An Evaluation Technique for Assessing Daylight Design within The Hospital Interior.

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1.0 Introduction

In this dissertation, I have sought to create an evaluation technique that allows me to make an objective judgement about a particular daylight design within its host building, The Chelsea & Westminster Hospital.

I choose the architectural category of hospitals, as it is within this environment that the successful inclusion of daylight is fundamentally entwined with the activities and operation of the building. I felt a specific assessment technique was required to evaluate the needs of a hospital daylight design.

I have attempted to set out these needs and create a method to assess them, in three parts;

Firstly, I have researched the concept and practice of creating a natural lighting design within the hospital environment in a general sense, covering guidelines, the implications of the design for the occupants, architectural considerations, the nursing environment and hospital daylighting within a historical framework. The research enabled me to define the specific elements that create a hospital daylight design.

The second part is the resulting evaluation technique, the creation of a questionnaire by which to assess a hospital scheme.

Finally, I have undergone a study of the Chelsea and Westminster Hospital using the evaluation technique to form a conclusion as to the success of the design and the success of the assessment method.

To conclude, I sought;

a) to develop a workable method of quantifying the success of a daylight design within a hospital interior that considered the concerns uncovered in my research.

and

b) to illustrate this by undergoing an example study.

1.1 Aims of the investigation

There are many methods for assessing daylight design in general, the majority of which assess the design independent of building function.
Within these assessment techniques there are standard questions which one can apply to a natural lighting design. These questions can be applied to any building type to determine whether the daylight design is a successful one. For example, Do the occupants experience glare from the inclusion of daylight?

However, a daylight design per se can be considered successful whether the building is a church or a school if it fulfils the criteria required. i.e. desired lux levels are achieved.
Another approach is to subjectively assess a building for its architectural successes and failures in terms of use of space and flow of light through the building.
Neither methods provide a truly considered study of the natural lighting design. It is essential to consider the function of the building, as the nature and requirements of the activities within the space, the role of the occupants and times of use will effect the success of the design.

This investigation therefore intends to consider;

a) The overall building design.
b) The implications of a particular building type upon the daylight design.
c) The integration of the daylight design with the other building services.
d) How the design works in tandem with the tasks that take place within the building.
e) The human response to their surroundings.

in terms of daylight design within the hospital interior in general and also specifically within the Chelsea & Westminster Hospital.

Before creating the investigative method, I established the grounds for assessment by researching relevant aspects of daylight design and hospital design. I therefore was able to develop and expand my understanding of the complex building type in question and identify the specific design criteria it is incumbent on the architect to fulfil. The design criteria should include not only requirements for patient needs, but those of the visitors, staff and current medical standards.
The architect can consider the examples that centuries of hospital design provide to create a environment conducive to healing.

CONTEXT

2.0 A Historical Perspective of Daylight Design within the Hospital

"The outside of the building looks like a gothic castle. The hall is high, gloomy and so dimly lit that, in contrast to outside, it looks dark..." (1)
"... a flight of gleaming brass stairs rises and disappears upward into darkness. At any moment one expects to hear the pealing of celestial trumpets or demonic laughter".(2)

The design of the hospital environment, especially the inclusion of daylight, has not always been considered an important factor in the healing of the sick. The above two descriptions of mental hospitals in the last century evoke a typical image of hospitals of the period. Hospital layout was inextricably linked with church design. Wards were in the shape of a cross so that patients were orientated toward an altar with light penetrating through tall stained glass windows. In times of contagion, there were no communal wards but tiny, prison-like cells, that received no light except from grilles in the door. Hospitals at this time existed under appalling conditions and most treatments were akin to torture (Pevsner [3] mentions the discovery of patients in chains in Wales, 1853). Anaesthetics were not available while overcrowding, lack of sanitation and ventilation prevailed.

Architects of the period were not concerned with the health or recovery of the patient;
"The architecture contributes very little to making a patient well" James S. Moore [4]

It is difficult to believe that people became cured in this kind of environment. The Victorians believed that only the weak willed became sick and that comfortable conditions in hospital wards would encourage people to succumb to illness. They believed patients would recover if kept in a darkened room and it was only toward the end of the century, that a patient's physical environment and the inclusion of daylight became considered as part of the process of care. These beliefs were pioneered by "The Lady of the Lamp", Florence Nightingale.

"No ward is in any sense a good ward in which the sick are not at all times supplied with pure air, light and a due temperature" [5]

In "Notes on Hospitals" [6], Florence Nightingale wrote what could be considered a contemporary design guide for hospital buildings. She stipulated that a hospital footprint should be spread over a large area and that building walls must not be so high as to interfere with the sunlight and ventilation of neighbouring hospital buildings. She recommended a layout of a long, oblong ward with windows on both sides. The Nightingale Ward had an ideal width of 30 ft, a length of 128 ft and height of 16 ft. *(see figure 1)*. She also stipulated that windows should reach within 1 ft of the ceiling and start 2/3 ft off the floor, taking up a third of the wall space. The ward should be orientated on a North to South axis and contain a maximum of 30 patients. Nightingale also insisted the walls be painted white, preferring the ward too light than too dark and stated that while window shades could be pulled down, "gloom is irremediable".[7]

Florence Nightingale's barrack-like ward layout consisted of 30 beds arranged at right angles to the windows. For a length of time, the typical hospital ward followed this format, until in 1910, a new approach was tried out at the Rigs Hospital in Copenhagen. Here the wards were made wider, and the beds placed parallel to windows to break up the regimented arrangement. The Nuffield Study [8] assessed the traditional Nightingale ward layout and verified Percy Waldrum's 1933 report which indicated the amount of sunshine falling on a bed is twice the amount in a Rigs ward (with 70% window area) than a Nightingale ward.

Despite the general adoption of the Nightingale ward with its prerequisite of good daylight, few of the sources referred to above mention the role of daylight in the development of hospital design. Windows are described as tools of ventilation, as if the quantity and quality of the light is without significance to the hospital environment and the tasks that take place within.

Many old buildings are still used as working hospitals with little or no adaptation to modern thought on daylight design. For example, some still retain anachronistic design features. i.e. bricked up windows from the 1696 window tax evasion.
The Chelsea & Westminster hospital was built to replace five such outmoded buildings, one of which, St Mary Abbots was so dark and foreboding, it was used as a location for Hammer House of Horror films.

<u>Examples of hospital design where daylight has been considered an important factor.</u>

Conversely, there has always been a minority of designers that believed daylight was a crucial factor in the recovery of the sick. One of the early hospitals, The Asklepieion of Epidauros in 5th Century BC Athens [9], was designed so that patients were flooded with natural light and could see the sun from their beds *(see figure 2).* The ward was closed on three sides and open to the South with a row of pillars separating the patient from the exterior.

In Paimo in 1928, Alvar Aalto designed a sanatorium *(see figure 3)* along the same lines, so patients could experience direct sunlight and large amounts of daylight. At the time, the accepted medical treatment for tuberculosis was optimum exposure to sun and fresh air. The modern architectural movement also believed: "The health of every person depends to a great extent on his submission to the "conditions of nature". The sun which governs all growth, should penetrate the interior of every dwelling, there to diffuse its rays, without which life withers and fades".[10]

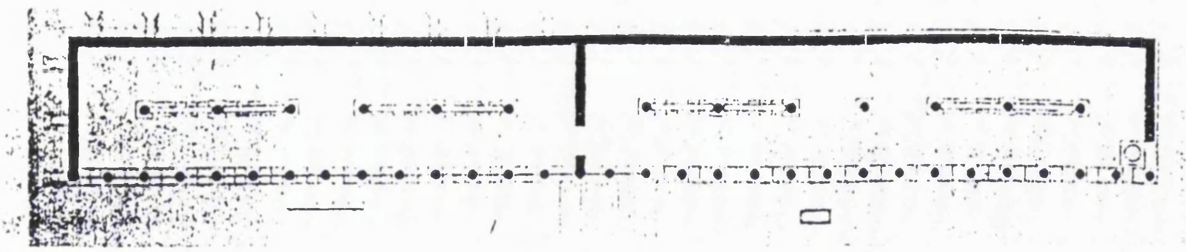


Figure 2 The Asklepion of Epidauros - Plan of ward area and portico

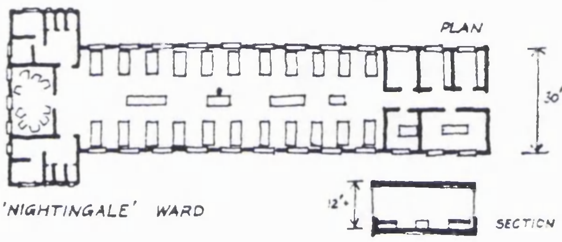


Figure 1 The Florence Nightingale Ward Layout

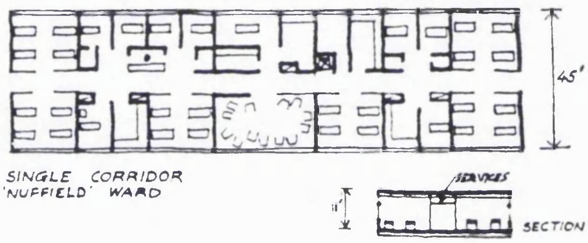


Figure 5 The Nuffield Ward

WINDOW SHAPE AND APPROXIMATE AREA		APPROXIMATE DAYLIGHT FACTORS		
		5' 0" FROM WINDOW	12' 0" FROM WINDOW	19' 0" FROM WINDOW
A	110 sq.ft	10·5 %	4·0 %	2·0 %
B	110 sq.ft	10·0 %	3·5 %	1·5 %
C	110 sq.ft	5·5 %	3·0 %	1·5 %
D	30 sq.ft	4·5 %	2·0 %	1·0 %
E	70 sq.ft	5·5 %	2·5 %	1·0 %
F	65 sq.ft	6·5 %	2·5 %	1·0 %
G	80 sq.ft	5·5 %	2·5 %	1·0 %
H	110 sq.ft	6·5 %	3·0 %	1·5 %
I	120 sq.ft	7·0 %	2·5 %	1·5 %

Figure 6 The Nuffield Study of Window Types

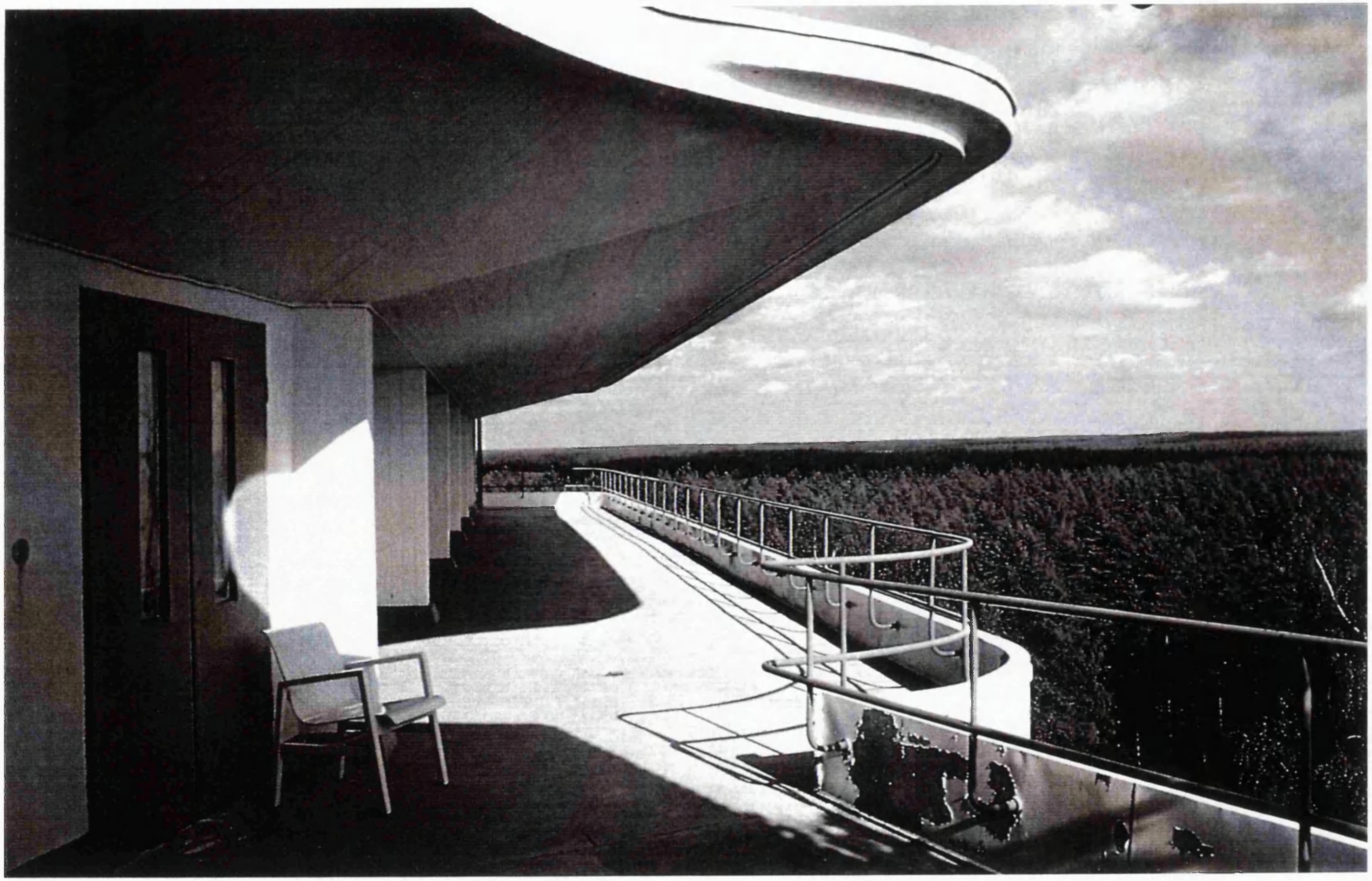


Figure 3 The Paimo Sanitorium

Aalto created a functionally zoned layout within the Paimo hospital. The building was "bio-dynamically" [11] aligned to the compass. He allocated room positions within the landscape in line with the sun requirements of hospital areas.
The patients wing was orientated south, south-east to catch the morning sun and reduce solar gains in the afternoon with south facing sun terraces onto which patients could be wheeled out from their rooms whilst still in bed. The two-bed patient rooms each had a window, with the ceiling painted darker than the walls so as to be more restful to the gaze. The electric lighting was wall mounted and shone up onto a white semicircle which was painted above the lamp, so that light reflected off the wall and ceiling onto the bed.

Le Corbusier also realised the advantages of opening up the hospital building to the beneficial properties of natural light. In his plans for The Venice Hospital *(see figure 4)*, he created hanging gardens upon each ward roof. These could be seen through skylight openings in the wards, creating an opening that allowed natural light to penetrate. Glare was prevented by filtering the light through planting. He believed the hospital of the future would use daylight to its full advantage; "The historic tradition of the hospital functioning as an asylum, run according to the medieval methods of the hands of craftsmen is finished. The hospital will now take the place which should be hers in the world of advanced technology of our century".[12]

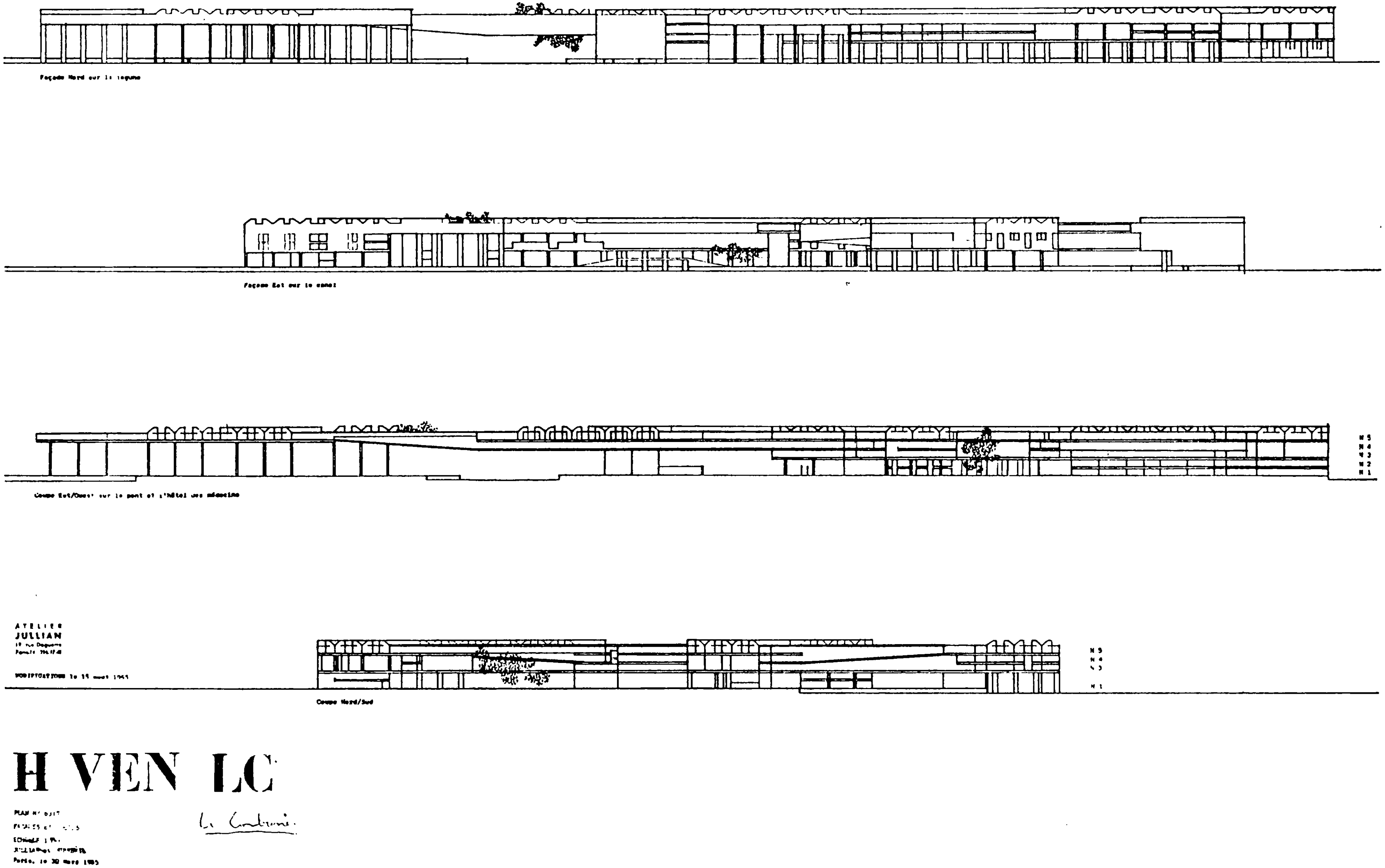


Figure 4 **The Venice Hospital**

2.1 Current Guidelines

The Nightingale guidelines were widely adopted in hospital layout for many years. The next major influence, was the Nuffield [13] study of hospital design, undertaken in 1955. It concluded that natural lighting was an important consideration in the planning of hospitals. After measuring the daylight factor in a variety of ward styles, the report rejected the traditional Florence Nightingale ward layout and decided that wards with bed groups of 4, 6 or 8 were more efficient in their use of natural lighting *(see figure 5)*. Decisions about whether wards could be 4, 6 or 8 beds were dependant on (after medical requirements had been met), the degree of daylight which could penetrate the depth of a ward.
The ward layout governed the design of the whole ward unit and hence the hospital itself.

The architecture's dependence on light was stated unequivocally in the Nuffield report. Before this most studies had been concerned solely with providing guidance on artificial lighting. After the report was published, it raised so many enquiries, that a symposium was held at UCL by the Building Research Station and the Ministry of Health in order to answer them.
One of the main points in the study argued that an excess of daylight is both unnecessary and unpleasant. The report recommended that windows be limited in size and provided with efficient shading to combat sky glare and decrease discomfort from solar gain. It suggested the best protection was the use of external blinds.
Additionally, the daylight factor within the ward should not be allowed to fall below 5 and the interior should be designed to aid the range of daylight over a room. This should not exceed 10 to 1 and preferably be nearer to the ratio of 5 to 1.
The report also took a close look at window types A-I *(see figure 6),* suggesting that the window of a ward should form one fifth to one quarter of the room size. The results [14] give a good indication of how the size and shape of the window affect daylight distribution within a room. The example room had a ceiling height of 10 ft and a width of 20 ft. The average interior reflection factor was 40% and the view consisted of unobstructed sky. The results showed that Type A windows, with a sill that stretched from wall to wall provided an even distribution of light across the room and a daylight factor ratio of 5:1. Type C with solid panels either side of the glazed area, reduced the amount of illumination at the bedheads and the amount of sky that was visible. Type H gave good light distribution characteristics. The side walls were not full height and a limited view of the sky was obtained through the high level window area from the bed positions. Type I had a horizontal baffle at the top. This effectively limited sky view from the bed nearest the window and thus reduced discomfort from glare. The window above the baffle allowed light to penetrate further into the room. The part of the window that reached the floor level made a useful contribution to increasing the daylight factor by the additional light reflected from the floor and allowed patients to see out of the ward at a low level.

Contemporary guidelines

The 1987 CIBSE applications manual on window design [15] illustrates the contemporary approach to window design. It includes design guidance for all types of windows, requirements for glazing, statutory regulations and daylight calculations.

Independent studies that research daylighting within the hospital are also available to provide guidance. At the National Lighting Conference of 1986, Mansfield, Roe & Rowlands [16] discussed the findings of a study they had undertaken. It measured daylight performance of a number of 6 bed wards within various hospitals with each ward having a different configuration of windows, rooflights and interiors. The daylight factor was measured in grid points and staff and patients were interviewed to obtain an indication of window performance. They discovered that the wards which were most successful had roof lighting and helped to create feelings of "lightness and space". The highest lighting levels they found were at the New East Surrey Hospital and reached 700-1000 lux. Staff found this too bright and stated the changes in going to lower, less well lit parts of the building were disturbing. They concluded that a Daylight Factor of 3% to 5% with a uniformity of 0.4 (minimum to average) was necessary if a space was to appear "well daylit".

The CIBSE booklet, LG2 specifically gives recommendations for lighting practice within hospital buildings, but does not advise particular daylight factors. It states the major component of lighting should be natural and briefly discusses daylight as an alternative source to artificial lighting. The recommendations concentrate mainly upon electric lighting and lux levels are suggested for all areas of the hospital. The guidelines also state that the electric installation should integrate with the daylight design, and the designer should consider that the flow, quality and colour of electric light and daylight are very different. The artificial light is primarily to supplement daylight illuminance and preserve the daylit character of a space. It also states that care is needed when choosing glass, recommending that neutral tints should be selected if colour rendering of the skin is critical. The IES technical report mentions daylight even less. It recommends a daylight variation of 3000 lux near the window of a ward to 50 lux at the back and states that it should be restricted on the face of a patient to allow maximum rest.

The Department of Health publish guidelines that relate to specific aspects of hospital design with regard to nursing and medical requirements.

2.2 The Influence of Nursing upon the Architect

"The mode of construction in hospitals is, it is presumed, to be determined by that which is best for the recovery of the sick" H. Gainsborough.[17]
Hospitals are spaces that deal with life, death and the healing of sickness. Therefore special methods of evaluation and design guidelines apply to this building type. The architect is not designing for the simple relationship of building and occupant, he must also consider the complications of nursing and illness. It is impossible for the architect to design a building apart from the society it serves. It is fundamental that this particular type of building matches up to the speciality requirements of nursing.
The architect must also consider the financial restrictions placed on the design. Hospital conditions were originally determined by the economics of charity or a voluntary hospital system. Today, within the U.K, they are subject to the limited resources of local authorities or private funding.

An architectural design for a hospital will become out of date very quickly, but the building will remain in use for long period of time. Therefore, the design of a new hospital has to keep pace with the advance of medicine, nursing, the rise in general standards of living, architectural and technological progress in all areas including daylighting. Each individual hospital will have it own medical requirements, and it is necessary that the architect should consider these, whilst attempting to avoid an institutional atmosphere.

Hospitals are complex structures due to the diverse activities that take place within them. The hospital is not just an architectural shell, but a living organism run by people for other people. It is one which is never static, the interior is filled with occupants both day and night. Therefore, the daylight design must consider the conflicting requirements of staff and patients. For staff it is a place or work and for patients, a place of treatment and recovery. The wards are not like normal living spaces. Patients are predominantly horizontal and static whereas staff are required to continually move about. Layout is normally determined by efficiency of travel for staff and patient comfort requirements and must also accommodate visitors. The ward space must be able to cope with a regular influx of extra people. The ward layout must encompass two opposing factors, long stay and short stay patients with differing requirements. For those unable to leave for long stretches of time, it is important that their immediate environment is a comfortable one. People have entered a space they are unable to personalise and contentment with their environment aids recovery. The architect has to encompass all aspects of human need when creating the hospital and the understanding of the inter-relation of mental and physical sickness and its surroundings plays a significant role in treatment.

The reception area

The entrance area must create a positive first impression. It should display the efficiency of the staff and be unintimidating to visitor or patient. Psychologically, a patient must feel that they are entering a place of recovery, not illness. From a daylighting angle, the reception space is the transitional area between outside and in and therefore it should aid the adjustment of the eyes from their exterior adaptation state.

Corridors

The corridors and circulation areas must do more than satisfy functional requirements, they must create an atmosphere conducive to patient recovery, aid orientation throughout the building and provide a palliative to the potentially traumatic ward environment.
For safety and comfort reasons, the designer should consider the adaptation of the eye as people move from room to room.

The ward layout

In terms of its potential ability to influence patient recovery, the ward layout is the most crucial design element within the building. It is in the ward, supplemented by the dayroom, that patients spend the majority of time. The more complex the ward shape is, the harder it is to provide the optimum amount of sunshine and daylight entering the building envelope. A circular layout maximises building perimeter and therefore sun and daylight availability, but increases the potential for glare. A narrow ward, situated on a N/S axis with beds on both sides ensures that at some point in the day, sun is incident on both faces of the block, and thus upon the beds. It also ensures periods of shade. *(see figure 7 for variety of ward layouts).*
Planning principles must also include visibility of patients at all times, cross ventilation and economise on maintenance needs. A ward layout must contend with the difficulty of noise, the lack of privacy and maintain a constant climate (particularly important for geriatric and paediatric patient care). In larger wards, divided into bays, light will fall off in level away from the window. Creating single bed rooms avoid this problem but can make a patient feel alone and isolated. Positioning a bed near the window to maximise daylight is not a simple solution. Although the patient has light, air and a view, the daylighting decisions must include preventative measures ensuring the patient is not subject to glare or the results of thermal loss or solar gain.
The ward space should have enough general light for circulation and cleaning within the area. Light must be evenly distributed for inspections and observation of patients to take place with ease. And, at the bedhead, task lighting must be included to minimise disturbance to others within the ward.

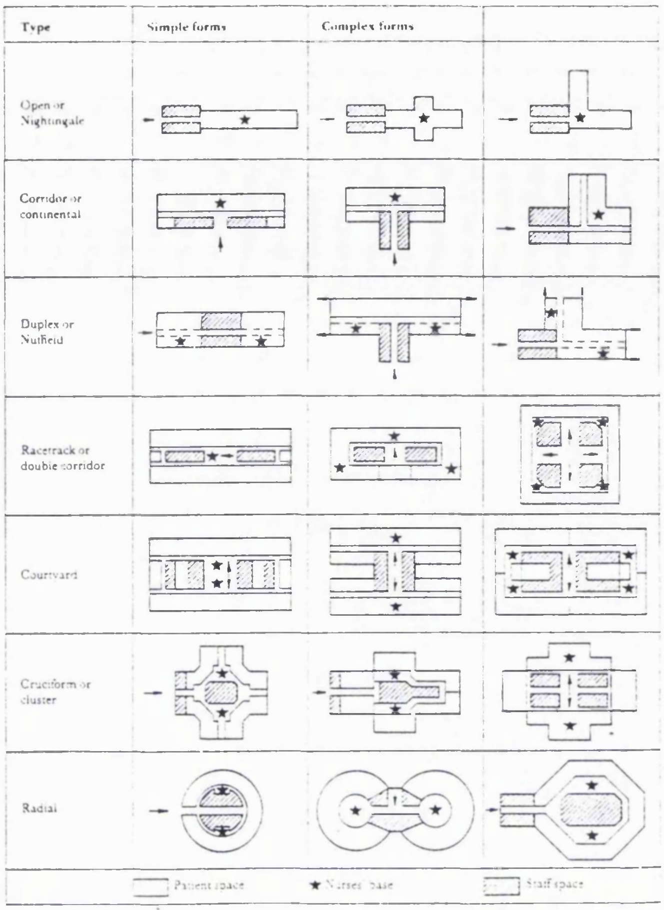


Figure 7 Styles of Ward Layout

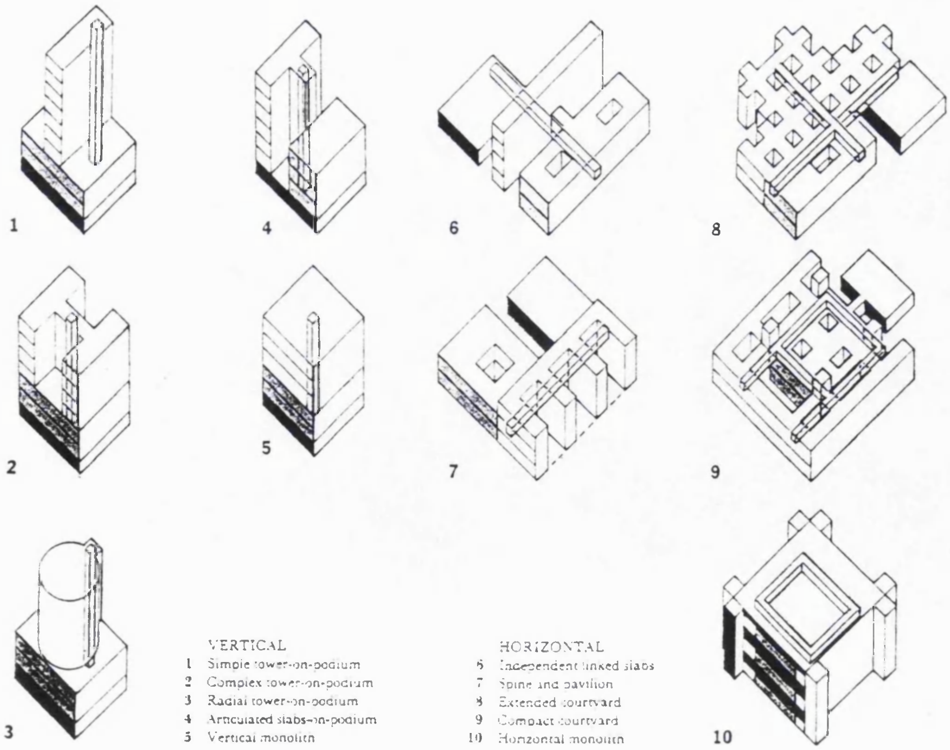


Figure 8 Styles of Hospital Buildings

The dayroom

Before World War II, a patient was not encouraged to get out of bed. The bedside chair only found its way into ward design when it was discovered chances of recovery improved if the patient sat up or moved around. Thus the dayroom was created because it was thought that patients would get up if they felt they had somewhere to go. The dayroom is an extended patient living space. It should be domestic in appearance as it is where refreshments, television and meeting visitors and other patients occur. It is a respite from the nursing space and should enable relaxation.

Colour rendering

Probably the most important factor of daylight inclusion, is the medical requirements concerned with colour rendering. Daylight is the only light that closely matches human visual response and is the source against which all other sources are measured. It is a full spectrum light and is therefore considered the best source for colour rendering and diagnosis regarding the colour of skin, eyes and mouth etc. Enough daylight must penetrate the ward in order for accurate medical judgement to occur.

Glare control

Glare is equally important as a nursing consideration as visual discomfort should be avoided at all times. The mentally and physically sick tend to be more sensitive to their surroundings. Therefore distressing areas of brightness must be limited.
The excessive brightness of the sky can raise our adaptation level and reduce apparent brightness of internal surfaces. To decrease this brightness contrast, window frames, glazing bars, and the wall around the window should be light in colour. If matt finishes are used within the ward interiors, reflections and glare will be minimised.
Deciding whether it is the patients or staff who adjust the glare control system is an important consideration. The glare indexes that are recommended in The CIBSE Code [18] apply to healthy people. It is possible that the sick have a heightened sensitivity to glare or even daylight itself and should therefore be allowed individual control over shading devices. It is also possible that among a group of patients resident in a ward, preferences for light and shade will differ. Shading should be of a design that allows as much versatility as possible and maximum daylight access where required.
Glare control in the form of curtains and blinds must be carefully considered due to their attraction of dust and its attendant bacteria. This is particularly significant in surgical wards where cross infection may occur.

Although there are specific medical requirements that must be met when creating a daylight design for a hospital, there are also fundamental building design decisions that will affect daylight inclusion into the hospital.

2.3 Daylight Inclusion within The Hospital Form

The hospital location

The location of the hospital, whether it is in urban or rural surrounds, will shape the building style and elements of the daylight design.
It is the aim of planning authorities to ensure good conditions for all buildings in the local environment, with enough daylight/sunlight on and between faces of the building blocks to enable good interior and exterior conditions. However, in an urban location, "rights to sunshine" [19] can be problematic.
"Closely grouped buildings, to provide for the manifold activity of people at home, on business or on pleasure, are the essence of the city".[20] Dense areas of building make an urban location unique, but it is difficult for the architect to maximise daylight penetration in an urban building as surrounding buildings will restrict the amount of daylight available to it. Careful allocation of areas within the building can optimise daylight inclusion.

The impact of reflective components in the surrounding buildings is an important factor, as the choice of pavement material or the colour of the opposing building can affect daylight distribution within the building. The orientation of the hospital is also crucial as the path of the sun will dramatically shade or penetrate into areas where it may or may not be wanted at certain times of the day.

The hospital form

There are a multitude of hospital building styles to choose from e.g. skyscraper versions or long shallow complexes *(see figure 8).* The form should correspond to the amount of daylight inclusion that is required.

Rooms and areas should be allocated a position within the hospital building according to their daylight requirements. i.e. The ward should receive the most daylight as adequate visibility and efficiency are needed at all times and the areas are always in use.
Spaces such as laboratories, offices and operating theatres require less daylight as the frequency and duration of use is less.

The window

Windows are the means by which daylight penetrates the building. Their size, style, orientation and method of shading are all crucial elements in determining the amount and quality of daylight entering a room. Their geometry also effects the visual impact of the buildings exterior.

The window also has a psychological and physical importance to the occupants, it does not merely provide a set quota of light to enable completion of tasks. It adds spaciousness to a room. The use of windows can increase a room's apparent size. A window provides a visual communication channel to the outside world, a source of contact. It also allows a sense of vitality, when sunlight falls into a room from a window: "Just think that a man can claim a slice of the sun...." [21]

Integration of daylight design with other building elements

The daylighting element of the hospital should be made an integral part of the design philosophy as a whole. It should work as an environmental system and integrate with other parts of the building services i.e. cooling/heating systems.

The design should not be just an understanding of the aesthetics of light and its effects within a space. It must also be concerned with the functional arrangement of spaces, the occupants comfort, visual and thermal impacts of the scheme, energy usage, integration of the electric lighting installation and a system of control. The design must also consider elements on a micro-scale i.e. task lighting.

Advantages of daylighting

The advantages for maximising the use of daylight within an interior are numerous. On a purely aesthetic level, a daylight design can have a powerful visual impact. People have a preference for daylight which is based in a "subconscious recognition of the quality of the light".[22] Daylight is a dynamic quantity. It is constantly changing in colour (daylight is toward the blue end of the spectrum in the morning and toward red at night) and intensity and can therefore provide a building with a living quality. Boredom can evolve within spaces that have large uninterrupted areas of uniform brightness. Daylight can provide a stimulus of variety that artificial light cannot. When daylight penetrates a structure, our sense of matter changes; "The material and immaterial no longer oppose each other but enter into an exchange".[23]

As the quality of the light is so good, less quantity than electric light is required to perform a task. Therefore, daylight is an energy saver, also reducing electricity demand in general and easing the building through peak times. Although daylight does not completely eradicate the need for electric light, it reduces the demand in the day time. It also decreases Co^2 emission into the atmosphere and makes running costs more economical.

There are many mistaken assumptions that are made regarding the maximising of daylight within a building design. It is often assumed that daylit buildings must have larger expanses of glazing, that the windows must have clear glazing to maximise transmission and that the maintenance must be greater. However, it is more important within a naturally lit building how the glazing is distributed and the glazing types to choose from are expansive. Maintenance can possibly be more extensive, but most large buildings have re-lamping periods for the electric lighting, and cleaning of blinds etc. can be done at the same time. The general maintenance procedure should be considered as part of the initial design.

Disadvantages of daylighting

The use of windows can create problems for the architect, as he seeks to integrate them within a building shell. They can cause glare for the occupants as the eye is naturally drawn to areas of high brightness. Therefore it is essential that daylight sources have a method of control, some kind of flexible shielding from the direct source.
Types of daylight control are numerous, but the choice must suit the users needs and the buildings maintenance schedule. Throughout history, varied methods have been used to protect the occupants from harsh daylight. Daylight control has always been a consideration in hospital design. For example, in 1788, the St Charles building within the famous hospital, the Hotel Dieu, Paris used wet sheets over the windows to filter light and prevent discomfort from glare. The Greenwich district hospital, completed in 1969 [24] uses pneumatic blinds that are lowered by solar sensing devices when thermal energy incident upon the window exceeds a predetermined level, again aiding glare prevention.

Windows also pose problems with creating thermal balance within the buildings interior. Approximately 55% of thermal energy in solar radiation passing through a window is in the visible spectrum. So without careful control, daylight apertures can be the main culprit for loss of heat/solar gain.

The interior

Lastly, the character of the interior must be considered. The internally reflective components of a room and the room proportions will contribute to how the daylight will behave within a space. The floor is the most important in determining the daylight levels, then the ceiling and finally the walls. Colour, texture and contrast of surfaces and furniture must be designed so that areas of shade and light are balanced and control the daylight in the required manner.

A successful daylight design will consider not only how the light will be shaped within a building shell, but also how the occupants that will live and work within the spaces will react to the design.

2.4 The Implications of Daylight upon Building Occupants

"Light is the key to well being." [25]
"Light is an elixir vitae, our bodies are calibrated to the oscillations of the sky and the patterns of luminous change." [26]
"Most of us unconsciously exhilarate around places alive with light." [27]
"....melodies of passing light are essential to our sense of feeling alive." [28]

Writers have always tried to express the therapeutic effervescence of light and its effect upon our state of mind. Walt Whitman wrote that the sun brought on "the feeling of health" and that light is vivifying, "It gives our surroundings a pulse and a soul".[29] Buildings become rejuvenated or more possessed of life when radiant with natural light. All manmade structures modulate light in some way and thus it is necessary to understand the implications of daylighting upon building occupants.

The human response to natural lighting is subjective and can not be measured in absolute or objective terms. Light is crucial for our physical and mental health. Humans are phototropic by nature and crave light for efficiency in many aspects of mind and body.

The window

Stone [30] states that the human response to the interior environment and light has its roots in evolution. We acquired our "biological identity" [31] living under the naked sky attuned to the phases of the sun and moon and the changing seasons. Human visual satisfaction with their environment originates in basic brain systems that respond to environmental signals providing information about our security. Windows facilitate our access to critical information about the outside world. We also derive pleasure from the exterior visual stimulation. Any interior environment requires constant change and variety of information for healthy mental functioning to be achieved. The window provides these by virtue of changing light patterns and the information content of the view. The brain's information system, the alerting system (where sensory stimuli help to sustain brain alertness), and our bodily rhythms (i.e. sleep and digestion) are all affected by visual inputs from our environment.

Light affects our emotional well being as well as our physical health. Emotional well being is controlled in the brain by the limbic system. There are "deep emotive reverberations between atmospheres and our feelings".[32] and any form of visual sensory deprivation effects our behaviour, our feelings and reduces mental efficiency. People therefore have a psychological and physical need for windows. The human preference for daylight means that its inclusion in a building is essential.

Studies on the effects of windows

In 1970, Ruys performed a study of female office workers [33] and found that the majority were unhappy with their work environment. This dissatisfaction was rooted in the amount of daylight they had access to. The lack of natural light in their work environment caused feelings of isolation, claustrophobia, depression, monotony, boredom and tension. On the physical side, headaches, fatigue, eye-ache and insomnia were prevalent. Symptoms of Seasonal Affected Disorder i.e. sleeplessness, lethargy, carbohydrate craving and depression can also occur in environments with a majority or total of artificial light.

In general, many hospitals are similar to offices, with a large percentage of internal rooms being windowless. Kornfield and Wilson [34] studied Intensive Care Units and found that patients were 40% more likely to have post operative delirium in a room with no windows. Keep (1977) worked for a year in a windowless intensive therapy unit and noted that the mental state of patients dramatically improved following their transfer to daylit rooms. Staff were also affected, and a decline in morale, absenteeism and resignations were evident. He concluded that "such a design is unacceptable and that no further units of this type should be built".[35]

The Yale Studies in hospital function and design in the early Seventies issued questionnaire cards to patients as they left hospital. One of the questions was: "What do you like most about your room?". The answer by men and women across the social classes, was the windows. One woman stated the window opened the whole room to the outside and made her feel less like a prisoner. Most patients spent a great deal of time looking out of the windows. The placement of the bed in relation to the windows determined patient opinion of the windows themselves. In rooms where angled beds prevented patients from seeing out of the windows, the same windows were rated unsatisfactory. Fixed windows frustrated many patients "If I see a large pane of glass, I want to be able to open it".[36]

Daylight provides a sense of cheerfulness and therefore has a highly positive impact. Sunlight is also found to be desirable but the desire varies by building type. In Longmore and Ne'man's 1973 survey of building occupants [37] they discovered a preference for sunlight in dwellings and hospital patient rooms of 90% compared to a preference of 73% for office workers. Conversely sunlight was considered a nuisance by 52% of the hospital staff questioned. It cannot be taken for granted that sunlight or daylight is welcomed by everybody although the majority of people require its inclusion within a building for their environmental contentment.

Verifying the benefits of daylight

Detailed research on the beneficial influences of daylight upon the sick has yet to be verified in scientific terms. Phillips [38] raises some interesting questions in his dissertation which question the automatic inclusion of maximised quantities of daylight within the hospital environment. They are as follows;

1 How much daylight is required to have an effect on the recovery time of patients? (Daylight factors vary from 0-100%, so there is presumably a point when the levels cease to have an effect on recovery.)
2 Is the recovery time of a patient dependant on the daylight factor in the space? Could the same effect be achieved through daylight presence in the ward but not in the patients locale? Does the patient need to see or merely experience daylight?
3 Is the improvement in recovery time associated with view rather than daylight?
4 Is the recovery improvement related to the spectral composition of daylight, its intensity or the dynamic nature of both in the daily daylight cycle?
5 Could the same results be gained using artificial light with a dynamic control system using higher intensity, full spectrum lamps?

These questions need comprehensive research so that we can fully understand the nature of how daylight affects those who are ill. Consequently, medically valid guidelines could be created regarding the use of daylight within the hospital interior.

2.5 Colour in the Hospital Environment

The interaction of daylight and colour can also help to shape the hospital environment and aid the healing process.
In the DHSS booklet [39] about colour application in hospital interiors, the following objectives for use of colour are made:

1 To make the hospital a cheerful place, thus increasing the patients confidence in the staff and the efficacy of the hospital.
2 To create a pleasant working environment for staff and to aid their efficiency as they carry out duties.
3 To ensure that dirt can be seen easily.

The use of colour is essential within the hospital interior. It provides visual stimulus and can assist the lighting with the colour of surface affecting the amount of light seen. Curtains, the bed linen and the furniture all play a part in the psychological reaction to our surroundings.
T Gimbel [40] discusses our psychological reactions to colour. Red signifies alertness, presence, power and stress, green makes us feel balanced or neutral. Gimbels' research suggests the use of blue lowers our blood pressure and symbolises peace, calm, relaxation, sleep and laziness. This indicates that some colours have a "healthy" impact with blue being a preferred choice for hospital interiors. There are of course diagnostic considerations when choosing the colour of an interior i.e. Will it affect colour rendering of the skin?

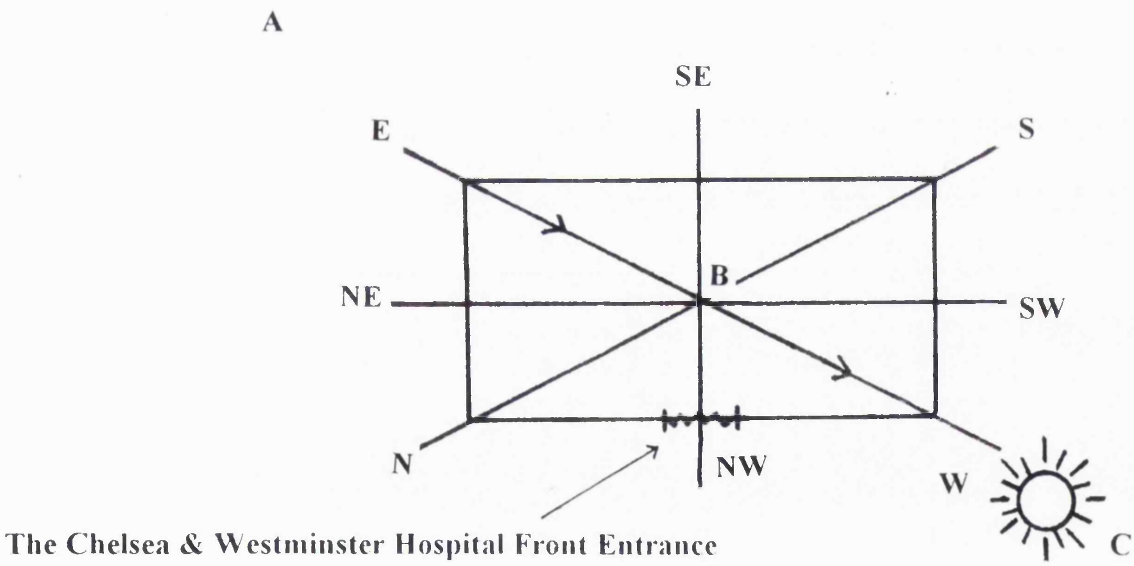
The universal application of colours throughout a building such as white, cream, pale green and grey can create a monotonous rendering of surfaces by the daylight. An element of contrast needs to be introduced to provide visual variety i.e. strong colours broken up with neutral colours (Mondrianesque). However, in a long stay ward a high contrast of bright light and darkness would be tiring. The opportunity to use strong colours and textures is more acceptable within the dayroom space.

The natural pattern of daylight can be rounded out by the colour of surfaces. Shaded areas can be painted white. Partially shaded areas, a colour of medium reflectance and well lit areas, a colour of low reflectance. Colour can balance a space or it can be dramatic, controlling our attention, and thus distracting from glare.

Florence Nightingale in "Notes on Nursing" [41] observed the "effect in sickness of beautiful objects" and that the "variety of form and brilliance of colour in the objects presented to patients have a powerful effect" and can be "actual means of recovery". She recommended works of art be hung in the hospital, recognising the need for visual stimulation. Where there are no windows but the quality of environment is important, works of art can provide the same benefits that a view does. Adopting this theory, Joe August, founder of Healing Environments International, after research into stress reduction alternatives for speeding patient recovery, created " bedscapes" [42] in 1984. He discovered that visual escapes to the outdoors were welcomed by the bedridden and concluded that biophillic environments (open spaces with no foreboding elements in the foreground) are the most restorative images. He therefore developed a new product, 4 x 5 ft high resolution photographic murals of nature scenes (i.e. beaches or mountains enhanced with sound), that can easily be attached to a hospital cubicle curtain *(see figure 9)*.

Le Corbusier worked on a similar principle in the designs for The Venice Hospital. Within each ward, an individual patient has a "Unite Lit" at his disposal. This is a 3m x 3m unit with movable panels that may be closed up for privacy or left open for visual stimulation. Above each unit is a glass opening (3m x 1m). Natural light pervades the aperture and reflects off a curved wall in front of the "Unite Lit". A coloured panel gives colour to the reflected light that varies in intensity throughout the day. Each panel has a different colour, creating variety for each individual patient. The design concept was to provide control over and soften the varying intensities of daylight. The variation of hue was correlated to the psychological importance of colour on the spirits of patients.

Figure 9 A "Bedscape" Curtain



A Morning sun
B Midday sun
C Evening sun

Figure 13 The Sunpath around the Hospital Building

METHODOLOGY

3.0 Introduction

The information and ideas in Parts 2.0 - 2.5 helped me to develop an understanding of daylight design within the hospital environment. Each section generated a set of questions that would enable investigation of the concerns raised in Part 2 when applied to an existing hospital daylight design. Part 3.0 is the resulting evaluation technique. The questions have been grouped together in areas that respond to those set out in the aims of the investigation. The method consists of a "checklist" of criteria the design needs to fulfil in order to be considered successful. It enables the user to perform an investigative study into various areas of the hospitals architecture and its inherent daylight design and to conclude whether it is successful or not.

It allows the evaluator to assess different areas of the design, the buildings daylight requirements and to question occupants, engineers, and the architect and consider their success in the process. It should simply be used in the style of a checklist, allowing the evaluator to record information about the design in an ordered manner. The data that is collected should then be analysed with respect to the concerns raised in Part 2 and a conclusion formulated.

3.1 Evaluation Technique for Assessing Daylight Design within the Hospital Interior.

BASIC INFORMATION

1 Consider the function of the building - Is it a particular type of hospital?

2 Which spaces are singled out for detailed assessment?

3 What are the nature or requirements of activities within the chosen spaces?

THE BUILDING DESIGN

1 What is the latitude of the site?

2 What is the orientation of the building?

3 Consider the neighbouring buildings and their impact upon the building under assessment i.e. overshadowing.

4 Consider the Exterior Reflective Components. i.e. the surrounding buildings and pavement etc.

5 Is it located in an urban or rural locale?

6 How does the sun move around the building?

7 What is the building style?

8 Consider the building layout and the functional arrangement of spaces within it.

9 What were the initial daylight design decisions taken by the architect?

10 Have they been followed through to completion?

11 How does the design operate?

12 Is it successful?

13 What are the physical conditions within the spaces? i.e. temperature and seasonal changes. Is thermal balance achieved throughout the hospital?

14 a Has the architect tried to use the advanced technology available to create a modern design within hospital?

15 Can it accommodate medical/architectural change?

16 How does the daylight design integrate with the building design?

17 Is it successful?

18 How does the daylight design integrate with the building systems? i.e. heating/cooling.

19 Do the combinations work?

20 What glazing types/roofing material have been used?

21 What is the transmission of materials used?

22 What maintenance difficulties could occur?

23 Has there been an attempt to include sunlight penetration within the building?

CONTROL SYSTEMS

1 What kind of system of daylight control has been introduced to the building?

2 Who controls the system? Can individuals control the amount of daylight entering their individual space?

ENERGY CONSIDERATIONS

1 Has daylight been maximised within the hospital? Is the building energy efficient?

2 How does the daylight design affect the running costs of the building?

3 Has energy saving been considered in the overall hospital design?

THE ARTIFICIAL LIGHTING DESIGN

1 What is the electric lighting installation like?

2 Does it integrate successfully with the daylighting?

3 Consider the nightscape lighting and the differences with the daytime appearance of the hospital. Are they compatible?

THE WARD LAYOUT

1 What ward layout has been chosen and why?

2 Is it successful in terms of daylight distribution?

3 How many beds are within each ward?

4 How are the beds positioned within the space?

5 Where are the windows positioned within the ward?

6 What kind of appearance do the windows have from the outside and the inside? What is there shape/size/percentage & relationship to the room.

7 What colours are used in the ward interior? i.e. ward furniture/curtains.

8 How is colour rendering effected?

9 Is there likely to be any glare within the space?

10 How is it controlled?

11 What are the estimated interior reflectance factors?

SPECIFIC AREA QUESTIONS;

THE CORRIDORS/TRANSITION SPACES, THE ATRIA & THE RECEPTION

1 What colours are used in this space?

2 How is the adaptation of the eye dealt with?

3 Is there likely to be any glare or visual discomfort within the space?

4 How is it controlled?

5 What is the contrast/brightness regime within the area?

6 What are the estimated reflectance factors within the area?

7 What is the character of the interior like?

8 How is colour rendering effected?

THE HUMAN ELEMENT

1 Is it possible to gather opinions of people who work and stay within the spaces? What are their impressions of the daylight within the space?
A subjective view of response to surroundings in valued.

2 Is there any dissatisfaction with the daylight design by the staff and patients?

3 Consider the occupants environmental comfort.

4 Are there factors to encourage the healing of the sick?

5 Is there a view? If so, what does it provide? i.e. timescale/activities/interest

6 What is the general atmosphere within each space? i.e. cheerful/relaxing/claustrophobic etc.

TASK CONSIDERATIONS

1 What are the roles of the occupants?
a) the patients
b) the staff
c) the visitors

2 At what times are the spaces in use?

3 Are there particular times when the demand for light within the spaces alters?

4 On a micro-scale, how is task lighting dealt with?

The assessor should also include elements of other methods of daylight assessment.

1 The use of a camera to perform a photographic study of the hospital under question. This will provide a visual record of the effects of daylight within the interior.

2 A photometric evaluation of the spaces under discussion to record light levels, light distribution or daylight factors. This can be done using computer methods, manual calculations, or taking readings within the space.
nb. Remember to observe and note down sky conditions.

RESULTS

4.0 An Example Study; The Chelsea & Westminster Hospital

This section details the data about the hospital that has been collected from the implementation of the evaluation technique. There is an element of analysis and conclusion incorporated in the answers to the study. A division of results, analysis and conclusion was found to be an inappropriate way of displaying the findings of the study considering the checklist method used. As "evaluation" means to assess or appraise, a report of the investigation that integrated considered comment with straightforward informative data was deemed to be the least confusing and uncomplicated method of imparting findings.

The disadvantages of recording results in this manner are discussed in Part 5.0.

Introduction

The capital city has always set an example by building hospitals such as St. Thomas (founded 1173), St. Barts (1123) and The Bethlehem Hospital (1696) which through time have found renown. The City & Westminster hospital follows this tradition. It has been described as a "celebration of architecture", and displays the "splendour of a man made building" [43] *(see figure 10)*. It is situated in the Fulham Road, West London and was designed by Shepard Robson Architects. It opened in 1993, completion costing 206 million pounds.

It is unique in the fact that it acts as a gallery space for up and coming artists and established masters as well as being a centre for nursing. Various patients of The Chelsea & Westminster Hospital have been cajoled into contributing to the hospital walls, and some artwork within the building is from the original hospitals it has replaced.

Basic information

The hospital is part of the National Health Service and therefore caters for a variety of minor and major illnesses. There are facilities for operating, teaching, intensive care and patients with AIDS. There are 580 beds in total within the hospital and the provision of a hotel for visitors that have reasons to stay upon the premises.
The spaces within the hospital that are singled out for detailed assessment are the ward areas, the atria, the corridors and reception space as they are frequented more and for longer periods of use.

Figure 10 The Chelsea & Westminster Hospital

The nature of requirements within;

a	The Reception are;	i)	To provide a positive first impression
		ii)	To create a comfortable transition phase from the exterior to the interior
		iii)	For visitors to make enquiries and to orientate themselves
		iv)	To allow building security to function efficiently
b	The Corridors	i)	To aid orientation
		ii)	To help the recovery of patients
		iii)	To allow a means of travel between two points
		iv)	To allow patients/staff to move safely between areas
c	The Atria	i)	To provide respite from illness for visitors/staff
		ii)	To generate a view
		iii)	To create areas where people eat & drink
		iv)	To perform as a gallery space
d	The Wards	i)	For the task of nursing
		ii)	To allow patients to live, sleep & rest
		iii)	To enable visitors to fit into the environment

The overall building design

The latitude of the site is approximately 51°30' North and the hospital is orientated on an axis of almost North to South. The Fulham Road elevation faces North West. Hardly any major overshadowing upon the hospital occurs. All the buildings that surround the site are much lower in height, the majority being domestic residencies. The hospital rises out of the site and appears to overshadow the surrounding buildings itself *(see figure 11)*. As the building primarily relies on toplight, no shadowing problem is caused by other buildings. The buildings surrounding the hospital are all quite small in comparison and the majority have pale finishes. The other shops and houses have surfaces of white, grey and yellow brick. The pavement and the road are grey. Therefore it is likely that they will play only a small part in reflecting light back into the hospital interior.

Shepard Robsons' original plan for the exterior was abolished to ensure the hospital fitted in with St. Stephen's and the building between the two. From the outside, it is an uninspiring building and it is not immediately evident that it is a hospital *(see figure 12)*. The building is located within a small and densely occupied urban area. Therefore, it is difficult for the architect to maximise daylight usage. It is achieved in this example by accessing toplight, the brightest available light from the zenith of the sky and channelling the light into other areas of the building. The sun primarily enters the building from the top

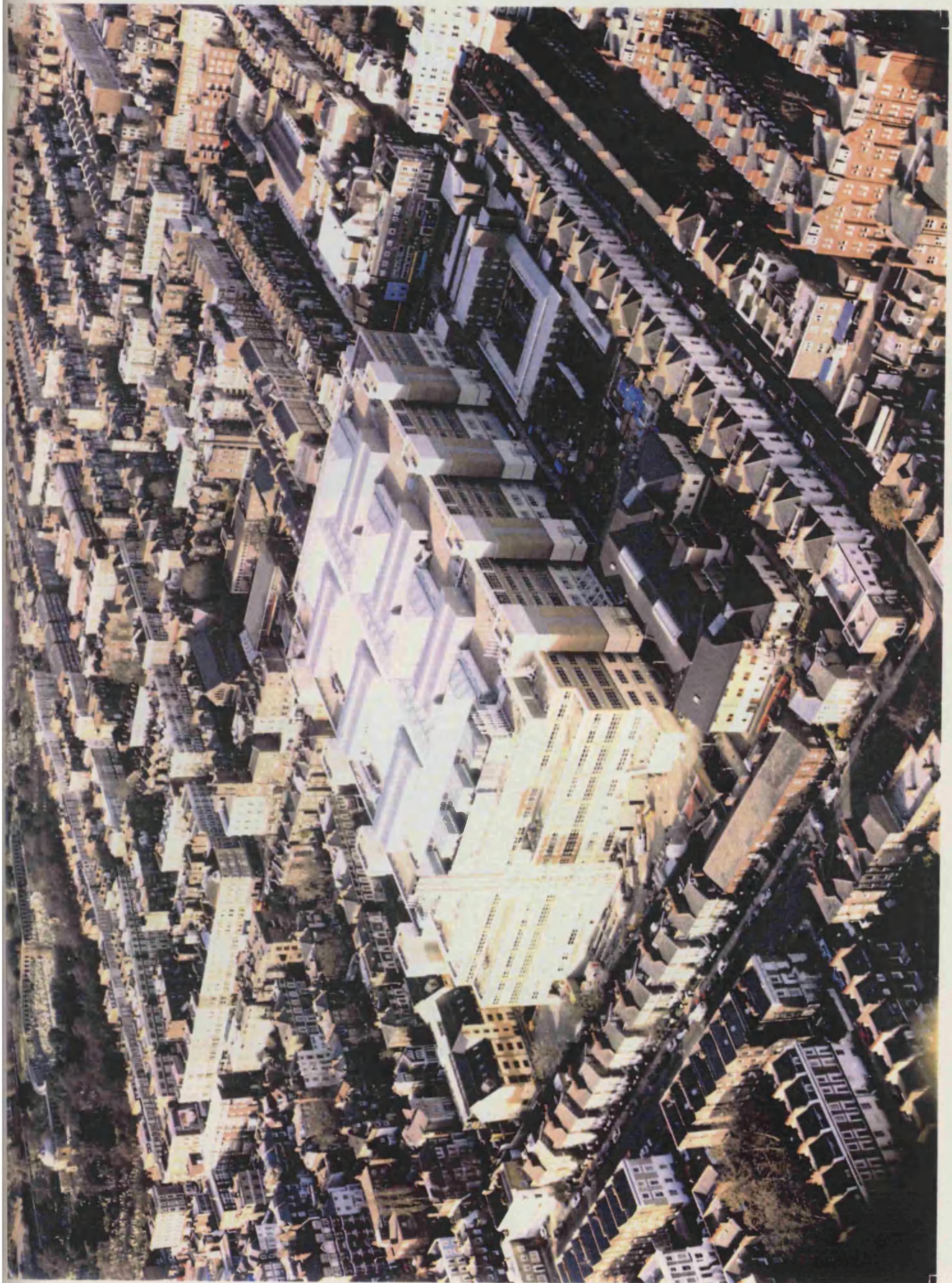


Figure 11 An Aerial View of the Hospital

Figure 12 The Exterior of the Hospital

of the envelope, where it is prevalent for the middle portion of the day. The sides of the building receive less direct sunlight as access is limited especially at times when the sun rises and sinks *(see figure 13)*.

According to Tatton-brown [44], the building style is known as a "Horizontal Monolith". It is not a complex shape and is in the form of a rectangular block that rises solidly out of the site.

The idea of building upwards means that nursing areas can be located on higher levels and therefore access higher sky intensities and increased amounts of daylight. The hospital has a total of seven storeys. A main atrium runs along the middle of the building with three ante-atria each side of the central space forming light wells at the centre of the wards and administration spaces. The upper floors are accessible via two lift cores made partly from glass *(see figure 14)*. This allows the user to see out and the effect of a large open space is undisturbed.

The architectal decisions regarding room allocation to floors and areas were primarily due to medical planning, not availability of light *(see Appendix 2)*. The nursing areas are located on the periphery of the hospital and the clinical and support zones on the inside. This enhances daylight penetration. All patient bedrooms and intensively occupied spaces have access to natural light, either externally or from the atrium. The six bed wards are located on the external perimeter to maximise the benefit of daylight in the relatively deep rooms and to give more views to the exterior. Whereas, the single rooms are located on the interior overlooking the atrium. Offices, teaching zones and building management i.e. canteen are located on the lower floors. Patient spaces are given daylight priority.

Shepard Robsons' general belief is that conceptual and detailed design should aim for clarity. Therefore they wanted to design a building that looked modern and simple *(see figure 15)*, "only the clean lines of the skeleton & muscle show" [45] and to create a space that did not essentially look like a hospital. They wanted to design a community building that encouraged people to come in even if they were not using the hospital itself.

The architects' had to develop the site right to its edges, so creating a covered central atrium allowed them to maximise utilisation of the space available. The main principals underlying the atrium concept were to create a major public space as a focus for the hospital and to contribute to the energy efficiency of the building. They also wished to create a gallery space within a working environment.

These initial aims seem to have been carried out. The building does not appear to be a hospital at first glance, it has a small, discrete entrance on the Fulham road among a row of shop units. It is only the signage and perhaps the welcoming canopy that give the building away. However, this means it is not an intimidating building to enter. White lines painted on the floor lead you in and once past the reception the central atria opens up like a shopping arcade with differing levels, escalators and a large fish tank. The ground floor is a semi-outdoor environment with seating areas, piazza cafe areas, planting and works of art to view. It appears almost street-like with several independent buildings i.e. the chapel placed in the centre of it. The main space is white and therefore provides a neutral background, a naturally and evenly lit gallery.

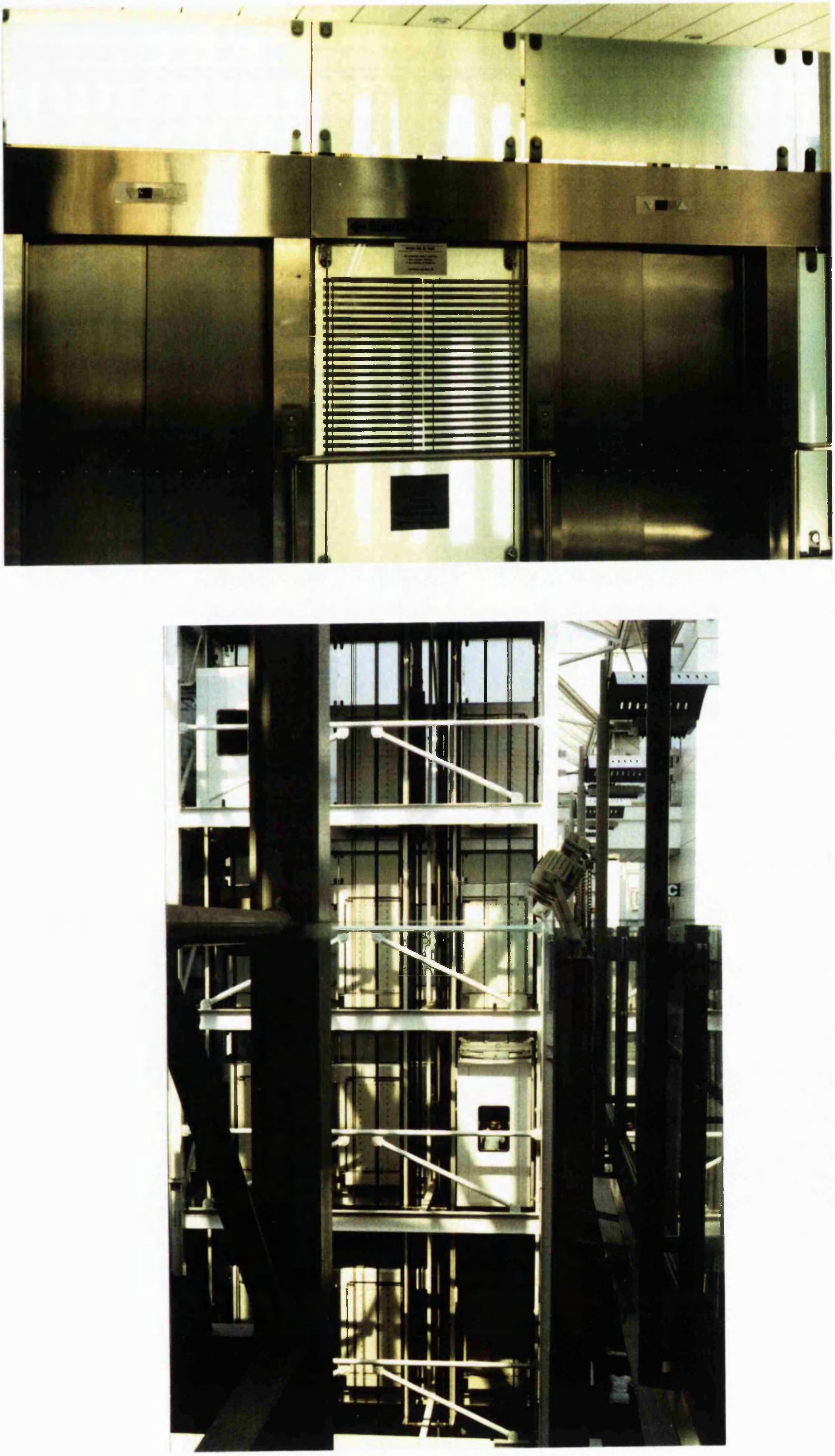


Figure 14 The Lifts

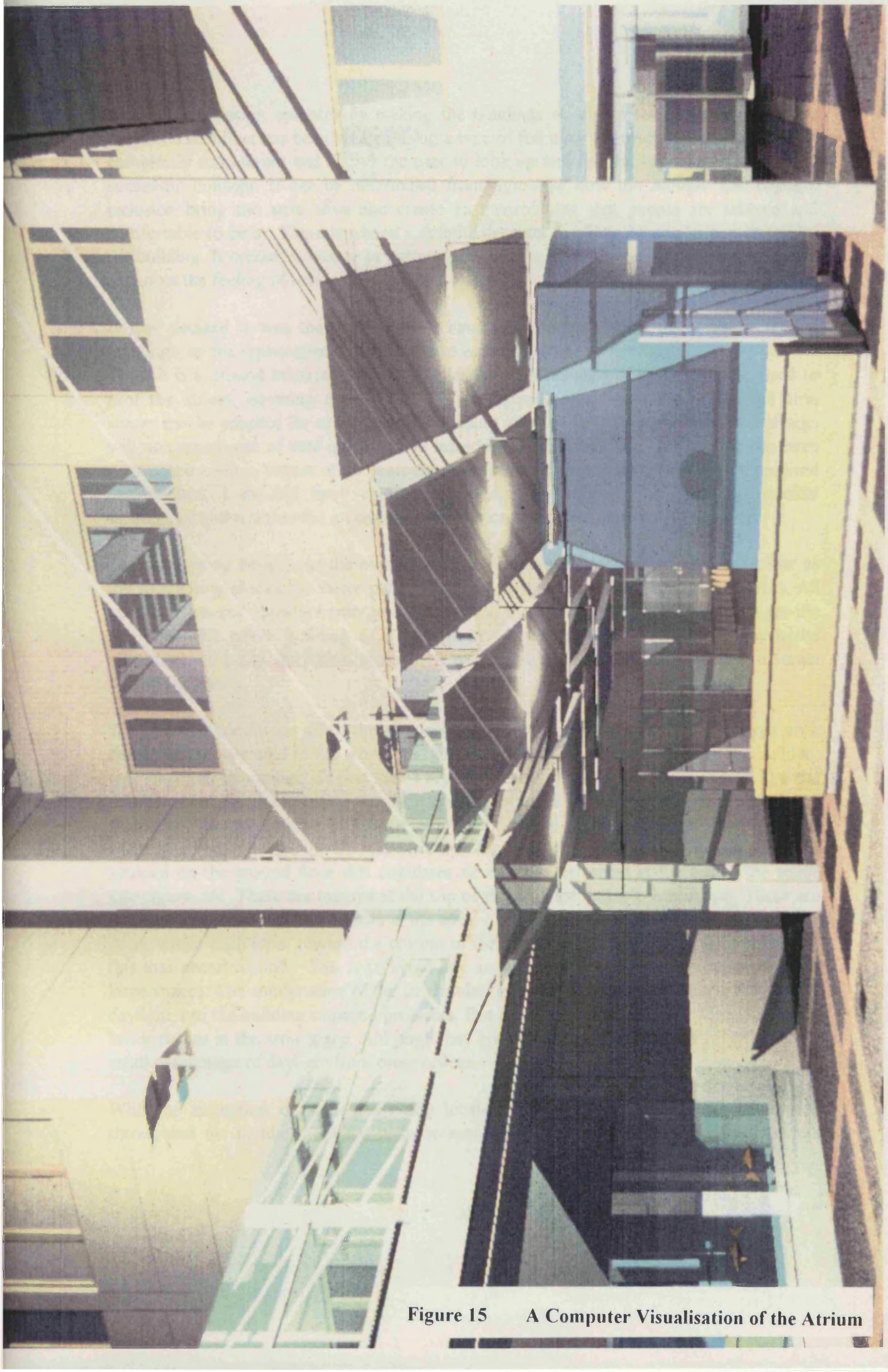


Figure 15 A Computer Visualisation of the Atrium

The daylight design operates by making the buildings interior main space appear to be outside. This effect has been created using a type of foil over the roof area which is almost completely transparent and allows the user to look up and see the sky. This is an entirely successful concept. It can be determined from *figure 16* how the sunlight and daylight inclusion bring the atria alive and create an environment that people are relaxed and comfortable to be in. There has been a definite decision to allow the sun to penetrate into the building. It creates a variety of patterns and effects upon the plain white walls. It also enhances the feeling of being outside.

It was decided it was more efficient to have one modern rather than five outmoded buildings, so the replacement building had to embrace recent technology.
Thus, it is a ground breaking project. The largest ever expanse of EFTE foil was used to roof the atrium, covering an area larger than Harrods *(see figure 17)*. The large atria spaces can be adapted for other uses in the future and due to the simplicity of their design will not appear out of date quickly. The material that has been used for roofing has been guaranteed a life in excess of 40 years *(see appendix 3)*, so no major refit will be required before then. I do not have enough knowledge to comment on changing medical technology and whether the architectural design can accommodate it.

The daylighting design and the overall building design are inseparable from each other as the daylighting shapes the major public spaces, which in turn shape the patient spaces. All nursing areas and corridors emerge or pass round the centre. The large daylit atria are the focus for the whole building as a garden or courtyard would be and also have the advantage of being attractive areas to travel through or sit in whatever the external conditions are.

The external conditions affect the physical conditions within the hospital. The large atria can get extremely cold in the winter and infra red heaters were installed after the building was inhabited to combat this problem. They are located at the bottom of each atria in areas that are used for such events as the gathering of sales representatives or blood donor sessions. Thermal balance is less of a problem in the warmer months due to an air extraction system at the top of each atria that also brings in fresh air. A venting system is situated on the ground floor that circulates air which is extracted at the top of the space *(see figure 18)*. There are louvres at the top of the atria for variable ventilation. These are automatically controlled by sensors in the atria.
Also, within each atria, toward the bottom of the space the walls are lined with horizontal fins that absorb sound. This is to avoid any acoustic build up that might occur in these large spaces. The combination of the air circulation within the atria and the transmission of daylight into the building cause no problems. But it seem as if the acoustic "fins" shade the lower rooms in the atria space. Although they are perforated, it appears as if they block a small percentage of daylight from these offices.

With the exception of some externally located rooms, single glazing has been used throughout the building. Special purpose spaces i.e. operating theatres and stair towers

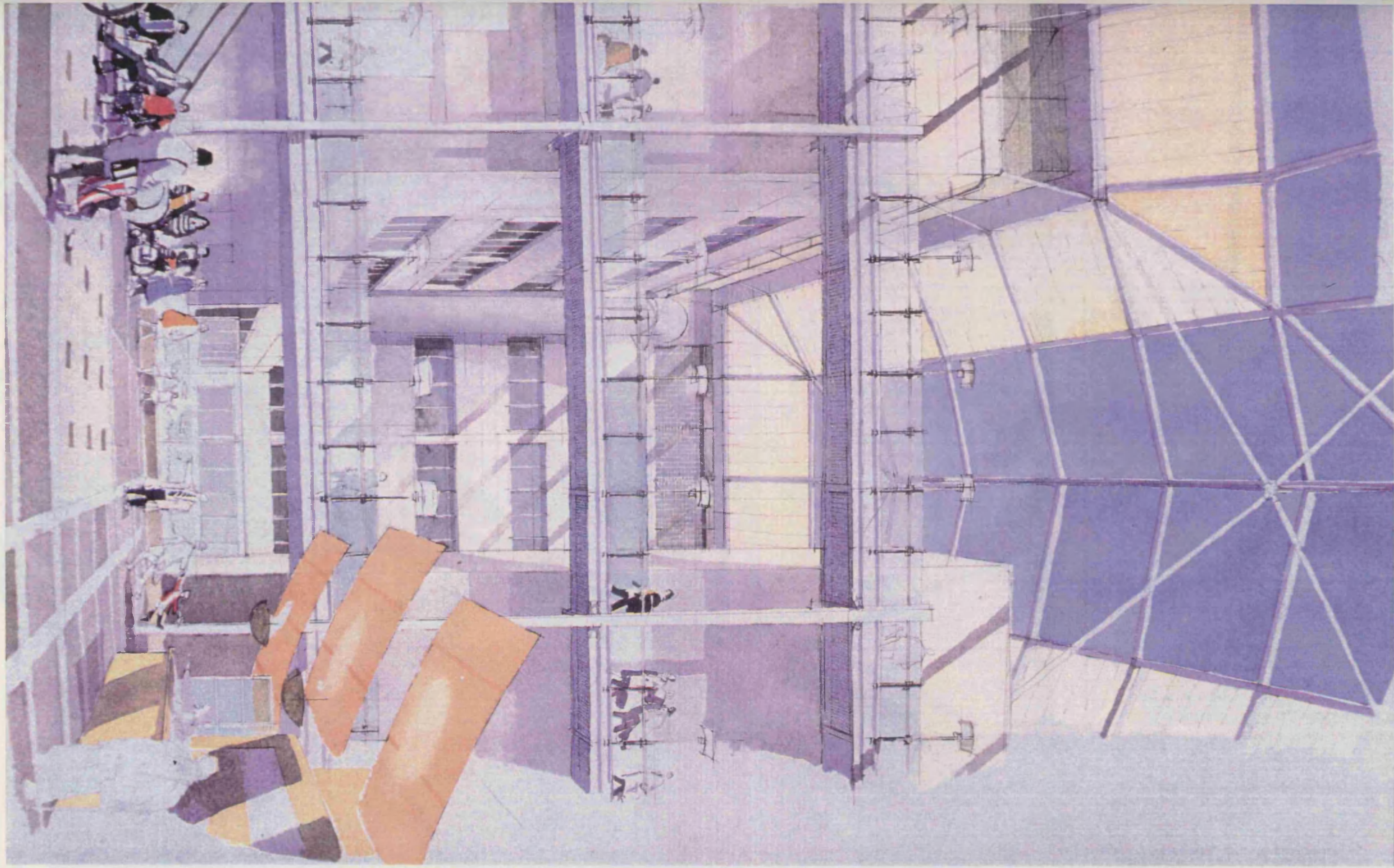


Figure 16 An Artists Impression

Figure 17 EFTE Foil Roof

specified double glazing. The semi-translucent skin over the central space of the hospital is covered by pneumatic cushions comprising of layers made from EFTE (Ethylene Tetra Flouro Ethylene) foil *(see appendix 3)*. The transmission factor of the single glazing is 80%. The foil membrane roof transmits 95% - 97% of total light (380 - 780 nm) and 83% - 88% across the ultraviolet range. The triple layer foil membrane forms highly insulated cushions that are kept inflated by a constant stream of air fed through the extruded aluminium framework. Unlike fabric structures, ETFE foil is an extruded material. This means that the roof surface is extremely smooth. The smoothness coupled with ETFE foils anti-adhesive properties means that the surface does not attract dirt, and any build up is washed off when it rains. ETFE foil roofs never need to be cleaned externally. Internally foil surfaces are usually cleaned on a 5 - 10 year cycle depending on the dirt in the internal atmosphere. This usually means that expensive internal access equipment is not required. The interior windows require cleaning 2 - 4 times a year and provision is made for a cleaning platform to be suspended within each atria. Should an ETFE foil cushion become damaged, the panel can easily be replaced from the outside with no internal access being required. Small repairs are easily effected to the foil in situ.

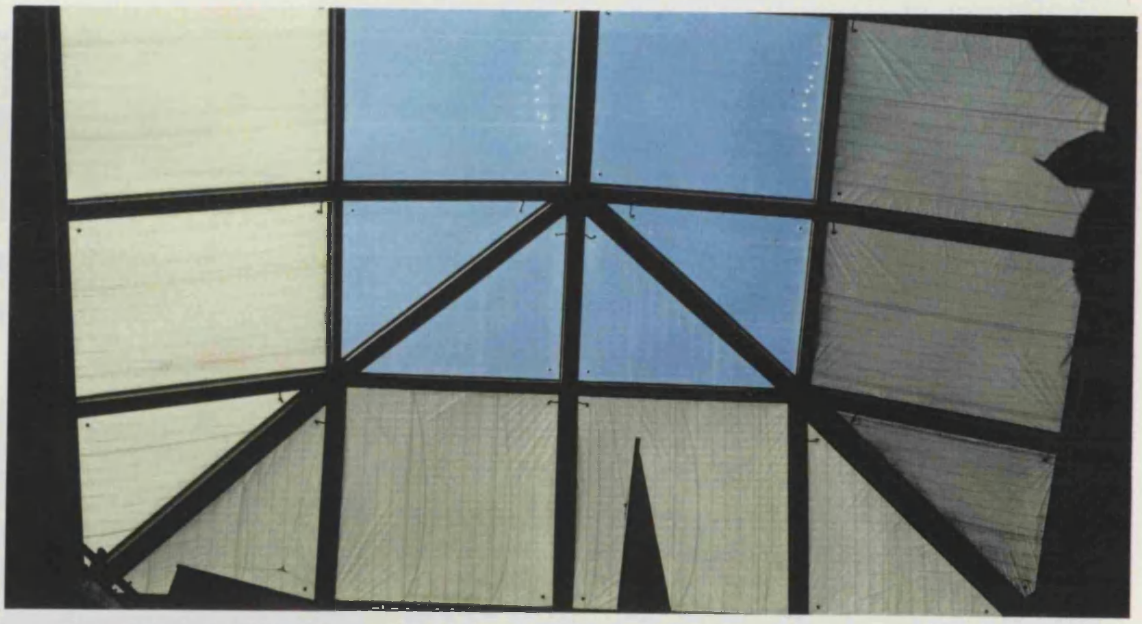
Control systems

The solar control system over the atria is integrated within the foil. While the base material is very transparent, EFTE foil can be treated in a number of different ways to manipulate its transparency and radiation transmission characteristics. The foil can be over printed with a variety of surfaces to affect transmission, or printed with graphic patterns to reduce solar gain whilst retaining transparency, or can incorporate a white body tint to render the foil translucent. The degree of translucency can then be manipulated by adding additional layers of foil into the system. Alternatively, cushions can be constructed with variable shading and reflectance by differentially pressurising air chambers in cushions to cause opaque graphics on intermediate layers to alternatively cover or uncover each other. In the Chelsea and Westminster Hospital, the roof consists of a span of four cushions with two to three layers of foil. Two cushions have a single layer of white foil for shading. The central two remain clear *(see figure 19)*.

Over the reception area are a series of "sails". These overhead blinds are made of white silicon coated glass membranes and they protect the reception staff from glare. (nb. Most polyester cloth is coated in PVC, this is glass fibre cloth.) They are manufactured by Landrell Fabric Engineering Ltd *(see figure 20)*.

The method of daylight control within the wards is simply by the use of curtains.
Within the atria, individuals have no ability to control the amount of daylight entering their space. But the use of curtains, though an unsophisticated solution, means that patients and staff have an ability to regulate daylight entering their work and living spaces. The daylight control on a macro-scale is unaffected by micro-scale decisions.

Figure 18 The Ventilation System



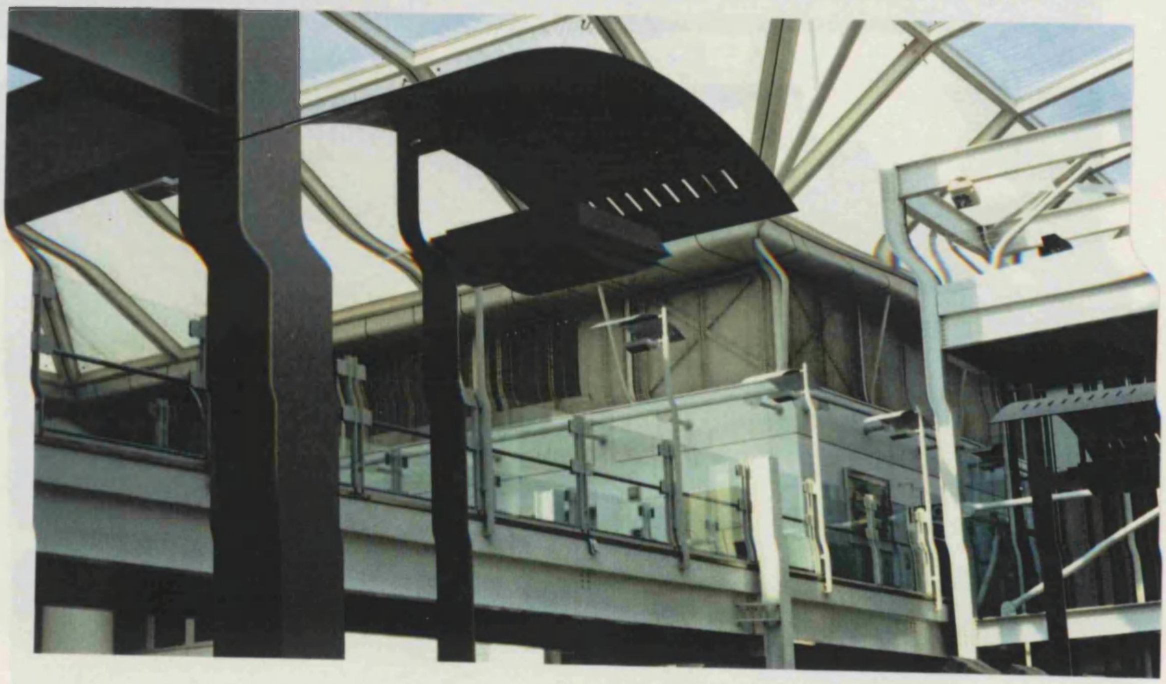


Figure 19 Shading of the Atria

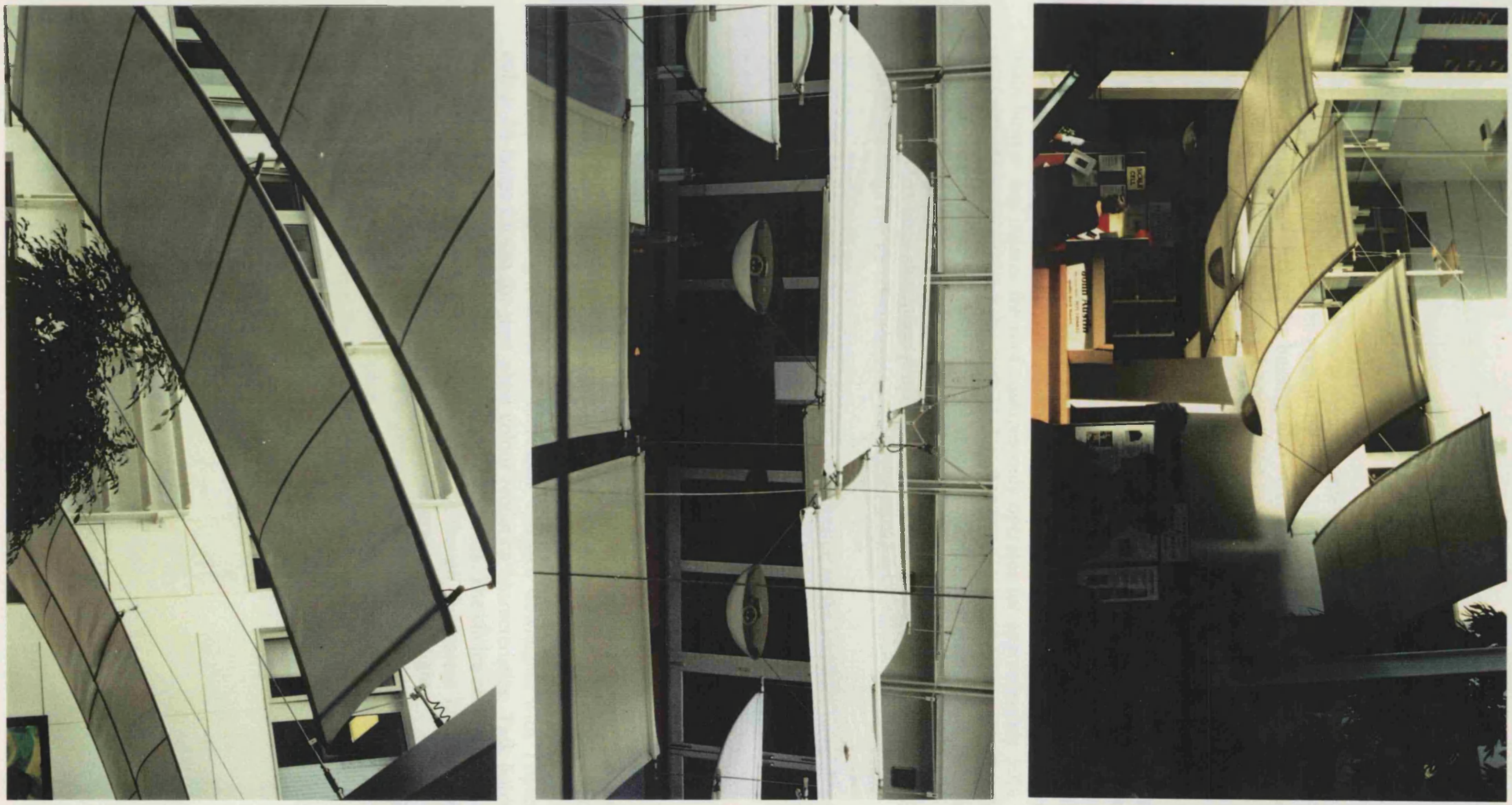


Figure 20 **Shading of the Reception**

Energy considerations

The atria contributes to maximising daylight penetration into areas of the building which might otherwise have been lit entirely by artificial light. The deep ward rooms that are located on the periphery of the building also make the most of their location for daylight penetration. The building depends on artificial lighting at night, on dark days and in the areas that are between the atria and the external walls and therefore have little or no access to daylight.

The daylight design effects both the energy efficiency of the building and the running costs of the hospital. The use of daylight decreases the need for electric lighting, thus savings are made. The hospital generates its own electricity and as there is such an efficient use of daylight, the excess is sold on to The National Grid, thereby creating revenue for the building. Maintaining the daylight system i.e. the roof is also relatively inexpensive. The main blower that inflates the roof cushions only operates for approximately 50% of the time with the power usage being in the order of 50 Watts i.e. half the cost of a light bulb.
The foil roof insulates the building in an efficient manner. A standard three layer cushion has a U value of $1.96 w/m^2$ °K. This more effective than triple glazing.
The foil also has huge absorption properties in the infra-red range, that can be exploited to reduce buildings energy consumption.

The initial decision to build a tall atrium is cost effective as the architect were able to use relatively inexpensive cladding materials. The atria are rated as courtyard spaces, so the overall building rates are low.

The artificial lighting design

The majority of the electric installation within the atria, the reception space and major corridor spaces consist of uplights. A PL lamp is situated below a surface that the light bounces off *(see figure 21)*. This avoids glare from the sources and creates an even diffuse light. The fittings also appear streamlined and do not clutter up the clear, open main areas.
The main ward lighting consists of fluorescent recessed downlights with Triphosphor colour 84 lamps chosen for their good colour rendering characteristics. Task lights with miniature fluorescent lamps are used over individual beds. The choice of fluorescent lamps ensures electrical efficiency and energy saving. Although fluorescent lighting is a cold light, the electric lighting appears very yellow in contrast to the daylight.
The night view of the hospital is like a negative of the daytime. There is a large black void of night time sky across the main space and the windows that people looked out of during the day, now provide a view for those in the atria to look into.

Figure 21 Artificial Lighting

The ward layout

There are a mixture of six bed and single bed rooms. This was determined by the brief which was based on Department of Health standards current at the time (the Health Building Notes). The six bed bays are 7 x 8m approx. *(see figure 22)* and the single rooms generally have en-suite bathrooms and a gross area of $15m^2$. Dayrooms generally look into the atria and are approximately $27m^2$ in area (Dimensions again based on DoH criteria).

In the six bed wards, windows are positioned in the marginally longer wall. In single bed rooms, the window is positioned on the wall that looks into the atria. Both room types are successful in terms of daylight distribution *(see Part 4.1 and Appendix 1)*. In the six bed rooms, the window panel is approx. 2.15 x 7.1m. The overall ward plan is approx. $50m^2$ so the window area proportion is 30%. For bed locations see *Appendix 2*.

The ward corridor floors are finished in blues with differing patterns, like the atria corridors *(see figure 23)*. The wall behind each nurses station is painted in a bold colour. e.g. pink *(see figure 24)*. Therefore, exiting from the six bed ward to the nurses station has a dramatic effect on adaptation. These areas appear much darker in comparison, though receive an adequate amount of daylight as the ward bays are open. Colour rendering is not affected as the amount of daylight is adequate and of good enough spectral distribution to enable correct medical diagnosis. The wards themselves, have white walls and ceiling and the floor is honey coloured. These serve to maximise the daylight and the warm coloured floor gives the ward a "sunny" feel. Coloured curtains e.g. blue, terra-cotta and green break up the monotony of the pale ward interiors.
The architect decided upon the use of curtains for privacy and to reduce institutional appearance, but they are used to control shading from the ward area. There is likely to be glare in the external wards from the sun early in the morning or later in the day. This is possibly more problematic the higher up the building the wards are situated. In the middle part of the day the single bed rooms are likely to receive a certain amount of glare reflected from large white expanses of atria wall. The curtains are available to protect the patient from any sources of visual discomfort. The ward windows do not reach to the furthest ends of the wall. An area of wall is left unglazed at either end to reduce daylight specifically at the patient bedheads. There are also curtains around each bed that can be used to protect the patient from glare or brightness. The overhead artificial lighting is generally positioned in the centre of the ward bay and not directly overhead. Each bed has an individual task light. This is mounted on a flexible arm so the patient or staff can position the luminaire at a comfortable angle and thus avoid glare.

Specific area questions; The corridors/transition spaces, The atria and the reception

The reception opens out into the main atrium and the corridors form balconies around it, branching out into the nursing and clinical areas. We can therefore describe them as a route through the hospital and look at their treatment as a whole.

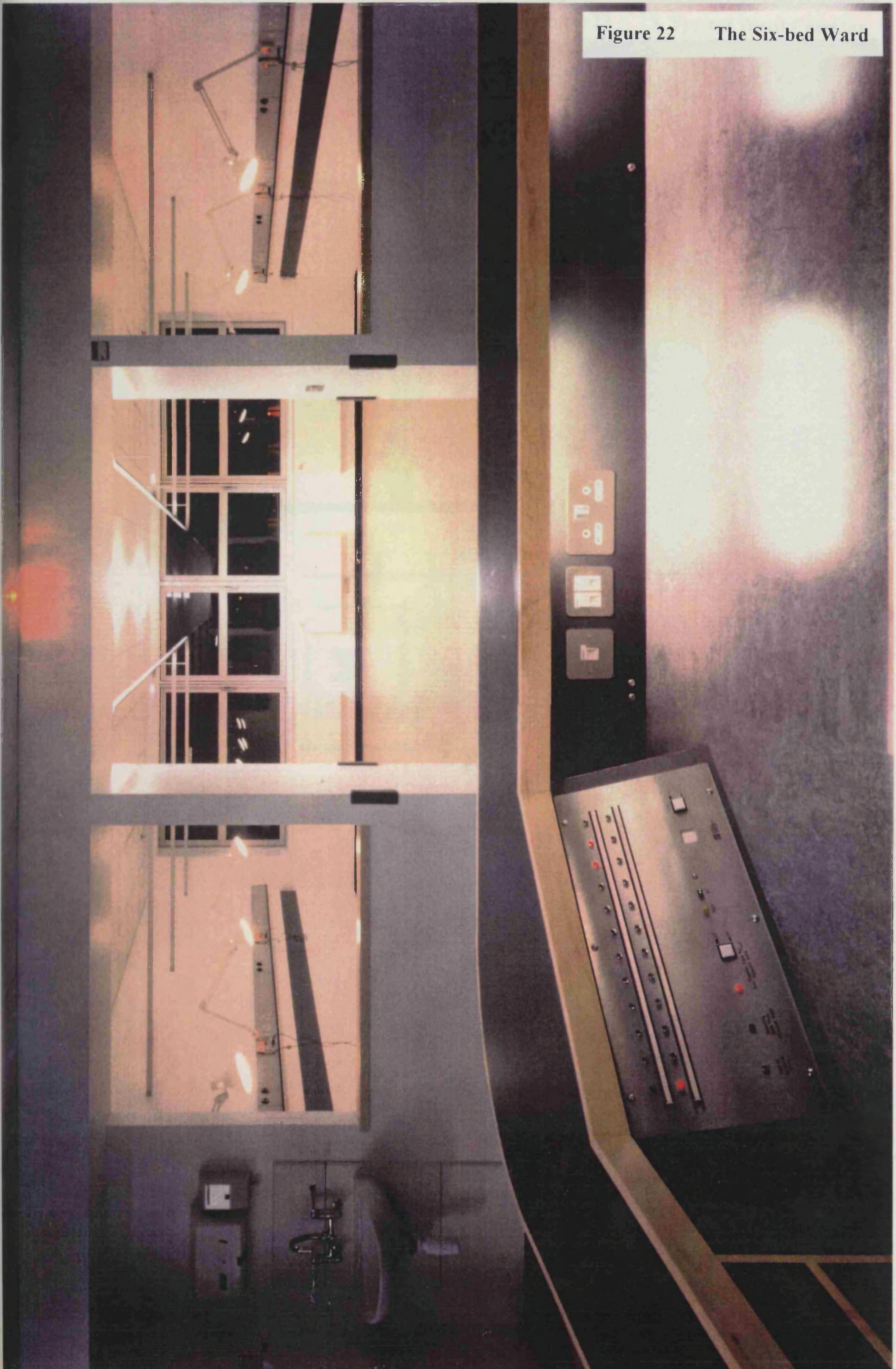
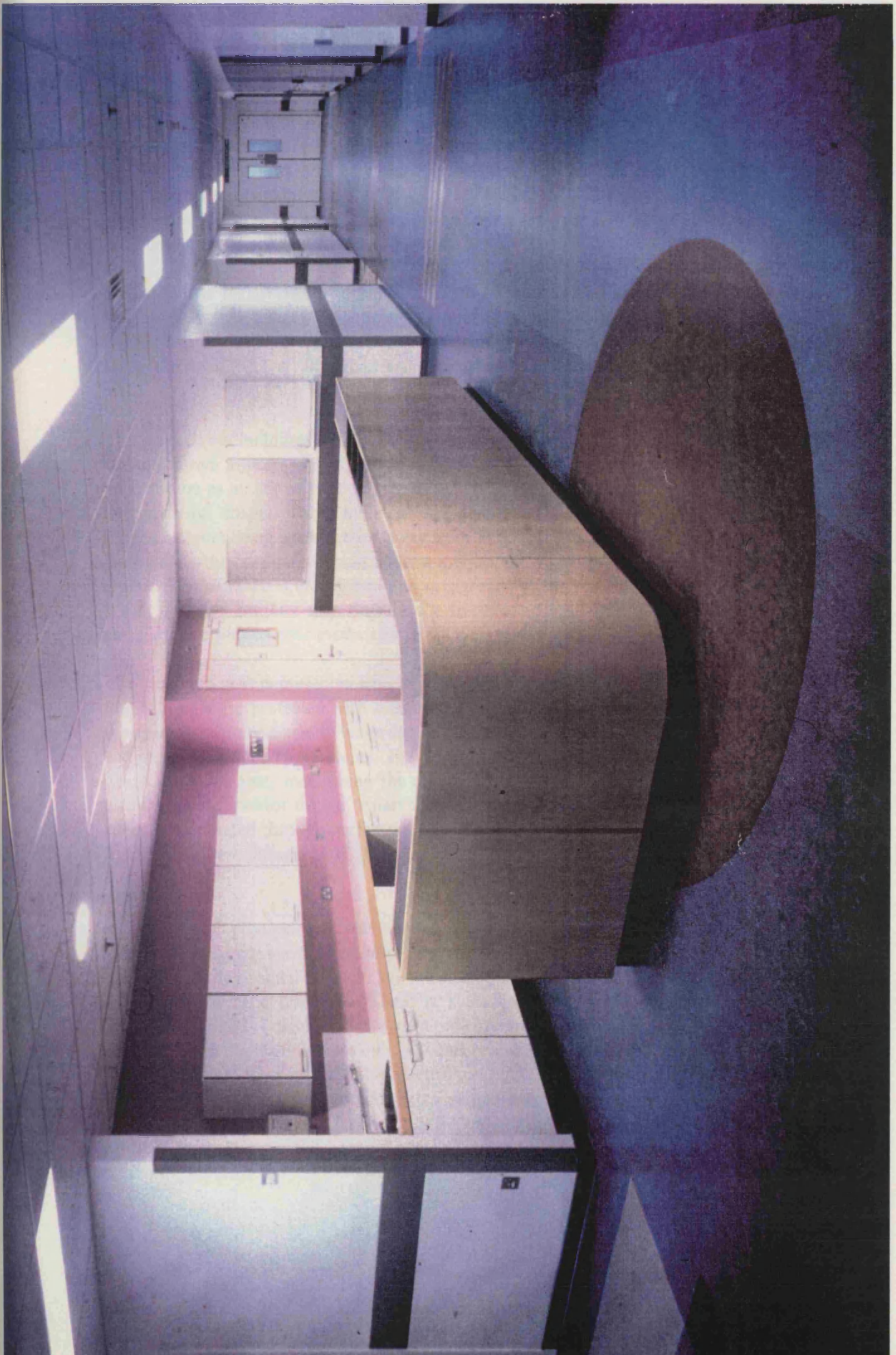


Figure 22 The Six-bed Ward

Figure 23 A Typical Ward Corridor

Figure 24 A Typical Nurses Station



From the reception through the atria, patterning was introduced to relieve large expanses of flooring, but also as an innovation to define particular points of activity such as waiting areas, reception points etc. There is a system of patterning in the corridors which effects the cross routes as opposed to the routes along the length of the hospital. It is too subtle to effectively help way finding within the hospital. The colours used are a terra-cotta, blue, white and a similar honey yellow to the ward floors. The prominent colour on the atria floors is yellow or white, but on the balconies and corridors above, blue is the main floor colouring, mirroring the sky above *(see figure 25)*.

The atrium is mainly white to enhance lighting levels and to create a bright and clean ambience. Intense colours have been used locally so that the space does not become too sterile in appearance, to create incident and to help orientation.
Upon the atria's universally white walls, splashes of colour are provide by the works of art.

There are three "buildings" within the central atria, that add to the impression that you are walking down a street *(see figure 26)*. There is a white cube for the reception area, a yellow cube as an administration area and a red cube which houses a church and a non-denomination chapel. These buildings aid adaptation throughout the main space. The darkest colours being used furthest away from the entrance into the hospital.
As we enter the hospital, we pass under a low ceiling which then opens out into a series of spaces. The entrance is mostly white to prepare us for the brightness of the central space, which is in fact brighter than outside due to reflected light from the multitude of white surfaces. *(see photometric evaluation at the end of Part 4.0)*

The reception area is protected from glare by a sail structure which is artificially uplit and the main atria are protected with a shading layer integrated into the foil sealing. However the spaces are predominantly white and the higher up the building one travels, the brighter and more intense the space seems. The sky ceiling is the brightest part of the building, the white walls are next, maximising the reflectance of daylight. The floors are the darkest element of the interior design. Apart from the main roof shading, glare within the main space is modulated through perforated stair risers, balcony barriers and the glass lifts *(see figure 27)*. These diffuse the daylight but also allow the majority of it to penetrate through into the atria.

A "visual and physical link between all areas of the hospital has been created with uncovered walkways which traverse the central atrium" [46]. We are able to view the efficiency of the hospital at work. We are also able to stand upon these balconies and look down into the atria ourselves. There is a sense of disappointment upon entering the nursing and clinical corridors. They seem ordinary and rather cramped with small works of art fitted upon the walls and are infinitely darker and gloomier than the busy main space.
The whiteness of the space and the spectral composition of the transmitted daylight means that during the day, colour rendering of people and the art work is not affected. The character of the atria is airy, large, colourful and comfortable. However, at night time, the artificial lighting gives the hospital atria a subdued appearance. As these areas are not

Figure 25 Corridors within the Atria

Figure 26 The Hospitals "Main Street"

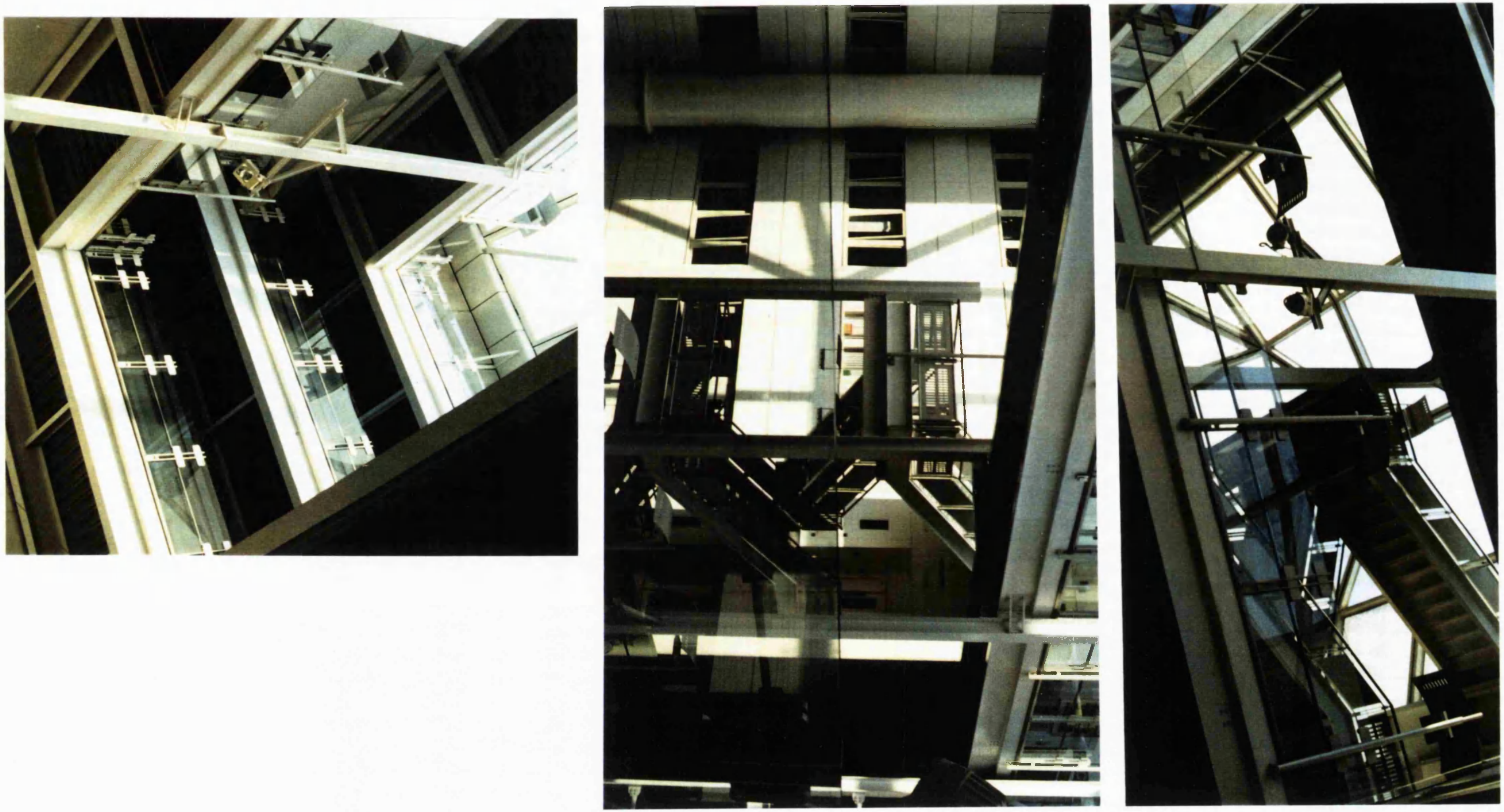


Figure 27 Stairs and Balconies within the Atria

critical for diagnosis and the majority of people entering the building see the art in the day time under natural light, accurate colour rendering is not important.

The human element

I was able to gather various opinions of visitors and staff from within the building and talked to the architects themselves, but the hospital would not grant permission for me to interview patients.

Subjective responses:

"The Chelsea and Westminster Hospital comes as a huge surprise after entering from a busy London Street."
"....a haven of peace"
"It is exactly what a modern hospital should look like."
"....hushed, but alive"
"It is not like one of those hospitals you feel that you will never come out of...."

Although Shepard Robson have carried out no formal occupancy evaluation, they say feedback has been positive from staff, patients and visitors; "The hospital is well liked and is seen by DoH and The Foreign Office as a showpiece for the NHS" states Gordon Kirtley of Shephard Robson. However, several staff I spoke to, were unhappy about the lower offices. They hated the windowless offices in the basement and felt others were also too dark. There seemed to be a consensus of feeling that most of the money for the hospital had been spent on the "showpiece" part of the hospital and the same quality of design had not been carried through in the nursing and clinical zones. Some people felt that the old masters in the basement were incongruous with the modern art upstairs and again intimated that certain less attractive parts of the hospital were hidden from public view.
Several people found it uncomfortable working at the top of the building as the brightness of the light in the top corridors, near to sky was sometimes too high and almost painful. This often caused difficulties with adaptation when entering the corridors to the ward areas. There were also complaints of claustrophobia when entering the corridors with low ceilings after being in the high atria space. But in general, people regard the hospital as an innovation and believe its pleasant environment is conducive to inspiring faith in the hospital and its treatments.

The factors included to encourage the healing of the sick are the implementing of an arts and theatre programme, the works of art situated in the hospital and the creation of a view.
The majority of wards and offices can see into the atria or an art work through their windows. Therefore a view has been generated in central London. The view provides those looking out with access to the outside world. There is a reference to the passing of time that can be determined by the changing properties of daylight within the space and

the stimulus of a variety of activities that people carry out within the atria. In the central atria, there is a theatre platform upon which concerts, plays and readings, take place. (The public are also invited to these performances and they can be seen from ward windows). There is also an attempt to simulate the outdoors by using real plants in the atria, their health guaranteed by the inclusion of natural light. But, the most important factor in the "view" are the large and colourful works of art that dominate the atria. The most notable include a 60 ft high steel "Acrobat" *(see figure 28)* supposedly the biggest indoor sculpture in the world, decorated silk banners that dance around one atrium in the ventilation drafts *(see figure 29)*, and a mobile called "Falling Leaves" *(see figure 30)*. Many of the pieces have been specifically designed for the hospital. A good example of this are the paintings beside the lift doors. They are sections of a waterfall with snippets of Wordsworth sonnets and the waterfall starts at the top of the building and culminates on the ground floor. There are also platforms for art with sculptures from such luminary's as Paolozzi wherever a "dead" area of space materialises.

Overall, the hospital has an uplifting and healing atmosphere.

Task considerations

The role of the occupants are varied. The patients role is to recuperate, the role of the medical staff is to treat and nurse those that are ill and the office staff to provide administration support. The visitors role is to alleviate boredom and encourage the sick. Patient tasks are limited and do not often expand beyond reading or writing. The scope of visitor tasks are even smaller. Nursing tasks and hospital maintenance are the primary activities within the hospital. These tasks take place 24 hours a day, 356 days a year. Therefore, the areas discussed are never in a position of rest. The demand for light is 24 hours a day and only reduces significantly at night time when the atria is not a focal point but the wards continue to be. The demand for high quantities of light reduces in the wards at night as the patients are sleeping, but adequate levels are still required for the task of nursing to continue efficiently.

Brief photometric evaluation

Conditions for measurements:	clear sky, very sunny, no cloud cover
Date of readings:	9 July
Ground floor:	average 30 000 lux
Fourth floor:	average 50 000 lux

nb. Standard Outdoor Illuminance is between 5,000 lux and 70,000

Figure 29 Patrick Heron's Silk Banners

Figure 28 "The Acrobat"- Allen Jones

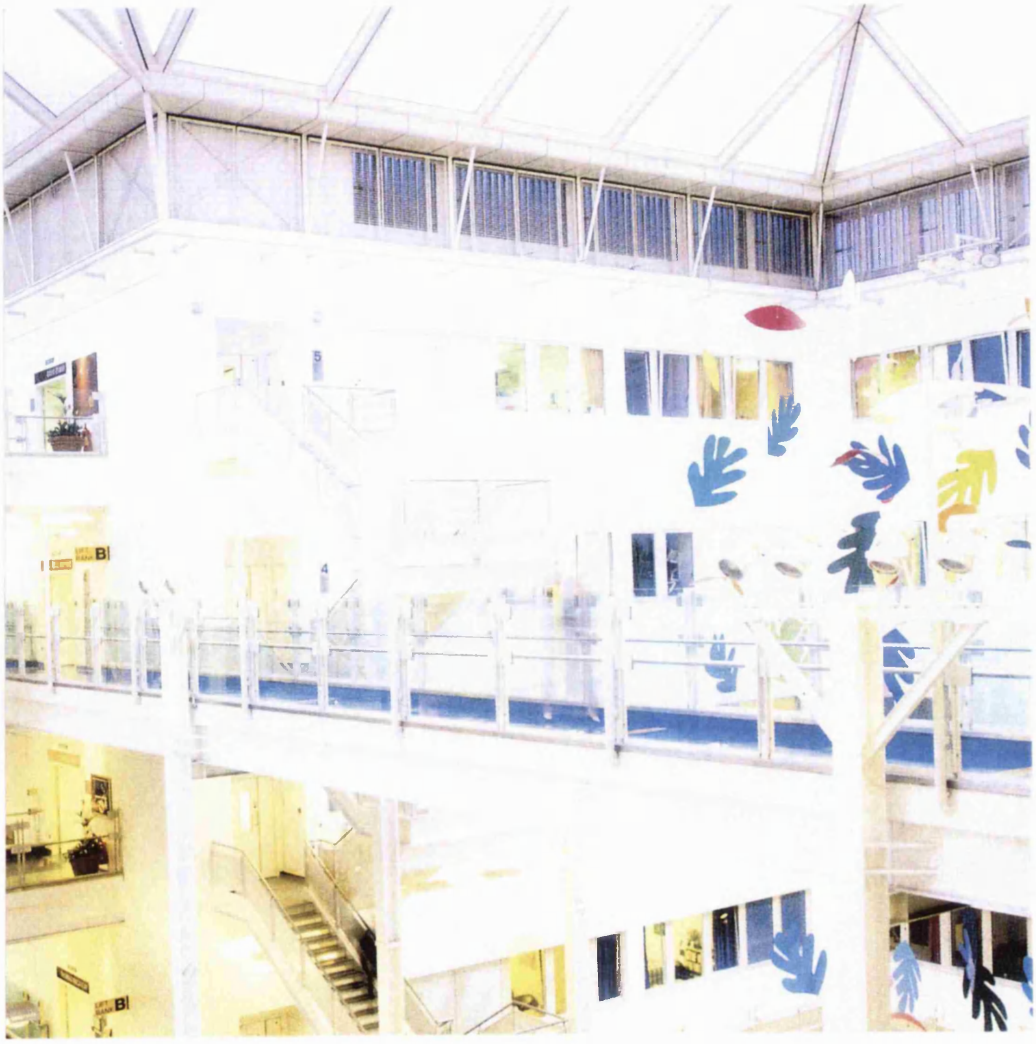


Figure 30 "Falling Leaves" - Sian Tucker

4.1 Analysis of Report

Part 4.1 is a summarised review of the results of the investigation. The results indicate that The Chelsea & Westminster Hospital has a daylight design that incorporates many of the considerations raised in Part 2.

- Florence Nightingale recommendations have been incorporated into the hospital design. The building is situated on a north/south axis to maximise sunlight and includes Nightingale's ideas on art.

- Aalto and Corbusier thought direct experience of daylight and the provision of a view were necessary for mental and physical well-being. Each ward space has access to natural light and there are no confining views except for the bed bound. Mental stimulus is provided for the occupants of the six bed ward from exterior views and from the single rooms by the atria view. The view provides patients and staff with a reference to the passing of time by nature of the changing light.

- The architect has allocated areas within the building according to their daylight requirements, therefore maximising daylight usage.

- The daylight design is integrated with the ventilation and air circulation of the overall building. The elements of all three are combined within the atria concept.

- The design ensures high transmission of light into the main spaces of the hospital. This aids daylight penetration into other areas such as ward spaces. The daylight design ensures energy efficiency as the demand for artificial light is minimal in the daytime.

- Glare control has been considered on a macro level, i.e. incorporated into the foil roof and on a micro level, i.e. the sails over the reception and curtains within the ward.

- The majority of wards favour the Nuffield six bed layout.

- Within the wards, daylight factors of upto 7 and 9 were found *(see Appendix 1)*. This exceeds both the Nuffield and the Mansfield, Roe and Rowlands study which recommend a daylight factor of 5 for comfort of occupants. The printouts which show lux levels *(see Appendix 1)* within the wards reveal that daylight quantities are adequate even at the back of the ward. The ratio of light within the space is 4:1 or 3:1. The Nuffield study recommended 5:1. At certain times of year the levels exceed 1000 lux. Mansfield, Roe and Rowlands found this to be too bright for occupants.

- The clinical nature of the building is accentuated by the predominant choice of white interiors and the cold colour of daylight. The inclusion of colour in the interior design and the art works alleviates the monotony of the white walls. It also adds warmth to otherwise cold spaces and occupants feel less alienated.

- An institutional atmosphere has been avoided by developing the focal area of the hospital into a space that resembles a shopping mall or plaza with cafes. This also provides space for the influx of visitors.

5.0 Conclusion

The Hospital

Based on the investigation of an example daylight design, the assessment technique used suggests the conclusion that the daylight design within the Chelsea & Westminster Hospital is primarily a successful one.

Although it is difficult to utilise daylight for health in a city, the Chelsea & Westminster hospital demonstrates that it is possible. The urban locale has not prevented the creation of an environment that is conducive to healing.

The hospital design illustrates that daylighting is both a science and an art. The scientific elements of the design include a roofing material that maximises daylight and the creation of a daylight control system. The artistic criterion within the design include use of shapes and materials to modulate daylight and sunlight and the creation of a view in an inner city interior.

However, it is not a flawless design. Reasons for this include:

- The concept of a "community" building is not fully realised as the uninspiring exterior makes it difficult to encourage people to enter.
- It is the atria that makes the Chelsea & Westminster hospital unique as the wards and corridors are essentially no different to other hospitals. No special daylighting treatment has been applied to these areas.
- Areas of the building are too bright for the occupants.
- The main method of glare control within the wards is not sophisticated enough to account for the variety of occupant requirements. When patients or staff require shading from daylight, their only choice is to close the curtains. This results in the inefficient use of artificial lighting.

For the hospital to have a truly successful daylight design, the building requires an overall daylight concept. The successful concept that is used in the atria needs to be continued and developed throughout the ward and corridor spaces.

The Evaluation Technique

The evaluation technique can be easily and practically applied to an existing hospital. It provides an ordered method of undergoing investigation of the workings of a daylight design within a hospital and considers the success of areas a-e as stated in Part 1.1.

The evaluation process emerged as a laborious one and the comprehensive checklist method meant it was inappropriate to display the collected data in a satisfactorily succinct format. It was also difficult to avoid making conclusive comments when reporting the results. Data tended to be inextricably entwined with both comment and opinion as to the success of the daylight design, making it difficult to independently state conclusions.

The evaluation technique can be used to determine which elements of the overall day lighting design are successful and which are not. It reveals both deficiencies in the design and deficiencies in the operation of the design. The evaluation technique identifies where previously accepted or new design ideas fail to work or operate successfully.
The evaluation technique can determine whether the architect has achieved their original intentions and whether the initial design decisions are correct.
It also allows us to expand and generalise our daylighting design assessments beyond the Chelsea & Westminster Hospital to all similar building types. It appraises the relationship of the building with occupant activities and the physical conditions that prevail, i.e. seasonal changes within the hospital.

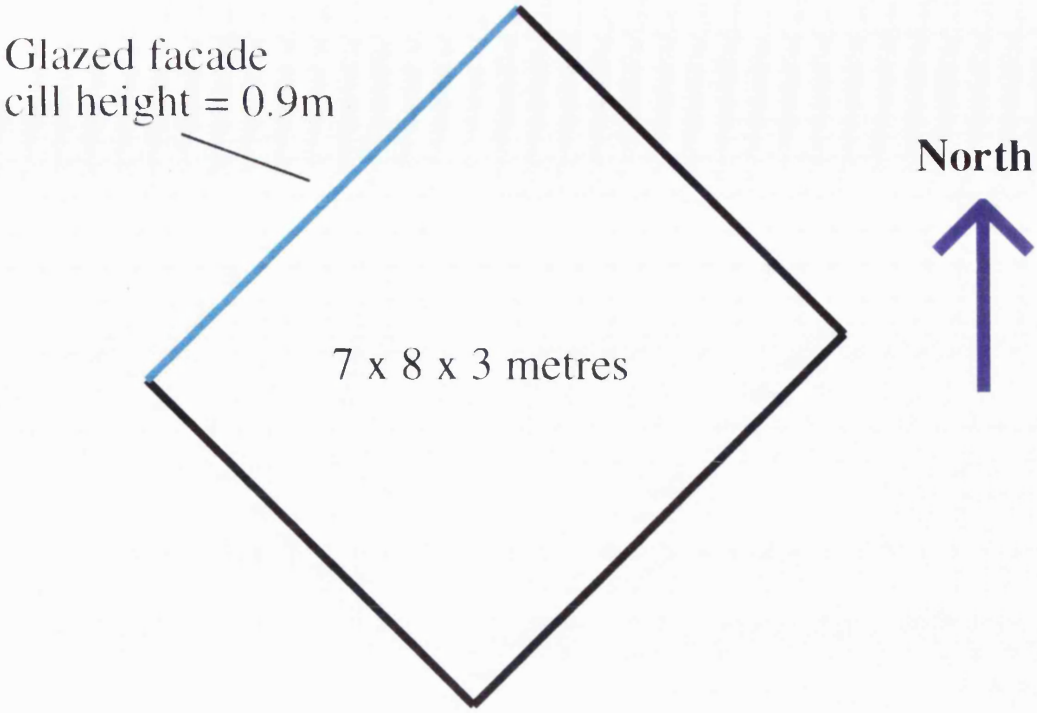
"The knowledge gained can be applied to future work." [47]

APPENDICES

6.0 Appendix 1 - Daylight Factors and Lux Levels within the Ward

CONTENTS

1 Information
2 Lux Levels for 21st June at 10.00 am, CIE Overcast Sky
3 Lux Contours for 21st June at 10.00 am, CIE Overcast Sky
4 Lux Levels for 21st December at 14.00 am, CIE Overcast Sky
5 Lux Contours for 21st December at 14.00 am, CIE Overcast Sky
6 Lux Levels for 21st June at 10.00 am, Sunny Sky
7 Lux Contours for 21st June at 10.00 am, Sunny Sky
8 Daylight Factor Contours

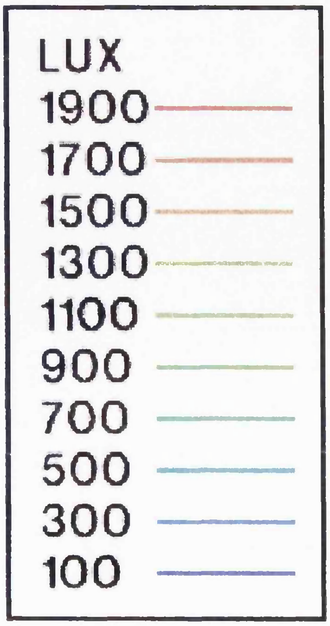


Surface Properties

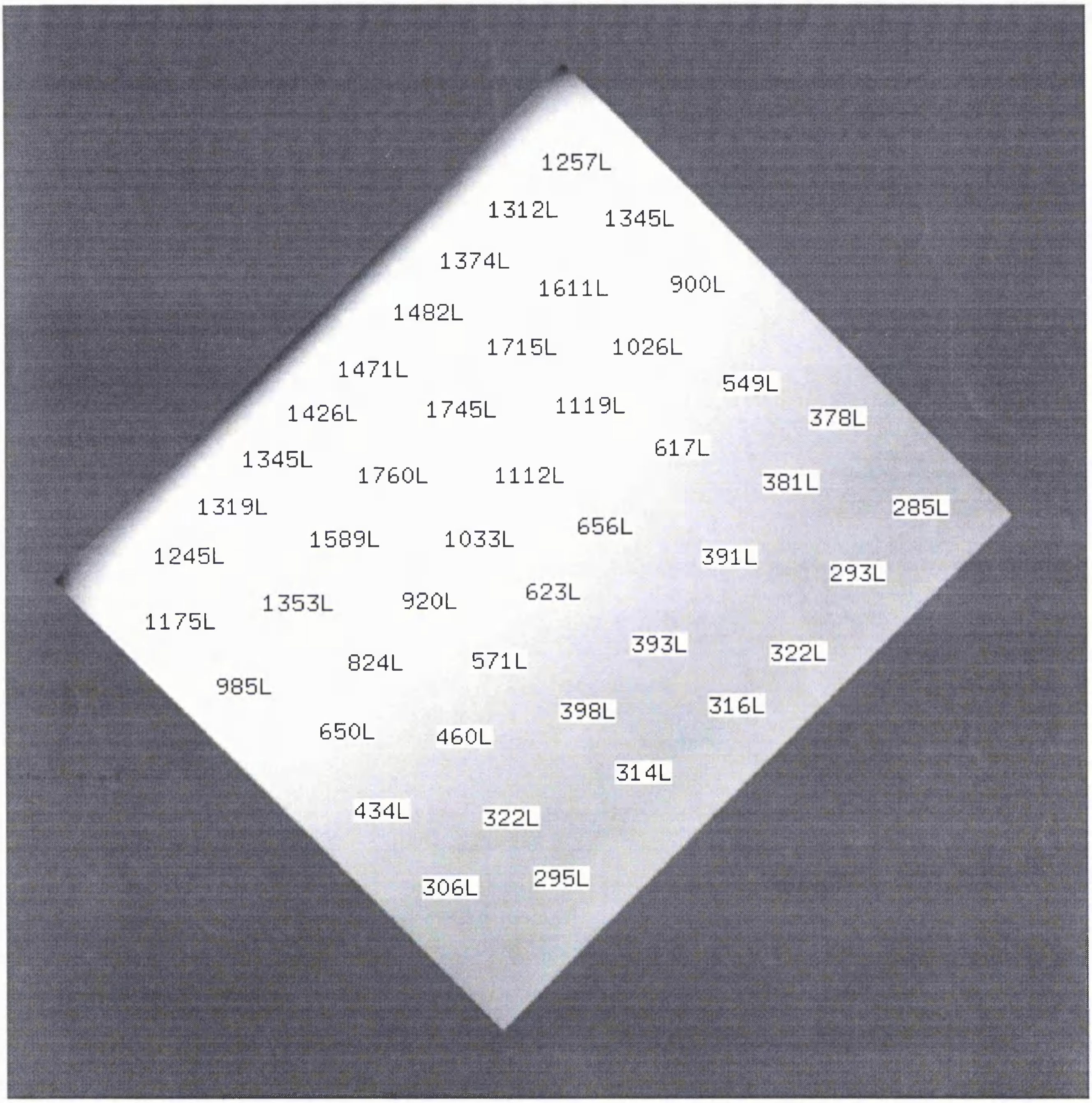
	R	G	B
walls & ceiling =	0.95	0.95	0.95
floor =	0.60	0.60	0.60

glazing (6mm clear float) = 0.87 transmittance

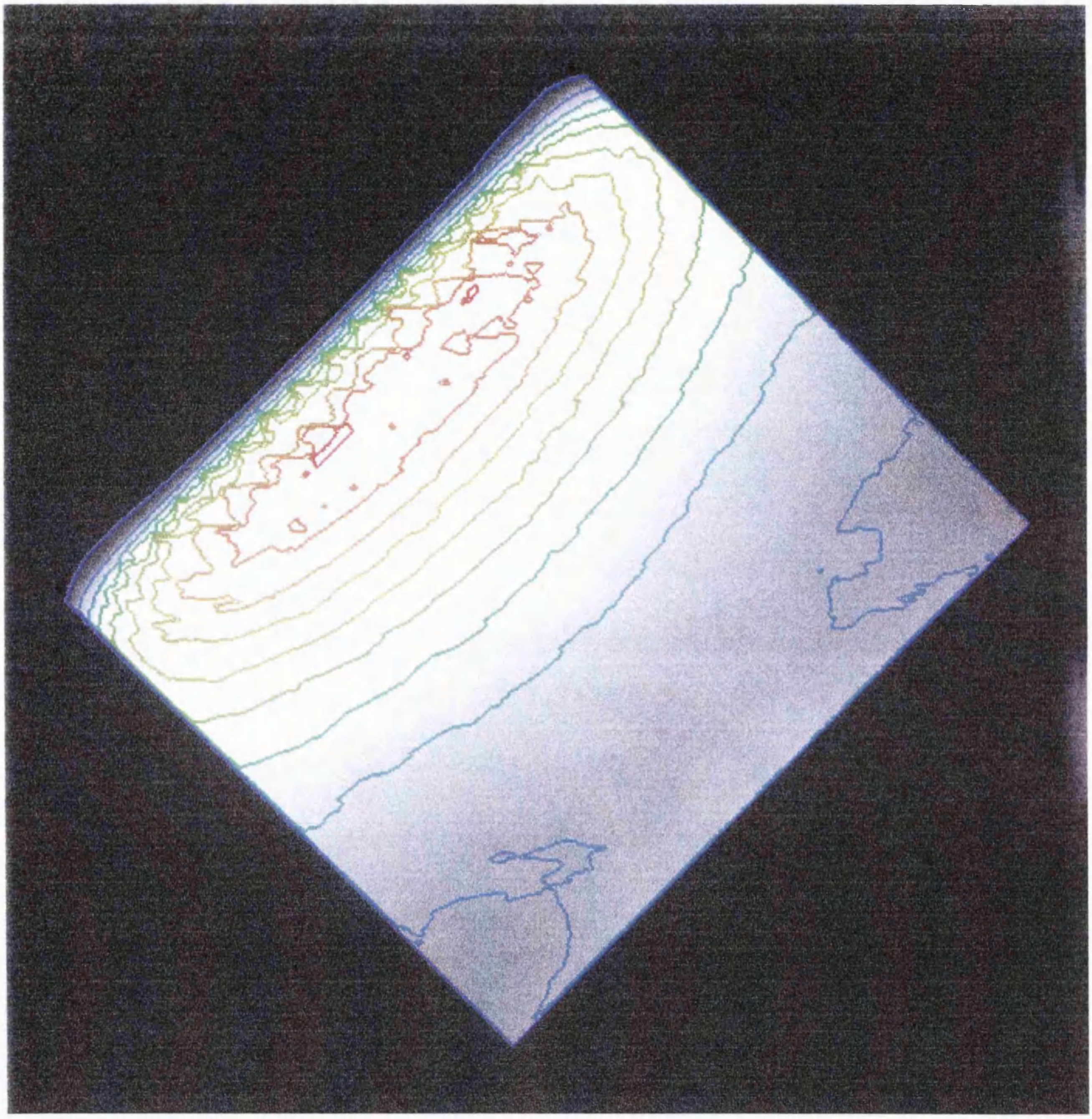
Key for Lux contours



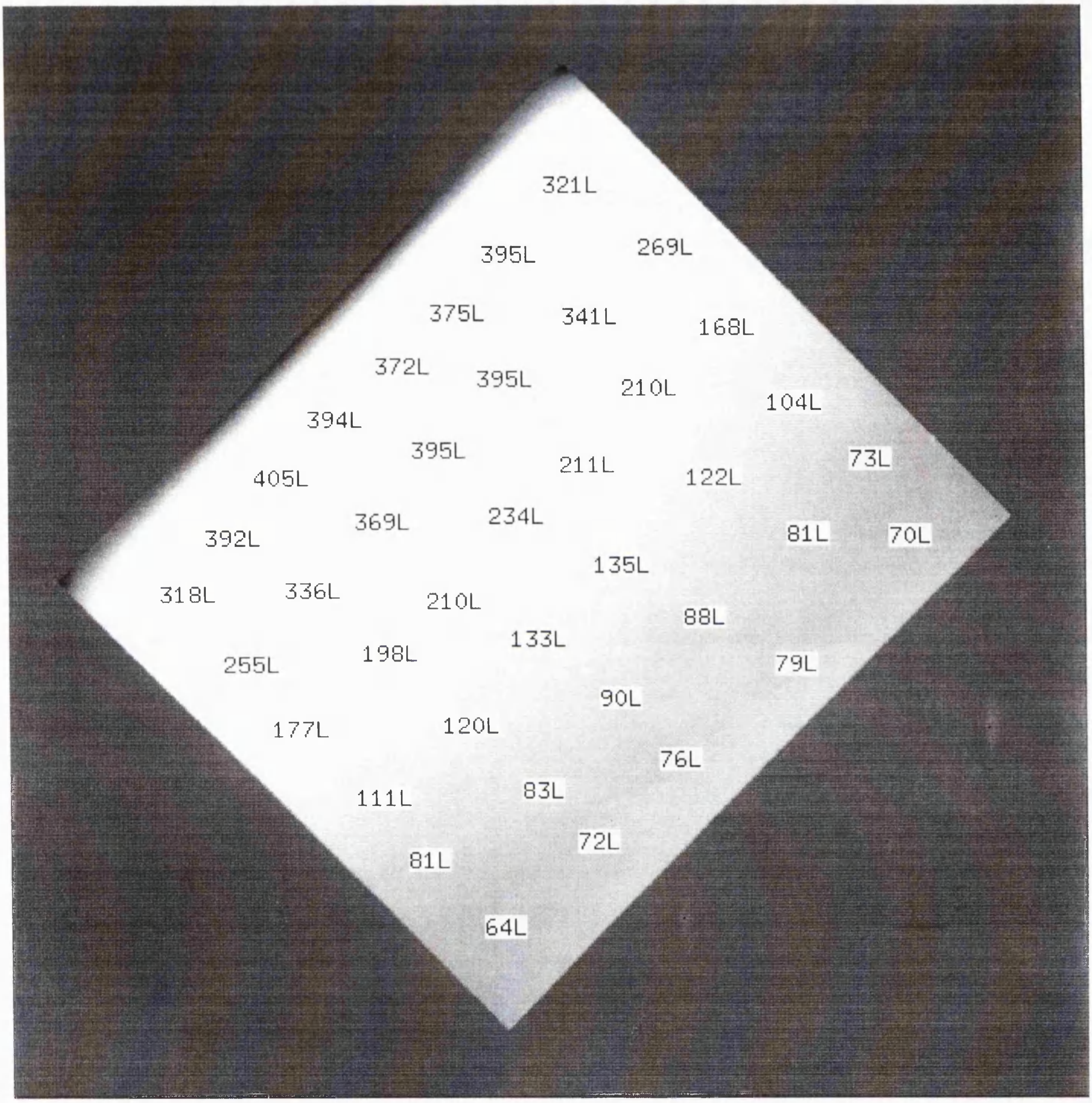
Lux levels for **21st June** at **10:00 am** with **CIE Overcast Sky**



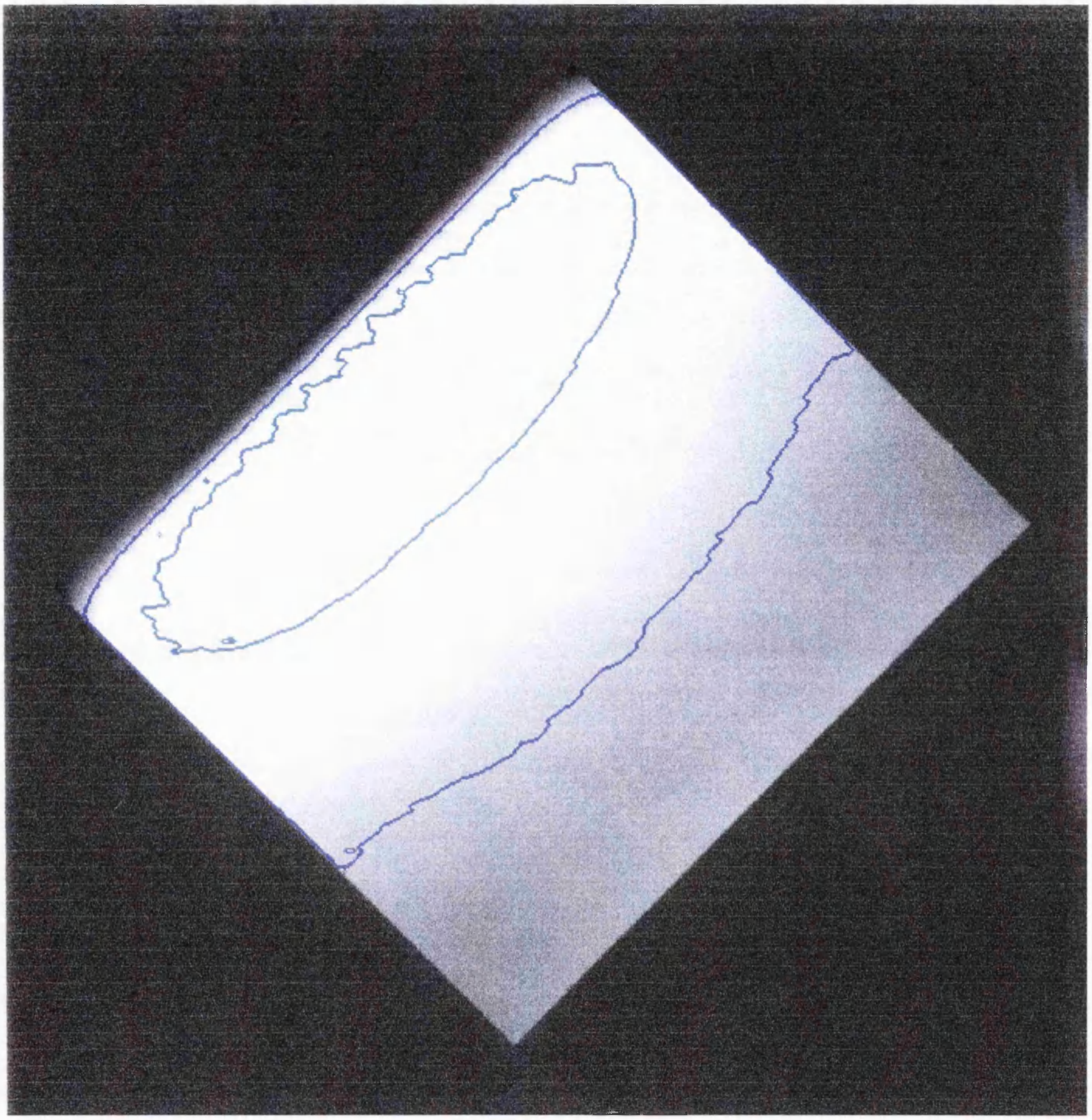
Lux contours for **21st June** at **10:00 am** with **CIE Overcast Sky**



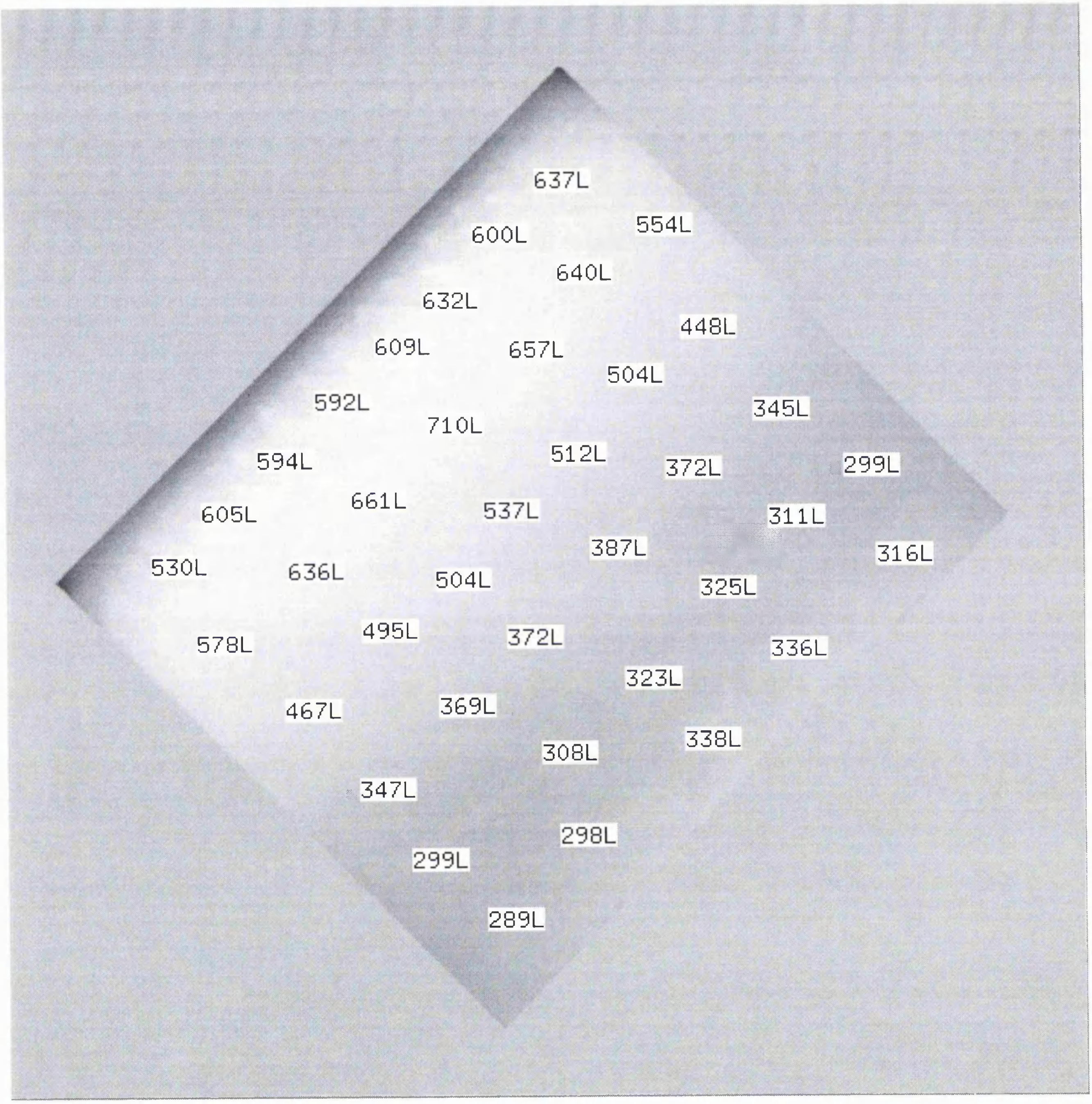
Lux levels for **21st December** at **2:00 pm** with **CIE Overcast Sky**



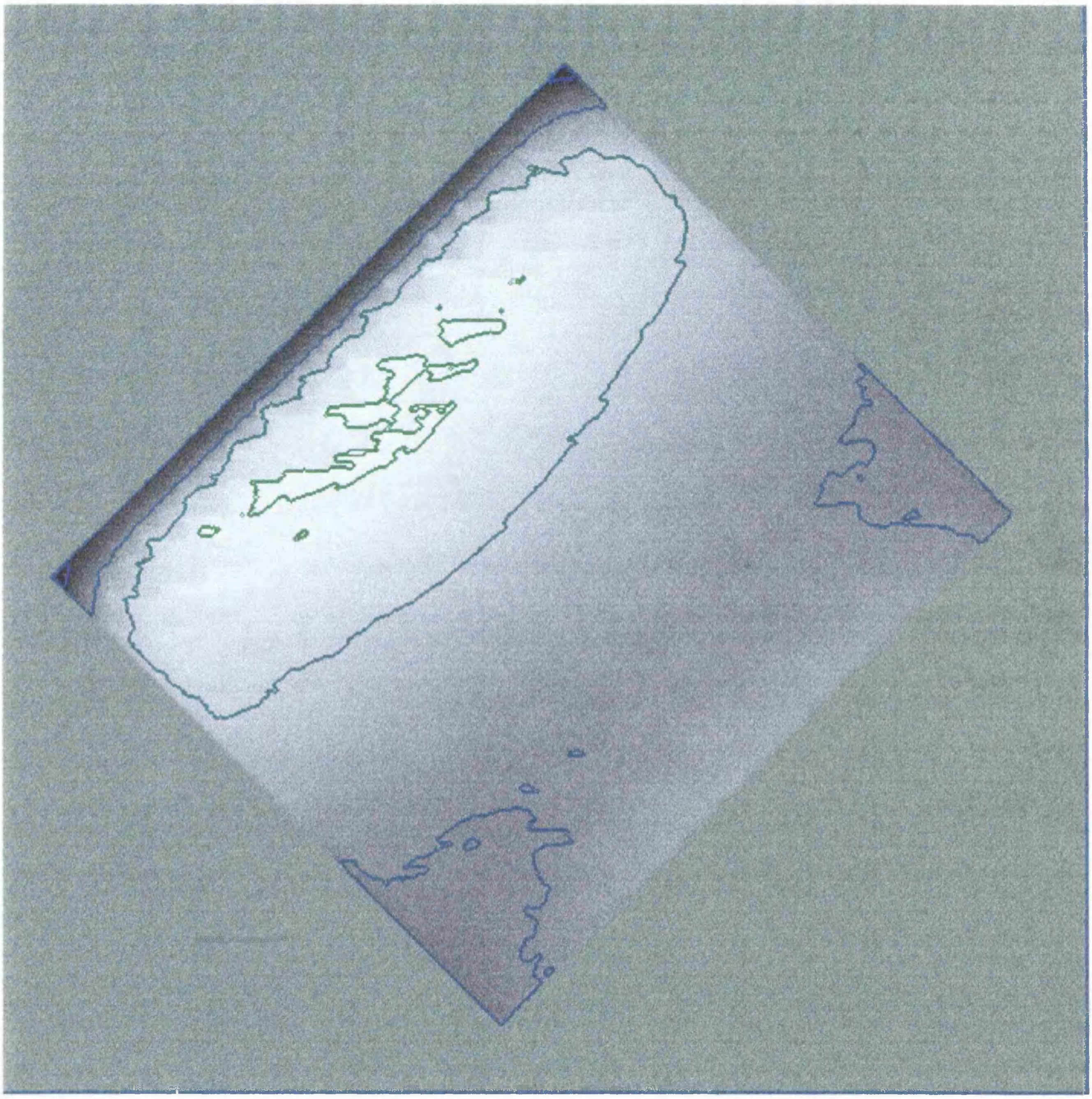
Lux contours for **21st December** at **2:00 pm** with **CIE Overcast Sk**



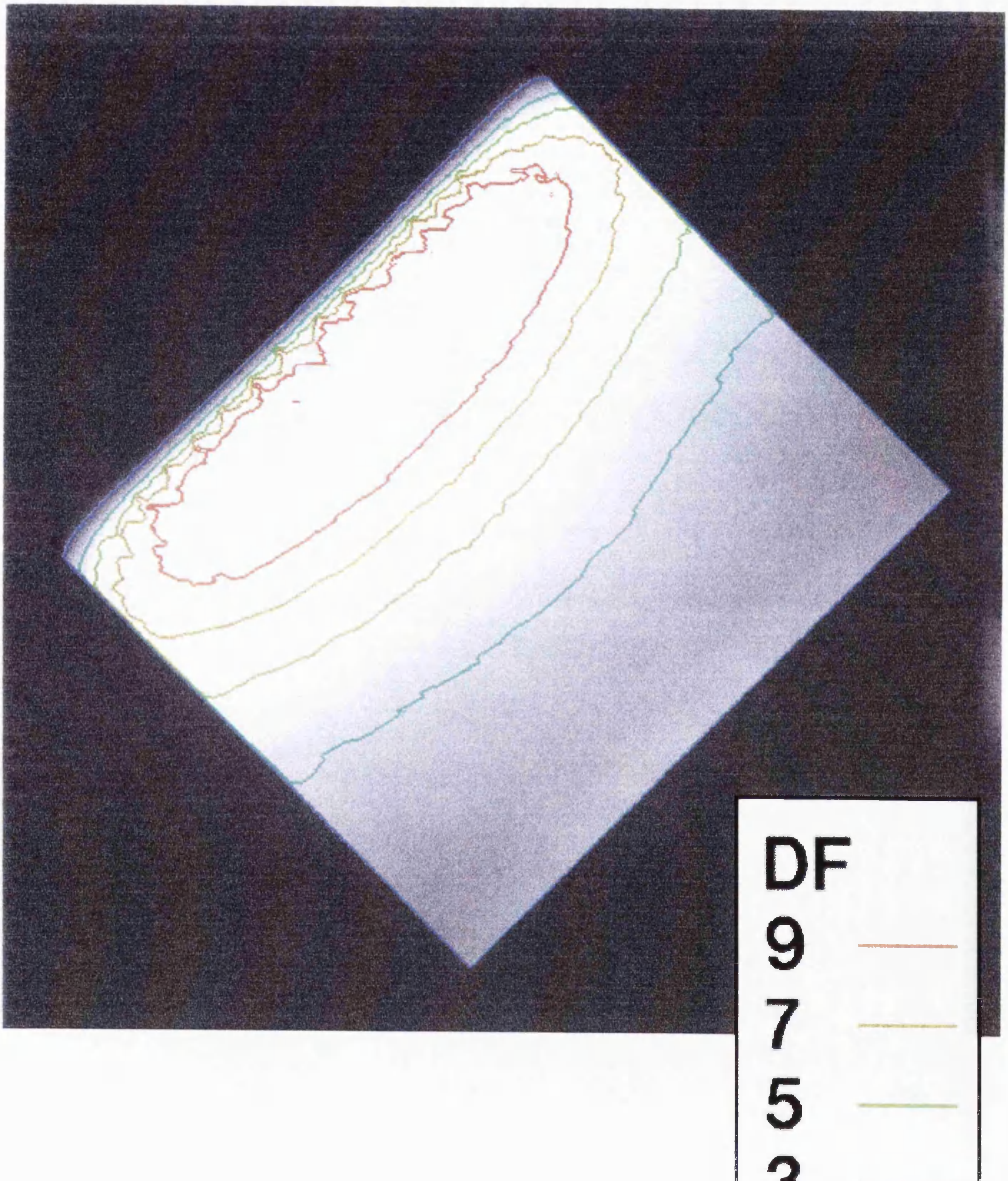
Lux levels for **21st June** at **10:00 am** with **Sunny Sky**



Lux contours for **21st June** at **10:00 am** with **Sunny Sky**



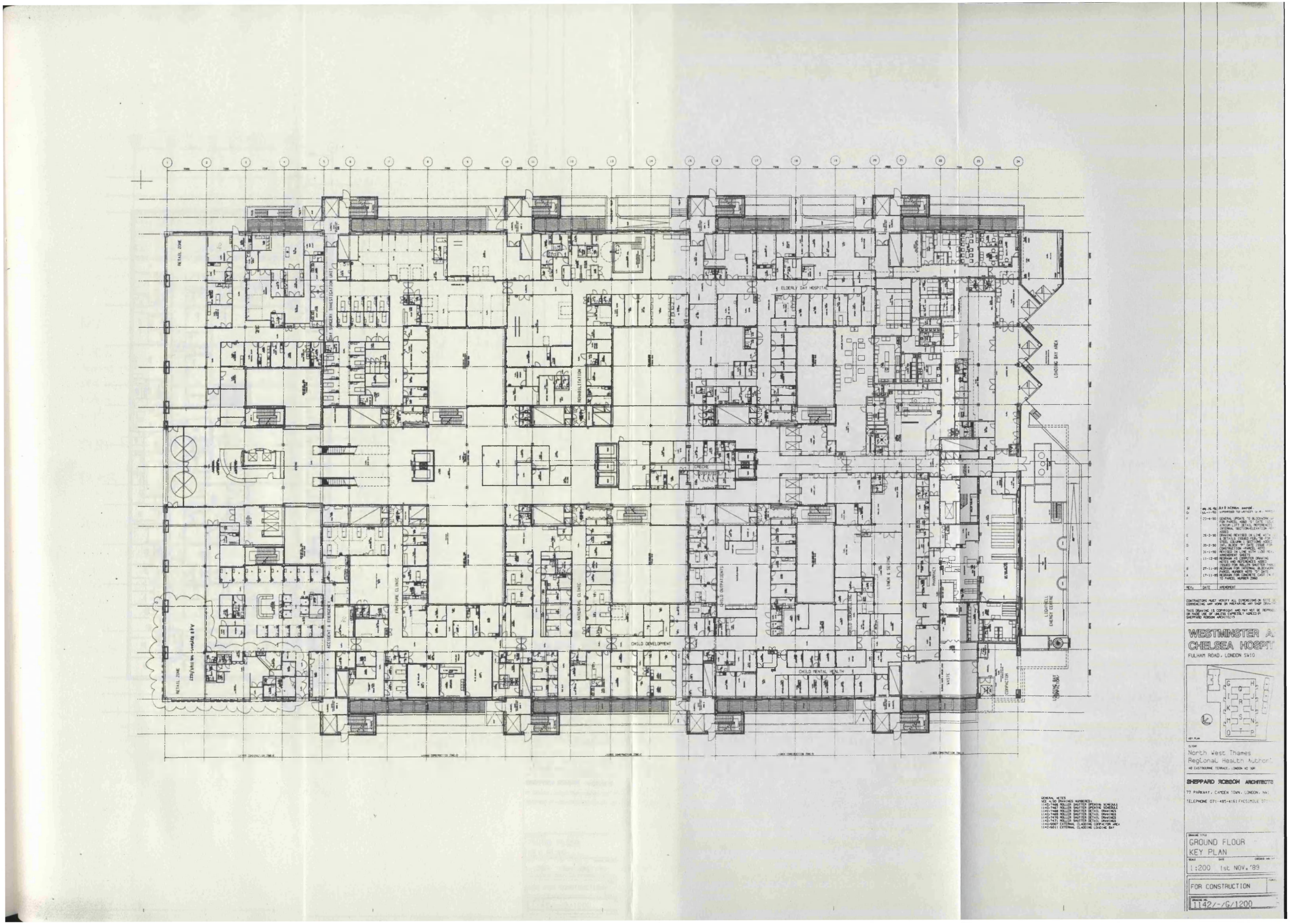
Daylight Factor contours

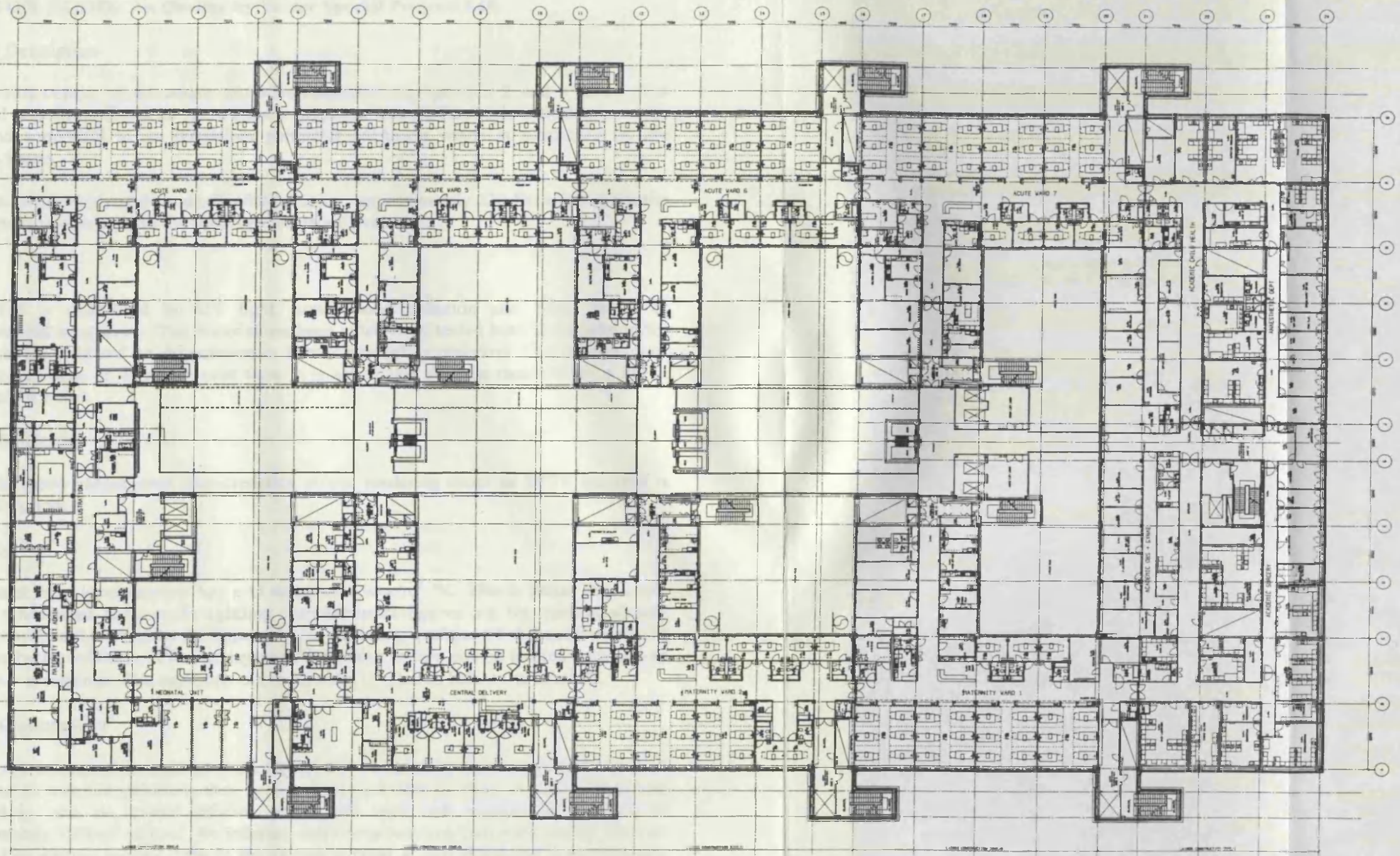


6.1 Appendix 2 - Chelsea & Westminster Hospital Plans

CONTENTS

1 Ground Floor
2 Third Floor


RETAIL ZONE
DAY SURGERY INVESTIGATION UNIT
ELDERLY DAY HOSPITAL
REHABILITATION
LOADING BAY AREA
CRECHE
ACCIDENT & EMERGENCY
FRACTURE CLINIC
ANTENATAL CLINIC
CHILD OUTPATIENTS
CHILD DEVELOPMENT
CHILD MENTAL HEALTH
LINEN & SEWING
PHARMACY
WASTE
COMPACTOR
LIGHTWELL
ENERGY CENTRE
WESTMINSTER A
CHELSEA HOSPIT
FULHAM ROAD, LONDON SW10
North West Thames
Regional Health Authori
SHEPPARD ROBSON ARCHITECTS
77 PARKWAY, CAMDEN TOWN, LONDON, NW
GROUND FLOOR
KEY PLAN
1:200
1st NOV.'89
FOR CONSTRUCTION
1142/-/G/1200

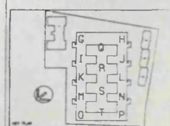


REV.	DATE	AMENDMENT
C	15-11-90	UPDATED TO LAYOUT ...
B	9-4-90	ATRIUM LIFT DETAIL REFERENCES ... INT. SECTION/ELEVATION REFERENCES
A	26-2-90	SECTION LINE DRAWING REFERENCES STEEL COLUMN I SECTIONS ADDED OPENINGS TO ALL 6 BED WARDS ...

CONTRACTORS MUST VERIFY ALL DIMENSIONS ON SITE BE... COMMENCING ANY WORK OR PREPARING ANY SHOP DRAWINGS

WESTMINSTER AN... CHELSEA HOSPIT...

FULHAM ROAD, LONDON SW10



KEY PLAN

North West Thames Regional Health Author...

40 EASTBOURNE TERRACE, LONDON W2 3QR

SHEPPARD ROBSON ARCHITECTS

77 PARKWAY, CAMDEN TOWN, LONDON, NW1 7P...

TELEPHONE 071-485-4161 FACSIMILE 071-267...

THIRD FLOOR KEY PLAN

1:200 19th JUNE '89

NOT FOR CONSTRUCTION

1142/-/3/1200

APPENDIX 3

EFTE FOIL ROOFS: An Outline by Vector Special Projects Ltd.

General Description

EFTE roofs consist of pneumatic cushions compromising between 2 and 5 layers of a modified copolymer Ethylene Tetra Flouro Ethylene. The EFTE foil is extruded into thin films and supported in an aluminium perimeter extrusion which is supported by the building frame.

The cushions are inflated by a small inflation unit to approximately 220 Pa, which gives the foil a structure stability and the roof high insulation properties.

Life

EFTE foil is unaffected by UV light, atmospheric pollution and other forms of environmental weathering. The material has been extensively tested both in the laboratory and out in the field and no degradation or loss of strength is observed. The material does not become brittle or discolour over time. It is anticipated that the material has a life in excess of 40 years.

Colour Rendering

Due to its good transmission characteristics, colour rendering under an EFTE foil roof is extremely good.

Insulation

A standard three layer cushion has a U value of 1.96w/m^2 °K. This is better than triple glazing when used horizontally (glazing manufacturers figures are for vertical glazing which considerably enhances the figures). The insulating qualities of the cushion can be enhanced by the addition of further layers of foil which in turn can be treated with one or more Low E coatings. The approach can reduce the U value to below 0.6 w/m^2 °K.

Energy Consumption

The energy consumption used by the inflation units is minimal because the blower units only need to maintain pressure, they do not need to create air flow. A roof is generally powered by one or several inflation units with each unit maintaining pressure to approximately 1000m^2 of roof. An inflation unit comprises two backward airfoil blowers powered by electric motors. One of the motors is rated at 220 Watts and is permanently on standby, whilst the other, rated at 100 Watts, is switched on and off by a pressure switch connected to a reference cushion. The main blower is thus only operating for approximately 50% of the time with the power usage being in the order of 50 Watts.

Safety/Explosion Risk

EFTE foil is a flexible material which can take extremely short high term loading. this makes it an ideal material for use where there is risk of explosion. Equally if there is risk of vandalism, EFTE foil cushions do not break and fall out of their frames risking life below.

Fire

ETFE foil has low flammability and is self-extinguishing. The cushions self vent in the event of fire as the hot plume causes the foil to shrink back from the source of the fire allowing the fire to vent to the atmosphere. The quantity of material in the roof is insignificant in fire terms and one does not experience molten drips of foil from the roof.

Acoustics

A foil roof is acoustically relatively transparent. This means the foil acts as an absorber for room acoustics, enhancing the internal perceived environment.

Weight

EFTE foil cushions are extremely light weight, weighing only 2 - 3.5 Kg/m^2.

Cushion Size

Cushions can be manufactured to any size and shape, the only limit being the wind and snow loading. This in turn is effected by the cushions orientation i.e. is it horizontal or vertical. As a general design guide for rectangular cushions, the cushions will span 3.5m in one direction and as long as one requires in the other. i.e. cushions 3.5m x 30m are possible. For triangular cushions, where the foil is two way spanning, the size can be increased. All cushions can be made even larger if required, by incorporating reinforcement into the internal and external foils of the cushion.

Vector foils next major project is Project Eden, an enclosed tropical garden in St. Austin, Cornwall.

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