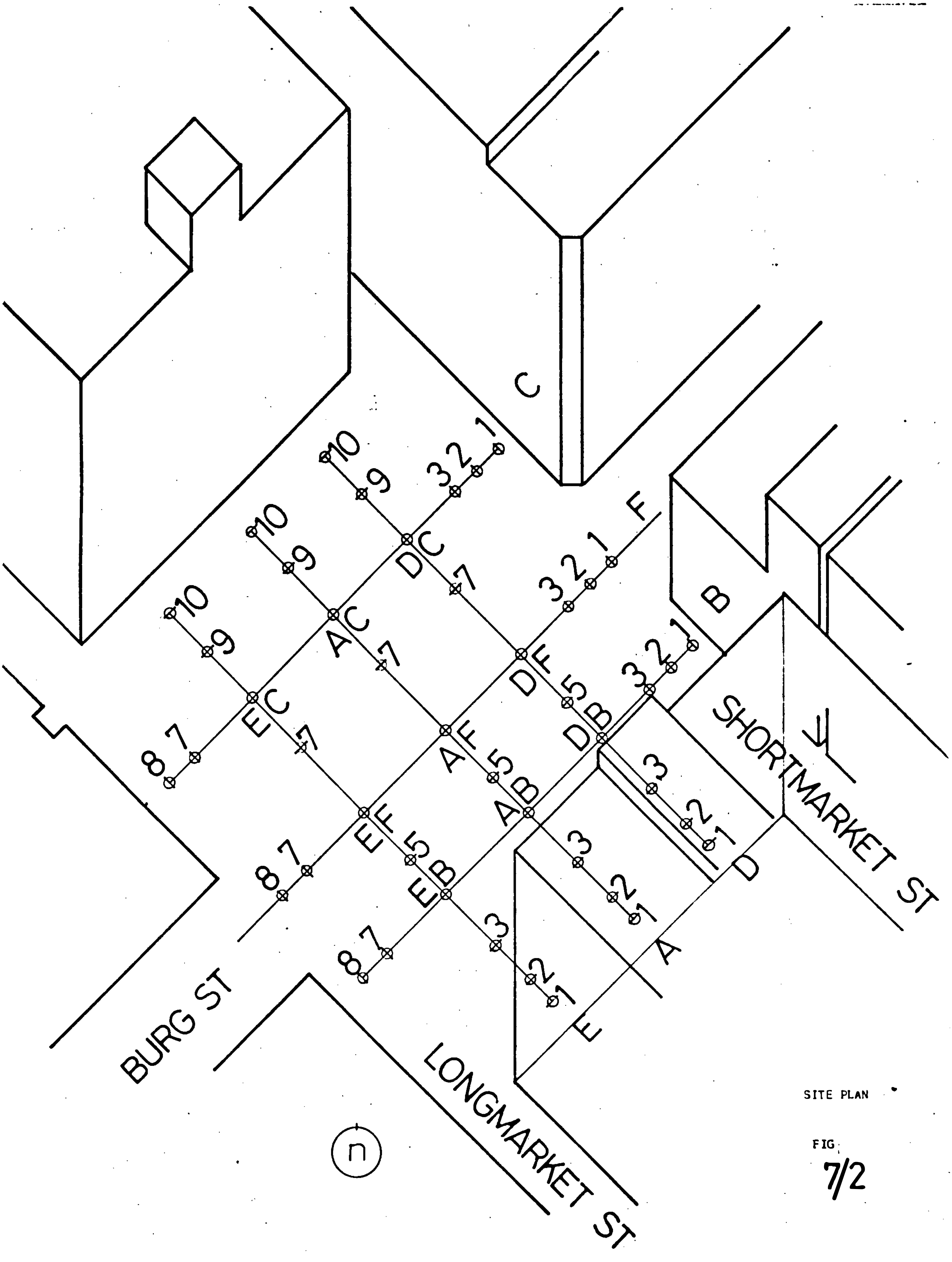

D2
RADIATION
1600
1400
1200
1000
800
600
400
200
70 80 90 10 11 12 13 14 15 16 17 18
TIME


DS
RADIATION
4000
3500
3000
2500
2000
1500
1000
500
70 80 90 10 11 12 13 14 15 16 17 18
TIME


DF
RADIATION
1600
1400
1200
1000
800
600
400
200
70 80 90 10 11 12 13 14 15 16 17 18
TIME

FIG

7/1



SITE PLAN

FIG. 7/2

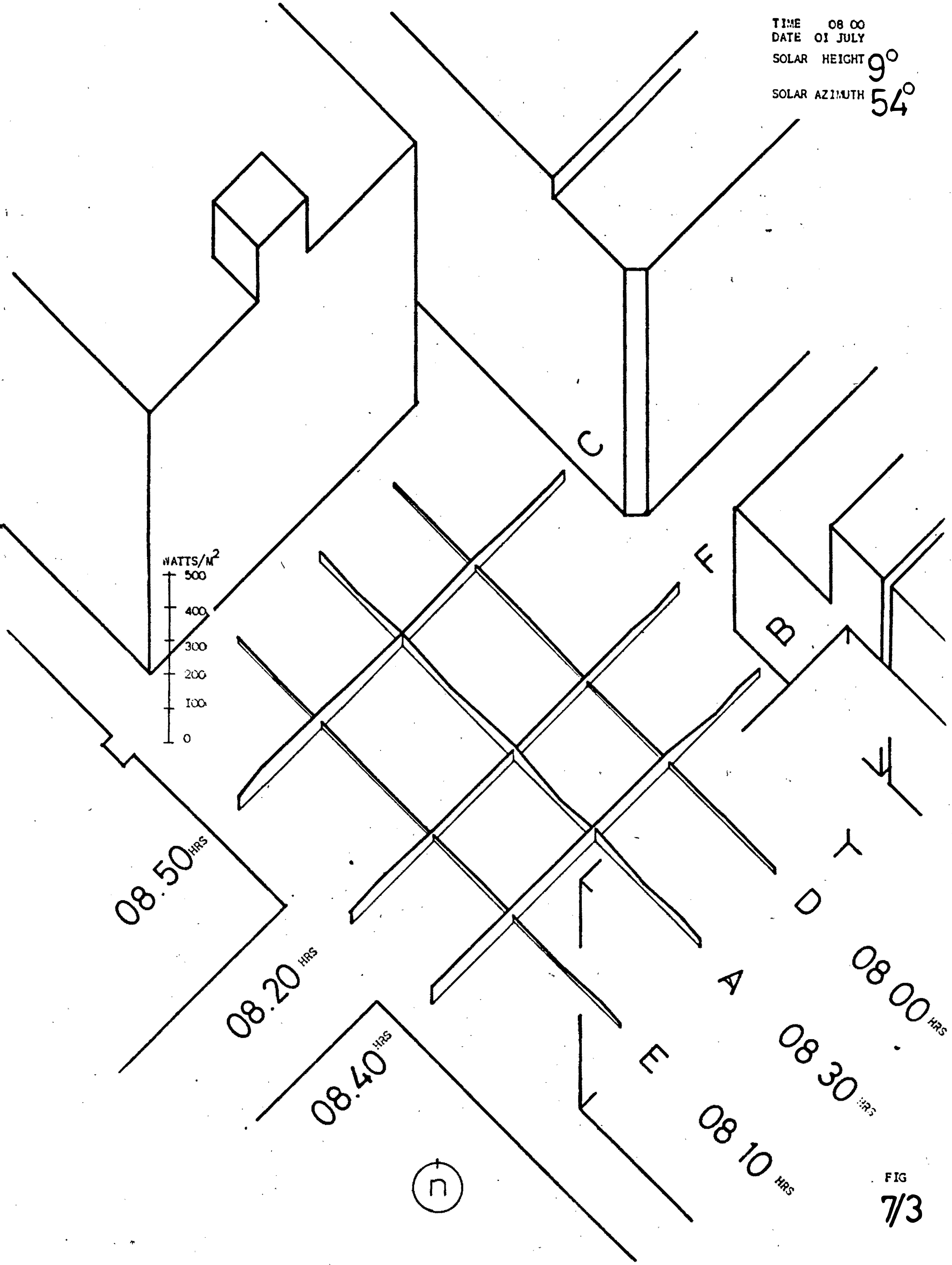

TIME 08 00
DATE 01 JULY
SOLAR HEIGHT 9°
SOLAR AZIMUTH 54°
WATTS/M^2
500
400
300
200
100
0
C
F
B
D
A
E
08.50 HRS
08.20 HRS
08.40 HRS
08 00 HRS
08 30 HRS
08 10 HRS

FIG 7/3

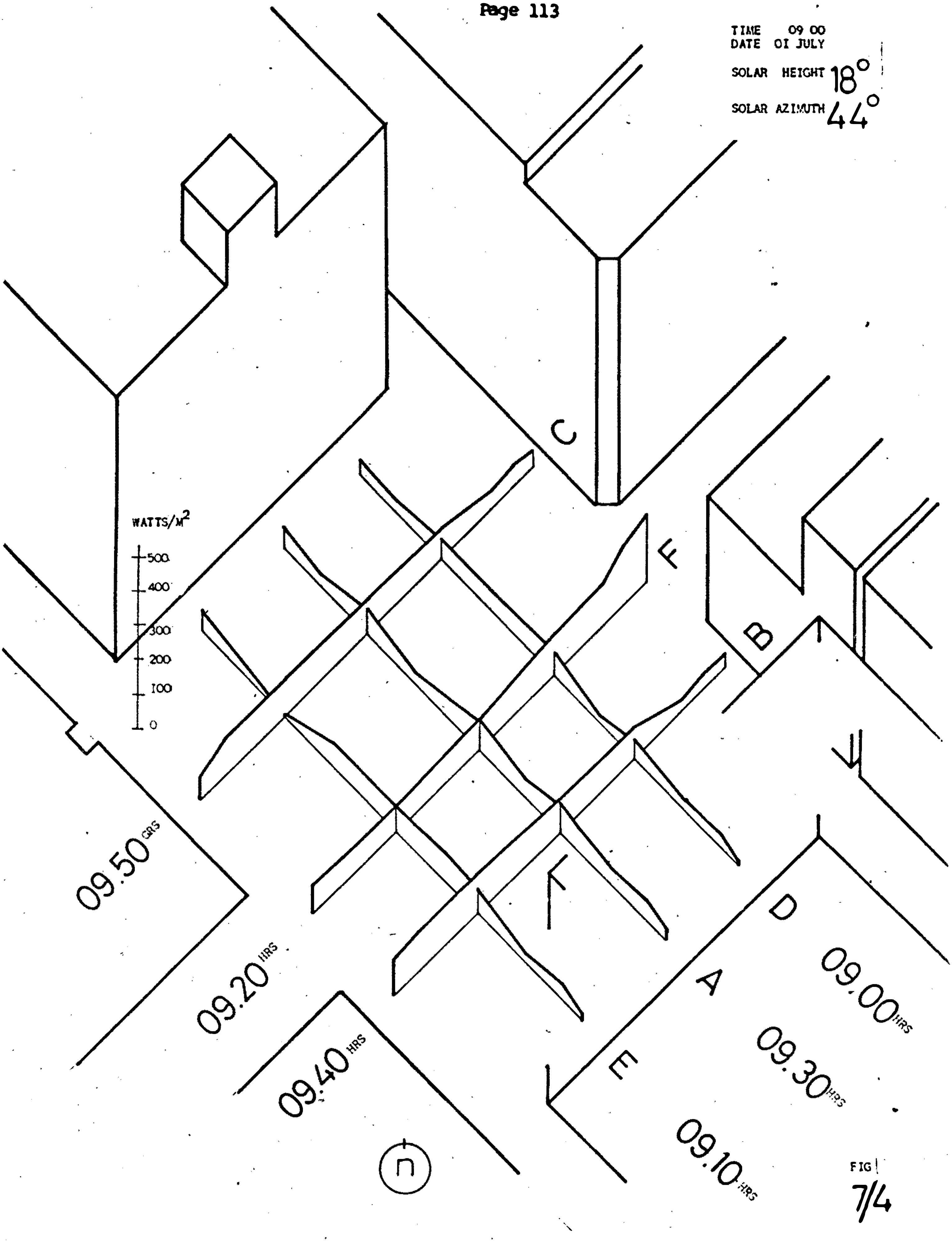
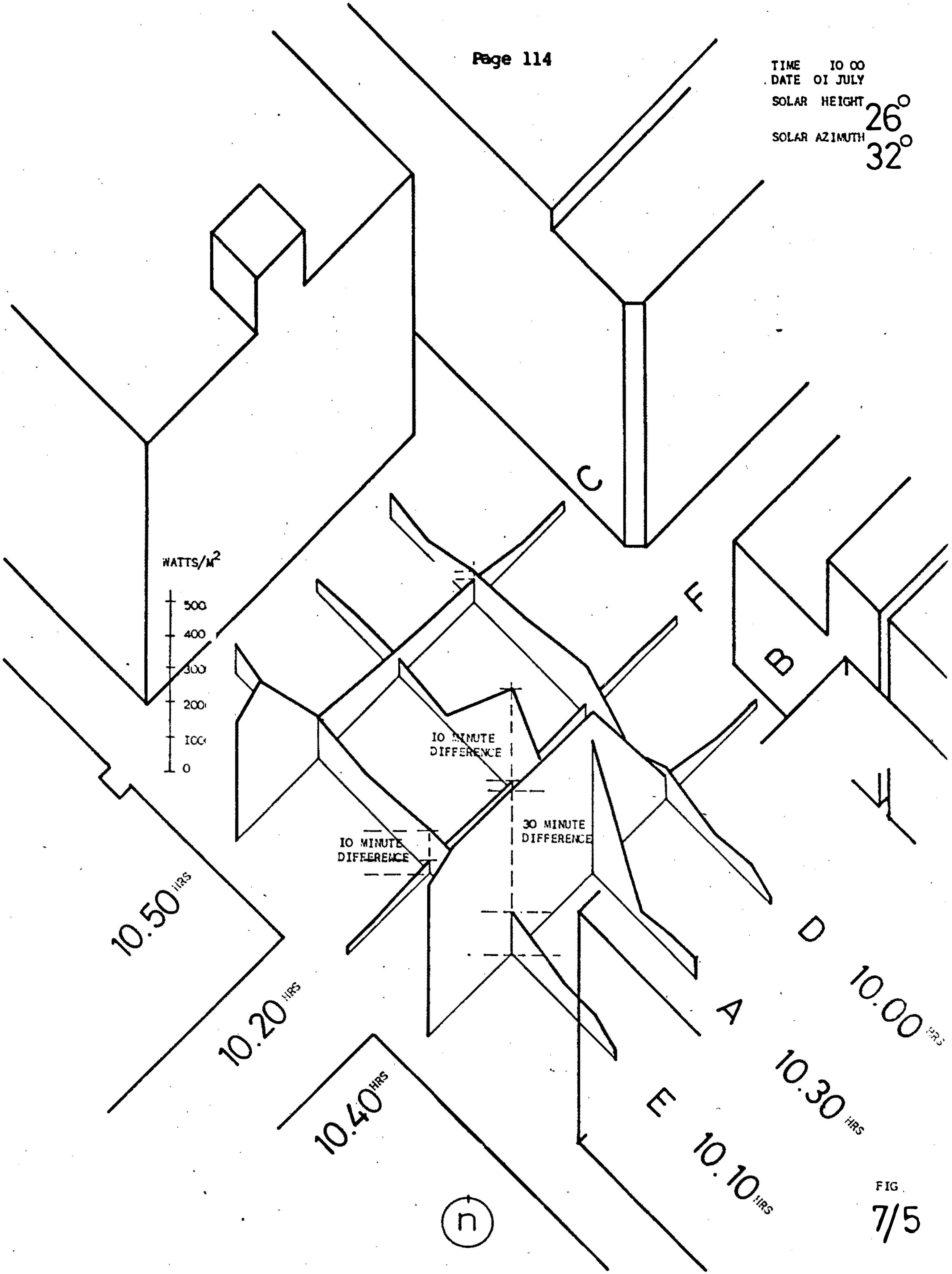
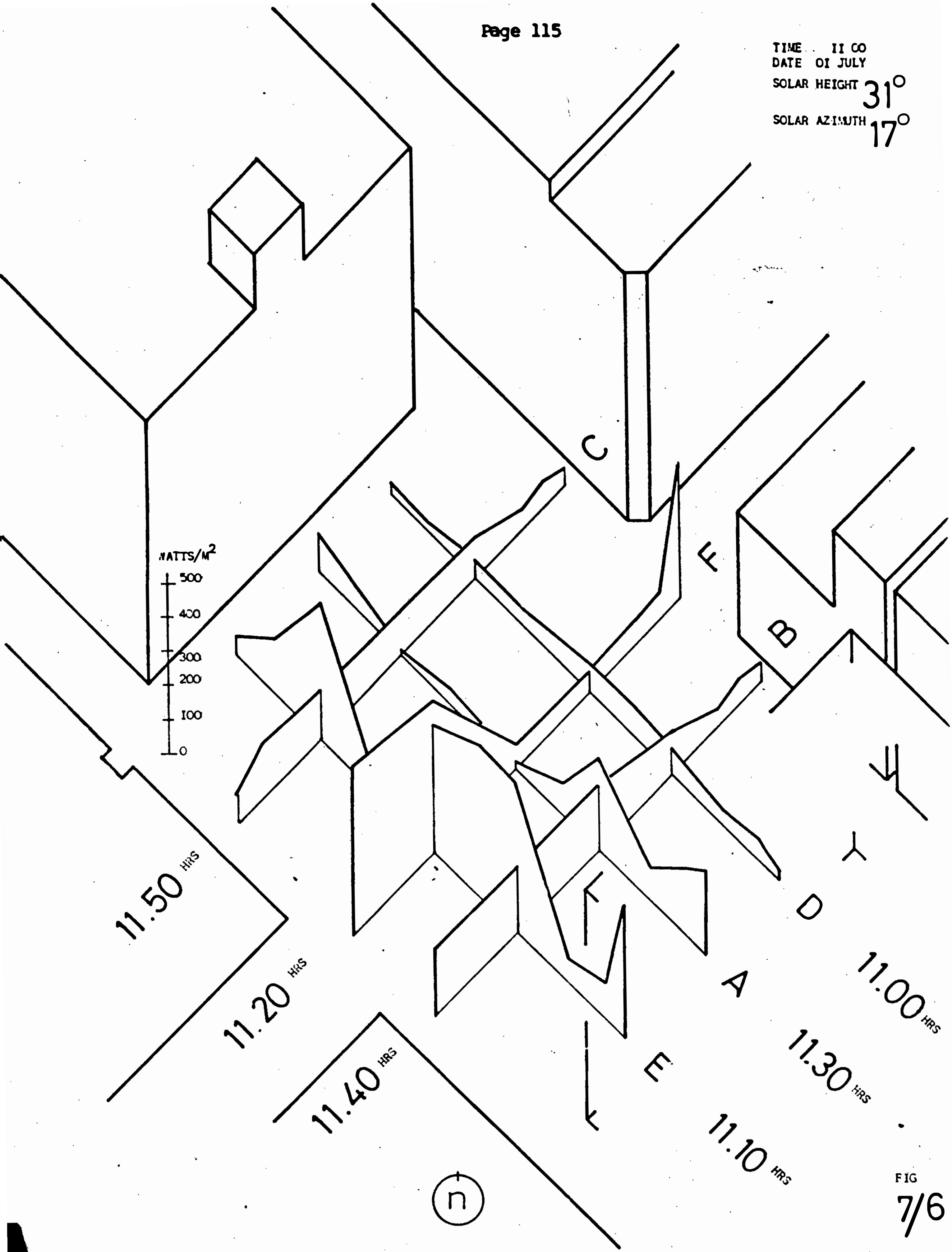

TIME 09 00
DATE 01 JULY
SOLAR HEIGHT 18°
SOLAR AZIMUTH 44°
C
F
B
D
A
E
WATTS/M^2
500
400
300
200
100
0
09.50 HRS
09.20 HRS
09.40 HRS
09.00 HRS
09.30 HRS
09.10 HRS
n

FIG 7/4



TIME 10 00
DATE 01 JULY
SOLAR HEIGHT 26°
SOLAR AZIMUTH 32°

FIG.
7/5



TIME 11 00
DATE 01 JULY
SOLAR HEIGHT 31°
SOLAR AZIMUTH 17°

FIG
7/6

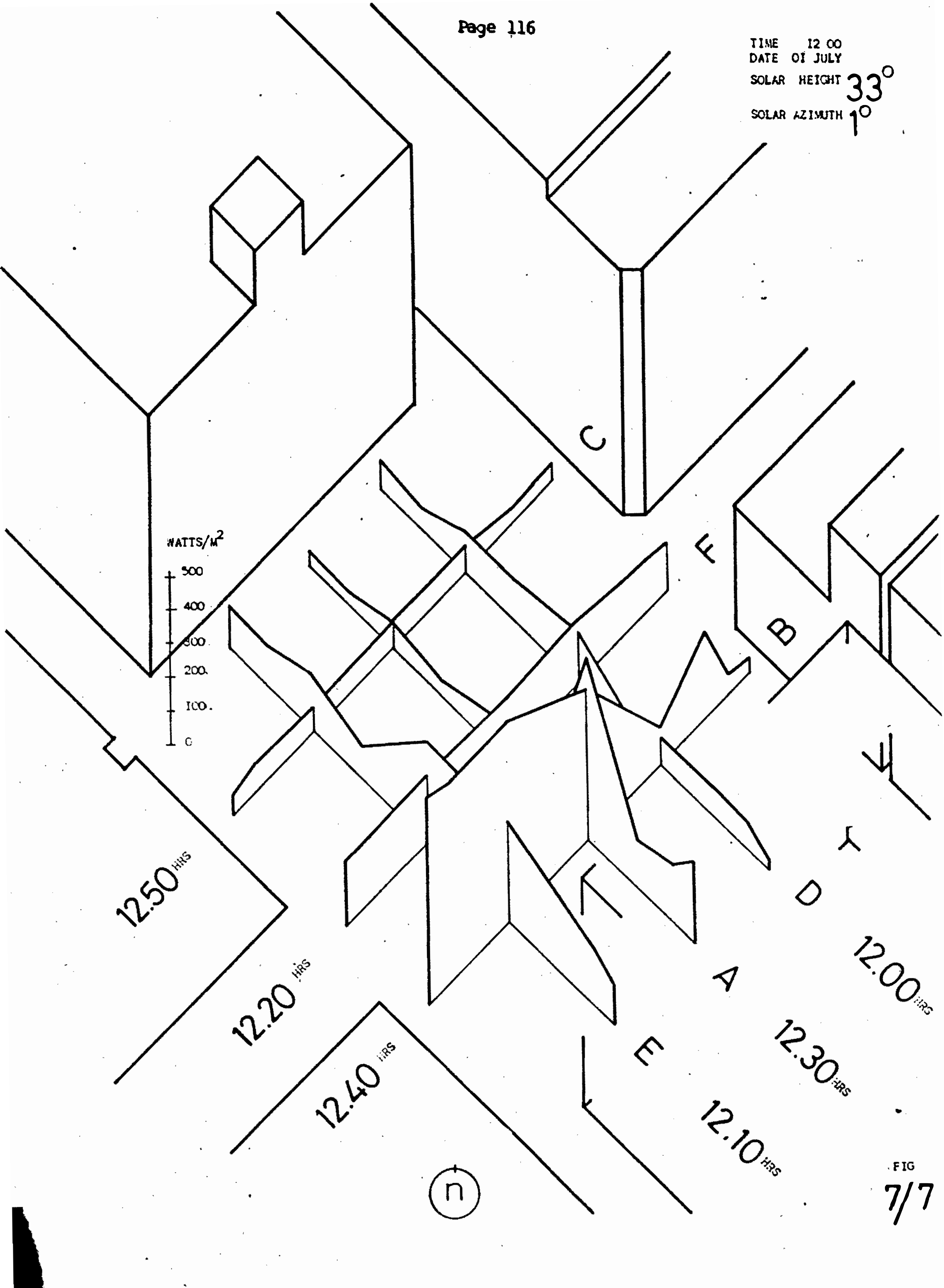

TIME 12 00
DATE 01 JULY
SOLAR HEIGHT 33°
SOLAR AZIMUTH 1°
WATTS/M²
500
400
300
200
100
0
C
F
B
Y
D
A
E
12.50 HRS
12.20 HRS
12.40 HRS
12.00 HRS
12.30 HRS
12.10 HRS
n

FIG 7/7

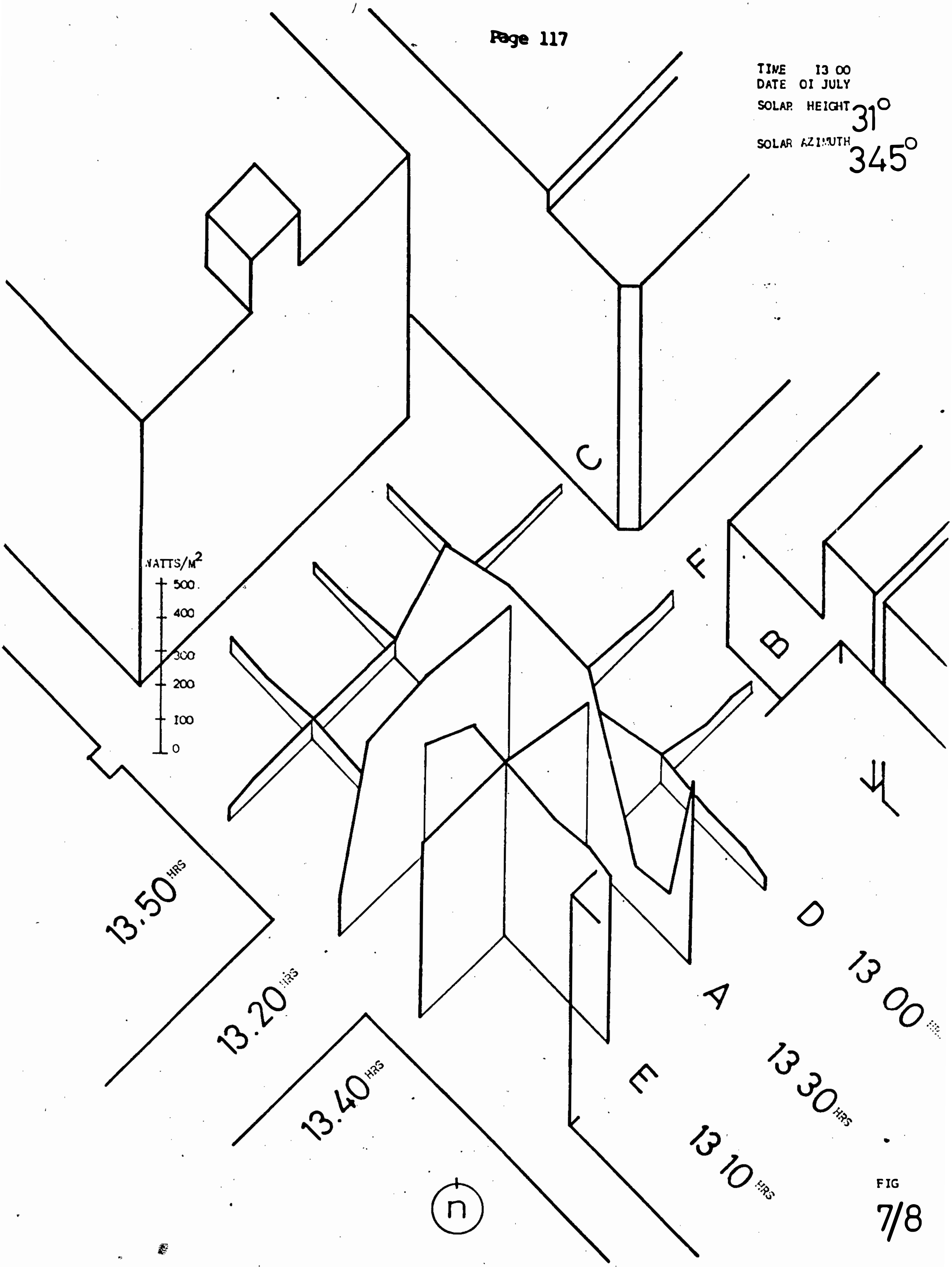

TIME 13 00
DATE 01 JULY
SOLAR HEIGHT 31°
SOLAR AZIMUTH 345°
WATTS/M²
500
400
300
200
100
0
C
F
B
D
A
E
13.50 HRS
13.20 HRS
13.40 HRS
13 00 HRS
13 30 HRS
13 10 HRS
n

FIG
7/8

TIME 14 00
DATE 01 JULY
SOLAR HEIGHT 26°
SOLAR AZIMUTH 330°

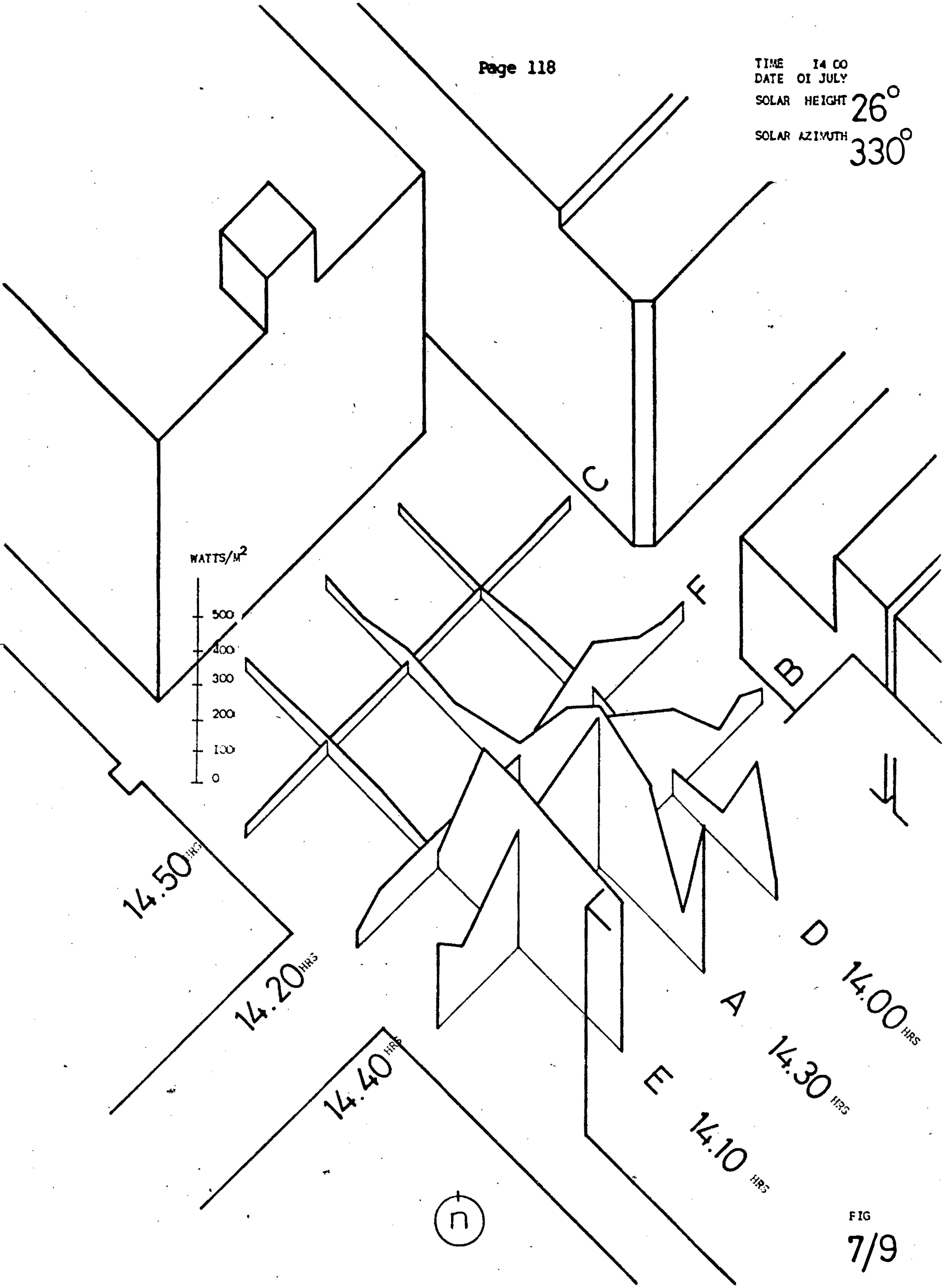


FIG
7/9

TIME 15 00
DATE 01 JULY
SOLAR HEIGHT 19°
SOLAR AZIMUTH 317°

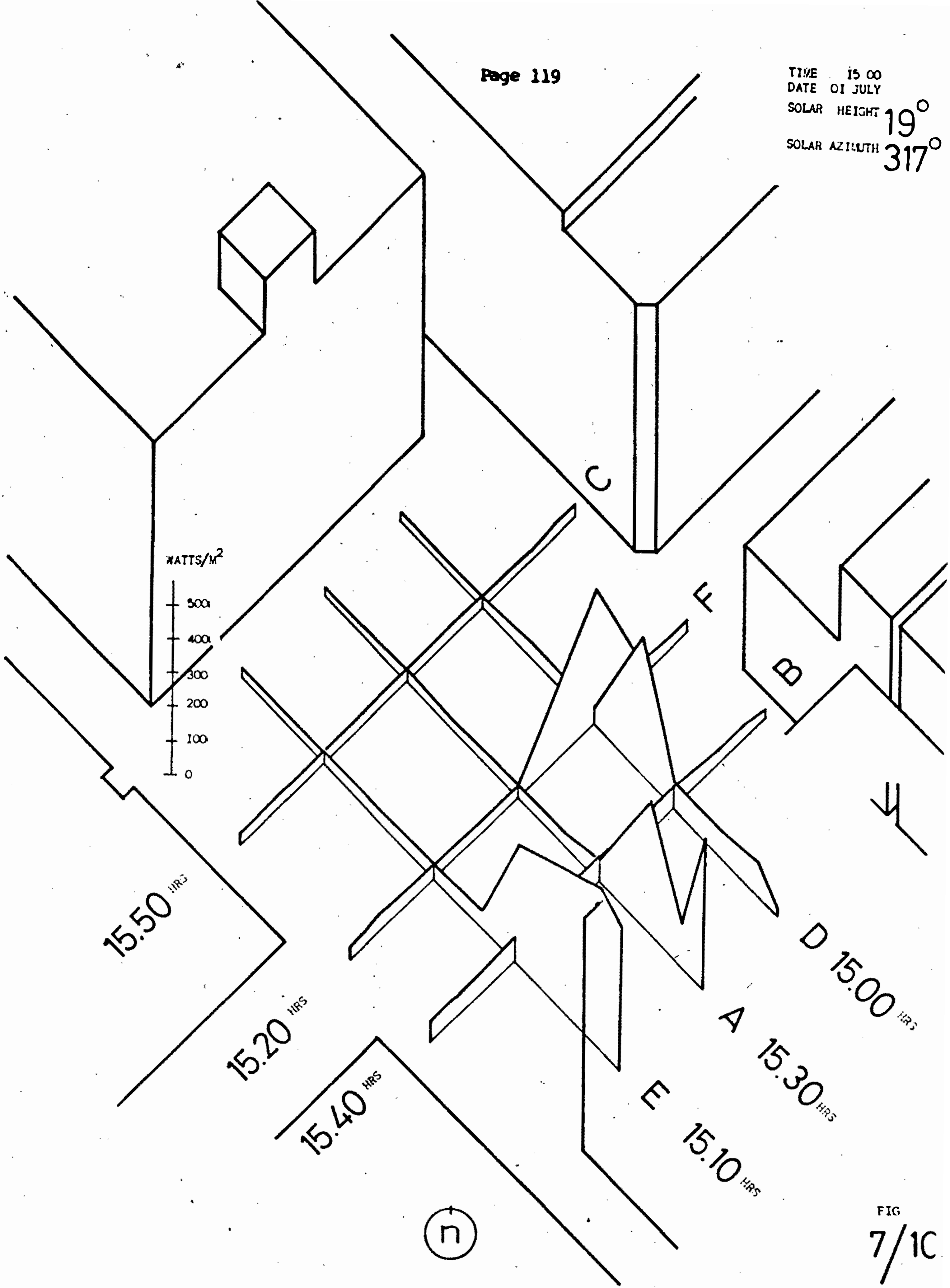


FIG 7/1C

TIME 16 00
DATE 01 JULY
SOLAR HEIGHT 10°
SOLAR AZIMUTH 307°

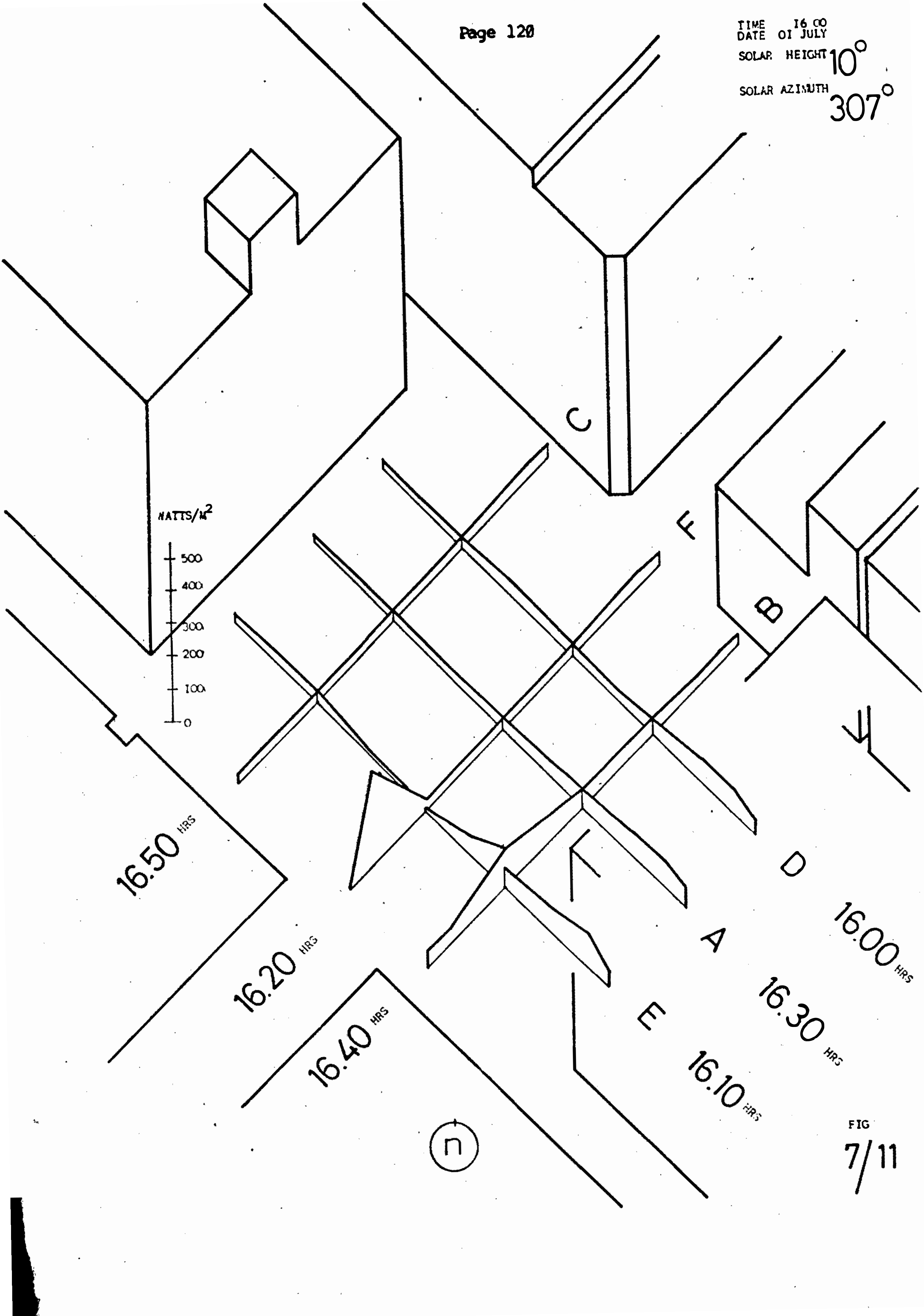


FIG 7/11

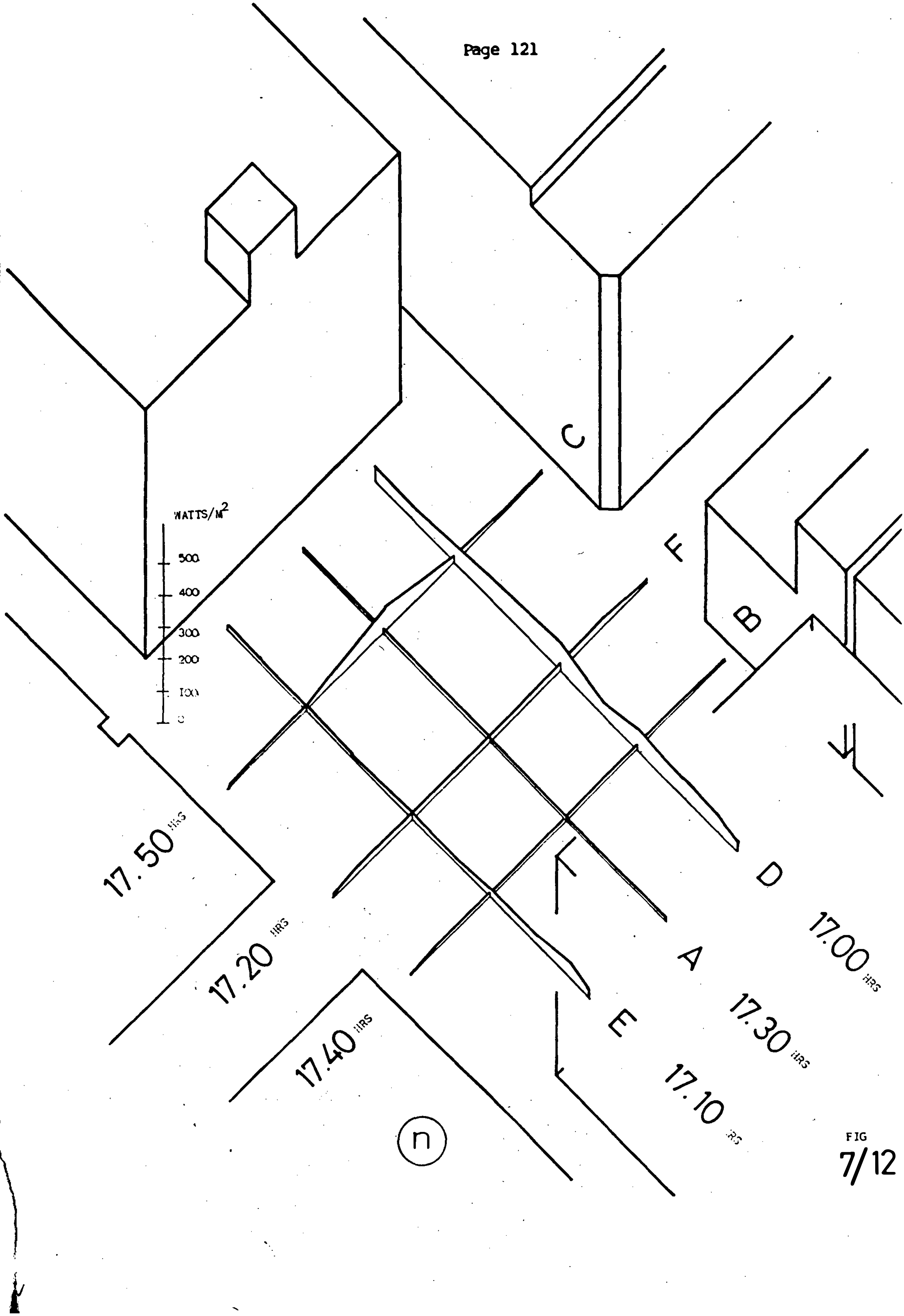
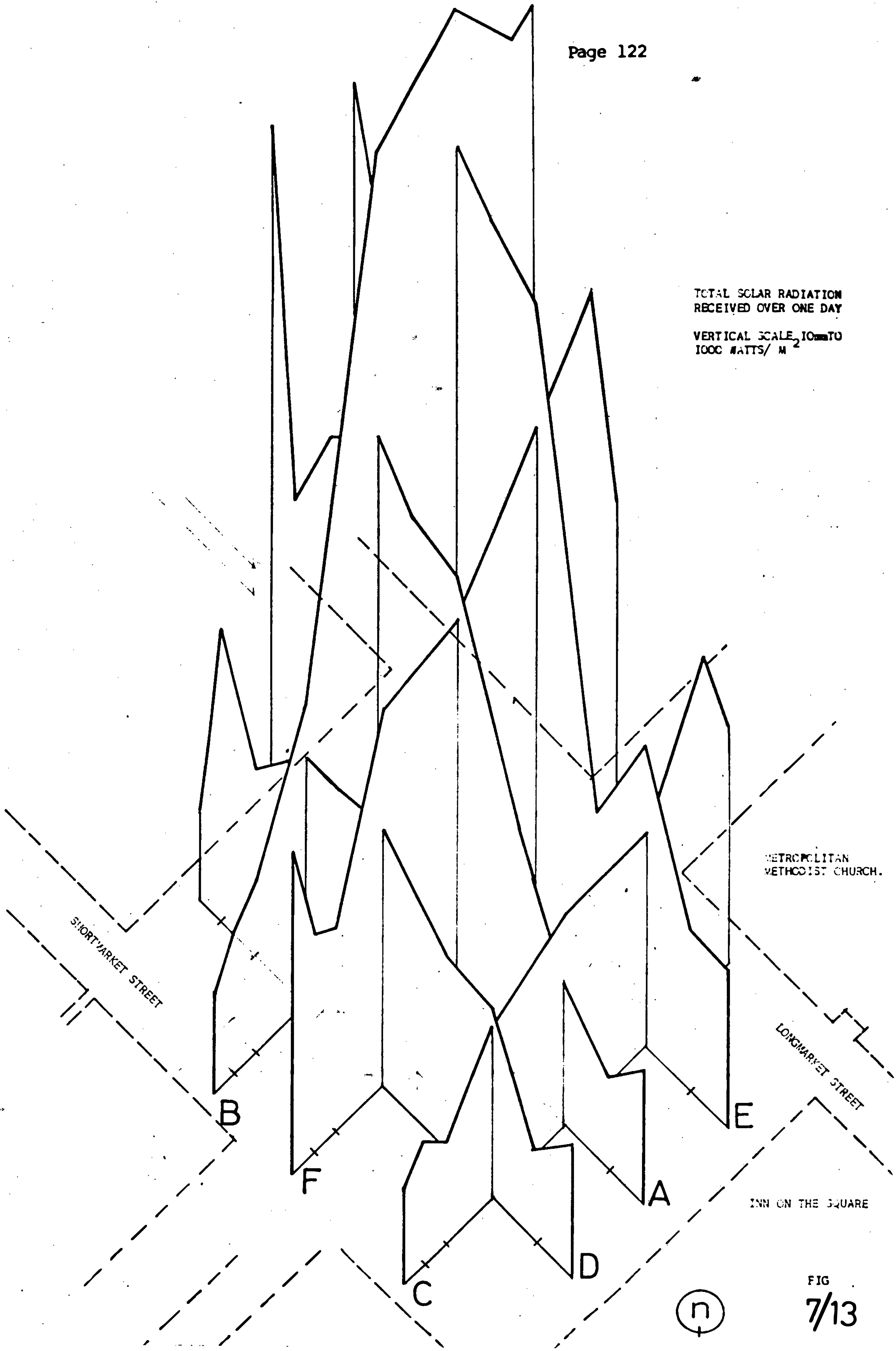

WATTS/M²
500
400
300
200
100
0
C
F
B
D
A
E
17.50 HRS
17.20 HRS
17.40 HRS
17.00 HRS
17.30 HRS
17.10 HRS
n

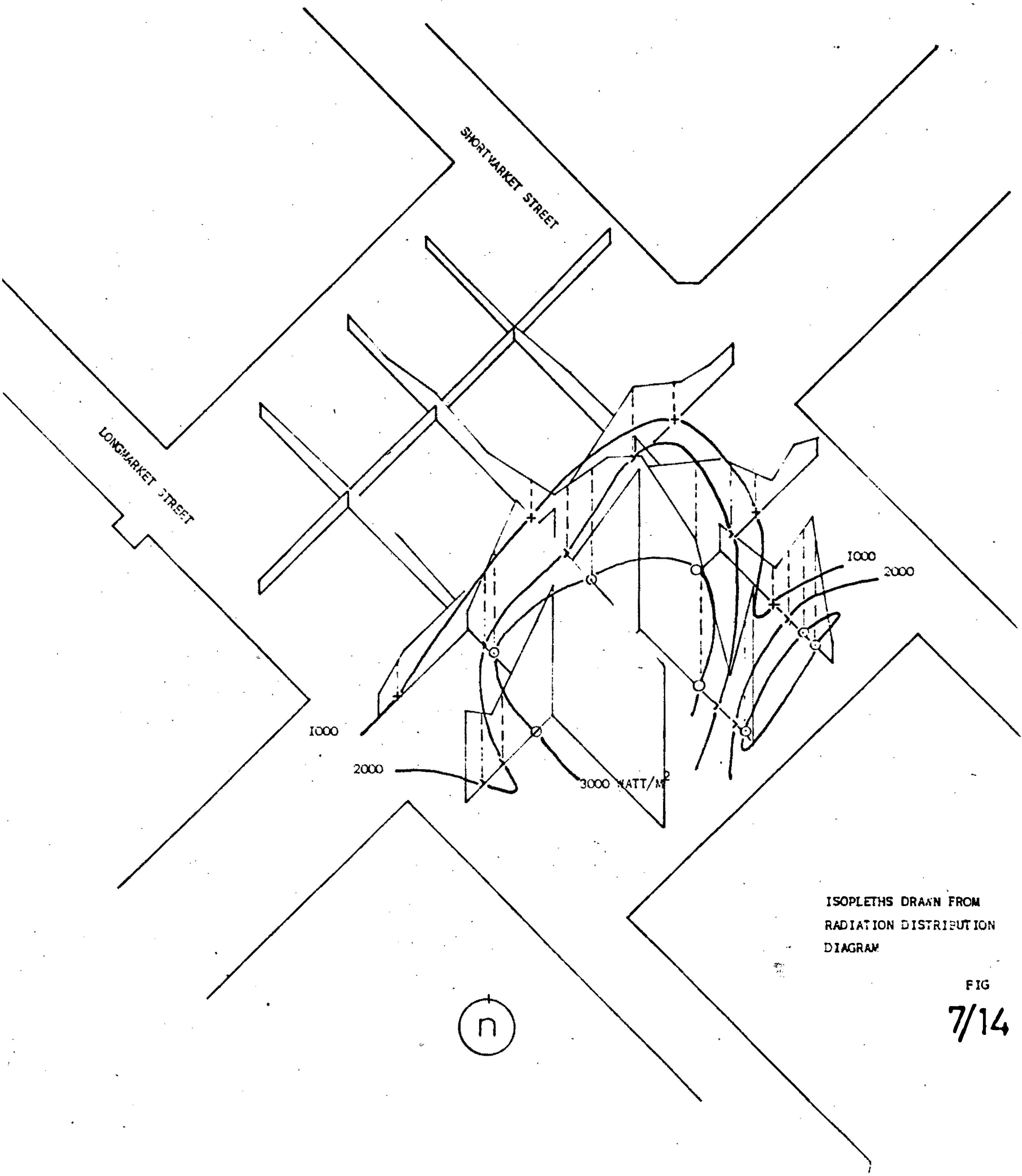
FIG 7/12



TOTAL SOLAR RADIATION
RECEIVED OVER ONE DAY

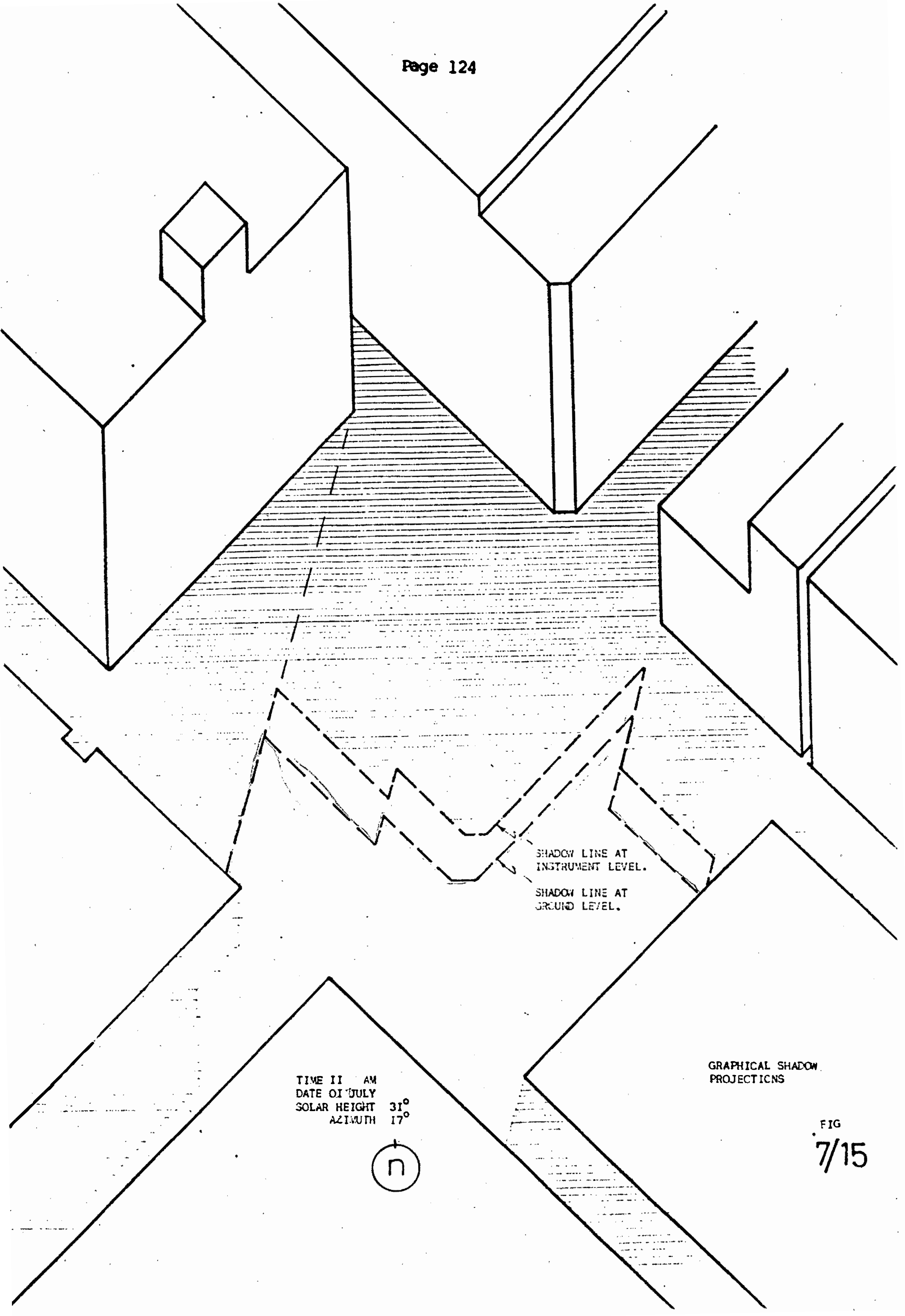
VERTICAL SCALE 10mm TO
1000 WATTS/ M^2

FIG
7/13



ISOPLETHS DRAWN FROM RADIATION DISTRIBUTION DIAGRAM

FIG 7/14



GRAPHICAL SHADOW PROJECTIONS

FIG 7/15

OBSERVED DAILY VALUES IN WATTS/SQUARE METRE OF SOLAR RADIATION IN GREENMARKET SQUARE 1 - 5 JULY 1980

Location	Time (SAST)												Total
	07,00	08,00	09,00	10,00	11,00	12,00	13,00	14,00	15,00	16,00	17,00	18,00	
D1	0,5	3,0	10,0	15,0	22,5	25,0	47,5	50,0	20,0	42,5	32,5	7,2	275,7
D2	1,0	7,0	35,0	60,0	65,0	85,0	62,5	350,0	92,5	80,0	50,0	7,2	895,2
D3	1,0	- 6,0	- 25,0	40,0	50,0	++ 80,0	+ 62,5	+- 92,5	++ 80,0	- 75,0	-+- 55,5	9,5	577,0
D/B	1,2	12,5	55,0	95,0	75,0	160,0	80,0	- 75,0	75,0	50,0	70,0	11,0	759,7
D5	0,5	4,0	17,5	32,5	95,0	- 40,0	- 40,0	++ 52,5	+ 400,0	+ 30,0	35,0	5,0	752,0
D/F	1,5	15,0	65,0	150,0	87,5	152,5	- 70,0	67,5	50,0	40,0	80,0	10,0	789,0
D7	1,5	13,5	50,0	+ 100,0	50,0	120,0	62,5	57,5	40,0	37,5	57,5	7,0	597,0
D/C	+ 1,5	14,5	50,0	95,0	52,5	125,0	60,0	47,5	30,0	32,5	60,0	7,0	575,5
D9	0,5	+ 7,5	- 25,0	40,0	30,0	+ 55,0	- 32,5	- 25,0	+ 20,0	- 17,5	- 30,0	3,0	286,0
D10	+ 1,0	11,0	40,0	70,0	37,5	90,0	37,5	30,0	25,0	20,0	42,5	5,0	409,5

In the following tables, 7/16 to 7/21, the plus and minus signs above the numbers denote arrivals and departures from the benches in the vicinity of the readings.

TABLE 7/16

OBSERVED DAILY VALUES IN WATTS/SQUARE METRE OF SOLAR RADIATION IN GREENMARKET SQUARE 1 - 5 JULY 1980

Location	Time (SAST)												Total
	07,10	08,10	09,10	10,10	11,10	12,10	13,10	14,10	15,10	16,10	17,10	18,10	
E1	0,5	6,5	10,0	35,0	+ 400,0	120,0	- 500,0	+ 450,0	425,0	45,0	30,0	3,2	2025,2
E2	1,2	12,5	45,0	70,0	100,0	175,0	525,0	142,3	475,0	115,0	52,5	5,0	1718,5
E3	1,2	- 9,5	++ 30,0	+ 67,5	65,0	-+ 225,0	+ 500,0	-+- 475,0	+ 350,0	+- 80,0	-- 25,0	47,5	1875,7
E/B	2,0	19,0	75,0	120,0	- 450,0	300,0	525,0	500,0	65,0	60,0	25,0	7,7	2148,7
E5	2,0	18,5	77,5	117,5	450,0	300,00	+ 525,0	500,0	50,0	55,0	20,0	7,2	2122,7
E/F	2,0	19,5	75,0	122,5	375,0	300,0	500,0	450,0	45,0	5,0	17,5	7,0	1918,5
E7	+ 1,5	18,0	65,0	100,0	62,5	100,0	57,5	55,0	35,0	5,0	1,5	5,7	506,7
E/C	2,0	18,5	6,5	125,0	400,0	170,0	60,0	55,0	35,0	- 37,5	1,5	5,5	916,5
E9	- 1,0	+ 11,5	++ 30,0	+- 47,5	+ 150,0	+- 120,0	37,5	- 32,5	+ 25,0	25,0	- 10,0	3,0	493,0
E10	1,5	19,0	55,0	85,0	50,0	130,0	42,5	37,5	27,5	25,0	10,0	4,0	487,0

TABLE 7/17

OBSERVED DAILY VALUES IN WATTS/SQUARE METRE OF SOLAR RADIATION IN GREENMARKET SQUARE 1 - 5 JULY 1980

Location	Time (SAST)												Total
	07,20	08,20	09,20	10,20	11,20	12,20	13,20	14,20	15,20	16,20	17,20	18,20	
F1	2,0	22,5	200,0	19,5	400,0	145,0	50,0	52,5	35,0	35,0	17,5	5,0	984,0
F2	2,2	22,5	180,0	25,0	72,5	157,5	50,0	60,0	37,5	42,5	17,5	5,5	672,7
F3	2,2	27,5	120,0	25,0	62,5	160,0	55,0	72,5	42,5	40,0	20,0	5,5	632,7
D/F	2,2	30,0	120,0	30,0	60,0	180,0	70,0	200,0	400,0	37,5	20,0	5,5	1155,2
A/F	2,7	30,0	85,0	35,0	65,0	195,0	500,0	90,0	40,0	35,0	20,0	5,5	1103,2
E/F	3,0	35,0	75,0	35,0	450,0	200,0	525,0	102,5	45,0	37,5	20,0	5,5	1533,5
F7	3,0	35,0	80,0	20,0	475,0	195,0	500,0	110,0	45,0	300,0	20,0	6,0	1789,0
F8	3,0	35,0	85,0	20,0	500,0	195,0	112,5	50,0	37,5	20,0	5,0		1063,0

TABLE 7/18

OBSERVED DAILY VALUES IN WATTS/SQUARE METRE OF SOLAR RADIATION IN GREENMARKET SQUARE 1 - 5 JULY 1980

Location	Time (SAST)												Total
	07,30	08,30	09,30	10,30	11,30	12,30	13,30	14,30	15,30	16,30	17,30	18,30	
A1	+ 2,5	17,5	30,0	60,0	250,0	250,0	550,0	450,0	+ 450,0	65,0	10,0	1,5	2136,5
A2	2,7	25,0	55,0	65,0	200,0	175,0	150,0	175,0	120,0	82,5	9,5	1,5	1061,2
A3	+ 2,2	+ 15,0	- 45,0	++- 35,0	+++ 100,0	++ 150,0	++- 125,0	-+ 400,0	++- 400,0	-- 75,0	- 7,5	0,7	1355,4
AB	4,5	- 35,0	85,0	400,0	275,0	550,0	550,0	475,0	75,0	60,0	12,0	1,5	2523,0
A5	3,0	15,0	55,0	90,0	100,0	++ 100,0	550,0	375,0	+ 40,0	40,0	6,0	1,0	1375,0
A/F	5,5	40,0	85,0	300,0	17,5	110,0	550,0	130,0	40,0	37,5	11,0	1,5	1328,0
A7	1,5	15,0	25,0	+ 27,5	50,0	+++- 50,0	+ 475,0	+ 57,5	25,0	-- 30,0	- 4,0	0,5	761,0
A/C	4,5	- 33,0	70,0	50,0	15,0	80,0	50,0	70,0	30,0	25,0	8,0	1,0	436,5
A9	2,0	17,5	30,0	40,0	65,0	35,0	30,0	27,5	20,0	17,5	3,5	0,5	288,5
A10	4,5	30,0	60,0	35,0	115,0	50,0	32,5	42,5	22,5	20,0	7,0	0,7	419,7

TABLE 7/19

OBSERVED DAILY VALUES IN WATTS/SQUARE METRE OF SOLAR RADIATION IN GREENMARKET SQUARE 1 - 5 JULY 1980

Location	Time (SAST)												Total
	07,40	08,40	09,40	10,40	11,40	12,40	13,40	14,40	15,40	16,40	17,40	18,40	
B1	3,5	20,0	35,0	17,5	57,5	42,5	30,0	42,5	25,0	25,0	4,0		302,5
B2	3,0	25,0	40,0	20,0	75,0	55,0	40,0	77,5	40,0	35,0	6,0		416,5
B3	+ 2,5	--+ 15,0	- 30,0	+ 25,0	+ 50,0	+-- 250,0	+ 32,5	++ 50,0	- 40,0	-- 30,0	4,0		529,0
D/B	5,5	40,0	85,0	67,5	135,0	110,0	75,0	250,0	65,0	50,0	8,0		891,0
A/B	8,0	50,0	97,5	475,0	195,0	450,0	500,0	450,0	75,0	62,5	10,0		2373,0
E/B	9,0	50,0	115,0	500,0	200,0	600,0	525,0	350,0	75,0	120,0	11,5		2555,5
B7	9,2	50,0	115,0	500,0	+ 200,0	600,0	525,0	175,0	65,0	47,5	11,2		2297,9
B8	9,0	50,0	+ 100,0	+ 450,0	+ 200,0	625,0	++ 525,0	+ 250,0	- 60,0	47,5	9,0		2325,5

TABLE 7/20

OBSERVED DAILY VALUES IN WATTS/SQUARE METRE OF SOLAR RADIATION IN GREENMARKET SQUARE 1 - 5 JULY 1980

Location	Time (SAST)											Total
	07,50	08,50	09,50	10,50	11,50	12,50	13,50	14,50	15,50	16,50	17,50	
C1	5,0	22,5	45,0	20,0	50,0	42,5	27,5	27,5	35,0	17,5	6,0	298,5
C2	6,5	30,0	62,5	22,5	75,0	50,0	30,0	30,0	40,0	22,5	7,0	376,0
	-	-	+	+-	-	++	--+	-		+	-	
C3	5,0	25,0	50,0	22,5	60,0	45,0	25,0	25,0	22,5	17,5	4,0	301,5
D/C	8,2	45,0	87,5	62,5	120,0	75,0	40,0	30,0	30,0	22,5	7,0	527,7
A/C	9,5	45,0	95,0	80,0	135,0	82,5	42,5	30,0	30,0	25,0	72,5	647,0
E/C	9,5	50,0	105,0	110,0	145,0	75,0	50,0	40,0	30,0	25,0	8,0	647,5
C7	105,0	55,0	107,5	400,0	160,0	80,0	50,0	35,0	35,0	25,0	8,0	1060,5
C8	5,0	35,0	67,5	350,0	95,0	57,5	37,5	30,0	30,0	25,0	5,0	737,5

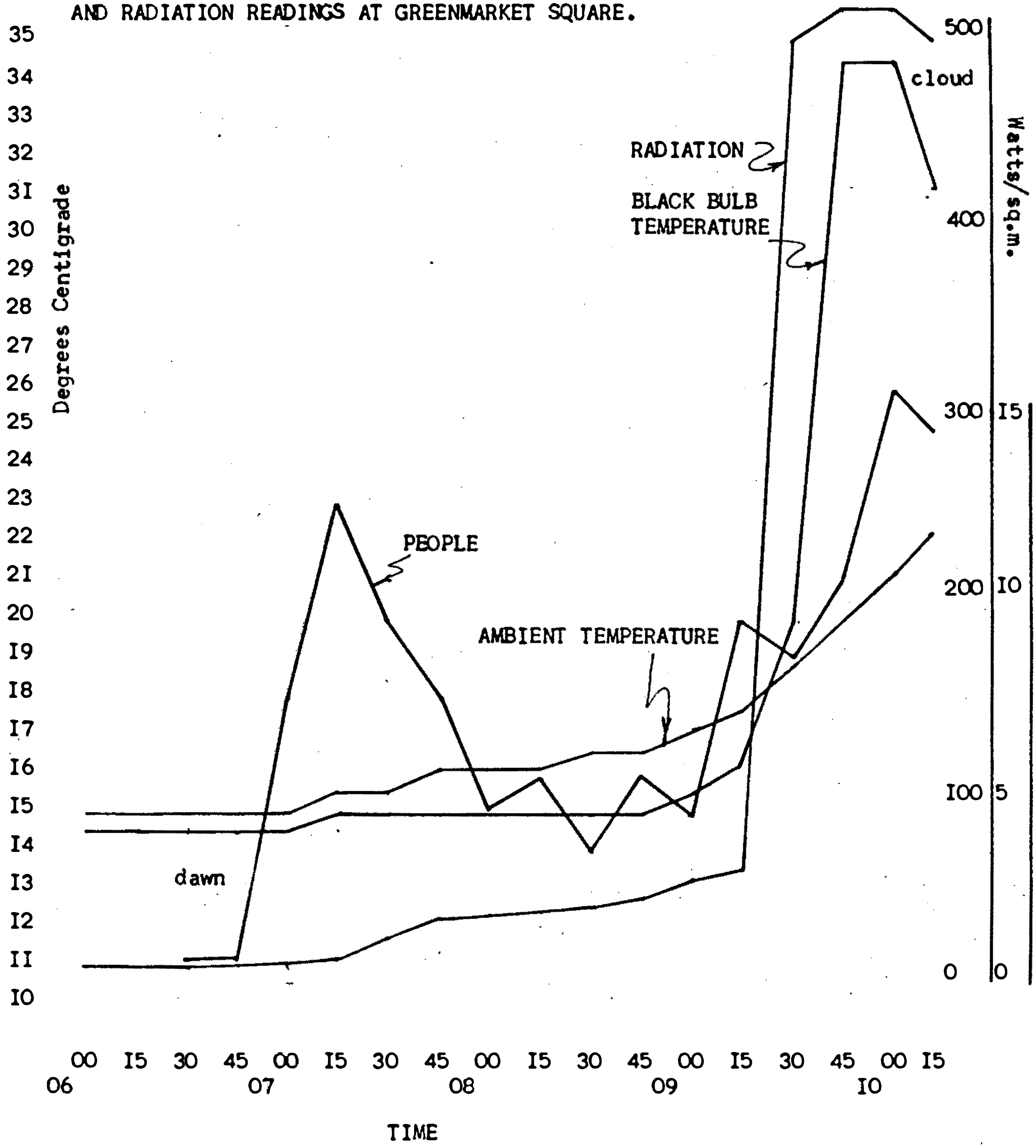
TABLE 7/21

Human occupation of the western half of the Square related to solar radiation, ambient, and globe thermometer readings at point C7.

TIME	RAD	BBTEMP	AMBTEMP	PEOPLE
06.30	0	14,4	14,4	1
06,45	0	14,4	15,0	1
07,00	10	14,4	15,0	7
07,15	40	15,0	15,5	12
07,30	150	15,0	15,5	9
07,45	250	15,0	16,1	7
08,00	250	15,0	16,1	4
08,15	270	15,0	16,1	5
08,30	275	15,0	16,6	3
08,45	350	15,0	16,6	5
09,00	450	15,5	17,2	4
09,15	500	16,2	17,7	9
09,30	5000	20,0	18,8	8
09,45	5250	34,4	20,0	9
10,00	5250	34,4	21,1	15
10,15	5000	31,1	22,2	14

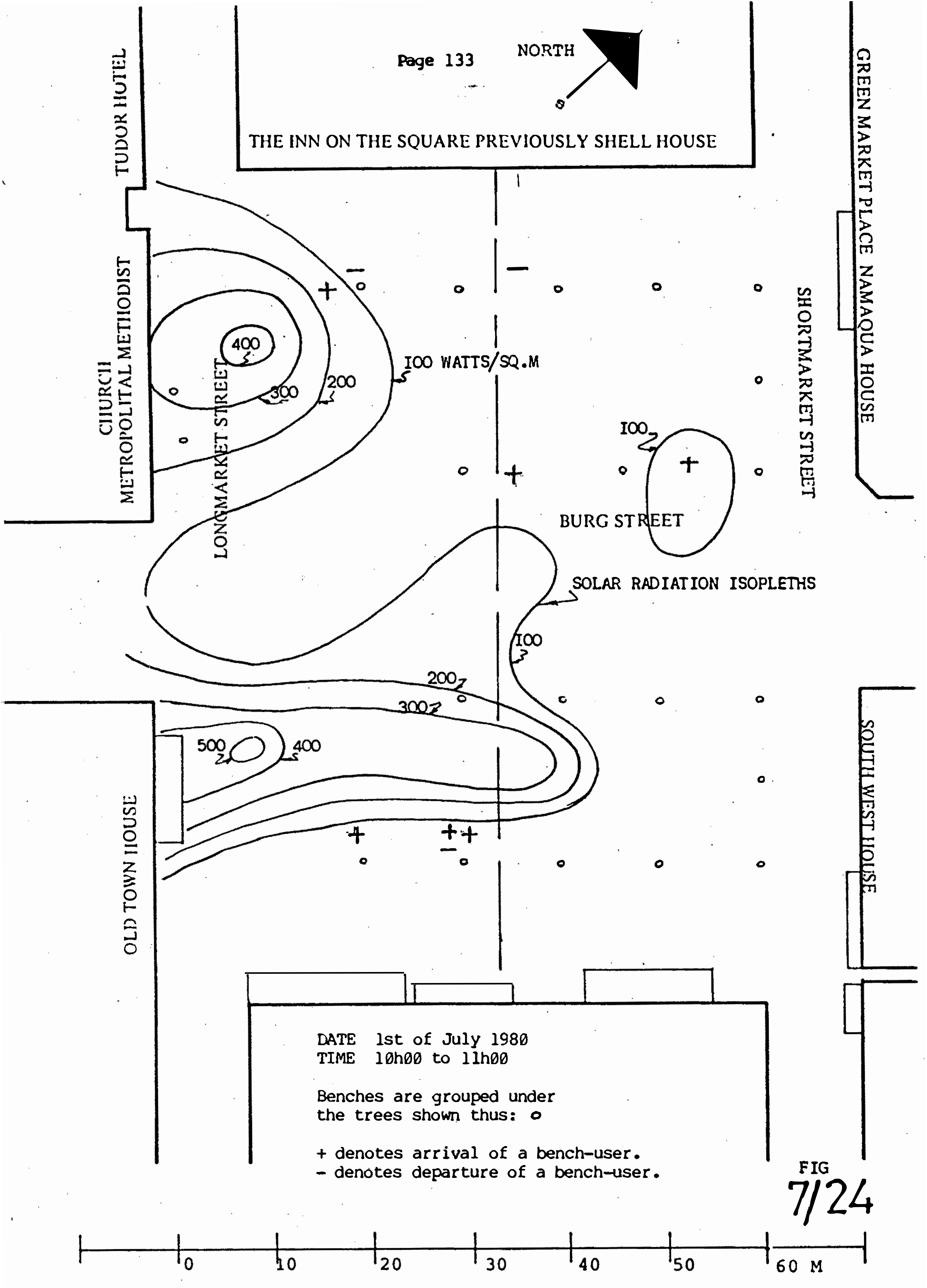
TABLE 7/22

RESULTS OF BLACK BULB THERMOMETER, AMBIENT TEMPERATURE, AND RADIATION READINGS AT GREENMARKET SQUARE.



FIG

7/23



DATE 1st of July 1980
TIME 10h00 to 11h00

Benches are grouped under the trees shown thus: o

+ denotes arrival of a bench-user.
- denotes departure of a bench-user.

FIG 7/24

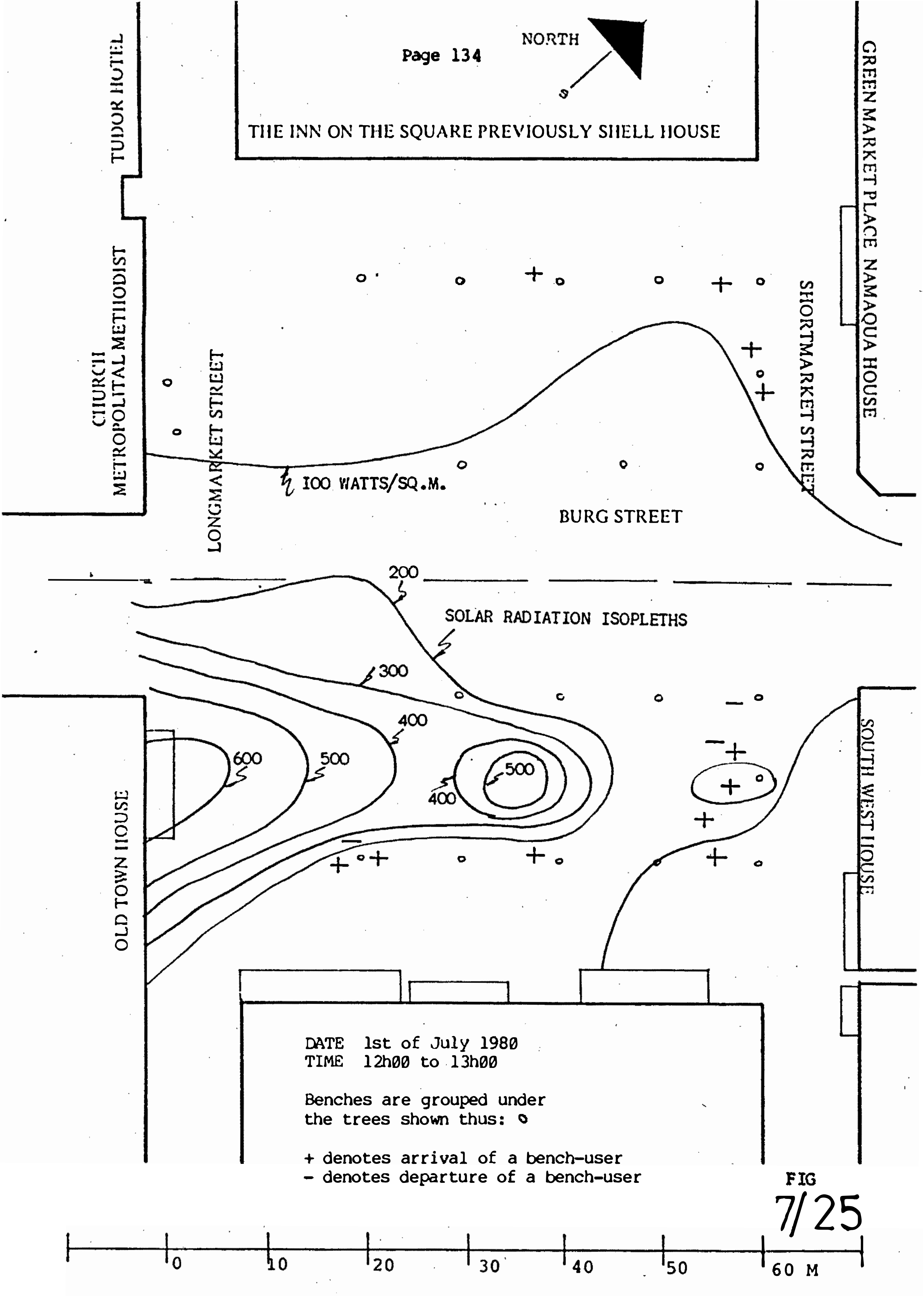
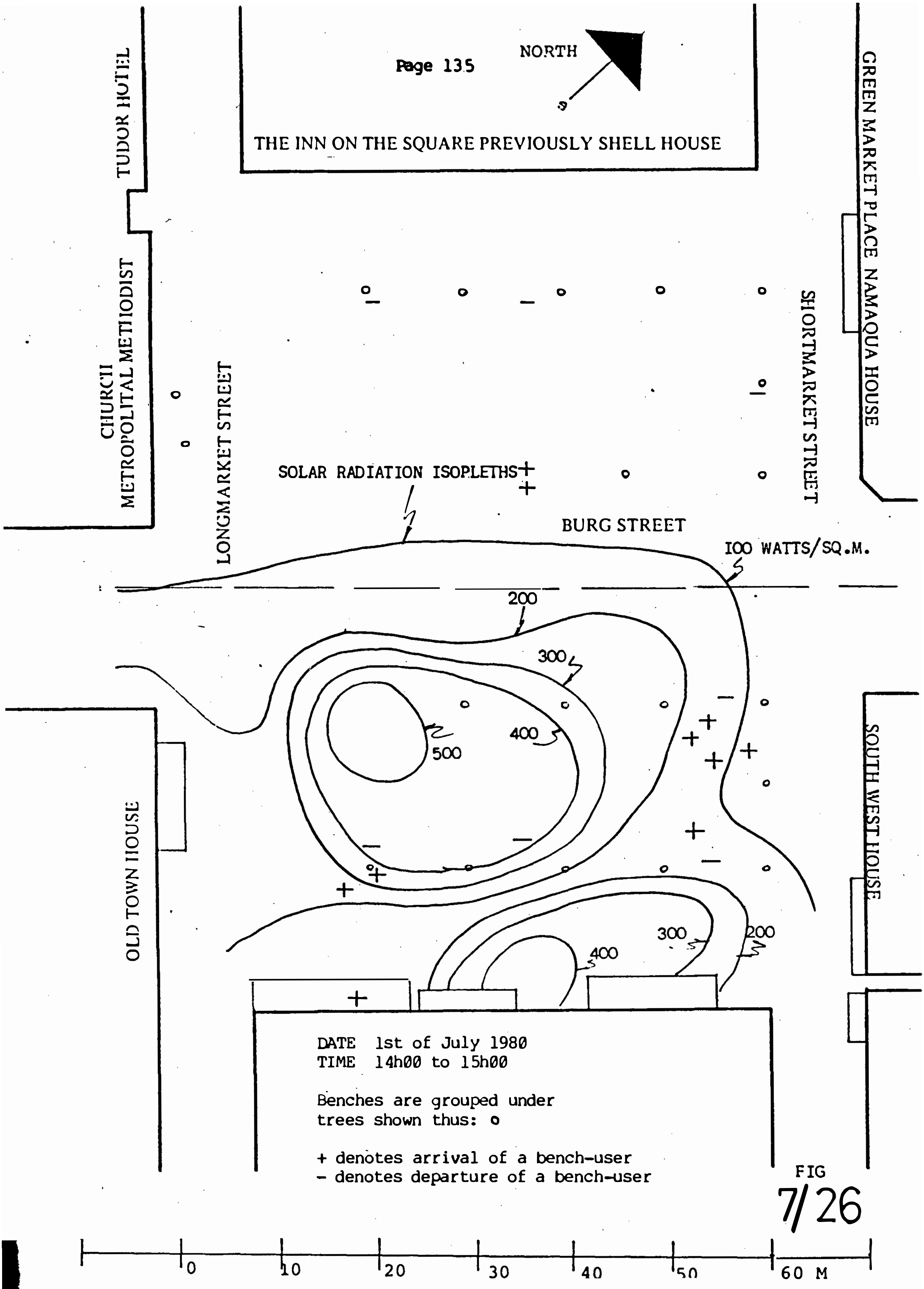

NORTH
THE INN ON THE SQUARE PREVIOUSLY SHELL HOUSE
TUDOR HOTEL
METROPOLITAL METHODIST CHURCH
LONGMARKET STREET
GREEN MARKET PLACE NAMAQUA HOUSE
SHORTMARKET STREET
100 WATTS/SQ.M.
BURG STREET
200
SOLAR RADIATION ISOPLETHS
300
400
500
600
500
400
OLD TOWN HOUSE
SOUTH WEST HOUSE
DATE 1st of July 1980
TIME 12h00 to 13h00
Benches are grouped under the trees shown thus: o
+ denotes arrival of a bench-user
- denotes departure of a bench-user
0
10
20
30
40
50
60 M

FIG 7/25



DATE 1st of July 1980
TIME 14h00 to 15h00

Benches are grouped under trees shown thus: o

+ denotes arrival of a bench-user
- denotes departure of a bench-user

FIG 7/26

APPENDIX ONE

HUMAN RESPONSE TO SUN AND SHADE

Two sections are included here which provide additional theoretical material on the human response to sun and shade. While the study is a first step towards establishing a relationship between environmental factors, such as sun and shade, and human use of external spaces, it does not aim to formulate an external comfort index. The background information on comfort indices and human adaptation is provided here, however, to assist in the formulation of an external comfort index if this should be seen as desirable at some future date.

COMFORT STANDARDS

Over the last sixty years there have been approximately thirty attempts to define comfort requirements for human habitation, and to establish an efficient method of measuring comfort standards over the range of atmospheric conditions typically encountered. Variables considered include temperature, humidity, and air movement. Adjustments in the calculations for the effects of radiation occur only recently. The lack of success in the search for a single scale which combines the effects of these four factors is due not only to the difficulty of dealing with four variables simultaneously, but also to the different requirements of the user/researcher. For example, a certain scale might be useful in assessing the comfort of a sedentary office worker, but would not be equally applicable to a worker in a steel mill, who would be clothed differently and would be producing far more metabolic heat.

Some examples of comfort indices are listed below. These have generally been devised as a result of experiments in controlled environments, where subjective reactions were recorded after each variation in the conditions. Results were plotted to produce a nomogram defining the relationships.

Effective Temperature Index (Houghton 1923-25, U.S.A.) -
considers air temperature, humidity, and air velocity.
Resultant Temperature Index (Missenard, France)
Operative Temperature Index
Equivalent Warmth Index
Equivalent Comfort Index
These indices were used for fairly still, saturated air.

Predicated Four Hours Sweat Rate (McArdle 1923, U.K.)
Index of Thermal Stress
These give the expected sweat rate under given environmental or metabolic conditions.

Heat Stress Index

Ratio of the evaporative cooling required by the body to the maximum evaporative capacity of the air.

Givoni (1969) observes the correlation between predictions and experimental result, and arrives the following conclusions on the reliability of the more common indices:

"Effective Temperature: of all the indices reviewed, the E.T.index appears to be the least reliable in predicting the expected physiological and sensory responses, both in comfortable conditions and under heat stress.

Resultant Temperature: the reliability of the R.T. index is satisfactory in predicting responses of people at rest or engaged in sedentary activity.

P/4 S R: the reliability of the P/4 S R index is satisfactory under light to medium heat stress conditions for people at rest or engaged in light to medium work. Under severe heat stress, it is still reliable in predicting the sweat rate, but this response alone is not so important, and so under these conditions the index is less satisfactory for predicting physiological strain.

Heat Stress Index: the H.S.I. is suitable for analysing the relative contribution of the various factors resulting in thermal stress, but is not suitable for predicting quantitative physiological responses to the stress.

Index of Thermal Stress: The I.T.S. is suitable for analysing the individual contributions of metabolic and environmental factors and for prediction of the physiological strain imposed on resting and working people. It is reliable in the range of conditions between comfort and severe stress, provided that thermal equilibrium can be maintained (stabilized rectal temperature and pulse rate). Beyond this limit the index does not apply."

Koenigsberger (1973) also points out that most existing indices have limitations on their practical application making, them valid and useful for a limited range of conditions, but not universally. He goes on to recommend the use of the Corrected Effective Temperature Index as a method for translating regional and site climatic data into a single index figure. Details of this index are set out below.

In Cape Town, the Factory Inspector (Premises) of the Department of Manpower Utilisation applies the C.E.T. Index to determine the quality of indoor environments, as well as taking readings of the sound and light levels. The C.E.T. Index would therefore appear to be recognised locally as a useful guide to the measurement of environmental quality, and could be the starting point for a wider study of urban environmental comfort standards.

The Corrected Effective Temperature Index

The C.E.T. is a refined form of the original E.T. Index which integrated the effects of temperature and humidity only, air movement being incorporated later. The Corrected Effective Temperature scale includes, in addition, the influence of solar radiation. This is achieved using a globe, or black bulb thermometer, instead of a dry bulb thermometer, to give the mean radiant temperature, which can be defined as follows: "If all surfaces in an environment were uniformly at this temperature, it would produce the same net radiant heat balance as the given environment with its surface temperatures"(Koenigsberger, 1973). Globe thermometer readings therefore reflect both the effect of any received or emitted radiation and the air temperature in combination.

Koenigsberger also observes: "...if the globe thermometer temperature is not available but the D.B.T. is known, in many cases it can be assumed that the surface temperatures are the same as the air temperatures....If there is a strong radiation source, with a known intensity, the globe thermometer value can be roughly estimated as 1 degree centigrade higher than the air temperature for every 90 watts/sq.m. radiation intensity".

In its present form, the C.E.T. Index is not able to integrate external climatic extremes, having been devised under strictly controlled indoor experimental conditions around the narrow range to which humans are adapted. These climatic extremes make it imperative, however, to plan urban spaces with human comfort in mind, by re-evaluating the environmental determinants in the light of contemporary human requirements. Thoughts expressed by Jackson at the C.S.I.R. Symposium on Design for Tropical Living (1957), can equally be applied to the Cape Town urban environment:

"So long as there is some chance of making use of the natural climate to attain acceptable living conditions we should be prepared to do so. But there is a further point. While it is relatively simple, though expensive, to alter indoor climates by mechanical means, so much time has to be spent out of doors that the comfort of the outdoor climate should be considered too and planning undertaken with the full knowledge of the importance of shade and ventilation".

HUMAN ADAPTATION TO SUN AND SHADE

Recurrent insistent effects of fluctuating environmental conditions have forced man to make appropriate adaptations, such as moving to a more congenial climate at the onset of winter. To those with limited means, there is often no alternative but to suffer the discomfort of environmental extremes. Recognising the wide range of this subject, it is necessary to concentrate on two main considerations: the human physiological response to the requirements of thermal regulation, and the adaptation of the natural situation to suit human requirements by the creation of a built environment.

Physiological response

Despite large variations in the external environment, it is essential for survival for the human body to achieve stability of heat gain and loss, and to maintain the temperature of inner tissues within a narrow range. The environmental factors affecting body temperature are radiation, air temperature, air movement, and humidity. Thermal balance is maintained by heat exchange between the body and its environment. Heat loss takes place by means of convection and radiation, by evaporation of sweat, and by evaporation of water in the lungs. The body's metabolism produces heat internally, while heat gain may also be achieved by convection and radiation, depending on whether the surrounding environment is colder or warmer than the body surface. Givoni (1969) summarises the factors determining heat exchange of the clothed body by dividing them into two groups, primary or independent factors, and secondary or dependent factors, as listed below:

Primary factors

metabolic rate
air temperature
mean radiant temperature
air motion
vapour pressure
clothing type and fit

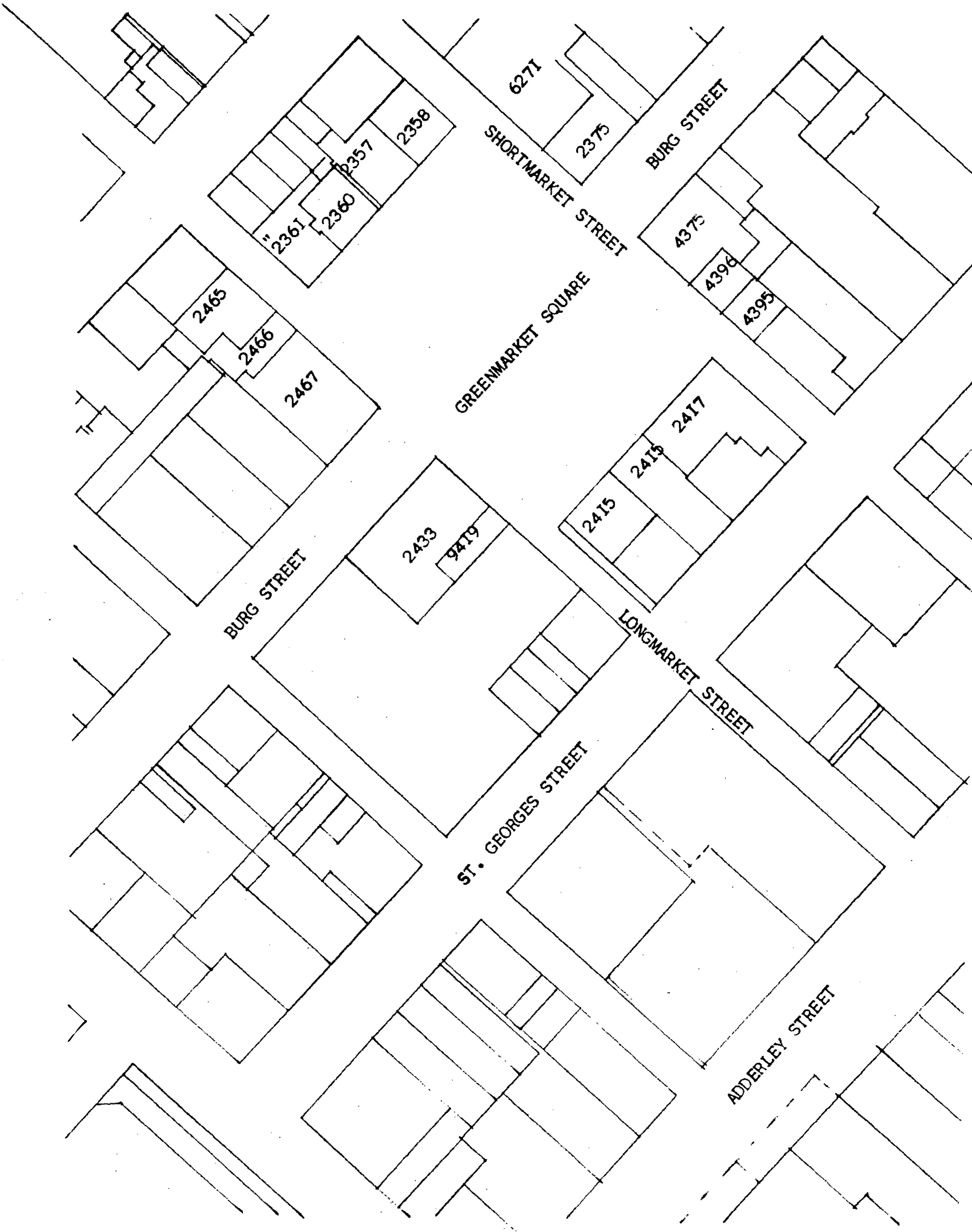
Secondary factors

clothing temperature
air motion beneath clothing
skin temperature
sweat rate
wetness of skin and clothing
cooling efficiency of sweating

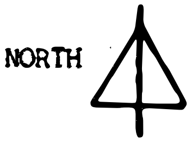
While heat exchange at the body surface is determined by temperature and vapour pressure differences betweeen the skin and the environment, the body can exert a measure of control, both by regulation of the physiological systems and by behavioural patterns. The extent to which this ability is required to exert a regulatory influence or not, is a measure of the comfort or discomfort experienced at the time.

APPENDIX TWO

The following diagrams provide details of the locality, size, shape, and erf numbers of the individual properties bordering Greenmarket Square. The future distribution and intensity of solar radiation in the Square is largely dependent upon the extent to which these properties are developed vertically. The future of the Square will be affected not only by development of the properties detailed in this appendix, but also by excessive vertical development of properties up to three blocks away in the path of the sun, as has been shown in this study.



KEY TO ERF NUMBERS

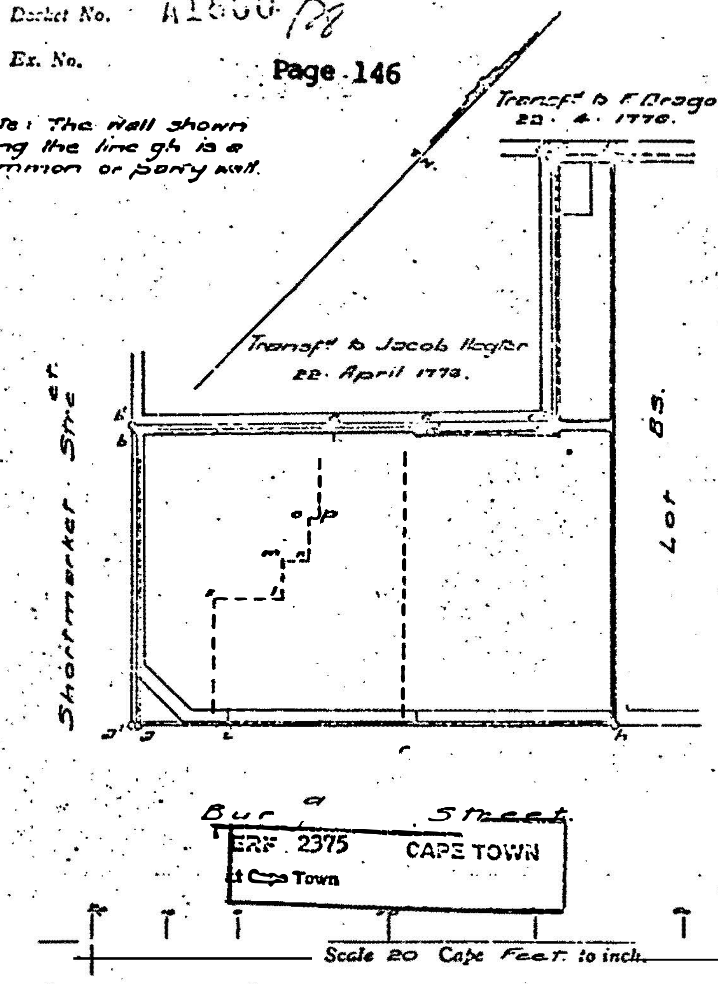


Docket No. A1600/28

Ex. No.

Approved
Surveyor-General.
13.6.1928

Note: The wall shown along the line gh is a common or party wall.



Sides

	Cape Feet	
ab	23	50
bc	37	75
cd	1	00
da	19	00
ef	37	00
fg	8	00
gh	70	00
ha	60	75

Angles. Table

Beacon Data.

Sides

a'b'	40	00
b'c'	56	00
c'f'	35	60
f'g	6	53
ha'	65	90

Area

20 Sq Rds. 05 Sq Ft.

The above figure a.b.c.d.e.f.g.h. represents 19 square roods $\overset{27}{53}$ square feet, 136 sq inch of land situate in the City of Cape Town, in the Cape Division, being Lot GM, consisting of first - the figure a.b.g.p.o.n.m.l.k.i. in extent 5 square roods 21 square feet, 100 sq. inches a part of Lot N°1, Block L, transferred to W. de Kruger on the 1st May 1783. Second, the figure i.k.l.m.n.o.p.q.c.r. in extent 5 square roods 22 square feet, sq inches a part of Lot N°1, Block L, transferred to Philip Hartogh on the 1st May 1783. Third, the figure r.d.e.f.g.h. in extent 9 square roods 53 square feet, a part of Lot 2, Block L, granted in freehold to A. Jansz on the 10th August 1695.

Bounded as indicated above

Surveyed and beaconed by us according to Regulations - April 1928.

Signed by candidate

Government Land Surveyor

This diagram belongs to the Transfer made this

in favour of S. Gesundheit, I. Gordon and J. Gordon

16/11/1928. 11740

ERF 2375
Comp. 1-73

Registrar of Deeds.

BU-103/1224

[illegible] Act No. 9 of 1927, Art. 24 [illegible]

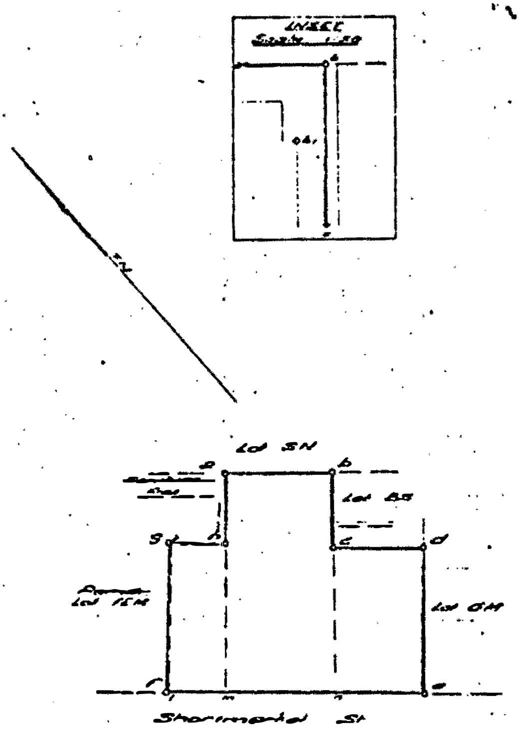
OFFICE COPY
KANTOOR AFSKRIF

No. 6356/61

SIDES Cape Feet		ANGLES OF DIRECTION		SYSTEM Lo 19° CO-ORDINATES Y	X
		constant		+[illegible]	+[illegible]
ab	42·00	359 57 30	a	+1094·63	+662·30
bc	20·05	91 16 20	b	+1062·21	+670·01
cd	25·19	311 08 20	c	+1088·76	+712·58
de	27·20	90 42 40	d	+1056·66	+735·13
ef	101·97	151 43 10	e	+1033·71	+779·10
fg	23·15	230 19 20	f	+1169·76	+711·85
gh	22·43	312 16 20	g	+1130·00	+668·10
ha	27·35	221 33 30	h	+1112·47	+683·19
			k	+1065·[illegible]	+691·[illegible]

Approved

[illegible]
Surveyor-General.
14.10.1961



1. The figure g h l f representing Portion 1 of Lot F.E.M. diagram 6355/61 annexed to D/T 1962 · 3833
2. The figure h l m l representing Portion of Lot No. 3, diagram 3/1801 annexed to D/T 801.1.37.
3. The figure a b n m representing land D/T 1776.1.67, diagram 5/1776 annexed to D/T 1776.1.67.
4. The figure c d e n representing Lot 5, diagram 6/1776 annexed to D/T 1776.1.67.

6271 CAPE TOWN

Scale 1:500

The figure a b c d e f g h

represents 7022 Square feet of land being

Lot Greenmarket Place

comprising the above components

in the Municipality of Cape Town

situate in the Division of Cape Province of Cape of Good Hope.

Surveyed in April 1960 by me

April & Jame 1960

Land Surveyor.

Description of Beacons

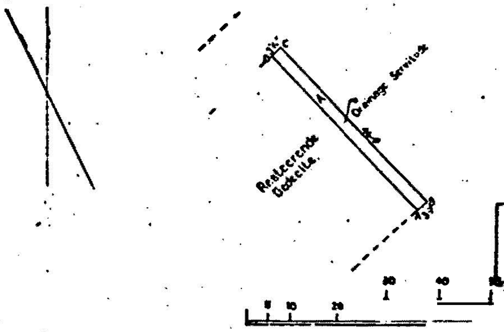
{a.e.d.f.g. - ½"x18" round iron peg at corner of wall.
{b. - no beacon.
{c.m. - ½"x18" round iron peg.
{a. - punch mark on iron channel.

This diagram is annexed to	The original diagram is ~~are~~ Noted ~~above annexed to~~	File No. S/7330/149 S.G. No. E. 1356/61
D/T 1962 · 3834 Registrar of Deeds.		CT She. 1-78 Bk 702. J. 242

The Drainage Servitude has been laid down as shown.
Vide Notarial Deed 269-1939.

for Surveyor-General.

Date 28.12.39.



Schaal van 50 Rhy. Voeten.

ERF 2358
te Kaapstad KAAPSTAD

Bovenstaande Figuur gem^t A Inhoudende Een Quad^t roeden 21 do. Voeten & 82 gelyke duimen, is gelegen in de Kaapstad aande Markt Plein, zynde een gedeelte van 't Erf van de Wed^{we} Hartong.

Strekkende N.W. aan 't Erf van de M^r Anosi.
N.O. aan die van Rob^t Phillips.
Z.O. aan de Markt Plein en
Z.W. aan 't resteerende gedeelte.

Gemeten door my
(Get.) Jno. Melvill.
Ge^t Gou. Land^t

Afskrif van kaart waarna verwys word
T/A Nr. 61
gedateer 10.5.1016/(Vol.2)
....
nms. Landmeter-Generaal.
27.5.1961

Signed by candidate

ERF 2358
Komp. I-7B
Verw.

NAGESIEN 224
GEGEWENS NAGESIEN

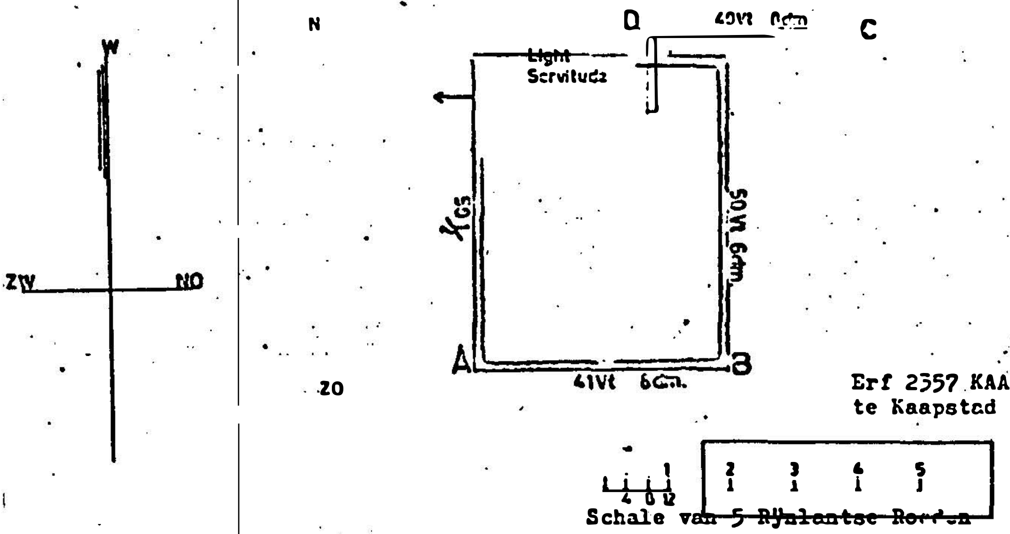
DW/T3

S.G.Dgm. No 1/1721

Signed by candidate

The Light Servitude has been
down as shewn Vide Not Deed No
369-1939 (Sgd)S.Güldinghennig
Date 29.12.39 F. Surveyor-General

Servitude Diagram affecting this property filed with Erf 2358



Schale van ~~5 Rynlantse Roeden~~

Erf 2357 KAAPSTAD
te Kaapstad

Dese bo~~venstaande Figuur voor~~ de Trompper

postman

groot 14 quad^t roeden 88 voets en 24 dito dm

verdeelt door

(Get) E. W. Cochius

ge^W landmeter

2357

Afskrif van kaart geheg aan
T/A 1721-1-111

-generaal
7·1977

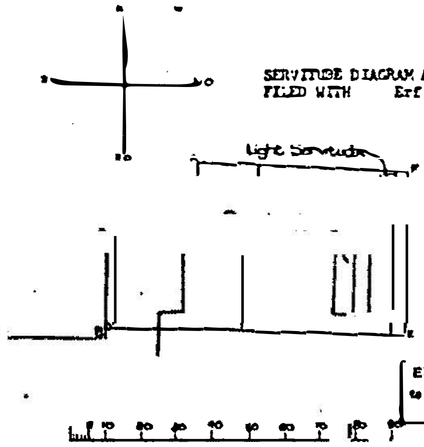
R.H

NR. 3/1722.

The Light Servitude has been laid down as shown. Vide Not.Deed No.369-1939.
(Sgd.) S. Güldenpfennig.
for Surveyor-General.
Date 28.12.39.

AB	23:2
BC	23:9
CD	23:7
DE	62.0
EF	46:9
FA	50v3 dm

SERVITUDE DIAGRAM AFFECTING THIS PROPERTY
FILED WITH Erf 2358



ERF 2360 KAAPSTAD
te Kaapstad

Schale van 90 Rijnlandse Voeten.

N: 2 en Blok TT.

Deze bovenstaande figuur groot 22 quad: rooden en 115 do. voeten en 42 do. duimen.

Gemeten en verdeelt door,

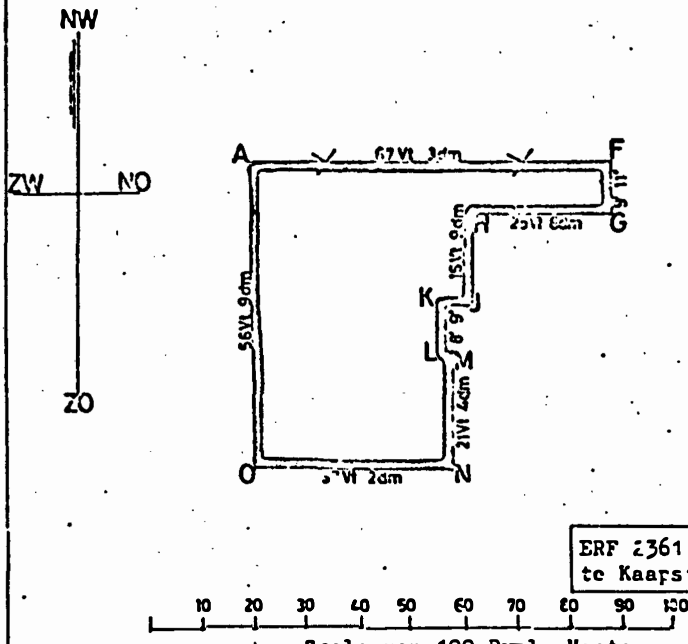
(Get.) E. W. Cochius.

gesw lantmeter.

ERF 2360
Aanst. I-73
Verw.

T/A 23
23.2.1722 (VOL. 1)
Signed by candidate
17.5.1960

ME/FS



ERF 2361 KAAPSTAD
te Kaapstad

Scale van 100 Rynl. Voete

Bovenstaande figuur A,F,G,H,I,J,K,L,M,N,O,
Zynde gelegen in deese TafelVally in 't
Blok JJ

groot 17 quad. Roeden 28 d° Voeten en 41
gelyke D^{m}

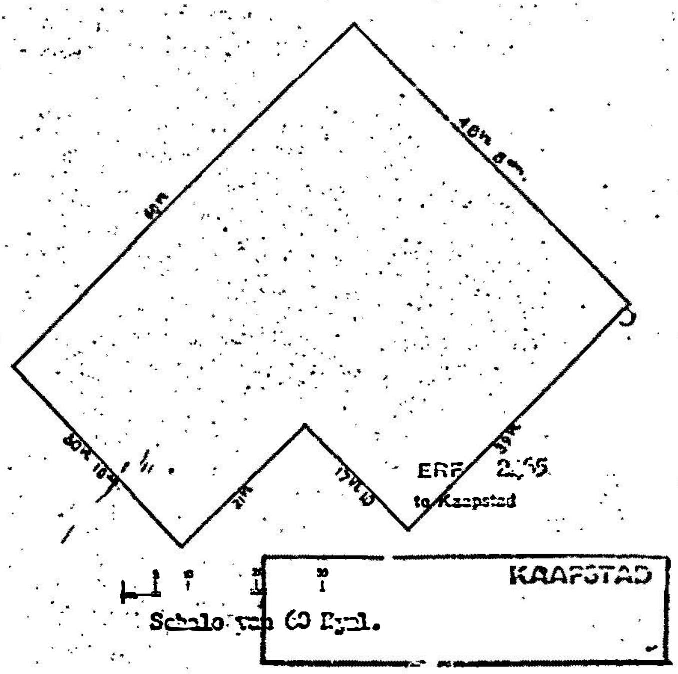
Gemeeten door my
(Get) C. H. Leiste
gesw. landmeeter

Afskrif van kaart geheg aan
T/A 1783-2-21

2.

R.H.

ERF 2361



Voeten.

Bovenstaande Figuur is gelegen in deeze Tafel valley in de lange
markt Straat en aldaar uit het blok MM een gedeelte van 't geheele
No.3 en 4 groot in zyn geheel 17 quad. roeden 97 do. voeten en
72 gelyke duymen.

Signed by candidate

Hermeten en gekaarteerd door

J. H. Wernich.

Signed by candidate

(Get.) C. J. Palm.

Gezw. Landmeter.

Nader na het Origineele gekaarteerd door

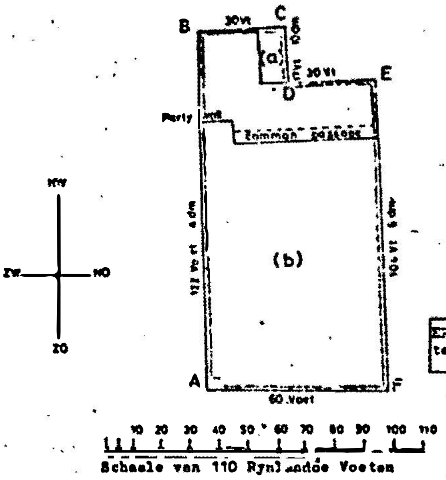
Gezw. Landmeter.

Afskrif van kaart waarna verwys word
in T/A Nr. 76
gedateer ERF 2465

22.5.1961

ERF 2465
Komp. I-7[illegible]

S.G. Dgm. No. 8/1772



ERF 2466 KAAPSTAD
te Kaapstad

Bovenstaande figuur A.B.C.D.E.F. zynde geleegen in deese TafelVally in het Blck KK en aldaar No. 1 en 2

en een gedeelte van No. 3 groot 47 quadt. Roeden en

37 dito Voeten

Signed by candidate

gemeeten door

(Get.) C.P. Brink.
gesw. landmeeter.

Afskrif van kaart geneg men
T/A 1772-1-'84

vir Landmeter-generaal.
Datum: 4.2.1977

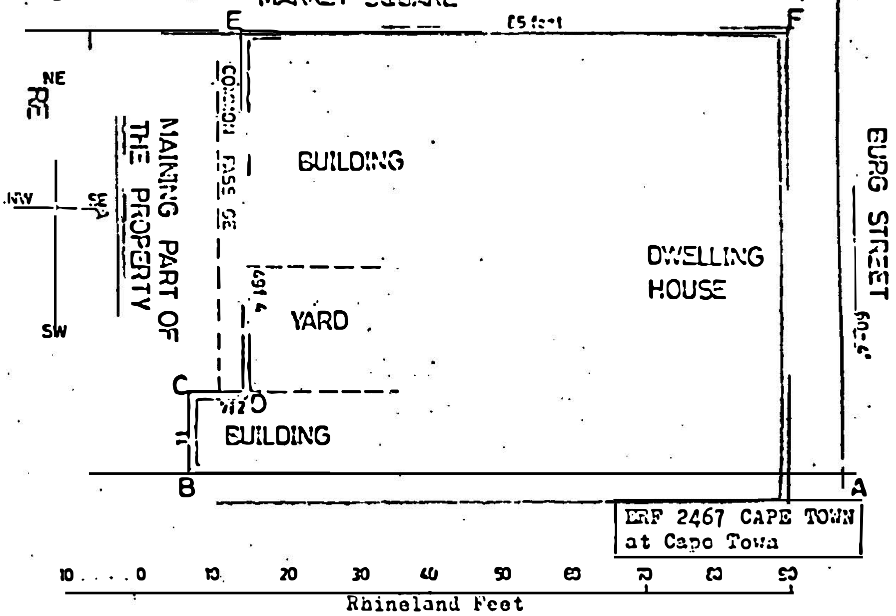
Signed by candidate

SIEN KEERSY VIR
ENDOSSEMENTE

DG
2466

Page 154

S.O. Dgm. No 24/1847



ERF 2467 CAPE TOWN
at Cape Town

The above figure A,B,C,D,E,F, represents 36 Square Roods 23 Sqr feet and 24 d^{o} inches of ground with a dwelling house and other buildings erected thereon, situate in Cape Town in Market Square Corner of Burg Street being part of the Property transferred to J. C. Gie ? ? ? on the 23^{d} January 1818

Bounded: on the NE by Market Square
on the SE by Burg Street
on the SW by the Premises belonging to Mr. Volsteedt
and on the NW by the Remaining part of the Premises

The above Property was Sold on Condition that the passage indicated on the diagram shall be Common between this part of the property and the part reserved by the Seller that neither of the parties, nor their Successors shall be allowed by any means whatever to obstruct the said passage and that both shall have an equal Right to lead off through the same the superfluous water from their respective Premises.- and that the wall indicated by the line BC shall be a common or party wall.-

Laid down from actual Survey
(Sgd) M. Ruysch
Sw. Surv.
January 1847

Signed by candidate

R.H.

SURVEY R-

2467

~~ERF2467~~

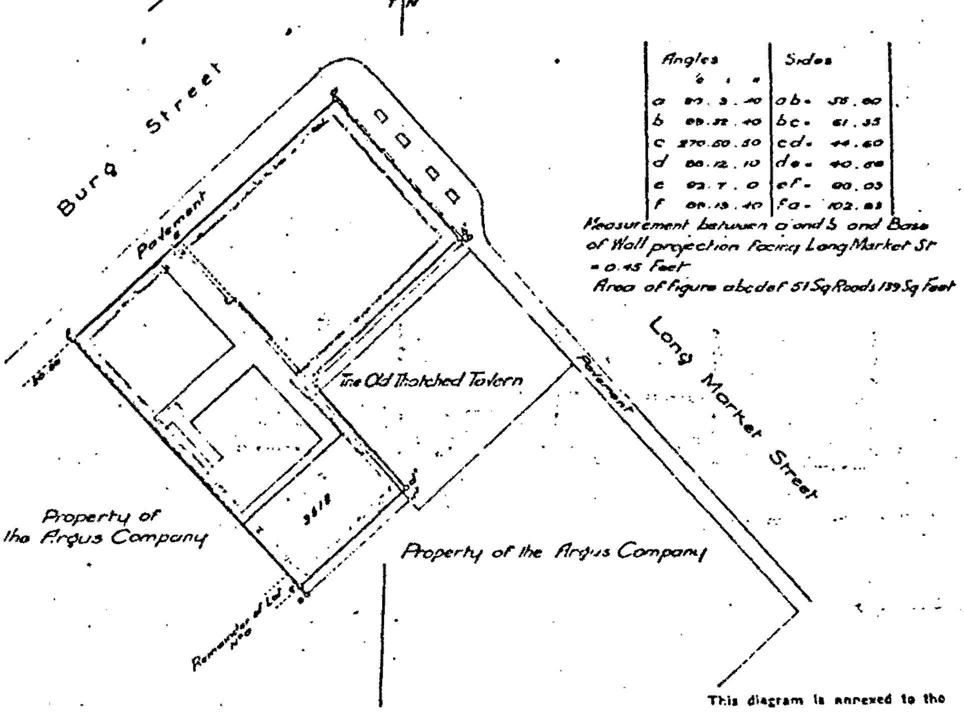
[illegible] N° 110.
2/2/1915.

2437
1914

The numerical data of this Diagram are consistent.

No. A. 1437 1914
Wesleyan Church

Examiner.



Angles ° ' "	Sides
a 89. 3. 40	ab = 58.00
b 89. 32. 40	bc = 61.33
c 270. 50. 50	cd = 44.60
d 89. 12. 10	de = 40.68
e 92. 7. 0	ef = 90.03
f 89. 13. 40	fa = 102.81

Measurement between a and b and Base of Wall projection facing Long Market St = 0.45 Feet
Area of figure abcdef 51 Sq Roods 139 Sq Feet

This diagram is annexed to the
Transfer ~~Title~~ Deed No. 1125
dated 9.7.1915 in favour of
the Govt. Union of S.A.

ERF 2433 CAPE TOWN
at Cape Town

Scale 30 Cape Feet = 1 Inch.

The above diagram lettered ~~[illegible]~~ a b' c' d' e' f represents ~~[illegible]~~

51 square roods 21 square feet of land situate in ~~[illegible]~~ CAPE TOWN. Cape Division ~~of~~ at the corner of Long Market and Burg Streets. being "THE OLD TOWN HOUSE" of which the figure a b' c' g in extent 22 Sq Roods 87 Sq Feet is the remainder of the land granted to C. Swor on 10 October 1709. and the figure g d' e' f in extent 28 Sq Roods 78 Sq Feet is part of the land granted to J Paassen on the 2 August 1712.

		by Long Market Street and The Old Thatched Tavern
	SE	The Old Thatched Tavern and Property of the Argus Company.
Bounded	~~SW~~ NE	Property of the Argus Company and Remainder of Lot No 6.
	NW	„ Burg Street.

Surveyed and beaconed by me according to ~~regulations~~ Land Surveyor.
Aug. 1914.

I certify that this diagram belongs to the Transfer issued this day in favour of

9/7/1915

ERF 2433
Comp. Ref.
-7B

Signed by candidate

FOR ENDORSEMENTS
SEE BACK OF DOC.

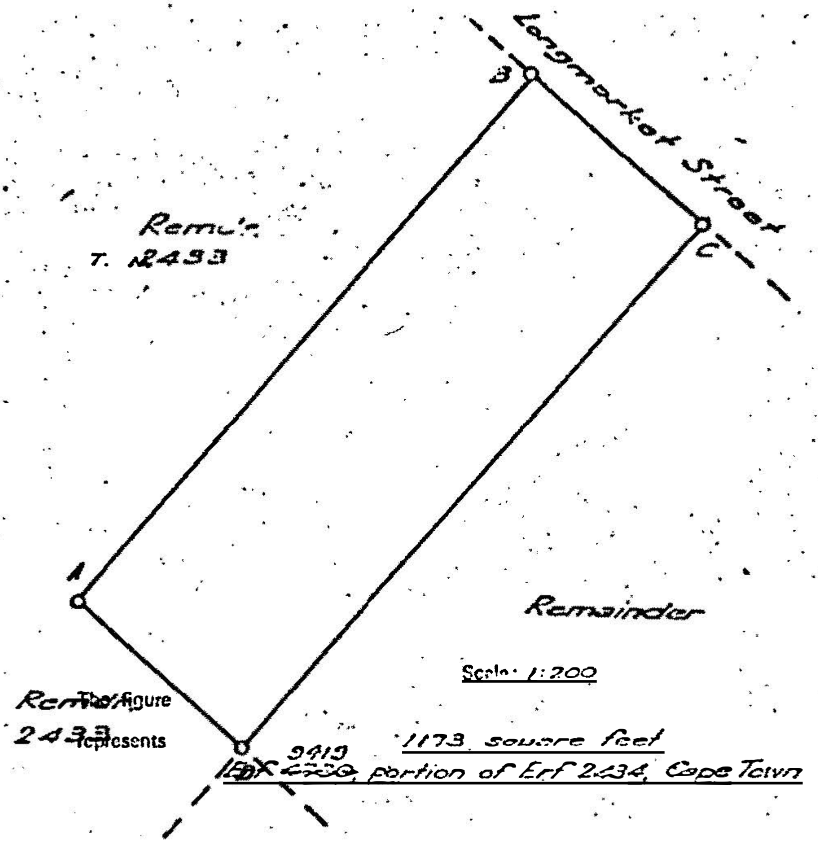
2433

SIDES	ANGLES OF DIRECTION		CO-ORDINATES Y System Lo 19°	X
	Constant		+0000·00	+3000000·00
AB 63·61	221.53.45	A	+73163·03	+26023·03
BC 19·36	311.22.20	B	+73120·17	+26050·51
CD 63·53	41.53.45	C	+73114·62	+26063·74
DA 19·36	131.19.45	D	+73155·14	+26108·78

S.G. No.
0663/69
Approved

Wall corner.
½" diam. iron peg in concrete.
Not beaconed.

Beacons.
A. B.
C.
D.



Scale: 1:200

The figure A. B. C. D. represents 1173 square feet of land, being Erf 9419, portion of Erf 2434, Cape Town

No. 5/1719 annexed to Comp.
Transfer/Grant
No. 1719·1·204
Registrar of Deeds

situate in of Cape Town in the City of Cape Town, Administrative District of Cape, Province of Cape of Good Hope.

Surveyed in Sept.-Oct. 1967
by me,

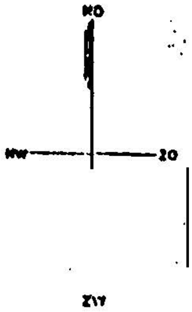
Signed by candidate

Land Surveyor

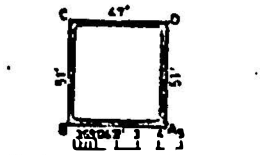
This diagram is annexed to	The original diagram is	File No. S/9390/535
No. 10/14473/71 dated i.f.o.		S.R. No. E. 6003/69 B11.70B/Y244

ERF 9419

S.O. Dgm. No



ERF 2420 KAAPSTAD
te Kaapstad



Schale van vÿf rÿnlandse Roeden

Groot: 16 Qu. Roeden
93 Qu. Voeten

(Get) E. W. Cochius

GEEN KEERSY VIR ENDOSSEMENTE

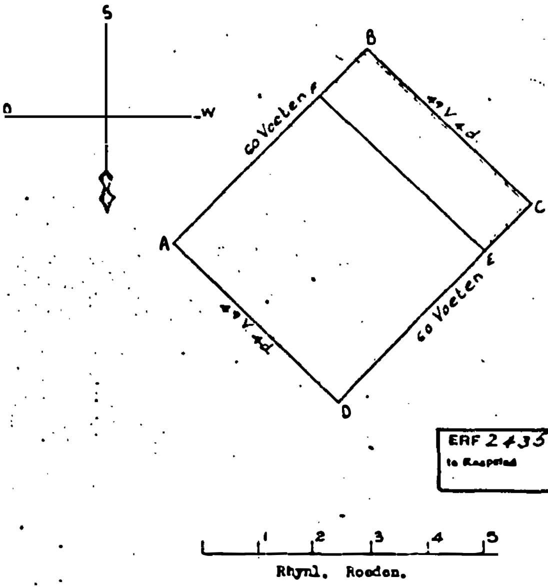
Afskrif van kaart geheg aan
T/A 1719-1-176

Vir Landmeter-generaal
Datum:- 2/8/1977

R.H.

2420

NO. 4/1708.



ERF 2435 KAAPSTAD
to Kaapstad

Bovenstaande Figuur A.B.C.D.A. inhoudende 20 Quadraat Roeden 80 Quadraat Voeten door my gemeten.

(Get.) K. J. Slotsboo.

CHECKED
Dig. 4 E.D Sewell

Afskrif van kaart waarna verwys word
In G/B No. Old C.F.2.-126
gedateer 20.1.1708.

1.5.1959

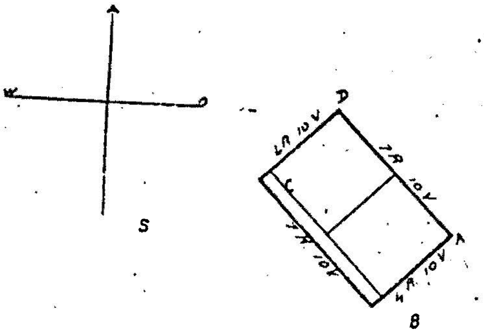
For list of deductions see back of diagram

ERF 2435
Kaart 4-70
Vol.

H.v.Z./F.S.

OC.F 2-146

NO. 9/1707.



ERF 2413
te Kaapstad

KAAPSTAD

Schaal van 10 Rhynl. Roeden.

3 BLKEE

Bovenstaande Figuur A. B. C. D. A. inhoudende

37 Quadt. Roeden 124 Quadt. Voeten door my gemeten.

(Get.) K. J. Slotsboo.

Afskrif van kaart waarna verwys word
in......C/B...................ter. Old C.P.2-93
gedateer....
Signed by candidate
Asst. Landmeter-Generaal.
10.6.1959

CHECKED
DAT 2-3-60

For list of deductions see back of diagram

O.C.F. 2-95.

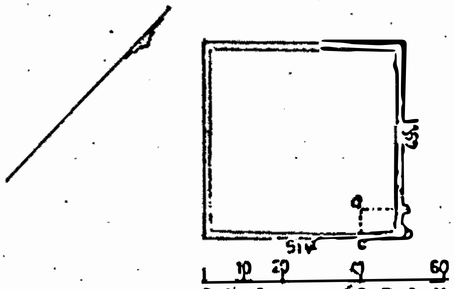
8H 725 / 744
M.J./P.S.
Nagesien deur

ERF 2413
Komp. J-7B
Verw.

S.G. Dgm No 16/1791

The Serv Light Well abcd
has been laid down as shown
Vide Notl. Deed No 80-1940
(Sgd) S. GULDENPFENNING
Dated 8.4.40 For: Surveyor-General

ERF 2415 KAAPSTAD
te Kaapstad



Schaale van 60 Ryl Voeten

Bovenstaande figuur is geleegen in deeze TavelValley in't Block EE en aldaar een gedeelte van No 3, groot in zynen grond 17 quad^t Roeden 51 d^o Voeten.

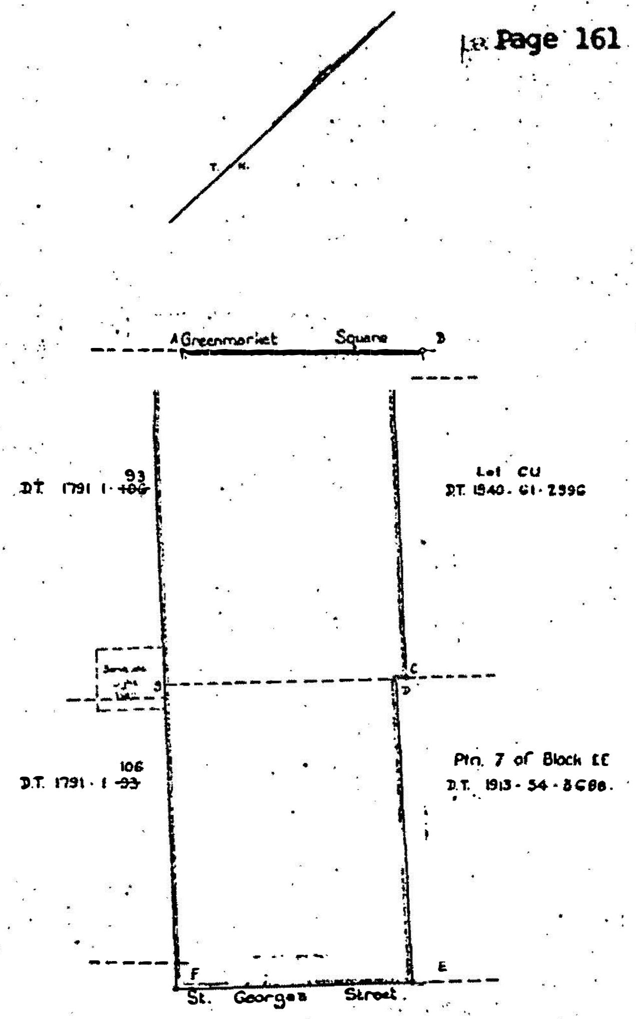
Gemeeten en verdeelt
door my
(Get) J.W. WERNICH
gesw Landmeter

Afskrif van kaart geheg aan
T/A 1791.1.93

Signed by candidate

Vir: Landmeter-Generaal
Datum: 2. 9.1977

V.d.R.



C... Registration of Deeds Act No. ... of 1937.

OFFICE COPY

No. 1650/56

SIDES Cape Feet		ANGLES OF DIRECTION			System Lo. C.T. Local CO-ORDINATES			
AB	88 · 22	222	21	00	A	+ 2033	11	+ 22022 · 22
BC	47 · 14	311	00	00	B	+	Signed by candidate	
CD	1 · 08	41	19	30	C	+		
DE	47 · 53	310	22	30	D	+ 1978	47	+ 22028 · 65
EF	57 · 18	41	00	20	E	+ 1942	2?	+ 22036 82
FA	95 · 08	130	41	30	F	+ 1997	02	+ 22084 22

Servitude Note

Approved

Surveyor-General.
11-4-1956.

The wall along the boundary DE is a party wall Vide Notarial Deed of Servitude dated 9th August 1881 annexed to DT 1847-16-71 ✓

Beacon Description

Beacon	Description
A.F.	corners of building.
B	½" round iron peg at building corner.
C.	wall corner.
D.	computed point
E.	¾" square iron peg at building corner.

1 The figure A.B.C.D.g representing Land D.T. 1745-1-60 Vide Diagram No. 6/1745. D.T. 1745-1-60

2. The figure g D.E.F. representing Land DT 1745-1-56 Vide Diagram No. 4/1745. D.T. 1745-1-56.

ERF 2416
at Cape Town
CAPE TOWN

Scale 1:200

The Figure ABCDEF represents 3565 sq. feet of land being

LOT N B S

and comprises the properties specified above.

situate in the Municipality of Cape Town

Division of Cape Province of Cape of Good Hope.

Surveyed in Jan 1954 - Sept 1955 by me,

Land Surveyor.

This diagram is annexed to Cert. of Cons. Title Deed No. dated in favour of DT. 7105/1956. Registrar of Deeds.	The Original Diagrams are as quoted above Signed by candidate ERF 2416 Comp. I-93 Ref.	S.G. File No. S. ... ... 2416 · ...

Amalg. C.T.

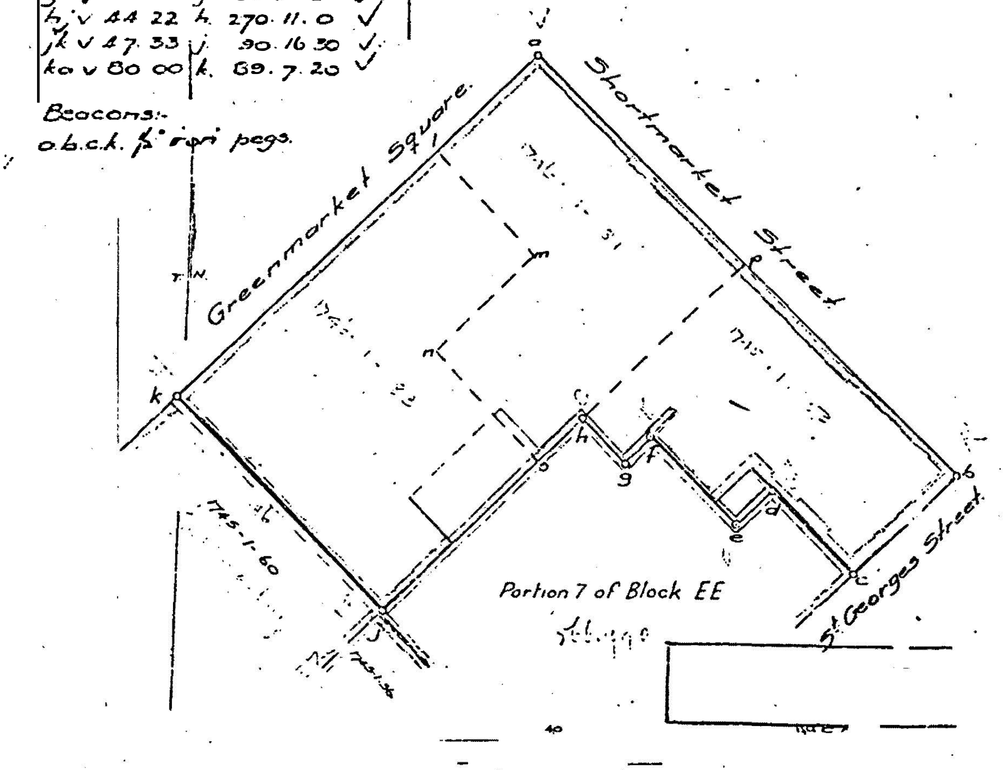
567/1939

Approved

Surveyor General
15-8-1940

Sides. C.F.			Angles.		
ab	✓	34.32	a.	91 25.40	✓
bc	✓	22.50	b.	89. 1.30	✓
cd	•	18.17	c.	91. 0.30	✓
de	✓	8.28	d.	268 6.40	✓
ef	✓	19.31	e.	91. 29. 0	✓
fg	✓	5.70	f.	268. 31. 0	✓
gh	✓	10 04	g.	90. 52.50	✓
hj	✓	44 22	h.	270. 11. 0	✓
jk	✓	47.33	j.	90. 16 30	✓
ka	✓	80 00	k.	89. 7. 20	✓

Beacons:-
a.b.c.k. ⅝" iron pegs.



ERF 2417 at Cape Town **CAPE TOWN**

Scale: 1: 250.

The figure lettered a.b.c.d.e.f.g.h.j.k. represents
5136 Square feet of land called Lot C.U. and comprises:-
1. Figure l.m.n.o.j.k. representing land trans: to J.B. Deek. 14.3.1746 (1746.1.83)
2. Figure l.a.p.o.n.m. representing land trans: to J. van Rhenen. 14.3.1746. 4/(1746.1.81)
3. Figure p.b.c.d.e.f.g.h representing remainder of land ~~trans~~ to S.G. File No 9390/234 B. Pieters. 23.7.1745. (1745.1.53)
Situate in the City of Cape Town, Division of Cape, Province of Cape of Good Hope.
Registrar of Deeds.

Surveyed in November 1939, by me,
L.G. Ewet
Government Land Surveyor.

This diagram is annexed to Certificate of Consolidated Title Nº 2996 dated 3rd April, 1940. in favour of Commercial Union Assurance Co. Ltd.

The original diagrams as quoted in the description.

Signed by candidate

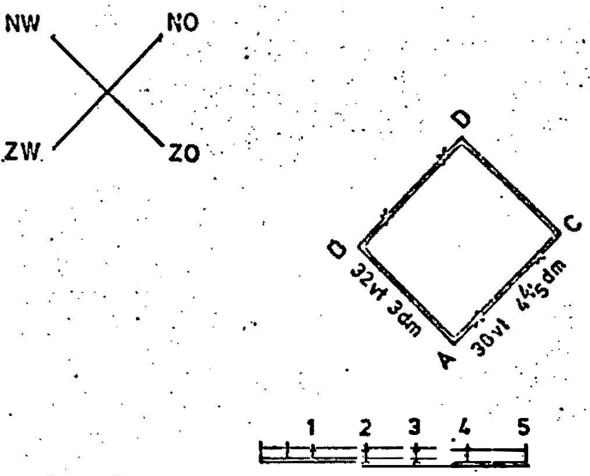
Survey Records

ERF 2417
Comp. I-7B
Ref.

Nº E 178/1940
C.T. Shts I7, J7

S.G. Dgm. No. 6/1775

ERF 4395 KAAPSTAD
~~te Kaapstad~~



Schaale van 5 Rÿnlandse Roeden.

Bovenstaande figûûr A.B.C.D. zÿnde geleegen in deese Tafel Vallÿ in het Blok H en aldaar een gedeelte van No. 1 groot 8 quadr^{t} Roeden 84 quadraat Voeten en 36 dito duÿme gemeeten door

(get.) C.P.Brink
gesw:landmeeter

Afskrif van kaart geheg aan
T/A 1775.1.93
nms. Landmeter-generaal.

BH-7DB/Y244 (981)

Datum: 26-10-1973

AvW
4395

DIAGRAM FOR SUBSTITUTION
(Sect. 22 (3.) Act No. 9 of 1927).

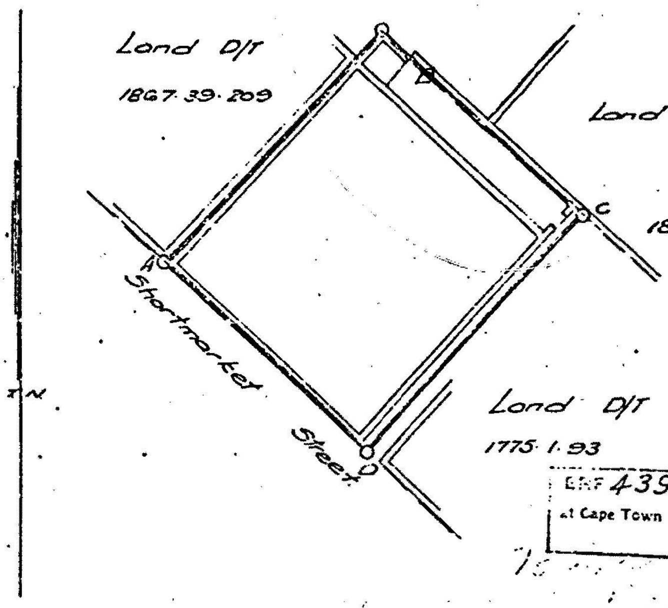
No. 2862/49

SIDES Cape Feet		ANGLES OF DIRECTION ° ′ ″	SYSTEM LO CO-ORDINATES	y	x
AB	37.61	91 1 20	A	+ 503.94	+ 628.14
BC	32.31	180 4 30	B	+ 544.54	+ 627.47
CD	37.60	270 46 40	C	+ 544.50	+ 595.16
DA	32.47	0 4 10	D	+ 506.90	+ 595.67

Approved

Signed by candidate

Surveyor-General.
2 ... 1949



ERF 4396
at Cape Town

CAPE TOWN

Description of Beacons.

A.B. Corners of walls.
C. ½" hole in cement passageway.
D. ½" hole in granite stone.

20 0 20 40 60 Cape Feet.
Scale 1:2000

The figure A. B. C. D.

represents 1,218 square feet *of land being*

PORTION of LOT No. 1, BLOCK H,

situate in the Municipality of Cape Town,
~~*situate*~~ *in the Division of* Cape. *Province of Cape of Good Hope.*

Surveyed in March 1949 *by me*

Land Surveyor.

The original diagram ~~*is*~~ for ~~*No.*~~ ~~*annexed to*~~ which this is substituted is No.18/1775 annexed to D/T 1775.2.4755.

File No. 9390/30
S.R. No. E. 735/49
C.T. Sheet J-7

BEACONS ACKNOWLEDGED

ERF 4396
Comp. J-7/11.
Ref.

This diagram is annexed to

Registrar of Deeds.

ERF 4396

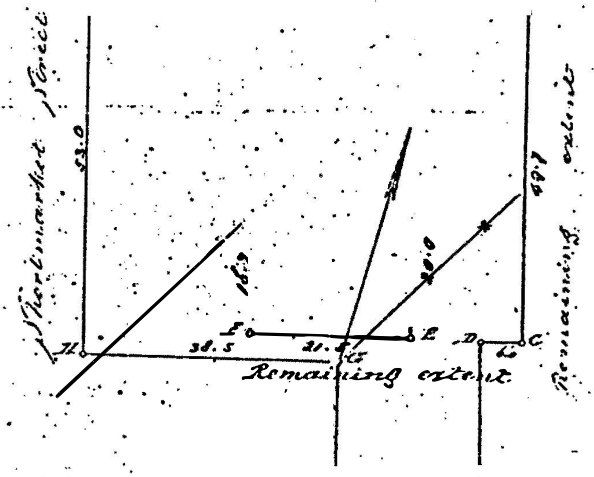
Undivided 29

…erical data of ~~Diagrams~~ Burg Street are ~~sufficiently~~ consistent

323/186) Page 165 B

Examiner of Diagrams.

October 1867.



This property is to leave all lights on the lines C.D.E.F undisturbed & to receive rain-water &c & to permit access for repairs to the same lines
The wall from B to C is a party wall.

ERF 4375 CAPE TOWN
Cape Town

SCALE OF CAPE ~~ROODS~~ feet
Sh J7

The above Diagram lettered ~~A to H represents a piece of land containing~~ 26 rods ~~roods~~ 63¾ square feet ~~rods~~, situated in the ~~Division of~~ Cape Town ~~Field-cornetcy of~~ and bounded on the North by west by Burg Street

South by east by remaining extents &

North-East by remaining extent

South-West by Shortmarket Street

being part of the ~~Farm~~ property transferred ~~granted in~~ to J. L

on the 20th day of February

and registered.

1838

Surveyed by me,

BI.700/92544

Sworn Govt. S… 4375

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