DAYLIGHTING AND ITS EFFECTS ON INTERIOR ATMOSPHERES

A THESIS
SUBMITTED TO THE DEPARTMENT OF
INTERIOR ARCHITECTURE AND ENVIRONMENTAL DESIGN
AND THE INSTITUTE OF FINE ARTS
OF BILKENT UNIVERSITY
IN PARTIAL FULFILMENT OF THE REQUIREMENTS
FOR THE DEGREE OF
MASTER OF FINE ARTS

By
Ayşe Banu Tevfikler
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tarafından bağışlanmıştır

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts.

Assoc. Prof. Dr. Cengiz Yener (Advisor)

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts.

Assist. Prof. Dr. Can Baykan

I certify that I have read this thesis and that in my opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Fine Arts.

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Approved by the Institute of Fine Arts

Prof. Dr. Bülent Özgüç, Director of the Institute of Fine Arts

ABSTRACT

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Ayşe Banu Tevfikler
M.F.A. in Interior Architecture and Environmental Design
Supervisor: Assoc. Prof. Dr. Cengiz Yener
September, 1996

In this work, daylighting has been studied from its effect on the interior atmosphere point of view. This required investigating the scope that it can be employed as a design element for the built form. Within this aspect, the various factors influencing the way that it can be presented within an interior space are examined. Several impressions have been defined previously by researchers through statistical analyses as results of lighting patterns employed within an interior. These are tried to be found out if obtainable by daylighting. Building examples which make use of different strategies of daylighting are chosen and examined if the defined impressions were felt as a consequence of the daylighting on the interior atmosphere.

Keywords: Daylight, Sunlight, Natural Lighting, Subjective Impressions.

ÖZET

DOĞAL AYDINLATMA
VE MEKAN ATMOSFERLERİNE
ETKİLERİ

Ayşe Banu Tevfikler
İç Mimari ve Çevre Tasarımı Bölümü
Yüksek Lisans
Tez Yöneticisi: Doç. Dr. Cengiz Yener
Eylül, 1996

Bu çalışmada, doğal aydınlatma, ve bunun mekan atmosferine olan etkisi ele alınmıştır. Bu amaçla, gün ışığının binada bir tasarım unsuru olarak kullanılması incelenmiştir. Bunun için, gün ışığının mekan içindeki etkisini ve dağılımını etkileyen unsurlar ortaya konmuştur. Varolan doğal ışığı içeriye aktarmada bir araç olan bina açıklıkları detaylı olarak incelenmiştir. Önceden, araştırmalar sonucu statistiksel yöntemlerle belirlenen, ve kullanılan ışık modellerinin sonucu oluştuğu söylenilen bazı subjektif mekansal izlenimlerin, doğal ışık kullanılarak da sağlanabilirliği araştırılmıştır. Doğal aydınlatma yöntemlerinin kullanıldığı değişik bina örnekleri seçilmiş, ve bu aydınlatma şekillerinin sonucu oluşmuş etkilerin, belirlenmiş mekan izlenimlerini verebilirlikleri incelenmiştir.

Anahtar Sözcükler: Gün Işığı, Güneş Işığı, Doğal Aydınlatma, Subjektif İzlenimler.

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1.1. Historical Background of Daylighting

Recognition of the importance of daylighting is not new. When examining the use of daylight throughout history of architecture, it can be seen that daylight, or more precisely the sun as the source of it, has been worshipped or appreciated, just because of its benefits. Lam (1986) points out that the recognition of its benefits ensured the sun to be praised and prayed for; thus the potential problems of its presence have been adapted to. From the beginning of the history of man-kind on earth, the sun has been the source of worship, and when people began to build spaces for various activities of interest, they continued this tradition of specifying the importance of the sun. This constituted the basis for the shaping of architecture. The importance of activities performed within spaces were graded with the amount of daylight received. Within this aspect, Moore (1985) states that a special event, such as an altar in a church, is signified by the brighter areas within spaces that corresponds the building's openings. Even in the early cultures, the use of light was absolutely essential, whether intended or not. The use of daylight was indispensable, because spatial atmospheres were created "not just through any square or rectangular openings perforated in the walls, but also through refined channelling of light" (Annual of Light and Architecture 1994, 1995: 102).

1.2. Why Daylight

For considering daylight as a source of light for a space, and defending it against the other sources, some concrete evidence has to be provided. When daylight is intended to be used as an illuminant of a space, the effects of it should be considered on all aspects of the building and its occupants, regardless of the extent to which it is used. Each type of building has different needs, according to many features like the occupancy, or the scale of the building. Robbins (1986) states that, just because of this fact, the use of daylight should be decided, like other environmental systems, specifically for different cases. He further supplies some characteristics of daylight that justify the advantages of the use of it within interiors, some of which are as follows: Quality of the light; importance of daylight as a design element; view; energy conservation; no cost change in construction; the genuine desire to have natural light and sunlight in a space; and the psychological and physiological benefits not obtainable with electric lighting or windowless building.

Quality of daylight is a very important reason to provide it for interiors: Its quality comes from the point that it is a full spectrum light source, and people compare all other sources against this full-spectrum source. Because of the quality of daylight, less amount of it is needed to perform a certain task than an artificial light. Villecco (1979a) states that "our most fundamental biological, as well as aesthetic needs" results in the fascination of daylight, and that "orientation in time and space" is important for our survival and well being, which can both be answered by daylight (49). Color rendering under daylight is another quality issue of it, which should be considered. Daylight is considered to be the standard against which all the other sources' color rendering properties are matched (McNicholl, 1995). Robbins (1986) states that the human eye adjusts to the light sources and changes the perception of colour, matching the spectral colour composition of the source. Therefore, colour of objects may change depending on the light they are object to. The quality of daylight is said to be good for vision, and thus daylight is considered to provide a good visual environment. A good visual environment affects the ability of people to see objects properly, to differentiate them in space by discerning foreground from background, and therefore to perform visual tasks.

Daylight is an important design element; because varying quantities of daylight is needed in different spaces of a building to obtain the general form, and the spatial arrangement. Daylight can be used at a small scale to add a visual effect to a corner, along a wall, or any other point within a space; or it can be used to specify a piece of sculpture or to add a certain mood to a space.

Apertures of a building are the means through which the spaces can obtain daylight. Providing visual communication channels to the outside is an important feature of these daylighting apertures. Robbins (1986) states that, studies have shown that the need of view to outside is something not included in a list of environmental factors, if they are already provided for a space. However, the lack of it makes people aware of its necessity. As daylight adds an aesthetic quality to a space as a design element, and also provides illumination for visual tasks, lighting of buildings through daylight should be designed to get as many utility as possible from the daylighting apertures. The issue of the importance of daylight within architectural concerns is pointed out by Villecco (1979a) as follows:

> Natural light has long been accepted as a form issue in architecture and therefore, undeniably the province of the architect. It is perceived as an aesthetic concern related to the quality of an environment. The concern with numbers is a newer one that must be addressed, but does not overwhelm the fundamental human and aesthetic factors for architects. The numbers are an index to performance and therefore important, but light is still first and foremost a perceptual and qualitative issue (51).

1.2.1. Economical Aspects of Daylight

Daylight can reduce the energy consumption within a building. Button (1993) states that the effective use of daylight can be one of the largest single means of saving energy. Within this aspect, Robbins (1986) states that in a correctly designed daylighting which integrates with energy conservation in the design criteria users are enabled to turn off, step down, or dim the electric light when there is sufficient daylight to perform task or background illumination.

An efficient lighting design of a space involves taking account on some aspects that enable energy conservation. Within the case of daylight, energy conservation involves the use of window specifications to admit daylight in an effective manner. This is related with the shape of the space, orientation of apertures, patterns of occupancy, and tasks. The relation of apertures with the surrounding is also important.

Villecco (1979) states the recent ideas on energy conservation aspect which urges the designer to integrate building and nature, rather than isolate them from each other. The location and form of the building have become the focus of energy conscious design rather than mechanical systems.

1.2.2. Physiological Aspects of Daylight

Daylight has physiological effects on people. As pointed out by Evans (1987), many studies have shown that there is a number of desirable physiological benefits that can be obtained by daylighting. Humans are evolved in the natural environment, and therefore, this full-spectrum light answers all their physiological needs. For example, some radiations within daylight are essential to human health, such as the ultraviolet radiation that provides vitamin D for the body. Stimulus is another physiological benefit obtainable through daylight. People need reasonable stimuli to remain sensitive and alert. Evans (1987) suggests that the human organism is not adapted to a steady stimuli or to a complete lack of stimuli. When people are exposed to it for a long time, uniformity in the environment produces monotony.

Lack of change is inconsistent with people's natural tendencies. This is the reason why the constantly changing nature of daylight automatically and naturally answers to the need of body and mind for a change of stimuli. However, overstimulation through lighting can cause emotional and physical fatigue. Therefore, the lighting design should avoid excessive stimulation from direct light sources and provide some visual flexibility and stimuli. These valuable variations can best be provided for an interior by the proper introduction of daylight into the space. Orientation is another physiological need of people. Evans (1987) suggests that people are frustrated and distracted when they are not able to sense what the weather is like outside and have little sense of nature's time.

1.2.3. Psychological Aspects of Daylight

The psychological impact of interior daylighting on people are perceived, but are difficult to quantify. Having a direct sunlight within a space is one of the strongest psychological benefits. Direct sunlight in the right location and quantity is stimulating and desirable. Good building design should include direct sunlight without destroying visual acuity. Another psychological benefit of daylight is that it produces a gradation and colour of light on surfaces and objects that is biologically natural for people. As Evans (1987) states, daylight is the standard against which human mind measures all things seen, mainly because of a life-time association with it. A gradation of daylight through an aperture on a wall seems natural, and the wall seems smooth. Colors appear real and appropriate through colour constancy, although the colour produced by daylight changes with time throughout the day. Within this aspect, Moore (1991) defines constancy to be the visual tendency to perceive the environment as it is known to be, not as it appearance. That is to say, although the amount of light reaching a white ceiling at the rear of the room from side windows may be only one twentieth of the light on the ceiling at the front of the room, the ceiling is perceived as white all over. It is not perceived as white near the aperture and dark grey further away from it. It is stated further that it is possible to show that the measured luminance of a dark grey card placed on the ceiling near the aperture may be as much as the ceiling at the back, but it is not perceived as such. The observer knows from experience that the ceiling is uniformly white, and therefore discounts the fact that not all of the ceiling surface receive the same degree of illumination. This is reinforced by the awareness of the location of the aperture as the light source. Thus the observer unconsciously concludes that, because the location of the light source is consistent with the appearance of brightness gradation, the ceiling is uniformly white.

Robbins (1986) suggests that in many buildings, occupants really desire to have natural light and sunlight within the building; and that daylight introduces a sense of cheeriness and brightness which can have a definite positive psychological effect on the occupants. He added that although sunlight is also desired, the degree of this desire seems to vary from one building type to another. Within this aspect, he provides results of a survey by Longmore and Ne'man (1973) that shows the preference for sunlight which varied from %90 of the people who preferred it for dwellings, %73 for office personnel space, to %42 for school classrooms. Light is not only essential for vision, but also has biological and psychological benefits which affects health and psychological well-being.

1.3 Scope of the Thesis

Light is a design element that has certain characteristics affecting the mood or the atmosphere of a space, and this is said to influence the emotional responses of the users (IESNA, 1983). Flynn et al. (1977) explains the importance of light as a vehicle that facilitates the selective process of searching for a meaningful information and alters the information content of the visual field. They further state that lighting design should be evaluated for its role in adequately establishing cues that facilitate or change the occupant's understanding of his environment and the activities around him. The architects who are known for their masterfully use of light through their designs, such as Louis Kahn, Mies van der Rohe, Frank Lloyd Wright and Le Corbusier, are stated by Annual of Light and Architecture 1994 (1995) to be aware that light can strongly influence man's moods, and that light atmospheres can give rise to both a happy state of being or make man suffer. Within this aspect, DeNevi (1979) stresses the Wright's understanding of light, and states that Wright believed that the sunlit spaces could elevate the human spirit to the highest order. The mentioned architects are said to understand the importance, and thus use the shadows. Synder (1994) presents daylighting of three masters of light, one old and two modernists, namely Sinan, Saarinen and Belluschi; and compares them. She states that their sense of light throughout the building is fluid. Also, she finds this fluid sense of light throughout Sinan's buildings comparable to that of Le Corbusier's and Louis Kahn's.

Masters of architecture are cited as masters of light (Villecco, 1979a). Within this aspect, Rasmussen (1964) states that "light is of decisive importance in experiencing architecture", and that by changing the size and locations of the openings, the same space can give very different spatial impressions (qtd. in Button et al., 1993). A good light does not mean only much light, as most people are mistaken. If anything is not seen well, more light is demanded, but this is found to be not enough, which means that the quantity of light is not nearly as important as its quality.

The luminance patterns in a space can influence perception of the space's intended function, comfort level, and size (Steffy, 1990). It is further stated that Flynn found specific impression factors that are influenced by luminance patterns as: visual clarity, spaciousness, relaxation, privacy, and pleasantness. These impressions are advised by Flynn (1977) to be used to establish design directions that ultimately will result in more occupant-sensitive spaces. These impressions that are defined to be obtainable through lighting are taken as the basis for this study, and it is searched to find if they could be obtained by daylight. Also buildings are searched if they employ such applications of lighting which fulfills the requirements of these impressions.

Within this aspect, the thesis covers the following chapters:

Chapter one deals with the introduction of the subject. It is tried to point out importance of daylighting and its historical background together with the presentation of its advantages like the economical, physiological and psychological aspects. The scope of the subject and the aim of the study are also stated.

In the second chapter, the natural factors affecting the quality and the quantity of daylight have been investigated. Under the scope of this investigation, sun's movement; types of skies; latitude and climate; topography, immediate surrounding, and orientation have been studied.

Factors which are under control of designers have been examined throughout chapter three. It is underlined that daylight daylight is not something one adds to building design, but that it is implicit to every design desicion. It is stressed that this naturally available phenomenon on earth, can be used as a design element affecting the interior mood of a space, and that this can be achieved through proper design. Fenestrations which are the principal vehicles through which daylight can enter into an interior have been studied. The importance of their orientation, size, form, material, and the like, which affect the interior illumination have been pointed out. Types of daylighting apertures, media of glazings used on fenestrations, and control of fenestrations have been investigated within this aspect. Then the effect of scale on daylighting has been studied, beginning from a wider consideration as the urban design, and ending up in a narrower one as the building scale. Occupancy and lighting, which defines the lighting requirements of different spaces, has been investigated.

Chapter four deals with the creation of the desired atmospheres through daylight. It is searched through examples that employ various daylighting strategies whether the defined atmospheres obtainable through lighting were also obtainable through daylighting. Several atmospheres and the possibilities of the creation of these atmospheres by daylight have been searched.

It is concluded in chapter five that the defined atmospheres that were resulted from lighting can also be resulted from daylighting. From the research on examples, daylighting strategies capable of producing the related atmospheres are pointed out.

2. NATURALLY AVAILABLE FACTORS AFFECTING THE QUANTITY AND THE QUALITY OF DAYLIGHT

Daylight, as a naturally available light source for buildings, can be affected by certain factors. Movement of the sun; types of skies; latitude and climate; topography immediate surrounding, and orientation, as naturally availablle factors, contribute to this effect.

2.1. Sun's Movement

Available light of sun on earth for architectural design purposes, is in two forms: direct and diffused. Direct sunlight makes an impact upon east, south or west building exposures intermittently (in the northern hemisphere). Diffused light is the skylight, which impinges on all surfaces of the building, simultaneously and more consistently than direct sunlight. The evaluation of skylight should be done in at least two forms: the overcast sky conditions and the clear sky conditions. Both the overcast sky conditions and the clear sky conditions excluding the presence of direct sunlight are large area diffuse illumination sources. The sun, on the other hand, functions as a high intensity, small area or point source. Lam (1986) states that when there is a clear sky, buildings receive sunlight, in addition to the diffuse skylight, both direct and reflected off the surrounding surfaces; on the other hand, when there is an overcast sky, the sun's light is diffused by clouds, and the whole sky becomes the source of light. Here, another component of daylight should be considered: Reflected light. Moore (1985) discusses this aspect, characterising the daylight sources as direct daylight, which is direct sunlight and diffuse skylight; and indirect daylight, which is the light from reflective or translucent diffusers that were originally illuminated by primary or other secondary sources. He states that direct sunlight illuminates perpendicular surfaces with 70-110 thousand lux, and that, therefore it is too intense to be used directly for task illumination. This is the reason why it is preferred to be excluded from interiors; however, as further stated by him, "the movement and sparkle associated with controlled shafts of sunlight add considerably to the visual variety and excitement of a space" (30).

The sun is at a great distance of 690 million kilometres from earth, and because of this reason, the rays of sunlight falling on the earth are virtually parallel (Lam, 1986). The seasonal differences in the daily path of the sun are due to the tilt of the earth's axis (Figure 1.). As a result of the importance of the contribution of direct sunlight to illumination, it is valuable to the designers to visualise the position of the sun in the sky (Moore, 1985). Within this context, Lam (1986) presents a detailed information on the movement of the sun, and points out that "at any given moment in time, each portion of the earth that receives the sunlight, receives it at a different angle that changes on a daily and annual basis" (41). At any point on earth, the sun is highest at solar noon of each day. The altitude of the noon sun is dependent on the distance from the equator. During equinox noon, the solar altitude is 90 degrees minus the latitude. At midsummer noon the altitude is 23.5 degrees higher than the equinox noon, and at midwinter, it is 23.5 degrees lower.

It is a known fact that the sun revolves 360 degrees laterally around its North-South axis in twenty-four hours, and this means that it moves 15 degrees in one hour. The location of the sun in the sky can be described as having two components: The bearing angle, and the altitude (Figure 2.). Its daily movement around the horizon is its bearing angle relative to south; and its height above the horizon, which varies seasonally, is its altitude. Sunlighting strategies for various latitudes should be based on predictable seasonal differences in the sun's altitude as well as other factors such as climate, proximity of water, vegetation, and buildings (Lam, 1986).

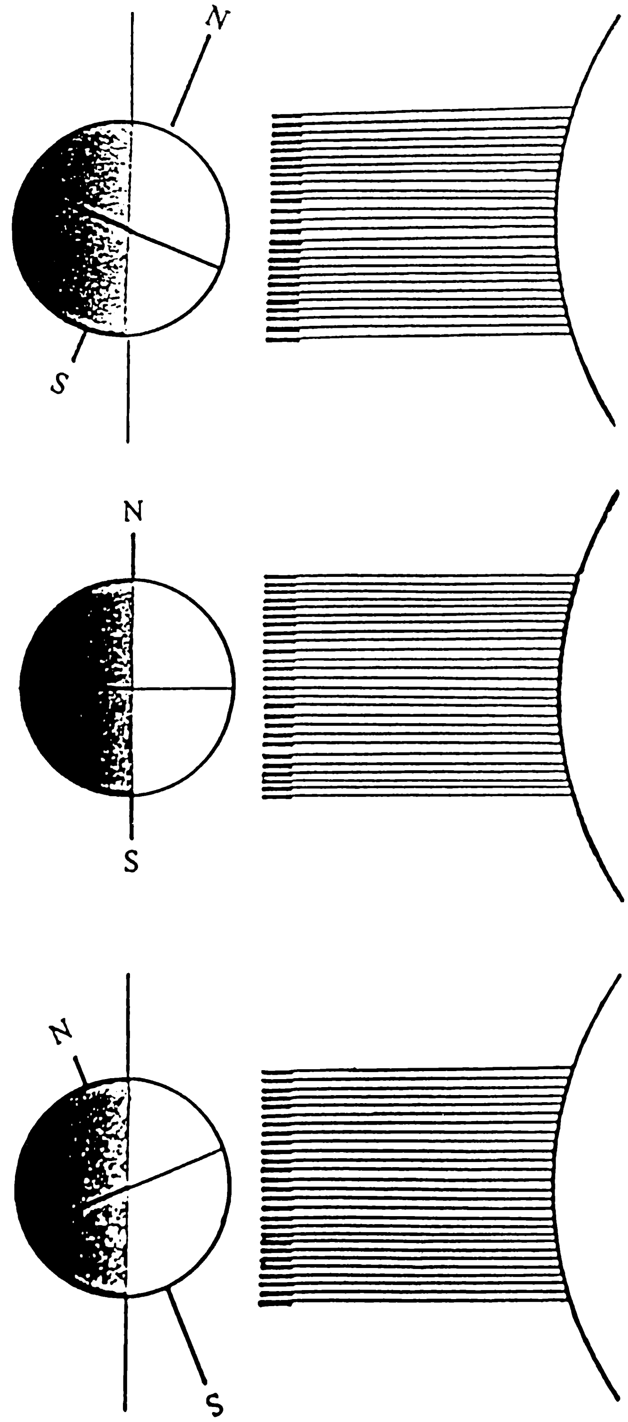


Figure 1. The tilt of earth creates the seasons and the altitude of the sun, from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold Company, 1986) 41.

The intensity of light normal to any particular planar surface is dependent on its angular relationship to the direction of the sunlight. When the sun is low and horizontal relative to a point on the earth's surface, the sunlight is received

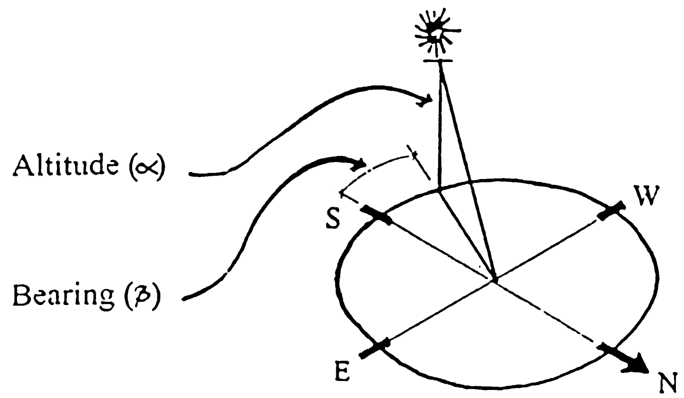


Figure 2. Bearing (β) and altitude (∝) angles of the sun,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold Company, 1986) 42.

directly on vertical surfaces and more obliquely on horizontal surfaces. When the sun is high, any given area of horizontal surface receives more light than a vertical surface of the same area (Figure 3.).

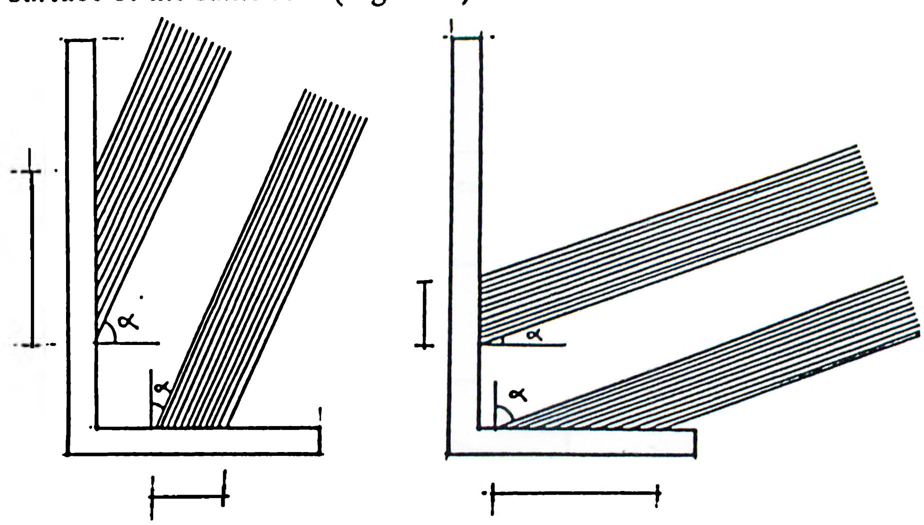


Figure 3. Sunlight is most concentrated when the receiving surface is normal to the incident angle of sunlight,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold Company, 1986) 44.

When sunlight passes through the air mass surrounding the earth, some of the light is absorbed, and some is scattered by water vapour molecules and dust particles. Sunlight on earth, that is received after this filtration, can be reflected by the reflecting surfaces on earth. Lam (1986) stresses the importance of this fact stating that the natural lighting of buildings should be designed by recognising the total light from the sun after its filtering by sky and clouds and its reflection by ground-level natural and man-made elements. The composition and the color temperature of the sunlight changes slightly after it passes through the atmosphere (Figure 4.). The sun radiates its energy in all directions. Lam (1986) states that at the edge of the earth's atmosphere, the level of solar illumination is approximately 155 thousand lux. He adds that even after passing through the atmosphere of a clear sky to sea level, the level can exceed 100 thousand lux. The instantaneous energy of 0.1 square metre of sunlight (on a horizontal surface of equinox noon, at sea level, 40 degrees north latitude) is equivalent to the visible light of 3.3x40-watt fluorescent lamps, or 6x100-watt incandescent lamps. Even if inefficiently used, there is obviously an abundant amount of radiant energy available from the sun.

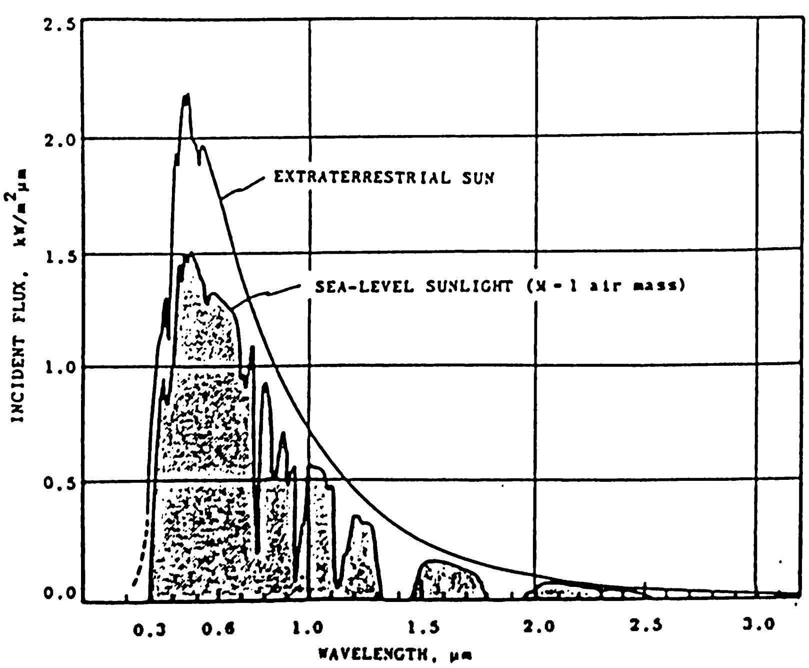


Figure 4. Spectral distribution of energy in sunlight above the atmosphere and after passage through one air mass containing 20 mm precipitable water vapour, from Lam, W. Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold Company, 1986) 44.

2.2. Sky Types

The relative amounts of light received by a building from sky and ground will vary depending on the position of the sun, sky conditions, and the shapes and reflectances of ground surfaces and objects on the ground. Three types of skies are standardised for design purposes as clear sky, cloudy sky, and overcast sky.

Clear sky: On a clear day, most of the illumination comes directly from the sun, and thus casts sharp shadows. The intensity of illumination from direct sunlight on a clear day varies with the thickness of the air mass it passes through (Figure 5.). It is therefore almost entirely dependent on the sun's altitude (Lam, 1886). It is less intense at sunrise and sunset at any latitude; and at noon it is less intense at high latitudes because the sun is lower.

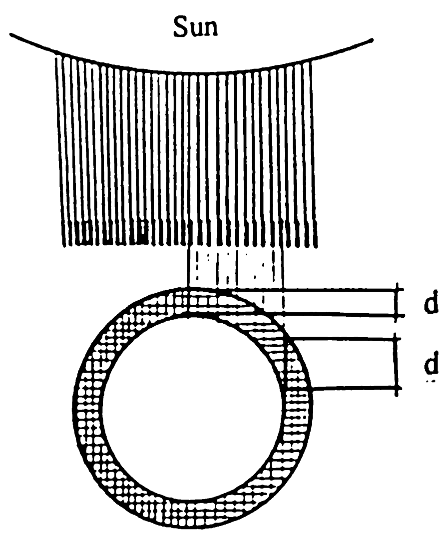
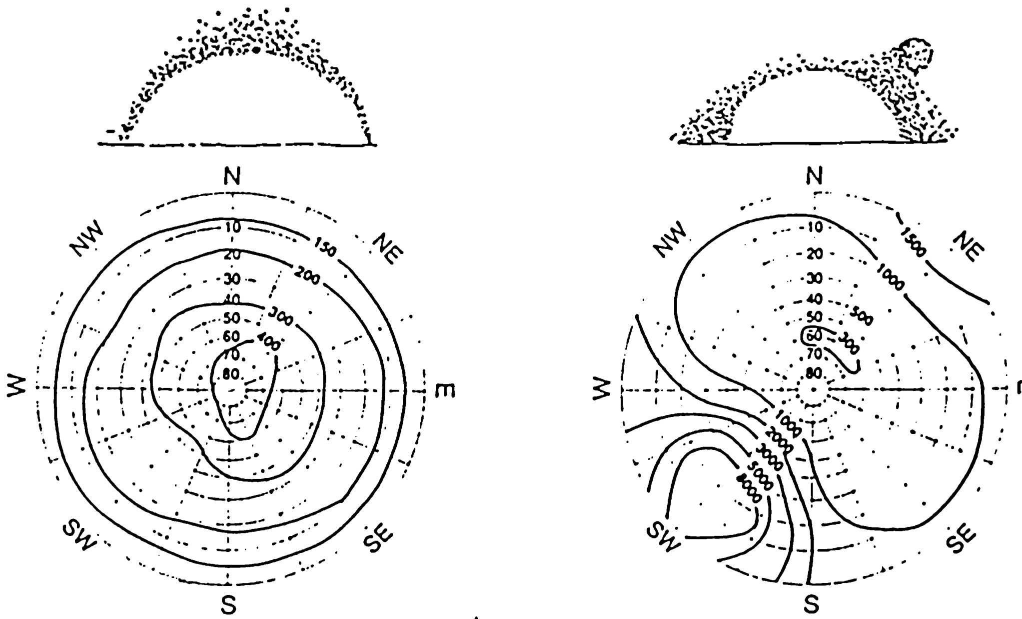


Figure 5. Intensity of illumination perpendicular to the sun's rays varies with the thickness of the air mass, d, resulting from solar altitude,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold Company, 1986) 42.

Cloudy sky: Unlike clear days and totally overcast days, the illumination on cloudy days changes constantly (from 23,000 to 100,000 lux) with moments of full sunlight and other moments when the sun is intercepted by clouds.

Overcast sky: Typical overcast sky reduces the sunlight by more than 90 percent. When the cloud cover is so dense that all evidence of the sun is obscured, the luminance distribution is independent of the altitude of the sun.



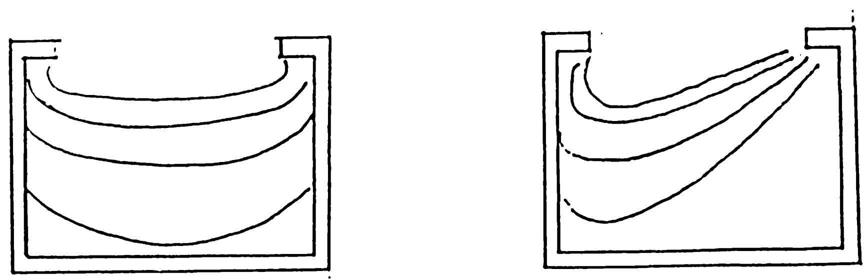
Non-uniform luminance which varies in accordance with geometrical parameter, and which pertains to a meteorological situation that corresponds to a sky covered with light cloud in a clear atmosphere, where the sun is not visible. The sky is three times more luminous at the zenith than at the horizon.

Sky of variable luminance, in accordance with geometrical parameters and the position of the sun, which pertains to a meteorological situation that corresponds to a sky with a clear atmosphere. The sky may be twelve times more luminous at the horizon than at the zenith.

Figure 6. Luminance distribution of the clear and the overcast sky conditions, from Daylighting in Architecture (London: James and James, 1993) 28.

The sky types asserts a great importance on the effects of daylight within an interior through various types of apertures. As it is clear from Figure 6., the luminance distributions of overcast sky is very different from that of the clear sky, and this affect the luminance penetration and interior distribution (Figure 7.). The overcast sky is three times more luminous at the zenith than at the horizon. This implies that the zenithal entry of daylight is greater under such conditions than under clear sky conditions. Under clear sky conditions, the luminance of the sky is dependent on the position of the sun, and may be twelve times more at the horizon than at the zenith.

This implies that sidelighting can be effective in obtaining deeper penetrations of illumination. Therefore, with changing conditions of the sky, the effects of daylight presented within an interior, through one type of daylighting aperture, may show great differences, and this should be considered for design purposes.



Distribution of overcast sky through a toplighting aperture — Distribution of clear sky through a toplighting aperture

Figure 7. Effects of sky condition on the luminance distribution within an interior, through the same aperture

2.3. Latitude and Climate

The latitude of a site determine the angle of the sun available at that point at various seasons. Angle of the sun, in turn, shape the geometric relationships between a building and its environment. Lam (1986) states that sunlighting strategies for various latitudes should be based on the predictable seasonal differences in the sun's altitude as well as other factors such as climate, proximity of water, vegetation, and buildings.

The degree and the way in which the building is daylighted is affected by climate. Also, the cost-effectiveness of alternative daylighting strategies and devices, and the ways in which they may be refined for a specific purpose, is determined by climate. For example, because of the generally low brightness of the clear sky in sunny climates, the light reflected from the ground and buildings is often more important than that received directly from the sky. The presence of adjacent buildings may well increase rather than reduce the available light. Even black surfaces in full sunlight can achieve a luminance greater than that of the darkest portions of a clear sky.

2.4. Topography, Immediate Surrounding, and Orientation

Building surfaces and forms affect sunlight received within a space, in the same way as the natural environment. As light is transmitted, reflected, or scattered, certain wavelengths may be absorbed or redirected more than others, affecting the color and/or efficacy of the light. The luminous efficacy of a light source is defined as the ratio of the total luminous flux (lumens) to the total radiant power (watts). The effect of atmospheric scattering and absorption on the efficacy of sunlight is to increase the ratio from approximately 94 lumens/watt in space to approximately 118 lumens/watt at sea level (at one air mass, zenith). The efficacy of sunlight also varies with solar altitude. This phenomenon may be applied to architecture when choosing the materials and locations for transmitting and reflecting surfaces.

The daylighting considerations might significantly influence the site selection. Within this aspect, Evans (1987) states several site features that should be considered as follows: 1) location of the building on the site; 2) highly reflective surfaces near the site; 3) trees and shrubs on the site; and 4) bright ground surfaces. According to him, the location of the building on the site should be considered so that daylight can reach the apertures without significant interference from nearby obstacles. Highly reflective surfaces near the site, such as glass covered buildings, can cause excessive glare. Trees and shrubs on the site may give shade and reduce skyglare from the interior. The bright ground surfaces can be used to reflect daylight into the interior (Figure 8.), and about 40 percent of the interior daylight can be that reflected from the ground surfaces. The considerations related with the site features can be summarised as the building location on the site; surfaces reflecting light that in turn affects the building; and the available shaders on the site.

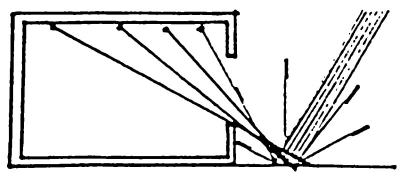


Figure 8. Ground-Reflected Light,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 49.

Sunny side (South in the Northern Hemisphere): In an open space, ground-reflected light is of the greatest potential benefit on the sunny side if the immediate ground is never in shadow. However, adjacent buildings and trees on the sunny side may place the immediate foreground in shadow, and their shady sides are likely to be darkest exterior surfaces seen. Keeping adjacent buildings and trees distant will maximize the lighting on the sunny side. Ground-reflected light is greatest when the sun is highest (Figure 9.): During summer and at low latitudes. Thus the high altitude of the sun make ground-reflected light more commonly available near the equator.

Shady side (North in the Northern Hemisphere): On the shady side, the quantity of light reflected off adjacent walls and buildings can be very significant. Generally, the benefits of adjacent buildings increase with their height and proximity, unless the reflecting surfaces are excessively shaded. The light reflected onto a building's shady side by sunlit vertical surfaces is maximised when the sun is lowest (Figure 9.): During winter and at high latitudes. Building reflected light can effectively illuminate the shady side of a building, as can be seen from Figure 10. Therefore, reflectance of the vertical reflecting surfaces is an important aspect affecting the light received on the shady side of buildings. Lam (1986) presents reflectances of certain materials as follows: An unpainted concrete building reflecting 40,000 candelas and a brick building reflecting 15,000 candelas may not be perceived bright as a 10,000 candelas overcast sky. This is an important characteristic that makes natural lighting delightful. Because sunlit objects are enjoyable to look at, they are perceived as pleasurable signals rather than visual noise or glare.

Ground reflected light is greatest when the sun is high

Building reflected light is greatest when the sun is low

Figure 9. Ground-reflected and building-reflected daylight,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 49.

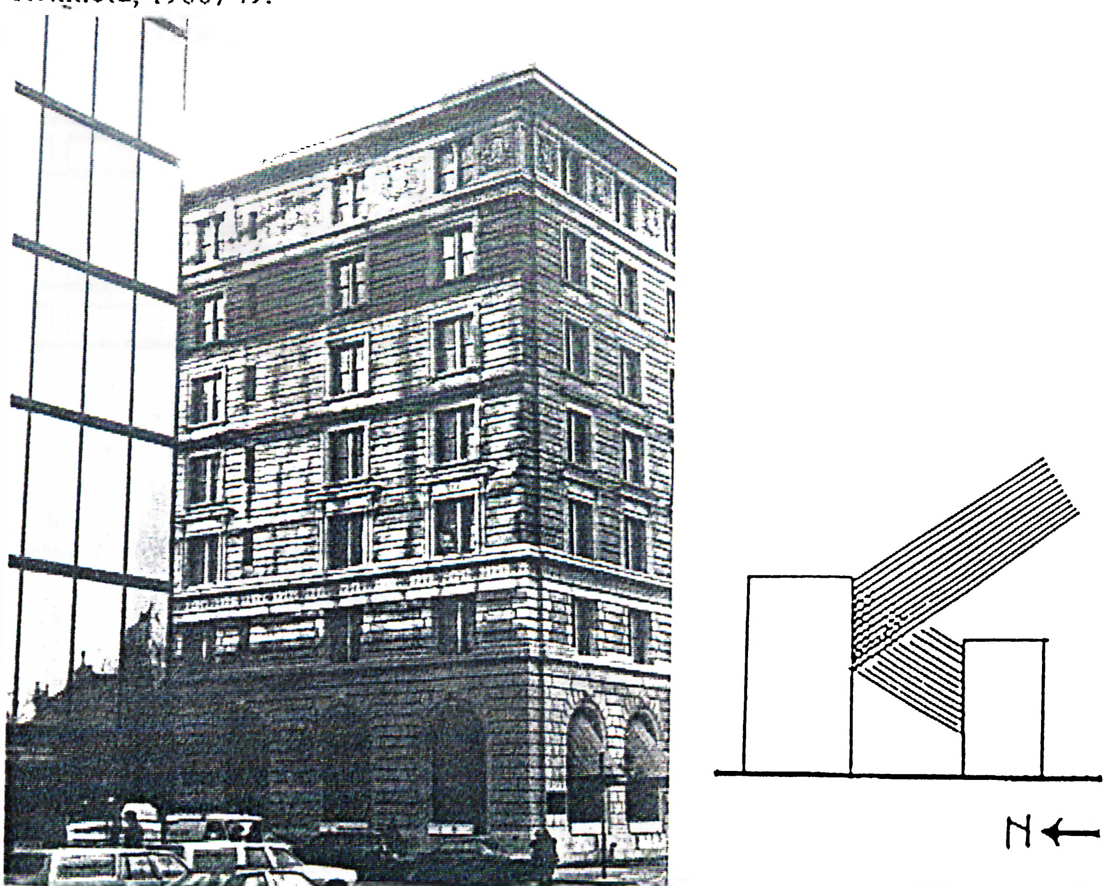
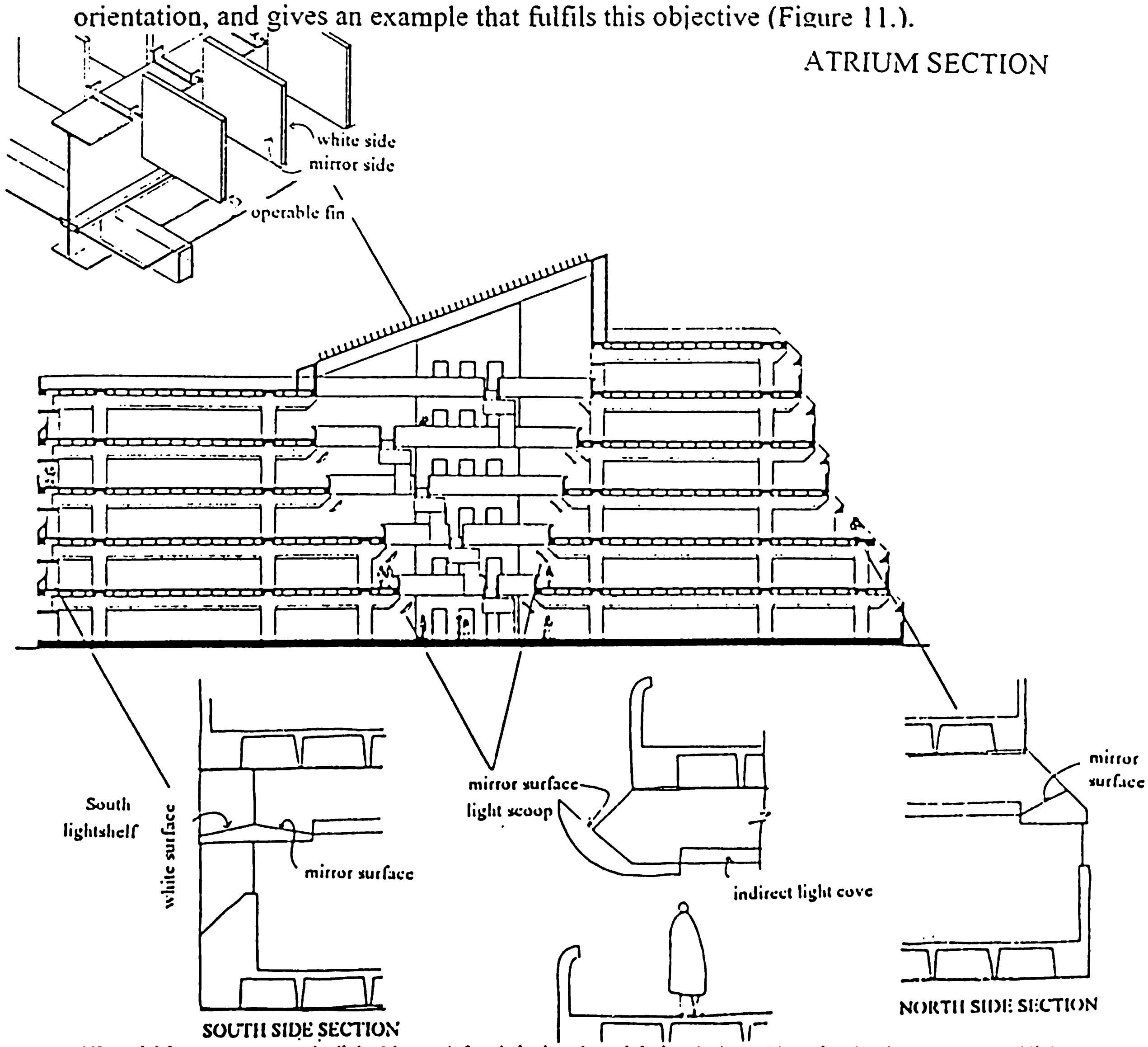


Figure 10. Building-reflected light illuminates the shady side of the building,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 84.

Even though the amount and type of the daylight available will vary with each wall surface, any building orientation can effectively make use of daylight. The difference in the quantity and quality of daylight received from different orientations is related with the location of the direct sun; which may have to be shaded and the intensity of the daylight will vary from south, east, west, and north. Mathews and Calthrope (1979) states that the building form should confront the different effects of orientation, and gives an example that fulfils this objective (Figure 11.).



Differential form responses to daylight. The north facade is sloped to minimize shadows. The atrium has louvers to control light according to office requirements.

Figure 11. Building section of the Tennessee Valley Authority Office Complex, from Matthews, S., and P. Calthrope, "Daylight as a Central Determinant of Design." AIA Journal (September 1979) 88.

Openings facing north will probably require larger glass areas than other orientations to achieve similar results. North windows never receive direct sunlight. Within this aspect, Grosslight (1990) states that the light coming in a north window is reflected from somewhere else -the sky, the ground, or another building. The advantages of the north orientation are that no sun control is necessary and illumination tends to be soft and diffuse. However, sky glare control may still be necessary.

The early morning and late afternoon low-altitude sun must be dealt with for the east and west oriented fenestrations, because at those times (early morning and afternoon), the sunlight is received at very low angles, which seems harsher and brighter (Grosslight, 1990). Vertical shielding (Figure 12.) is generally very effective on these orientation facades, because the vertical shading devices always redirect light downwards.

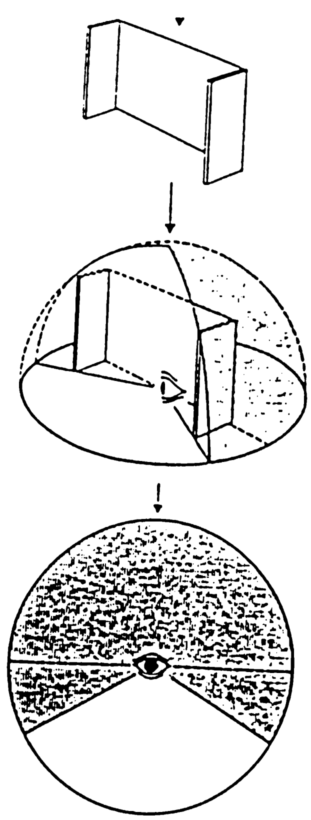
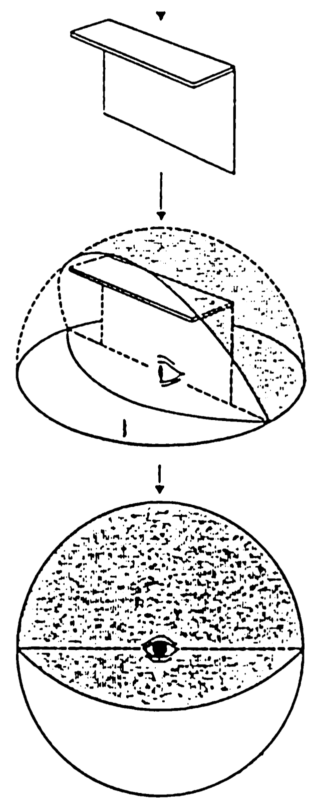


Figure 12. Vertical shading devices respond to the sun's bearing angle, from Olgyay, V., Solar Control And Shading Devices (Princeton: Princeton University Press,1957) 81.

The facade facing south provides the best opportunity for sunlighting, because this orientation receives the longest duration and the maximum quantity of sunlight.

Horizontal controls (Figure 13.) will provide control when the sun is in the southern quadrant, which will keep the high sun out in the summer, and allow the low-latitude winter sun to penetrate if desirable. A factor that still needs to be dealt with is the sky brightness, which can be done either through interior shades, blinds, or louvers, or with exterior vegetation.

HORIZONTAL



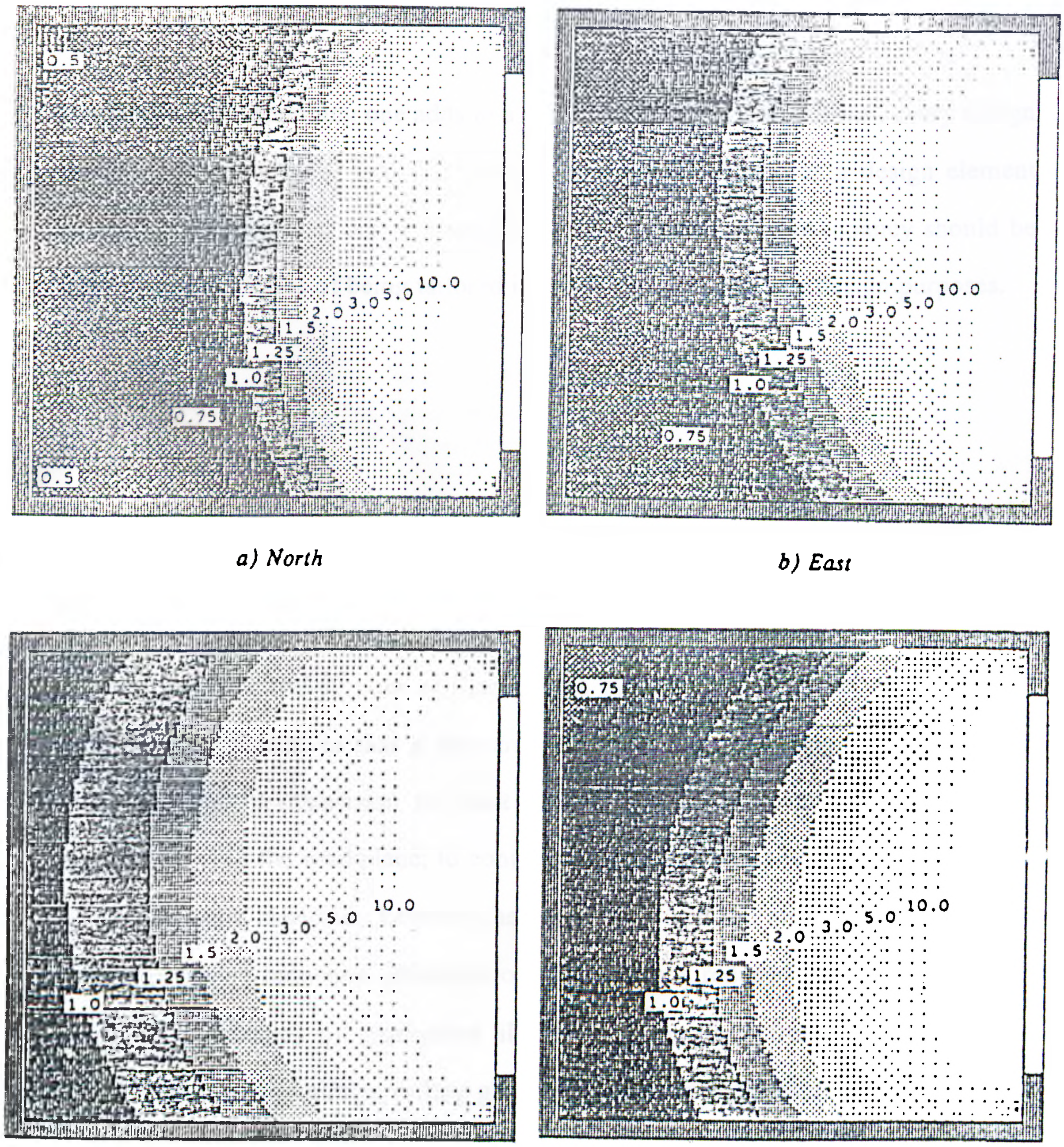
Devices obstructing areas of sky vault -------

Shading mask: The projection of the obstructed area of the sky vault -------

Figure 13. Horizontal shading devices respond to solar altitude. They shade most at noon, when the sun is highest,
from Olgyay, V., Solar Control And Shading Devices (Princeton: Princeton University Press,1957) 81.

The distribution of daylight factor by apertures facing these orientations is presented by Bales, et al. (1986) in Figure14. The daylight factor is defined to be a ratio of interior to exterior illuminance under an overcast, unobstructed sky; and measured in a horizontal plane at both locations and expressed as a percentage. It remains constant regardless of changes in absolute sky luminance, because the relative luminance distribution of an overcast sky is constant and does not change with time

(Moore, 1991). A daylight factor of 10 percent at a given interior location, for example, means that the location receives 10 percent of the illuminance that would be received under an unobstructed sky.



a) North *b) East*

c) South *d) West*

Figure 14. Examples of the distribution of the daylight factor by openings facing the four cardinal directions,
from Bales, E.J. and R. McCluney, <u>Proceedings II: 1986 International Daylighting Conference</u> (California: American Society of Heating, Refrigirating, and Air Conditioning Engineers, Inc., 1989) 92.

3. UNDER-CONTROL FACTORS AFFECTING THE QUANTITY AND QUALITY OF DAYLIGHT

Daylight is not something one adds to a building design; it is implicit to every design decision. This naturally available phenomenon can be shaped as a design element through proper applications. Fenestration, effect of scale, and occupancy should be investigated in terms of being tailored in relation with particular design purposes.

3.1 Fenestration

Fenestration is defined by Kaufman as: "any opening or arrangement of openings for the admission of daylight" (qtd. in Moore, 1985: 68). Fenestration of a building is thus the vehicle through which effects of daylighting on the interior atmosphere can be observed. For the purpose of illumination on a horizontal plane, Moore (1985) defines some objectives that a fenestration should confront, among which are: to maximize light transmission per unit area of glazing; to control direct sunlight penetration onto the workplane; to control brightness contrast within the visual field of the occupant, especially between the fenestration and the other room surfaces; to minimize cosine reduction (illumination on a plane is reduced by the cosine of the angle of incidence) of workplane illuminance resulting from low fenestration placement; and to minimize veiling glare on workplane surfaces, resulting from high fenestration placement.

The amount of daylight entering any fenestration is a matter of the size of the opening itself, type of the glazing used, and the available daylight. Evans (1987)states that the amount of daylight reaching any point in the interior is related with the area and brightness of both the exterior sources of daylight, and the interior daylighted surfaces that are "seen" from that particular point. As is clear from this statement, a point close to the aperture is confronted to a larger portion of the sky and has a higher illuminance level than a point farther away from the aperture (Figure 15.). Within this aspect, Robbins (1986) states that spaces need to be as close as possible to daylight apertures to benefit from daylight usage.

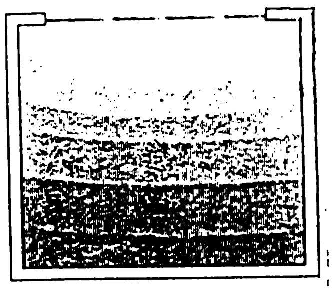


Figure 15. A point close to the aperture is confronted to a greater illuminance level, from Button, D. and B. Pye, Glass in Building: a Guide to Modern Architectural Glass Performance (Oxford: Butterworth-Heinemann Ltd., 1993) 91.

A daylighting system includes everything needed to make daylighting function as an environmental system in a building. In other words, the apertures of daylight, the media of glazing, and the control of daylight are the concerns of a daylighting system. The quantity of natural light needed, its character, its effects, its directionality, and the contrast it produces suggests that the most appropriate lighting components should be used for a given lighting situation.

3.1.1 Types of Daylighting Apertures

From the daylighting point of view, architecture is used to filter natural light into the building. This is done by manipulating the form of the building and building apertures so that daylight is provided for activities to be performed at specific points in the building as needed.

Robbins (1986) characterizes the apertures of daylighting in seven groups as: sidelighting; roof and top(horizontal) lighting; angled lighting; beam lighting;

indirect lighting; atria, light courts, and re-entrant lighting; and combinations of these (Figure 16.). Commission of the European Communities (1993) classify these apertures under two main groups as the conduction components; and the pass-through components. As defined by this commission, conduction components are the spaces that guide or distribute light towards the interior. Pass-through components are devices that let light in from one light environment to another. These components may be combined. Control elements can be incorporated to the pass-through components, which are devices to admit and/or control the light entrance into a building. The following graphical presentation (Figure 17.) facilitates understanding of the terminology.

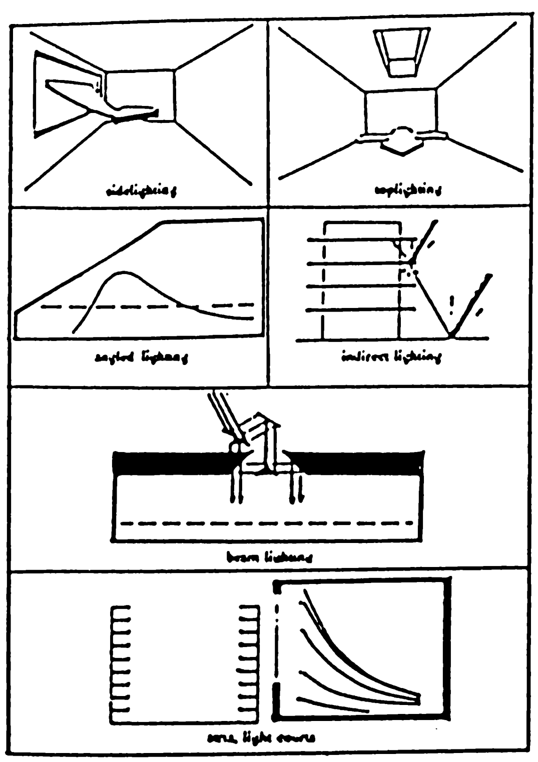


Figure 16. Robbins' classification of the daylighting apertures,
from Robbins, C. Daylighting Design and Analysis (New York: Van Nostrand Reinhold, 1986)

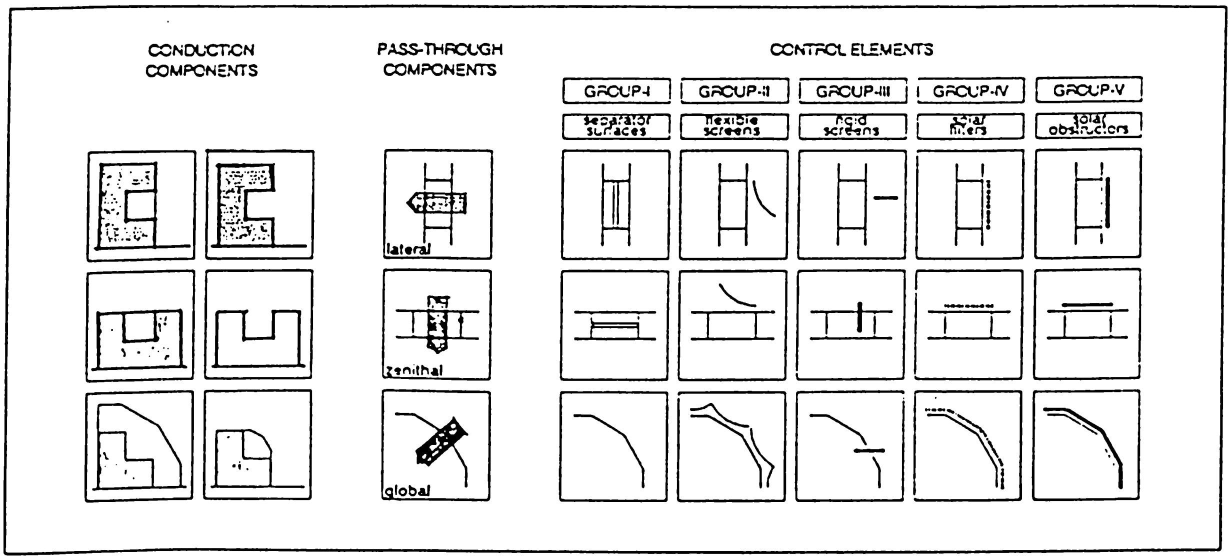


Figure 17. CEC classification of the daylighting apertures and control elements, from CEC. Daylighting in Architecture (London: James and James, 1993) 52.

Robbins states that the design of a building should be based on the geometric relationship between the space being daylighted and the sizes, shapes, and locations of various daylight apertures providing the space's natural illumination (1986). The penetration, distribution, quantity, and quality of daylight in the space can thus be manipulated by understanding of the proportional relationships between the space and the appropriate apertures. This aspect (the geometric relationship) should be considered before considering the impact of glazing, solar controls, interior furnishings, and other modifying attributes. The Commission of the European Communities states within this aspect that the sum of the surfaces of all the windows should be considered from a luminous point of view in relation to the area of the room; and added certain classifications for fenestration, which are: very low fenestration (less than 1%); low fenestration (1-4%); medium fenestration (4-10%); high fenestration (10-25%); and very high fenestration (greater than 25%) (1993). Having a large aperture or several small ones with the same total surface area within a space does not differ the quantity of light entering into the space, but the distribution of light (or the interior effect) is affected (Figure18.).

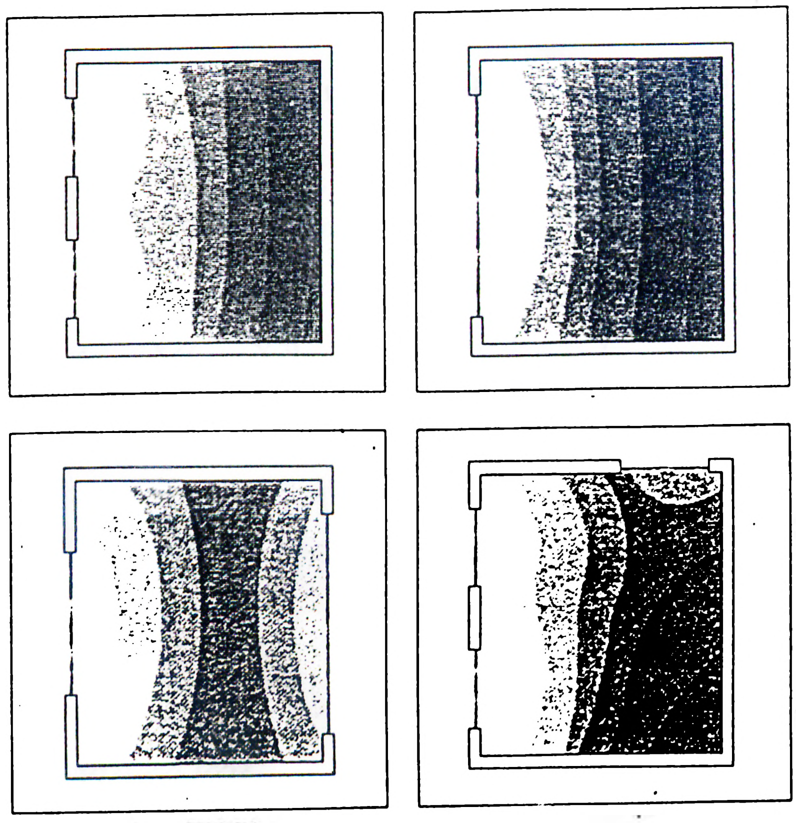


Figure18. Distribution of daylight within an interior is a function of the apertures, from Button, D. and B. Pye. Glass in Building: a Guide to Modern Architectural Glass Performance (Oxford: Butterworth-Heinemann Ltd., 1993) 91.

The way that the envelope of a building is manipulated is a matter of the functional requirements and arrangement of rooms and spaces in the building and the lighting needs of rooms or spaces that can use daylight as an interior illuminant. Sobin (1979) stresses the importance of this aspect, and presents Le Corbusier's concept of apertures. According to him, Le Corbusier specified the importance of windows as "to give light"; and developed certain types of windows and analysed them (Figure 19.). Also, orientation affects the performance of the apertures, as stated before. Discussing the aspect of orientation, CEC (1993) classifies windows as follows: a) High luminous levels are obtained via south-facing windows, but the illumination is somewhat variable; b) medium luminous levels are obtained via east- and west-facing windows, but the illumination throughout the day differs greatly as the east orientation provides a high level in the morning while the west oriented window provides a high level in the afternoon; c) low-luminous levels are obtained via the north-facing window, but the illumination is constant during the day.

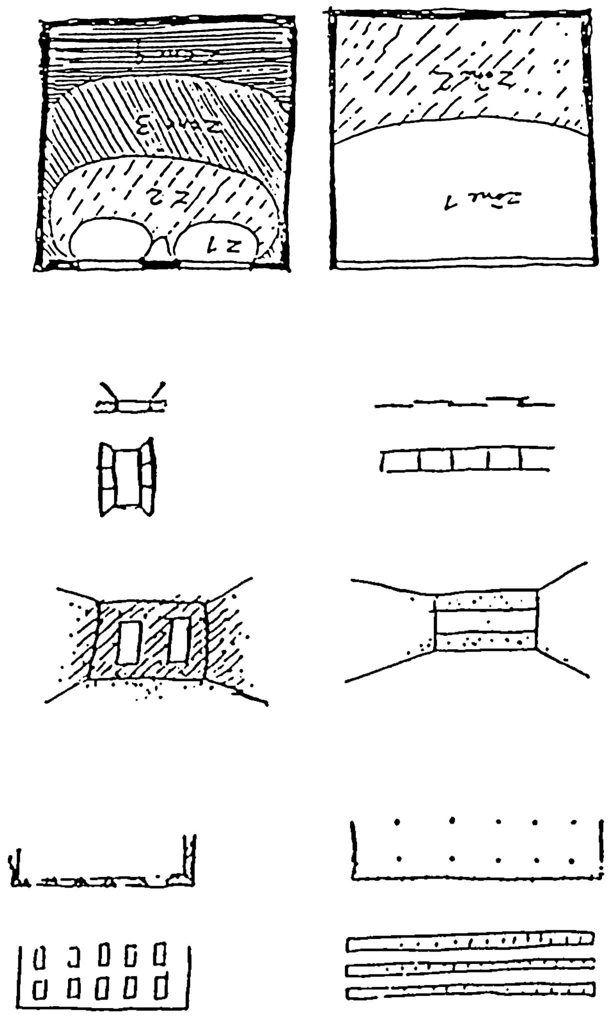


Figure 19. Le Corbusier's graphic window analysis, comparing performance of equal areas of different types of windows (namely, ribbon window and a vertical opening), from Sobin, H. "He Moved From Purist Typology to a Poetic Use of Light." AIA Journal (September 1979) 56.

The location of the daylighting aperture and the associated building form can be categorized as sidelighting; toplighting; angled lighting; beam lighting; indirect lighting; atria, light courts, and re-entrant lighting. When trying to achieve the desired effects of daylight within interiors, combination of these may be used. Therefore, in order to be able to design the desired specific atmospheres within spaces, characteristics of the apertures must be studied.

Three different types of daylighting apertures should be investigated in terms of their forms, directions, types of glazings, and the other controls which seem to have influences on the daylight received within an interior. These three different types of apertures are namely sidelighting apertures, toplighting apertures, and toplit shared spaces as ways of receiving daylight (atria, courtyards, lightcourts, litria, and lightwells). Sidelighting has the advantage of providing light together with view, which carries outside information to inside. Toplighting provides adequate daylight to the interiors having floor areas that are too large to be illuminated alone by sidelighting. The toplit shared spaces enable the massing of buildings while still retaining contact with nature and daylighting. Lam (1986) states that even if these spaces are not serving for the illumination of the adjacent spaces, daylight may be used for the illumination of the created shared space, which is required for the activities acquired within them.

3.1.1.1. Sidelighting

Sidelighting is a way of receiving daylight, where the apertures are located on the peripheral boundaries (walls) of the building, and light that sweeps across horizontal workplanes is provided.

Sidelighting is achieved via view and nonview apertures, namely windows. Robbins (1986) defines aperture as the "rough opening of the window, without regard to framing". Light, however, is defined to be an individual glazed area surrounded by framing.

Advantages of sidelighting apertures are that they include the strong directionality of the light and that they can provide primary lighting on two-dimensional horizontal surfaces. Some types of Clerestories can also provide lighting quality and quantity on two-dimensional vertical surfaces. The main disadvantage of sidelighting is that glare and high contrast may be obtained.

The daylight penetration into a space can be shown on a sectional view of the space by a line that depict the relative change in the quantity of light as it moves into the space from the aperture (Figure 20.).

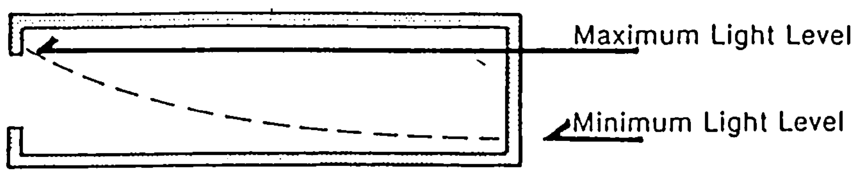


Figure 20. Daylight penetration through a sidelighting aperture,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 69.

As well as its visual effect, this illustration also shows the performance characteristics of the shown aperture. It shows also a negative characteristic of sidelighting that in wide buildings, areas away from the perimeter receive insufficient daylight (Figure 21.).

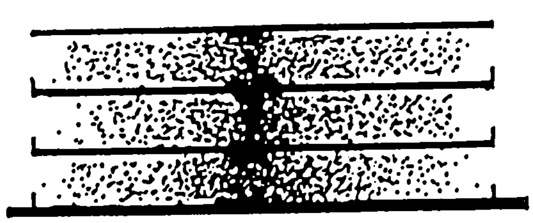


Figure 21. In wide buildings, sidelighting apertures provide inadequate illumination for central spaces,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 84.

While the illustration of penetration of daylight describe quantitative characteristics of light in a space, directionality and contrast provide indications of the quality of light in the space. Robbins (1986) states that therefore, understanding how daylight is penetrated into a space, is an important part of designing a system to achieve specific illuminance levels and distribution patterns while providing adequate lighting quality.

Sidelighting is the mostly preferred type of daylighting, because it can provide both daylight and view to the outside. Sidelighting apertures are the ones situated on the vertical envelope of buildings; therefore they enable the lateral penetration of the daylight. According to their forms, they gain certain names such as windows and translucent walls.

Lam (1986) states that sidelighting requires maximizing the indirect lighting potential of the sun and providing control. According to the type of glazing used, the colour of daylight received in a space can show certain differences. Glazing materials can transmit, reflect, or absorb the sun's rays. Because the main aim of glazing in buildings is to let light in, although there are many different types of glazing materials with different transmittance, reflectance, or absorbance characteristics, other controls should be used to obtain the desired quantity and quality of daylight within an interior. This issue is studied in detail throughout Section 3.1.2.

Color of the control devices are also important for the appearence of the interior daylight. When daylight falls onto an opaque or a translucent surface, the colour of the surface is redirected or transmitted back into the air. Thus the color of the reflected or transmitted daylight becomes the colour of the reflecting surface (Figure 22.).

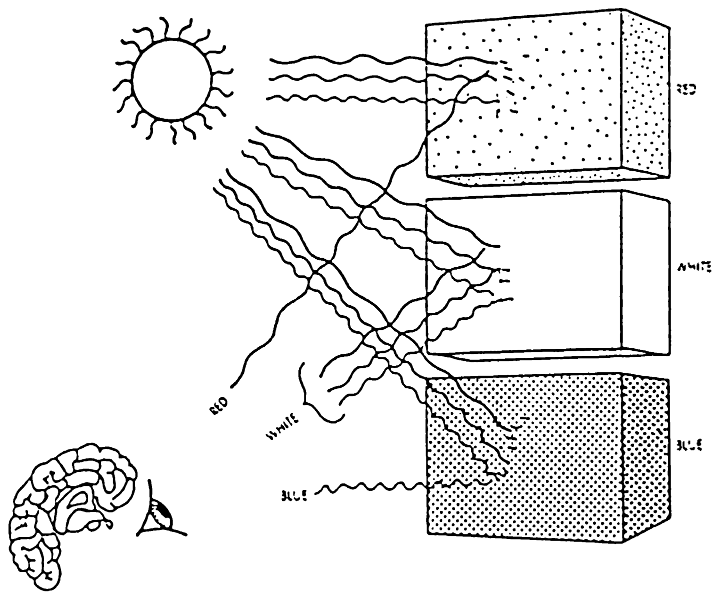


Figure 22. Color of reflected daylight,
from Bertolone, S., Bringing Interiors to Light (New York: Whitney Library of Design, 1986) 21.

3.1.1.2. Toplighting

Toplighting can be the most efficient form of lighting for low-rise buildings, because the distribution of illumination can be made very uniform, while the glazing area is kept minimal (Figure 23.). Toplighting apertures are situated on the roof of buildings. According to their architectural forms, they are named differently. Clerestories, monitor roofs, skylights and translucent ceilings are examples of toplighting apertures.

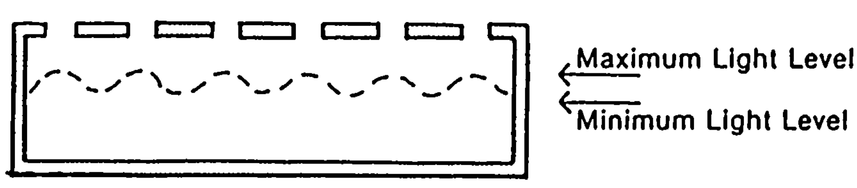


Figure 23. Toplighting provides a uniform distribution of daylight,
from Lam, W. Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 138.

Clerestory: It is a vertical or tilted opening constructed on the roof (Figure 24.). It permits penetration of daylight into the space below, sometimes protecting against direct radiation and/or redirecting it towards lower spaces. Usually, it supplies the space with diffused light, and increases the light level in it.

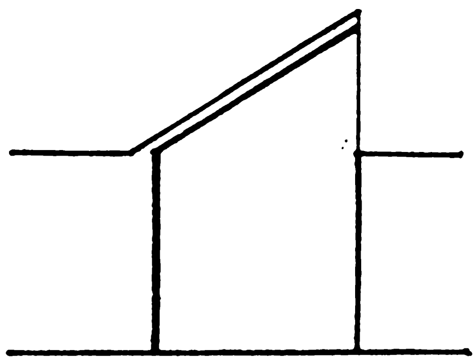


Figure 24. Clerestory,
from CEC, Daylighting in Architecture (London: James and James, 1993) 5.15.

Monitor roof: It is a raised section of a roof, including the ridge, with vertical openings (Figure 25.). Robbins (1986) states that the monitor aperture is "an excellent daylighting concept", which can be easily controlled to "allow specific daylighting levels" into a space. He stresses that a careful design of the aperture can introduce a very little difference between the maximum and the minimum illuminance points, and thus allows the area to be treated as "one lighting zone"; or it can introduce a considerable variation in illuminance, and thus allows the establishment of two or more lighting zones.

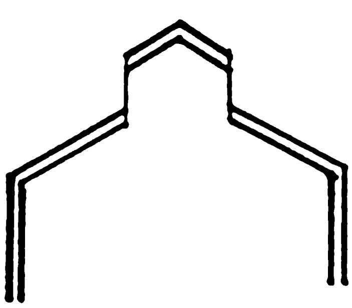


Figure 25. Monitor roof,
from CEC, Daylighting in Architecture (London: James and James, 1993) 5.15.

Skylight: It is an opening situated in a horizontal or tilted roof (Figure 26.). It is made up of transparent or translucent materials, and it can have many shapes and sizes. It permits the zenithal entry of daylight into the space below it.

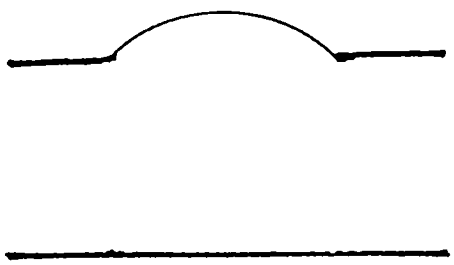


Figure 26. Skylight,
from CEC, Daylighting in Architecture (London: James and James, 1993) 5.16.

The horizontal skylights favour overhead light, and their performance is independent of orientation (Figure 27.). Under sunny conditions, their performance is dependent on solar altitude (Figure 28.).

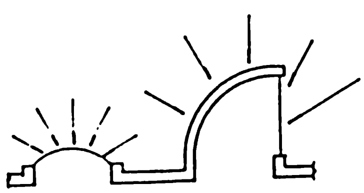


Fig.27 Horizontal skylights are exposed to the sky and are therefore the best method for collecting and distributing diffuse, overcast skylight,

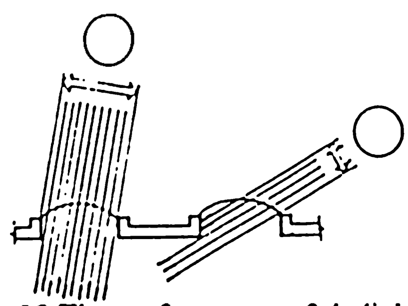


Fig. 28 The performance of skylights under sunny conditions is dependent on solar altitude.

from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 141.

Translucent Ceiling: The translucent ceiling is defined by CEC (1993) as a horizontal aperture partially constructed with translucent materials. It is the bigger form of skylight. It permits the zenithal entry of daylight diffused through the translucent material to the lower space (Figure 29.). It provides a homogeneous light level.

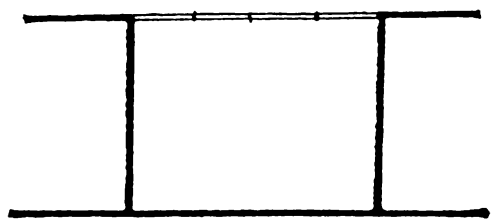
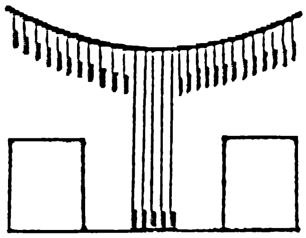


Figure 29. Translucent ceiling,
from CEC, Daylighting in Architecture (London: James and James, 1993) 5.16.

3.1.1.3 Toplit Shared Spaces

When massing a large building around a central space, the daylighting of this central space is characterized by courts, atria, lightcourts, litria, and lightwells. Courtyards and atria are shared spaces created primaly for pleasure of the users; and they also have some daylighting implications. Lightcourts, litria, and lightwells are derived from courtyard and atrium forms, and stress the utility of daylighting. The light reflecting and controlling qualities of their central spaces are maximized in order to provide daylighting for the surrounding spaces.

Courtyard: It is an outdoor area open to the sky and largely or entirely surrounded by buildings or walls (Figure 30.). Sometimes, courtyards can be formed by the landscaping, when there are spaces left between the buildings. The courtyard allows the daylight to reach the surfaces of the surrounding buildings, therefore allowing the use of sidelighting apertures. Also, the buildings may become the redirecting sources of daylight, depending on the distance across the courtyard. If the ground is made of light coloured materials, courtyards become good foreground reflected light. Lam (1986) states that it should be kept in mind that courtyards are primarily for the enjoyment of humans; the facade or ground materials should be chosen to suit to the human comfort and delight in the courtyard itself, rather than to provide reflectances ideal for daylighting surrounding buildings.



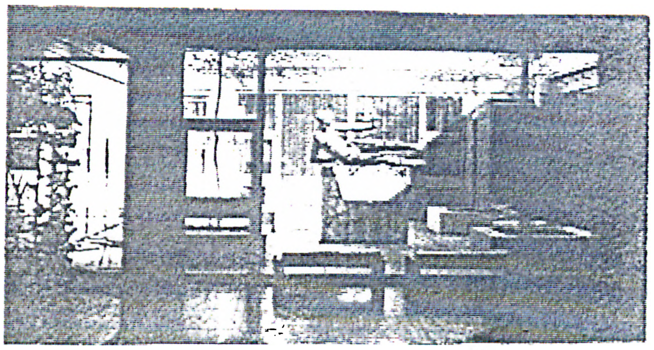


Figure 30. Courtyards can be attractive spaces for people,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 161.

Atrium: It is the central room of a building open to the sky at the center (Figure 31.). In other words, an atrium is formed when the interior space of a building is opened to the outside. Atria are usually isolated from the outside via glazing. The qualitative lighting objective in atria is to create sparkle. Within this aspect, Lam (1986) points out that some direct sunlight should be allowed to reach to the architectural surfaces, creating sharp shadow lines. Therefore, it can be stated that the primary concern of atria is not producing a calm atmosphere. Indoor plants provide much of the excitement of an atrium, and it becomes important that they do not obstruct the glazing or important light-reflecting surfaces.

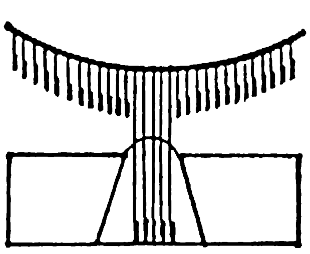


Figure 31. Atrium,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 157.

Lightcourt: It is a courtyard that is designed to optimize the sunlighting in the enclosed building (Figure 32.). Lightcourt should be designed to allow the maximum amount of direct and reflected sunlight to reach the adjacent building surfaces.

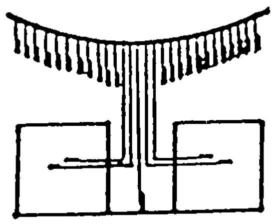


Figure 32. Lightcourt,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 157.

Litrium: It is an atrium that is to optimize the sunlighting in the adjacent spaces (Figure 33.). While an atrium provides the delight of a glimpse of sunlight to people in the atrium, a litrium admits enough sunlight to illuminate the spaces adjacent to it. For minimizing the shadows, and opening the spaces to sunlight, the form of the litrium should be such that it is equal in width at top and bottom, or wider at the top than at the bottom.

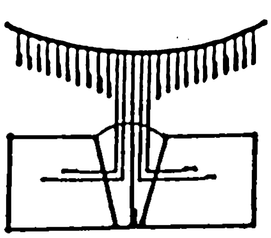


Figure 33. Litrium,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 157.

Litria are different from atria in that much more light is desirable. This is because of the greater area (the surrounding floors) that is using the light and the working illumination requirements of this area.

Lightwell: It is a vertical opening through one or more floors in a building, created for the primary purpose of distributing natural light to adjacent spaces (Figure 34.). The lightwell is usually an uninhabited shaft or slot within a building.

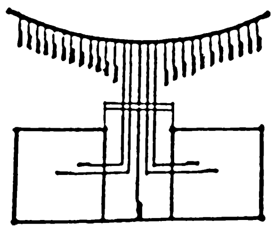


Figure 34. Lightwell,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 157.

3.1.2. Media of Glazings Used in Fenestration

The use of glass as windows to admit light dates back to Roman times, about 2500 years ago. Originally, mankind lived in caves and other natural structures. Later, they built dwellings out of brunches which were tied together, and covered with mud or animal skins. With those structures, the only interior light was from a hole at the top of the structure that allowed smoke from the fire to dissipate. At first, windows were solely the openings for providing light and air within a dwelling; and only crude shutters were used by those first windows. Linen, oiled paper, and sometimes mica or gypsum were used later, with wooden shutters.

The primary function of glass is to allow the transmission of light and view through the aperture. There are two main flat-glass manufacturing methods: The float and the rolled glass manufacturing methods. It is from this basic glass that all the other processed glass products are produced.

World's flat glass is mainly manufactured by the float process. Via this process, Molten glass at 1000°C is poured over a bath of molten tin, and spreads out forming a level. The thickness is controlled by the speed that the solidifying glass ribbon is drawn off the bath. After annealing, the glass emerges as a polished product with virtually parallel surfaces. Rolling process of glass manufacturing produces patterned, figured and cast glass products. A semi-molten glass is squeezed between metal rollers to produce a ribbon with controlled thickness and surface pattern (Button, 1993).

There are ways of modification to these basic manufacturing methods. Within this issue, Schuman (1992) states that it is not always possible or desirable to shade windows with attachments on the facade, like overhangs, therefore, the manufacturers developed tints and coatings as a way to provide shading within the glass itself. Body tinted, coated, and wired glass are modified through different ways; and body tinted and coated glass can affect the effects of daylight within the interior. Body tinted glass products are produced by small additions of metal oxides to the float or rolled glass composition. By this way, the glass may be coloured bronze, green, blue, or grey; but the basic properties of glass are not affected, except for changes in the solar energy transmission.

Coated glass is manufactured by means of surface coatings. On-line coating is done during the basic manufacture, and the glass which is on-line coated has advantages of hardness and durability over off-line coating which is applied after the basic manufacture. Coatings may modify some or all of the solar energy transmission, colour, and thermal insulation properties of glazings.

Recent developments in the glass manufacturing, enables the designers to achieve the desired effects within interiors. DeNevi (1979) presents the claim of Wright's within this aspect of being able to use the desired glass, which he realized as early as 1910 when it was not applicable. Wright states that:

> With the advent of inexpensive glass, as a modern material, the contemporary architect can employ thick, thin, coloured, and textured glass to delight and fascinate. Light diffused, light refracted, and light reflected will be used for their own sake, shadows aside..... No longer will appliances and appurtenances be needed (64).

Visible transmittance describes how transparent the glazing is to light. Schuman (1992) states that the common range is 0.9(clear) to 0.06(reflective). Many standard tints and mirror coatings achieve a low visible transmittance, where the window appears dark. She further points out that dark windows have become an accustomed design choice, at some circumstances to avoid glare, for example. However, clear views are stated to be important to the well-being of the occupants, providing visual relief and connection with the outdoors.

As stated by Lam (1986), glazings can transmit, reflect, or absorb solar energy (Figure 35.). Tinted glazings work by absorbing certain frequencies of light. Tinted glass acts as a color filter. Low-E glass is coated with a material that makes it reflect infrared portion of the spectrum, without altering its transmission of visible light.

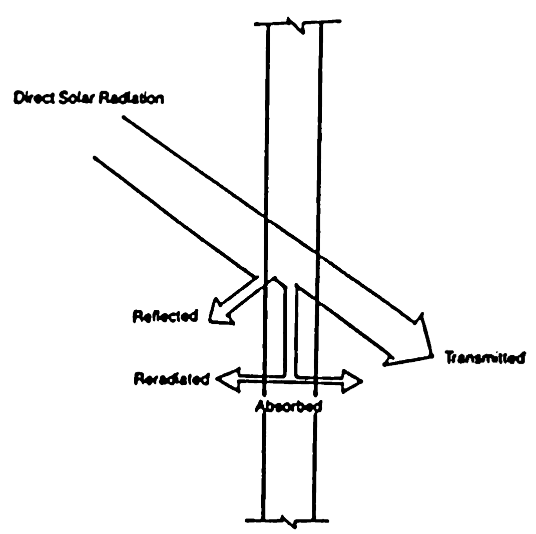


Figure 35. Transmission, reflection, and absorption of clear single glazing

Reflective glazings enable the transmission of less light, which often make interior spaces to feel gloomy. For daylighting purposes, the glazings must be chosen to admit the maximum amount of visible light, while admitting less of the ultraviolet and infrared portions of the spectrum (Figure 36.). As it is clear from the graph, green tinted glass is advantageous in this regard. However, Bertolone (1986) states that, as an act of tinted glass, green glass reinforces only the cool-colored finishes by the filtered daylight; and the warmer colors are dulled or greyed.

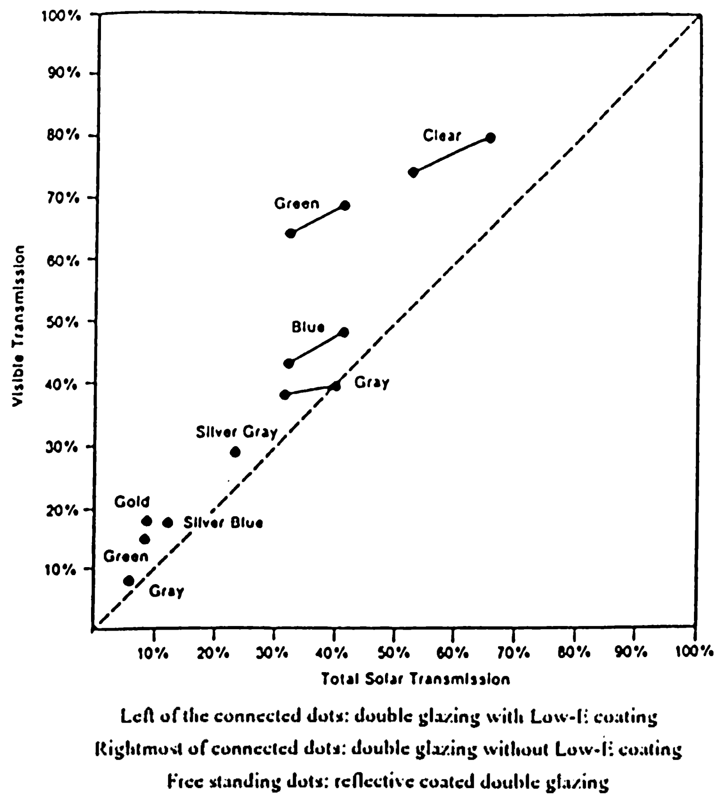


Figure 36. Visible transmission versus total solar transmission, from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 38.

Glazing materials vary in their light-transmitting characteristics. All lighting systems are potential sources of glare, if not properly tailored; and this is one of the most important disadvantages of daylighting systems. Steps can be taken to cure this problem. Robbins (1986) states that in a daylighted building, how the glazing is distributed and located is more important than the amount of glazing. Controlling and regulating the quantity and distribution of daylight within an interior can be achieved by the use of different glazing materials. Within this aspect, a great number of glazings having a great number of transmission characteristics in the visible spectrum can be used to daylight a building. The transmittance of glass is also affected by the form which the light is received. Within this aspect, Lam (1986) states that the transmittance from direct sunlight remains fairly steady from normal angle until 50, but diminishes rapidly after 60; because the light is reflected instead of transmitted at such high angles (Figure 37.).

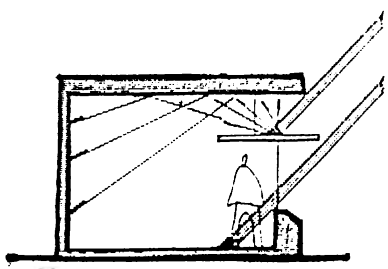
angle of incidence	single-glazed window	double-glazed window
0°	0.90	0.81
20°	0.90	0.81
40°	0.89	0.80
50°	·0.87	0.77
60°	0.82	0.71
70°	0.77	0.59
80°	0.44	0.29
90°	0.00	0.00

Figure 37. Transmission values and the angle of incidence,
from Lam, W. Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 39.

3.1.3. Control of Fenestration

The available daylight can be shaped according to desire, by the help of the control elements. The control elements are devices that control and thus influence the effects of daylight within an interior, received through an aperture. Control is necessary to prevent glare and achieve the desired effects of natural light. Vilades (1981) states that whatever the benefits of increased daylight illumination are, the primary goal of daylight control should be to provide natural illumination, while blocking the direct solar radiation. This direct solar radiation usually carries uncomfortable levels of heat and light. Within this aspect, lightshelves, sunscoops, lightscoops, suncatchers, overhangs, louvers, shutters, and draperies can be presented as examples of these control elements.

Lightshelves: They are the best devices for shading and redirecting sunlight by integrating with other elements of the architecture, confronts user needs, and "creates comfortable, spacious, delightful sunlit spaces" (Lam, 1986). They provide shading with view, and also provide excellent distribution of sunlight with minimum glare. They adjust the interior illumination by reducing it near the aperture and redistributing the light to increase the deeper illumination within the space (Figure 38.).



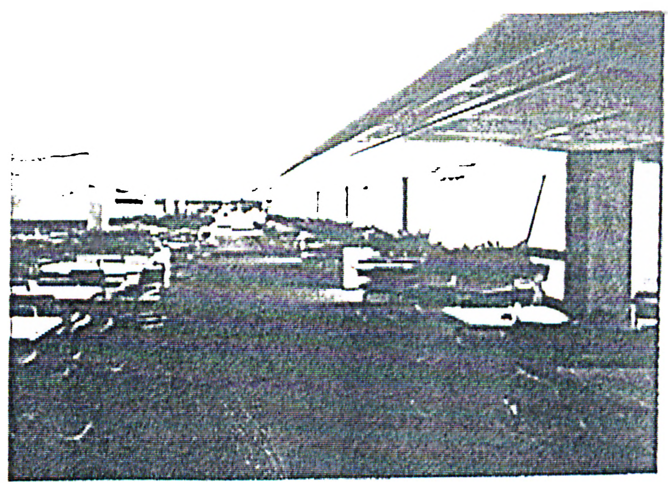


Figure 38. Lightshelves reduce the illumination near the aperture and redistribute the light to increase the deeper illumination within the space,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 96.

The important aspects that should be considered for lightshelves are their height and depth. The requirements of shading, the location of glazing, reflectances of finishings, and the slope of the shelf are also important.

For most advantageous reflectance of sunlight to the ceiling, the lightshelves should be located as low as practical. The lighting performance alone, may require a height just above eye level, consideration of other factors, like the clearance for doors along the wall, requires that it should be higher (above 200 to 210cm). The width of a lightshelf is a matter of the window height; and latitude and orientation, which in turn determine the shading angle requirements.

The upper portion (clerestory portion) of a lightshelf should avoid the direct penetration of sunlight onto work surfaces at any time of the year by controlling glare and eliminating any need for supplementary shading. The lower window may allow some sunlight penetration as long as it falls below eye-level. Within this aspect, Lam (1986) states that sunlight on the floor is very much enjoyed, except for those whose work is absolutely stationary, or involves critical visual tasks (Figure 39.).

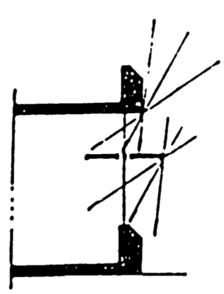
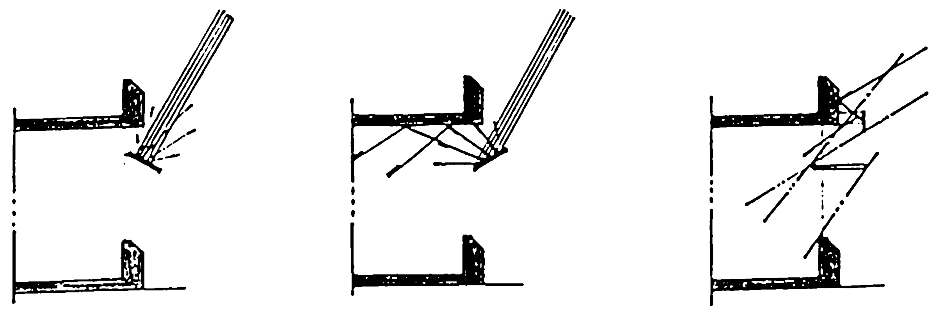


Figure 39. The upper and the lower portions of a light-shelf,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 96.

The upper clerestory portion of the lightshelf is generally smaller than the lower portion; yet an equivalent shading is required. This implies that either the lightshelf should be projected further from the facade, or the lower window be recessed.

Sloping the lightshelf downward reflects light away from the clerestory, rather than into it. Sloping them inward bounces sunlight deeper inside, but decreases the shading effectiveness. With these applications, care must be taken to avoid eye-level glare. For these reasons, the most effective daylighting through lightshelves can be often achieved with the compromise of a level lightshelf. Additional shading for difficult conditions can be achieved by adding a vertical baffle for a level lightshelf (Figure 40).



Sloping the lightshelf downwards provides effective shading but rejects light

Sloping the lightshelf in directs light inside building but does not shade as effectively

The lightshelf can be combined with a vertical baffle for additional shading in difficult conditions, such as east/west orientations

Figure 40. Different applications of a light-shelf for different conditions, from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 98.

The reflectances of lightshelves should be determined by the lighting requirements throughout the changing characteristics of daylight at various times of day and of year. The amount of reflected sunlight admitted into the interior is greatly affected by the reflectance of the exterior lightshelf. If above eye-level, the potential glare of a high reflectance is not a problem. By designing the outer band of a lightshelf to be light colored and the inner area to be darker, the quantity of light reflected from the smaller area that is illuminated by high-angle summer sun, can be equalized with the amount reflected by larger, darker area that is illuminated by lower-angle winter sun(Figure 41).

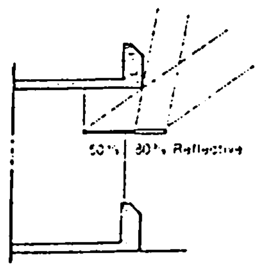


Figure 41. Non-uniform reflectances of a lightshelf reduce the seasonal variation by reducing winter light levels,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 99.

Sunscoops: They are clerestory monitors oriented toward the sun (Figure 42.). These devices are most suitable at high latitude climates, where the sun is very low in winter, and yet maximum light from it desired; because they provide glare-free lighting much more easily than windows (Figure 43.).

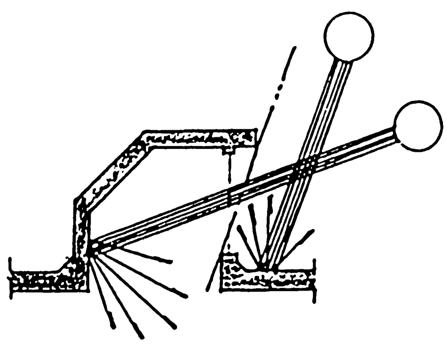


Figure 42. Sunscoops receive direct sunlight and sky light as well as roof-reflected light

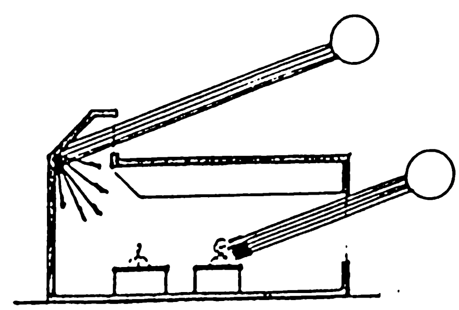


Figure 43. Sunscoops are better than windows for controlling the potential glare of low-angle sunlight

from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 146.

Lightscoops: They are clerestory monitors oriented away from the sun (north in the northern hemisphere) (Figure 44.). It is desirable in hot climates where light is needed, but the heat is not. Lam (1986) points out the advantages and disadvantages of lightscoops as follows: The steadiest level of illumination with a minimum of glare is obtainable through lightscoops (if the adjacent roof surfaces are dark coloured, lightscoops receive more light on overcast conditions, but on clear conditions, the reverse happens); no solar heat gain is achieved; and they require minimum shading and baffling to control light as advantages. Disadvantages are stated to be that the admitted light is diffuse sky light, which is nondirectional and thus does not penetrate as deeply into a building as sunlight. Also, the color of the sky light is cooler than that of sunlight, and although steady, may be uninteresting.

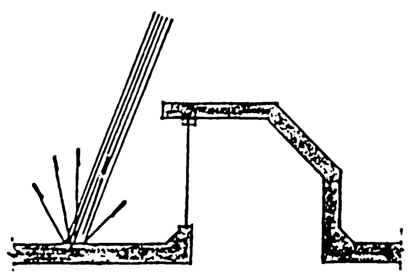
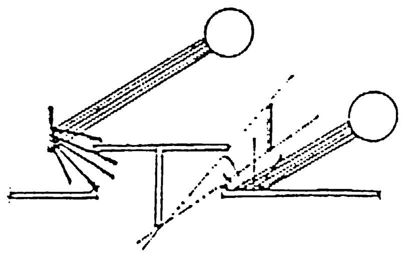


Figure 44. Lightscoop,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 148.

Suncatchers: They are shading/redirecting devices used at toplighting apertures. They are exterior devices that convert direct sunlight into indirect sunlight (Figure 45.). Because they are positioned to redirect sunlight into a window, suncatchers can significantly increase the illumination in north-facing windows (Figure 46.). Although they reduce illumination on overcast days, on sunny days, suncatchers always increase the illumination on the shady side. On east- and west-oriented windows, suncatchers both shade and redirect sunlight, significantly reducing daily illumination irregularities (Figure 45.). A suncatcher combined with a lightscoop can reduce the inequality between south and north exposures and also increase the average illumination of the space.



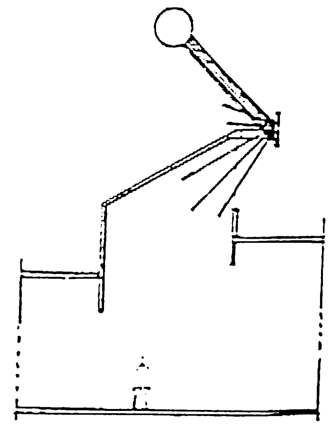
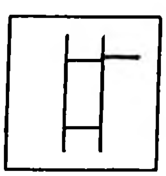


Figure 45. Suncatcher baffles provide both shading and redirection on east and west exposures.

Figure 46. Suncatcher baffles in north orientation.

from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986) 149.

Overhangs: They are part of the building, which protrude horizontally from the top of a sidelighting aperture (Figure 47.). They obstruct the direct introduction of high-angle sun's rays, and lower the interior light level. They frame, rather than compete with views. They are the most effective, dependable, durable, and economical control elements over time.



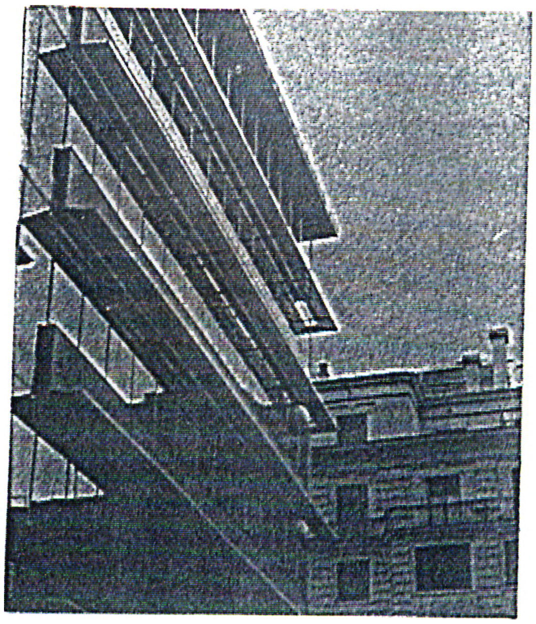


Figure 47. Overhang,
from CEC, Daylighting in Architecture (London: James and James, 1993) 5.21.

Louvers: They are series of exterior slats which may be fixed or adjustable. Direct solar radiation falling on the louvers may be obstructed, reflected or redirected to the interior zone. They may be horizontal or vertical (Figure 48). Horizontal louvers are usually located on southern facades, and the vertical ones on eastern and western facades (because of the reasons discussed in Section 3.4). Lam (1986) states that the top of the lowest reflective louver should be located below the seated eye-level. If located below this level, they should be dark-coloured to avoid glare.

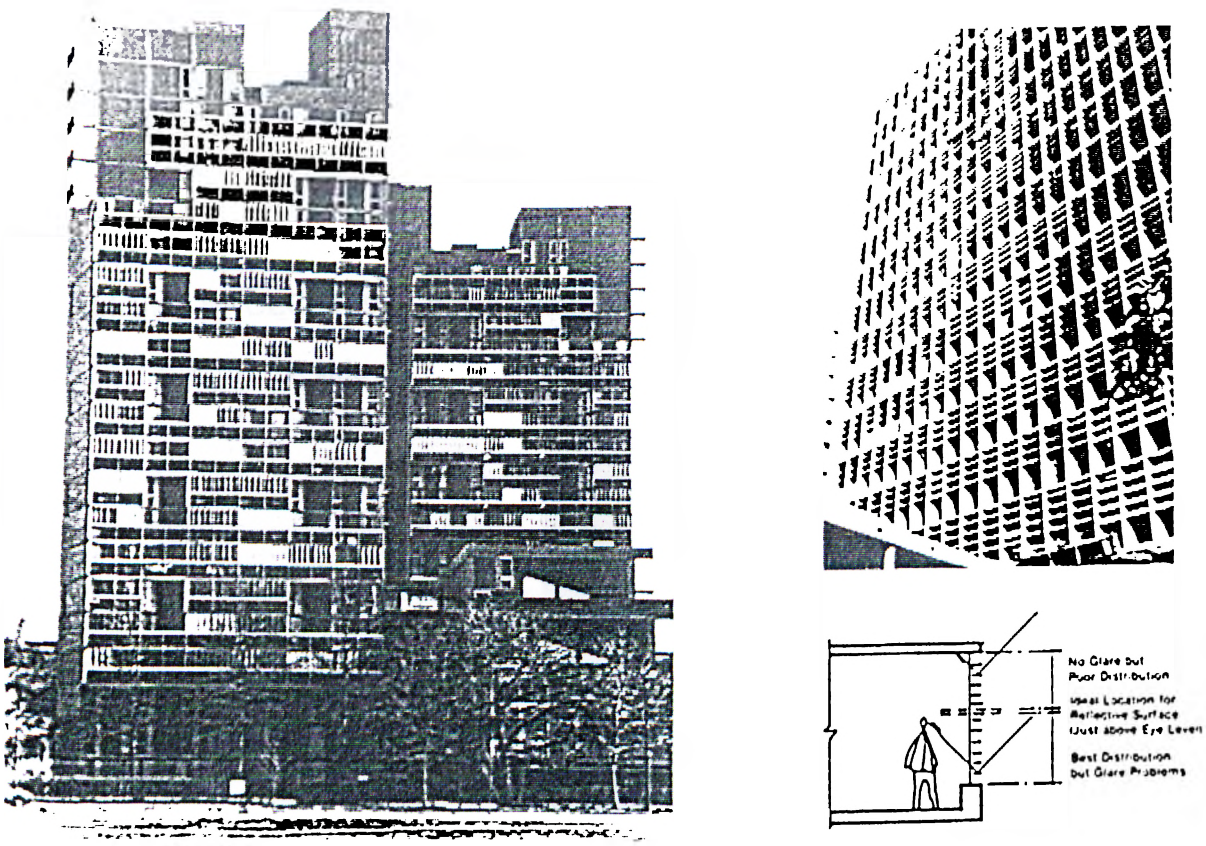


Figure 48. Horizontal and vertical louvers,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986)109 and 117.

The horizontal or the vertical louvers can be operable to answer the shading needs according to the changing position of the sun. Olgyay (1957) presents a graphic presentation showing the shading characteristics of such louvers (Figure 49.).

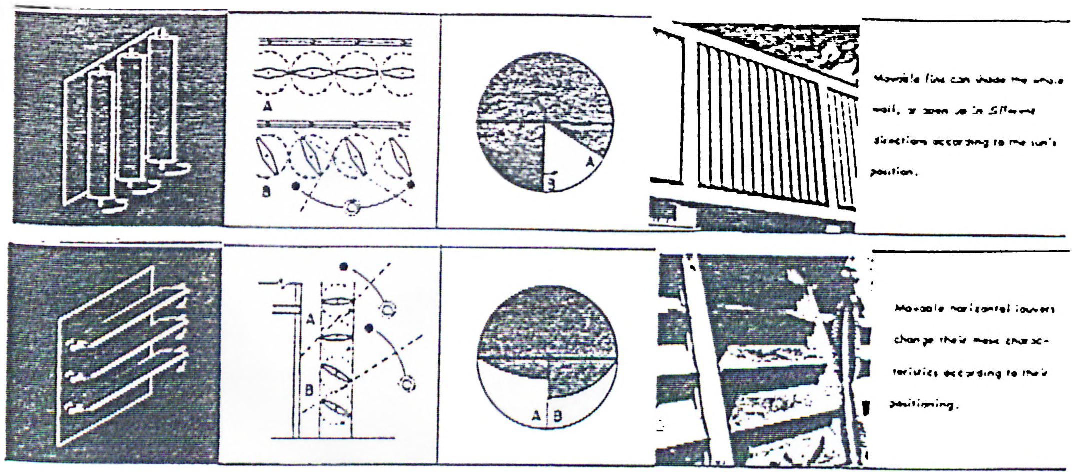


Figure 49. Examples of operable louvers
from Olgyay, V., Solar Control and Shading Devices (Princeton: Princeton University Press, 1957) 81.

Shutter: A shutter totally obstructs the introduction of daylight illumination. As explained by CEC (1993), it is a continuous opaque surface which can be folded or drawn towards the side of the opening (Figure 50.).

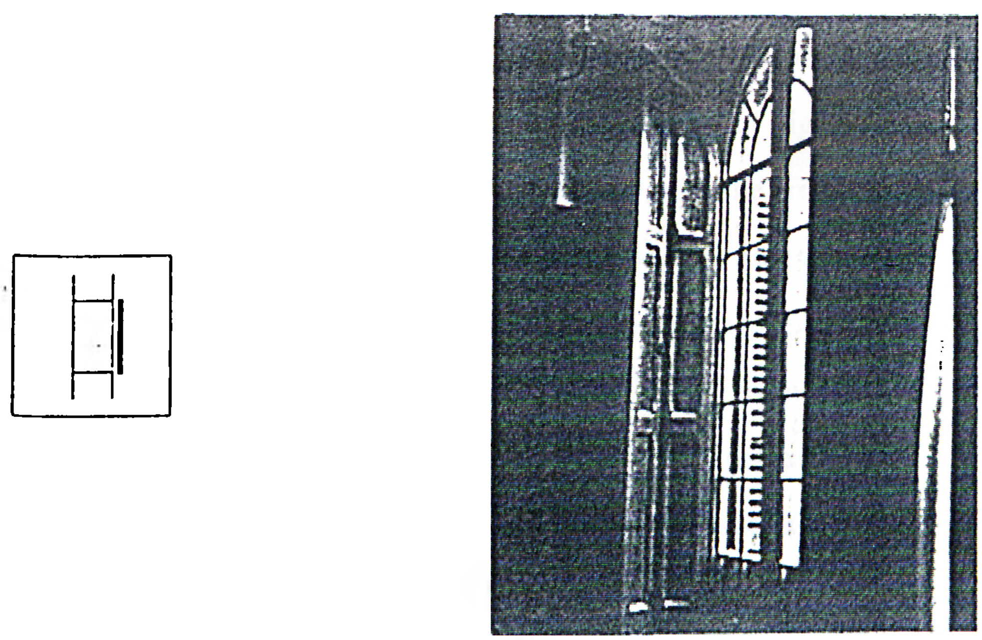
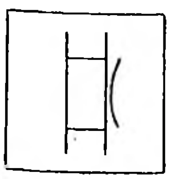


Figure 50. Shutter,
from CEC. Daylighting in Architecture (London: James and James Ltd., 1993) 5.25.

Draperies: They are described by the CEC (1993) as control elements that are made of opaque or diffusing flexible material and situated inside an aperture to protect the interior totally or partially from direct solar radiation (Figure 51.). Because they are movable, the aperture may be left open, when desired.



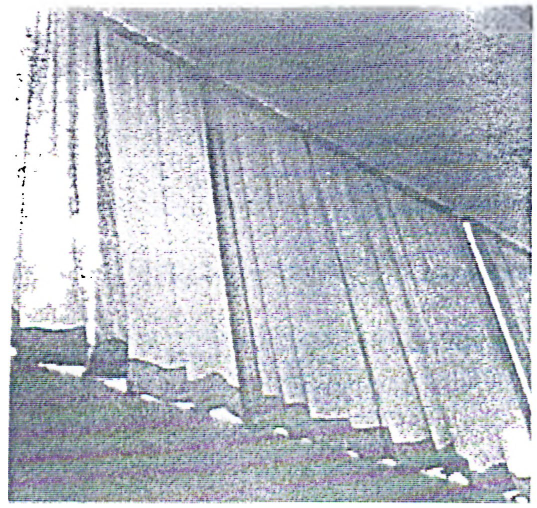


Figure 51. Draperies,
from CEC, Daylighting in Architecture (London: James and James Ltd., 1993) 5.25.

3.2 Effect of Scale on Daylight

Generally, lighting of a space is considered as obtaining the needed quantity of illumination on a certain plane, for the performance of certain tasks. As a general mistake, when daylight is regarded as the source of light for an interior, the fenestration is designed only with the suitability with the architectural style in mind. This consideration skips especially the psychological aspects, which should be the main determinant of the illumination design of a space, just because of the basic reason that spaces are for the people who occupy them for a certain purpose. Therefore, beyond the quantitative aspects of daylight necessary for the performance of certain activities within a space, some qualitative aspects should be considered to achieve the best solutions from the user satisfaction point of view." This implies that, from the daylighting aspect, every space should be designed with realisation of the function of the space, and the spatial effects that daylight can introduce into the space. Also, the nature of daylight should be examined thoroughly, in order to be able to design for it. Within this aspect, Villecco et. al. (1979) defines daylight as a dynamic phenomenon. She states that the relationship to "natural rhythms of the surroundings" requires a "dynamic design response", specific to time and place. According to her, designers must learn to approach the design process with this dynamism in mind and understand that the building will be visually and functionally different according to day and season. It should be kept in mind that daylight is not something that one adds to building design, but that it is implicit to every design decision. Harriman (1992) states that for any building type, natural illumination adds an intangible value by putting occupants in touch with changes in the time of day and season.

Atmosphere of a space is defined in the Collins Dictionary (1993) as the "general pervasive feeling or mood that the mind receives from a space". As can be understood from the definition, every space has an atmosphere of any kind. The atmosphere of a space is determined through many design elements, including the materials used, form, colour, texture, etc., and lighting, which is considered as one of the most important determinants.

Throughout this study, daylighting as a form of lighting, and its effects on the interior atmosphere is discussed. As a natural light source of a space, daylight can be considered as one of the most interesting elements that has an effect on the interior atmosphere. It changes from hour to hour, day to day, or season to season. This variability of daylight asserts an interest on what can be felt through the atmosphere, and the most important tools to obtain an interior atmosphere through daylight are obviously the daylight apertures of the space.

Of course, daylighting is very closely related with the interior finishing materials, and the perception of an interior atmosphere is largely dependent on the daylighting.

As daylight is affected in the interior (interior illumination) by the use of different materials having different characteristics, the interior atmosphere of a space as a result of daylight is also a matter of the finishing materials used within the space. One of the most important characteristics of materials within an interior is color. The color perception is affected by the light falling on the material, and this aspect may introduce differences on the perception of the atmosphere of a space. The other important characteristics of the materials is their reflectivity.

It should be realized that the naturally available daylight on earth can be used as an element that affects the interior spaces. This can be achieved through proper design. Efforts aiming at the conversion of daylight into a design element includes the examination of the effects of urban design, site-planning, and building planning scales.

Achieving the daylighting goals, or obtaining the desired spatial effects of daylight requires to proceed from the largest to the smallest scale through the design. The sequence of these scales can be as follows: Urban design scale; site planning scale; and architectural scale (Lam 1986). He further suggests that a thorough consideration of all these aspects together, enables the designer to achieve the desired atmospheres within spaces.

The urban design scale is the aspect to provide access to daylight throughout the built and natural environment according to the seasonally varying needs for light. Urban design influences include the local topography, microclimate, and circulation requirements, and the mix of building uses and required building densities, as well as the latitude, orientation, and climate. Lam (1986) defines the strategy for urban design as to arrange major landscaping to allow daylight to reach different building types according to their need for daylight, to encourage optimum orientations, and to simplify the achievement of comfortable environments and energy conservation. To be able to create the ideal microclimate, advantage of the area's topography should be taken into consideration. The characteristics of natural forms of the topography in terms of urban design for daylighting, can be achieved by the built environment. For example, locating the highest buildings further away from the equator lessens the impact of their shadow, and provides better sunlighting opportunities for lower buildings (Figure 52.).

Figure 52. Location of the higher buildings, to eliminate the impact of their shadows on the lower ones

The densely built areas can receive daylight via the help of the streets. Wide streets mean that the distance between the buildings are wide, and thus the degree of daylight penetration through them are high. Therefore, if spaced further apart by the help of wide streets, buildings can be taller without shading their neighbours (Figure 53.).

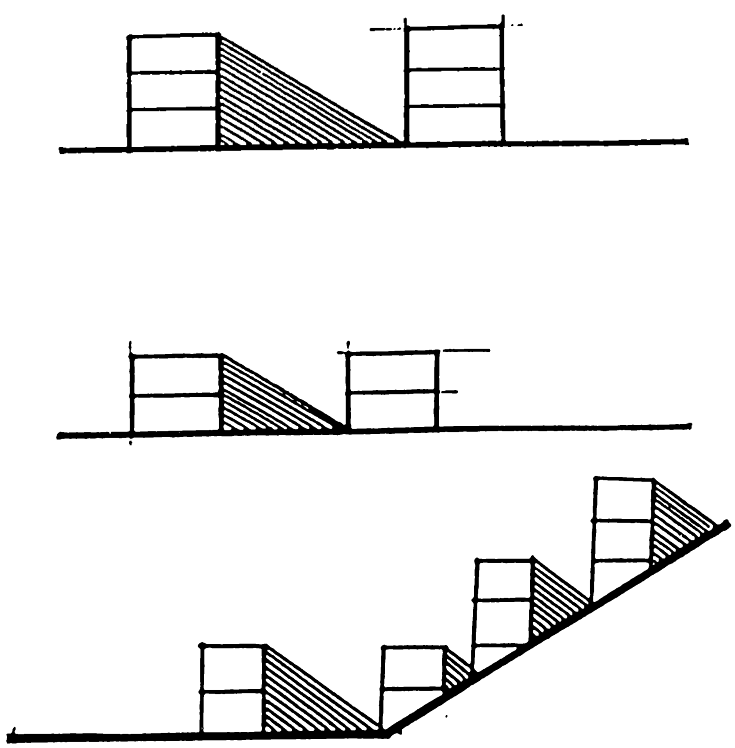


Figure 53. Wider streets or sloped sites enable the buildings to be higher, from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold company, 1986)

Running the widest streets along east and west minimizes the shading of buildings with equator facing facades. This implies orienting a building's longest sides north and south. This in turn allows for the easiest shading and exposure to daylight to meet seasonal daylighting requirements. In alike manner, running the narrower streets along north and south blocks the extreme low-angled sunlight at the beginning and end of the longer summer days.

Site planning should be done, in terms of daylighting, to get daylight within buildings where and when wanted, by carefully shaping and locating the building forms. The form is highly dependent on the site and building program. Lam (1986) states that in designing the placement, spacing, and massing of buildings and associated landscaping, to take advantage of daylighting opportunities afforded by an urban design, general characteristics of possible building types should be considered.

Daylight has a potential spatial effect which can be revealed through the architecture. Within this aspect, Lam (1986) states that the three-dimensional articulation of the building elements is the "most pervasive implication" of daylighting, and that the spatial qualities of light require that its use and control be three-dimensional. He further suggests that the most efficient and economical way to obtain the forms necessary to control daylight is to make them an integral aspect of the architecture, to achieve the daylighting goals.

On the subject of the sun's rhythms as generators of building forms, Ralph Knowles has conducted a research. Villecco (1979b) examines the concern and results of the research, and stated the concern of the research as to illustrate the force effects of "natural phenomena" such as the sunlight, on form. Throughout the research, it was taken into consideration that buildings are subject to the same natural forces that differentiate nature. The results of the research are summarized by Villecco (1979b) as follows:

> The implications of the work for architectural and urban design are now being rediscovered. The concept of a building as an ecological form that is differentiated in response to natural forces points to a new aesthetic based on rhythm. Buildings that are undifferentiated pay an energy price and result in illegible environments that isolate people from natural clues to time, space and orientation (66).

3.3. Occupancy and Lighting

The occupancy of a space is what the space is used for; and therefore is an important aspect for deciding upon daylighting strategies. Schools, libraries, offices, hospitals, art galleries, shopping malls, residences, etc., are spaces which are used for different functions. This fact suggests that different results of daylighting is needed within each of them, because the activities being performed are different. When comparing the daylighting of offices and museums, for example, Lam (1986) states that museums benefit more from the qualitative aspects than the quantitative (economic) aspects of daylighting. The reason for such a claim can be the daylight's colour rendering properties. However, it should be remembered that daylight carries UV radiation which has harmful effects on the fading of the artifacts being displayed. Therefore, depending on the type of the exhibits, daylight may be considered disadvantageous, and cautions must be taken when using daylight as the source of lighting within such spaces. Even the same type of spaces may serve in different manners. One type of a restaurant, for example, may be a place where special events are celebrated through the meal, whereas another one can be a place where the meal is consumed as quick as possible. The atmospheres of such different-function spaces should also be different. The one where the special meal is desired to be taken should provide more privacy than the other where the food consumption is the only destiny, and thus it is done in as shortest time as possible. This issue of occupancy and lighting is discussed by Peters (1979) as a mean that should carefully be considered in relation to the human functions it illuminates. No matter what the type of the space is, to put the light how and where you want is considered by him to be "an important lesson to learn".

The activities are the resulting tasks done by the occupants using the space. The occupant contribution for the shaping of daylighting increases as the number of the occupants (or the scale of the space) decreases. For a residential space, for example, the aspect of daylighting is shaped according to the life-style, age, personality, etc. of the occupants, which are all related with the personal properties or likings.

Sobin (1979) states that Le Corbusier developed certain types of windows which serve for different functions. Each window type was intended to symbolize a particular range of human activity, and at the same time, was specifically designed to deliver the correct amount of daylight thought to be associated with that activity. For ceremonial spaces, such as entrance halls, or for rooms containing functions requiring the greatest degree of illumination, including offices, hospital rooms, work rooms and studios, Le Corbusier utilized the window wall (pan de verre). This is an area of full height glazing, often supplemented by substantial areas of toplighting. For spaces requiring average light levels evenly distributed throughout the room, he utilized a ribbon window (fenetre en longueur). This window was running continuously across the entire length of a space between blank side walls. Where daylighting needs were modest, as in bedrooms or corridors, narrow vertical slots, square hole-in-the-wall openings or small skylights were utilized, spaced widely apart in large expanses of opaque, white surfaces.

4. CREATION OF DESIRED INTERIOR ATMOSPHERES THROUGH DAYLIGHT

Spaces, according to the type of daylight received within them, can gain certain atmospheres. In other words, calm, dramatic, relaxing, etc. atmospheres of interiors can all be created by the daylight being introduced into the space. The ways in which daylight is presented within an interior are functions of the architectural shaping of the building, the apertures, orientation and the cautions taken to direct or tailor the daylight received into an interior.

The forms and directions of the daylighting apertures, the types of glazings used for them, or other physical treatments within them, and the associated means of control should be studied to be able to understand how the desired moods within interiors can be achieved. Another aspect that should be studied is the concept of color, because its perception is closely related with the light it is exposed to, and it has an important impact on the atmosphere that a space possesses.

The effects that daylight has a potential to produce within an interior space are all resulted from the three main categories of daylighting apertures, which are discussed in detail in Section 3.1.1. Different types of atmospheres can be achieved through the different presentation of daylight within the interior. Synder (1994) claims that light is sometimes ignored as a primary element in a building design. However, she says, the color, proportion, perception, and "feel" of a space may be transformed through its conscious and controlled use. In this aspect, spaciousness, relaxation, calmness, privacy, drama, warmth, coolness, and depression are discussed as forms of atmospheres that are obtainable through the ways that daylight is presented in a space.

Flynn, et al. (1992) states that specific subjective impressions of observers can be influenced through some brightness parameters. These are defined to be brightness uniformity, brightness position, and brightness intensity. Within this aspect, light structure models have been developed to serve as partial guides for the use of environmental lighting effects appropriate for various applications.

Under the scope of Flynn's studies considering lighting as a behavioral cue which people "use to interprete or make sense of a space", Bertolone (1986) presents the effect of light on impressions (Figure 54.). He states that light controls how people experience a given place, and how they use it; and points out that the designers' understanding the importance of such applications that create certain impressions is very important in producing satisfying designs.

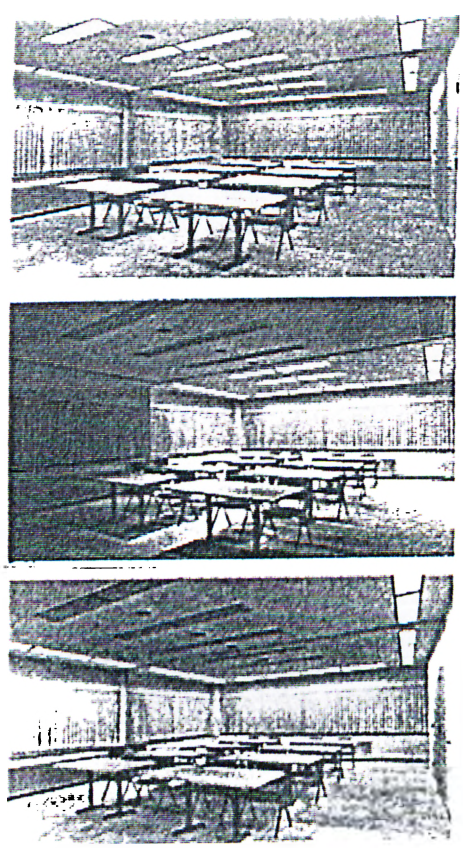


Figure 54. Effects of lighting on impressions,
from Bertolone, S., Bringing Interiors to Light (New York: Whitney Library of Design, 1986) 26.

4.1 Spacious Atmosphere

An interior having a spacious atmosphere is the one which seems wide and roomy. This does not necessarily mean that the space achieves this result through its dimensions. Any space can be given a spacious feeling with the help of the lighting. Flynn (1977) specifies that impression of spaciousness acquires a uniform peripheral lighting, where brightness can be a reinforcing factor. As a reason for this, he states that the impression of being confined is generally comes out when the vertical and/or ceiling surfaces are darker than the worksurface and/or floor. Under the light of this specification, it can be stated that a spacious atmosphere can be obtained through daylighting, with the help of the apertures which are tailored to present a uniform and a bright peripheral daylight and a fairly illuminated ceiling within a space. Uniform wall lighting is a reinforcing factor of a spacious atmosphere within a space, and Figure55. is a graphic representation of luminance patterning that introduces a sense of spaciousness.

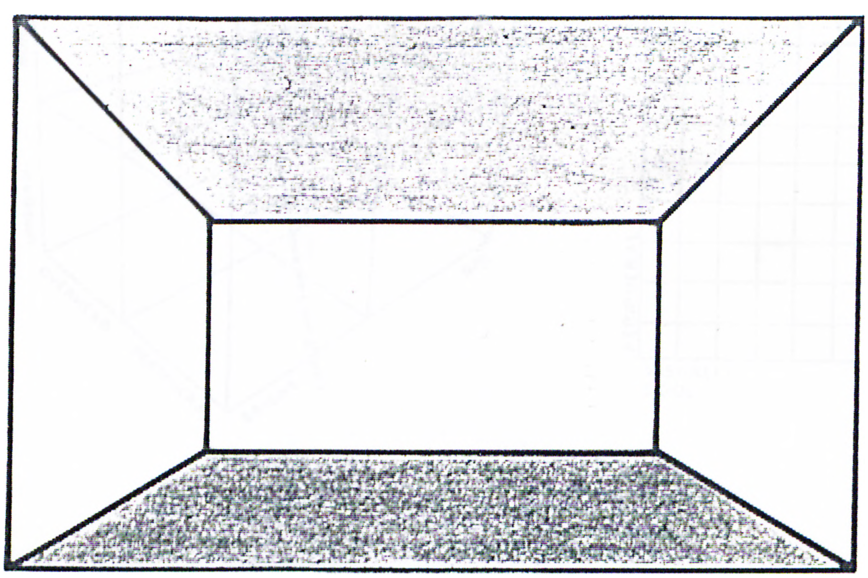


Figure 55. Graphical representation of spaciousness,
from Steffy, G., Architectural Lighting Design (New York: Van Nostrand Reinhold Company, 1990) 34.

Spaciousness, as a space characteristics, is especially important for spaces that are subject to gathering or passing of large numbers of people, or for the ones that are inherently small. Circulation and assembly spaces, together with some office spaces where small workstations exists, are the examples provided by Steffy (1990) requiring a sense of spaciousness.

The light structure model for the impression of spaciousness is shown in Figure56. From this figure, we can derive that the impression of spaciousness is reinforced by uniform, peripheral, and relatively high brightness. Color of the light itself appears to be a negligible factor. It should be stated, however, that the cool-colored surfaces appear to recede, while the warm-colored surfaces appear to advance.

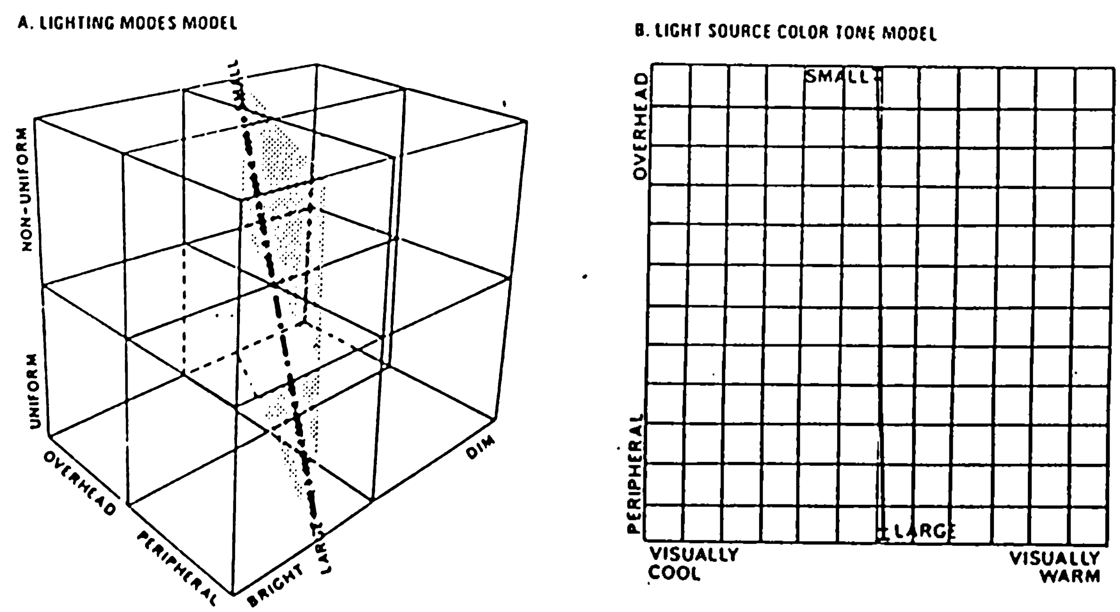


Figure 56. Light structure model for the impression of spaciousness, from Flynn, J. et al., Architectural Interior Systems (New York: Van Nostrand Reinhold Company, 1992) 20.

4.1.1 Achievement of a Spacious Atmosphere

According to the above definition, to be able to achieve a spacious atmosphere the apertures should be designed to obtain more daylight on the walls and ceiling than on the floor. Received daylight should also be intense and uniform. This can be done by having surfaces redirecting daylight in such a way that the final interior illumination is in accordance with the desired one.

Bright, highly reflective ground surfaces, redirecting the received daylight on the ceiling and walls, may be helpful within this aspect. However, ground reflected daylight may not always be available, because of the spacing of buildings (Figure 57.). As stated by Lam (1986), it is easier for low, single-story buildings to have adequate redirected light from sunlit ground than it is for urban multi-storey buildings. Another source of this redirected light is the building-reflected light. As stated earlier, the ground-reflected light is available when the sun is high, whereas the building-reflected light is greatest when the sun is low.

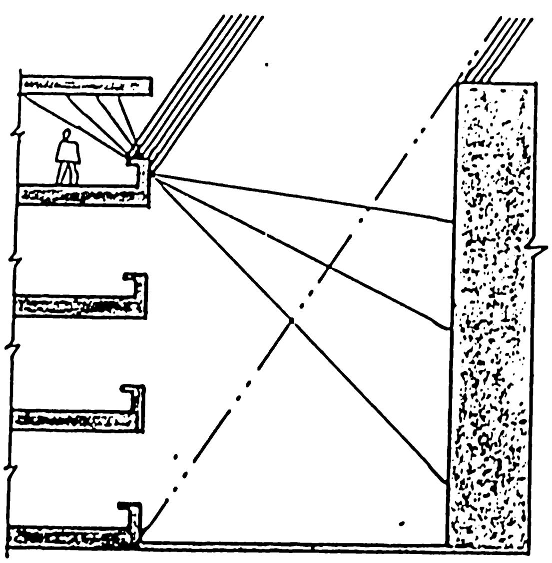


Figure 57. Ground-reflected light is not always available,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 81.

To take advantage of these reflected daylight for the creation of a spacious atmosphere, the uniform distribution of them should be acquired. Therefore, orientation of the sidelighting apertures should be studied carefully. As the different orientations provide different qualities of daylight into the spaces, different controls should be designed for them, to be able to obtain a uniform lighting on the peripheral elements and the ceiling.

The location of the apertures are also important for the distribution of reflected light in the interior. Because a specious atmosphere requires the ceiling to be illuminated more than the floor, upward reflected light which is uniform should be achieved. For upward-reflected light, a low aperture provides a better light distribution than a higher one (Figure 58.).

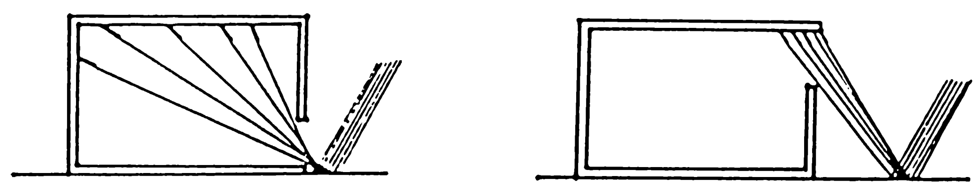


Figure 58. For upward-reflected light, a low aperture provides a better light distribution than a high aperture,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 76.

For low-ceilinged deep rooms, the reflectance of the ceiling is very important for the distribution of the light received from the sidelighting aperture. Therefore, the ceilings should have high reflectance (Figure 59.). Light colors can achieve this objective. Under overcast sky conditions, however, the sky itself becomes the principal source of illumination, and not the ceiling cavity. At such conditions, the ceiling does not influence the illumination levels and distribution (Lam, 1986).

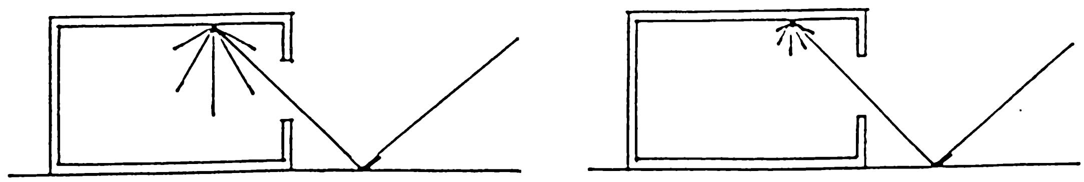


Figure 59. A highly reflecting ceiling is necessary for efficient utilization of light, from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 78.

A given amount of light is distributed more thinly over a configured ceiling than over a flat ceiling of equal projected area. The ceiling thus becomes less bright (Figure 60.). Lam (1986) states that the reduction in reflected light is similar to painting the flat ceiling with a lower-reflectance paint.

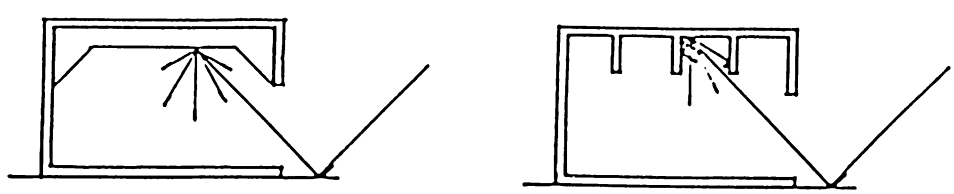
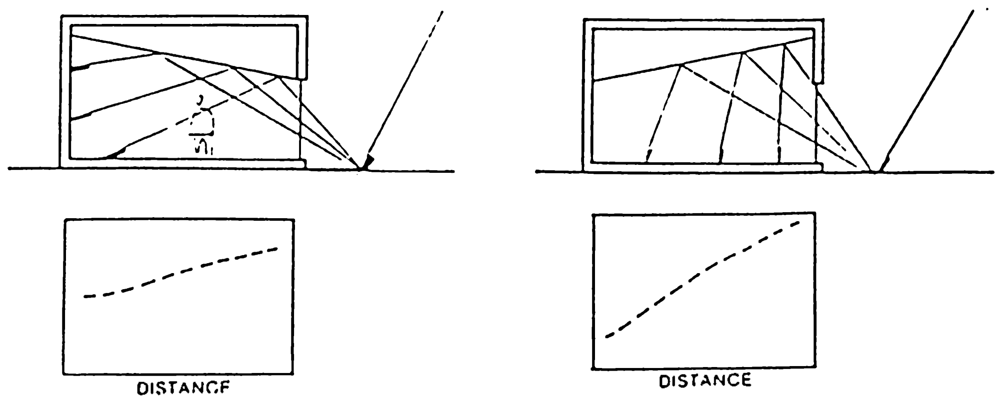


Figure 60. The configured ceilings have a large surface area and trap light. The ceilings with less surface area distribute light more efficiently,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 81.

The ceiling can be shaped to achieve the desired light distribution, after its surface area is diminished to redirect more light into the space. For example, a low ceiling or the one which slopes downward from the window produces the highest average illumination levels, but the illumination levels deep in the space where they are most needed are lowest (Figure 61.). Therefore, sloping the ceiling upwards will make the distribution of light within the space to be better. Other shapes (Figure 62.) produce even better results. It can be pointed out that the best shapes are those with the least surface area, that receive the reflected (building- and/or ground-) light deepest in the space, and that are angled to best confront both the floor below and the light source.



Ceiling that slope up from the aperture improve illumination uniformity when the back wall is white. Sloping ceilings downward from the aperture increases the average illumination level, keeps the light closer to the window and makes the illumination less uniform.

Figure 61. Sloped ceilings,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 81.

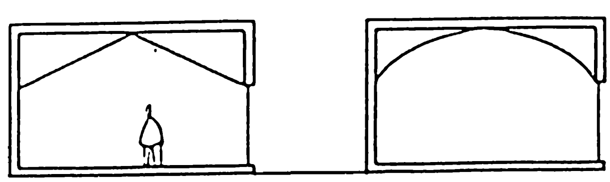


Figure 62. Some ceiling shapes are better than a single slope,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 81.

Achievement of a spacious atmosphere can be through the use of a toplighting aperture. The toplighting apertures are sources of daylight on the ceiling, therefore the ceiling is bright. However, patterns of direct sunlight on any surface must be eliminated with special treatments, as this will break the uniformity because of the changing position of the sun. These apertures should be designed to direct the daylight on the surrounding walls uniformly (Figure 63.). Use of translucent glazing materials on such apertures may be helpful within this aspect.

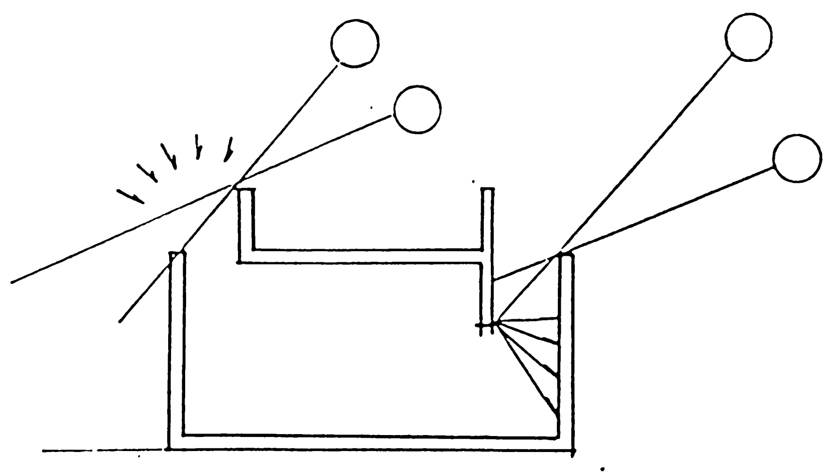


Figure 63. Treatments done to obtain a uniform peripheral lighting within interiors through the toplighting apertures.

Another way of achieving a spacious atmosphere passes through the use of toplit shared spaces. Daylight enters into these type of spaces through the top, therefore making these top parts brighter than the rest of the surfaces of the space. Also, this daylight is tried to be brought to the lowest levels. Therefore, the vertical surfaces all the way to the lowest level are also illuminated. These are the conditions that achieve a spacious atmosphere within an interior. However, provision of direct sunlight within the received light may cause some non-uniform patterns, and therefore, this should be avoided for the creation of a spacious atmosphere. Some control mechanisms can be placed at the entrance of daylight (top part) to obtain a uniform bright light on the vertical surfaces of the shared space. These control mechanism should show differences to confront the needs of seasonal changes. Such an application is shown in Figure 64.

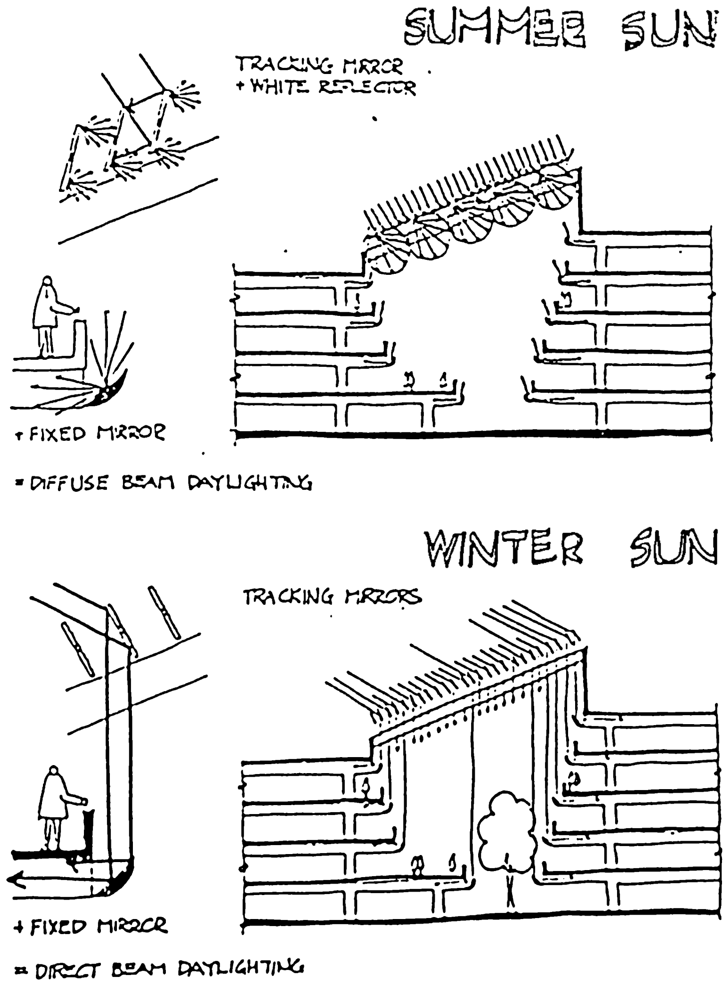
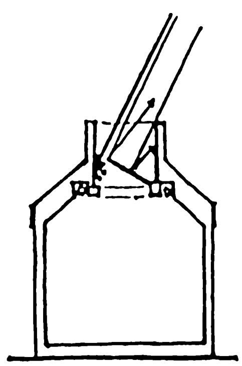


Figure 64. Control mechanisms at The Tennessee Valley Authority Office, Chattanooga, Tennessee,
from Mathews, S. and P. Calthrope, "Daylighting as a Central Determinant of Design." AIA Journal (September, 1979) 89.

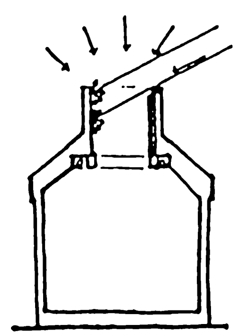
4.1.2 Example of a Spacious Atmosphere

Solution for the National Gallery of Canada Competition, in Ottawa, developed by the team whose lighting consultant was William Lam can be shown as an example for a spacious atmosphere. Daylight is used to achieve spaciousness within the interior. The concept of daylighting through this proposal is summarised below, accompanied by the daylighting diagrams and model photographs.

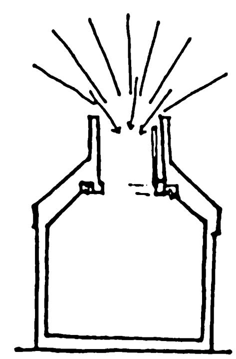
Clear glazing would be used on the aperture. Although the clear glazing would permit an unobstructed sky view when the control flap is opened, the depth of the skylight well, which would illuminate the peripheral display walls, enables the light to be reflected off the peripheral walls of the well (Figure 65.). These walls would be white, which absorbs a great deal of the incident ultraviolet radiation, which is very important in museum lighting, before reflecting the visible light into the gallery spaces (Lam, 1986).



High summer sun



Low winter sun



Overcast sky

Figure 65. The controllable flap for various sky conditions, from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 344.

These vertical surfaces of the wells would become the principal light sources for the gallery space on different sky types, both cloudy and sunny days. The single control flap would restrict the sunlight to the upper zone, and therefore when modulated by reflections from the deep well, all gallery walls would be evenly illuminated.

The natural light would reach the sloping ceiling at steep grazing angles that would render this surface less bright than the vertical walls below. Because the lower wall parts have more direct exposure to the skylight well than their upper zone, good uniformity of illumination would be achieved, although the wall has a great height. A dark finish material of the floor would cause the floor to be subdued relative to the vertical display surfaces.

The spacious atmosphere achieved through the above treatments is shown in the following model photograph (Figure 66.).

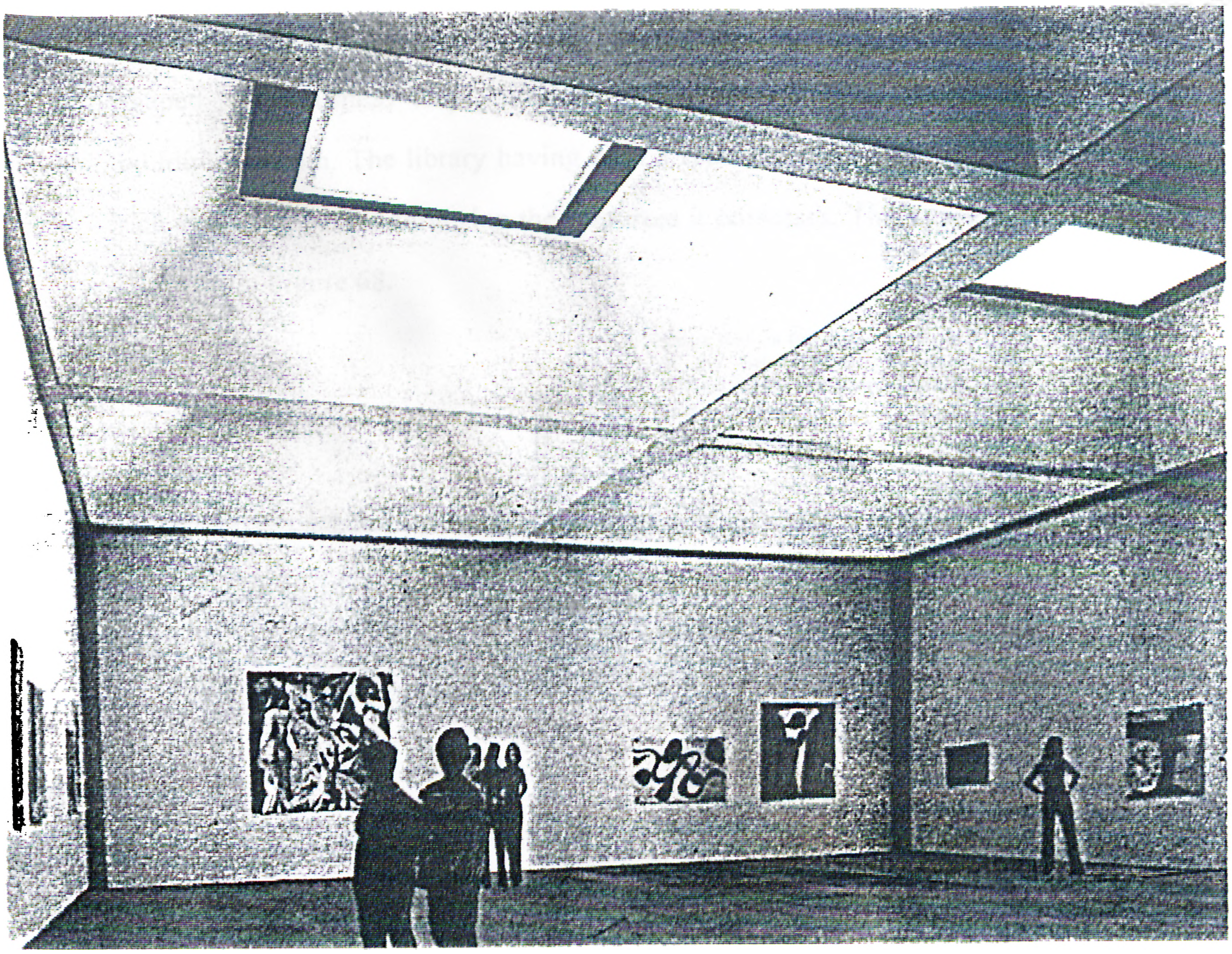


Figure 66. Model interior photograph from the proposal of Lam to the Daylighting of the National Gallery of Canada,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 349.

Another example of a spacious atmosphere is the additional library block at Bilkent, Ankara. At the central space of the building, a spacious atmosphere confronts the users, as soon as they enter into it. Spaciousness is felt, because there are white-faced balconies around a semi-circle which climb up to three floors, and this is enhanced by the daylighting strategies. Daylight is received via toplighting, and this received light illuminates uniformly the faces of balconies (peripheral surfaces) (Figure 67.). The users will use this central space for a short period of time, but because it is the entrance, it is the space where the first impressions of the building as a whole will be shaped. Spaciousness may introduce a further feeling to the users about the building's wealth. The library having such a spacious central space is observed as a rich one, even before surveying the resources it possesses. This spacious atmosphere is shown in Figure 68.

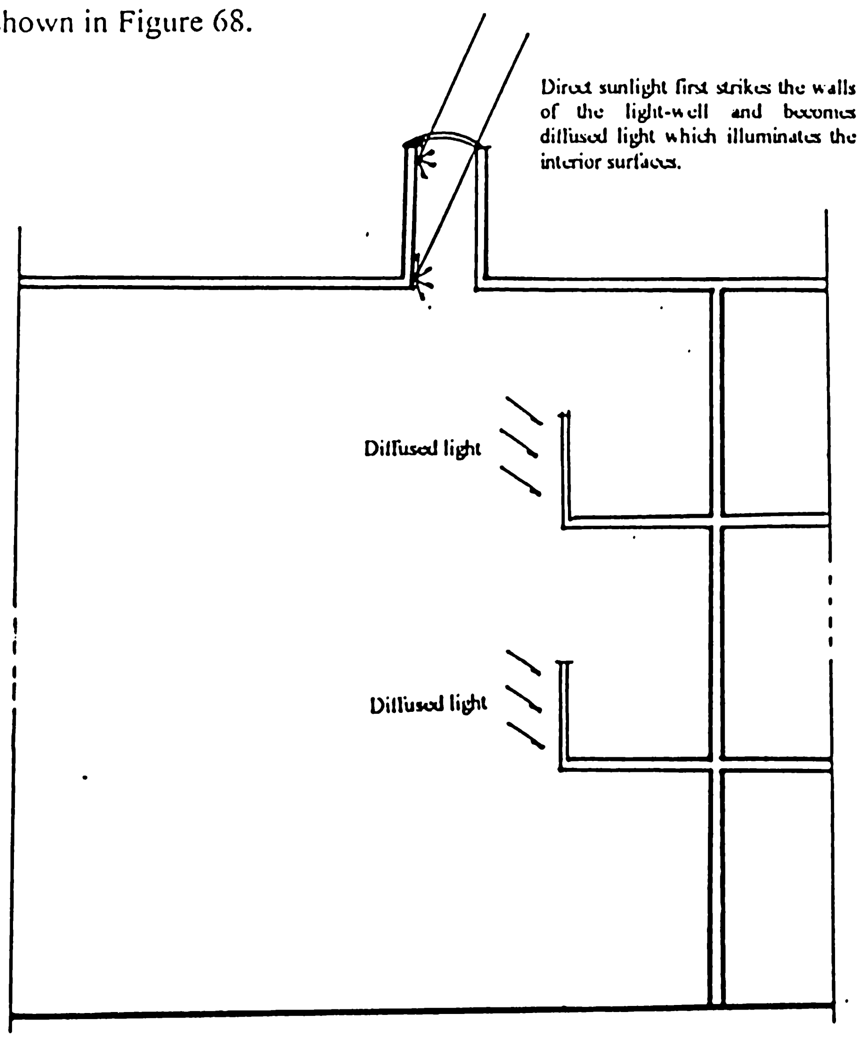


Figure 67. Sketch of the daylighting strategies employed at the central space

Figure 68. The spacious atmosphere of the additional library block of Bilkent University,
from Güzer, A., "Erkut Şahinbaş." Dekorasyon (February 1996) 90.

4.2 Relaxing Atmosphere

A relaxing atmosphere implies a comfortable space where the occupants perform certain tasks of their own choices comfortably. Daylight is the natural source of lighting through which this type of atmosphere can be achieved. Flynn (1977) suggests that non-uniform lighting with peripheral emphasis rather than overhead lighting produces an impression of relaxation within an interior. This implies that the use of daylight within an interior should be in accordance with this suggestion, where there is non-uniform peripheral daylight obtained via certain treatments on the daylighting apertures. Also warm-toned light sources can produce relaxing atmospheres within interior spaces (Steffy, 1990).

The graphical representation of a relaxing atmosphere can be seen in Figure 69. There are certain types of spaces where a relaxing atmosphere is required. Therefore, purpose of spaces should be a primary concern when discussing the aspect of relaxation within an interior. This space characteristics is especially important for casual spaces. Steffy (1990) specifies these spaces as waiting rooms, lounges, restaurants, conference rooms, and living areas; and states that because it reflects a comfortable pace of activities, it should be regarded in work settings. Of course there are other types of spaces which own such an atmosphere; and Ronchamp Chapel by Le Corbusier is an excellent example of it (Figure70.). Here, a relaxing atmosphere is welcomed within such a space, and the achievement of it is largely through daylighting.

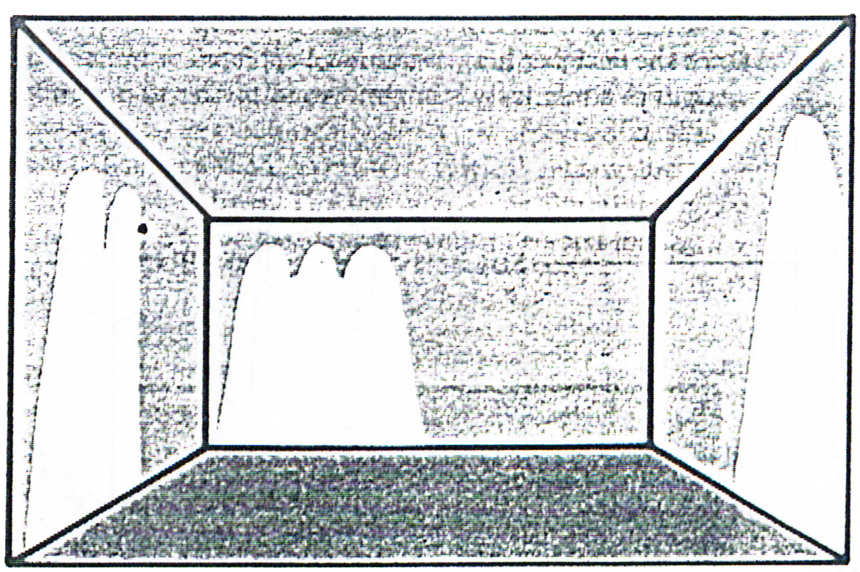


Figure 69. Graphical representation of a relaxing atmosphere,
from Steffy, G., Architectural Lighting Design (New York: Van Nostrand Reinhold Company, 1990) 35.

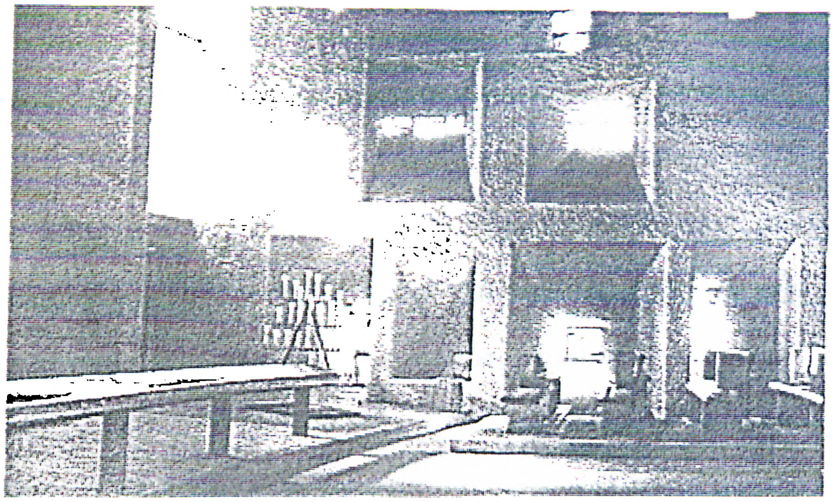


Figure 70. Notre Dame de Haut, Ronchamp, France,
from CEC. Daylighting in Architecture (London: James and James Ltd., 1993) 1.1.

Light structure model for the impression of relaxation is presented in Figure71. It is derived from the model that the impression of relaxation is reinforced by rather uniform, peripheral brightness which is relatively low.

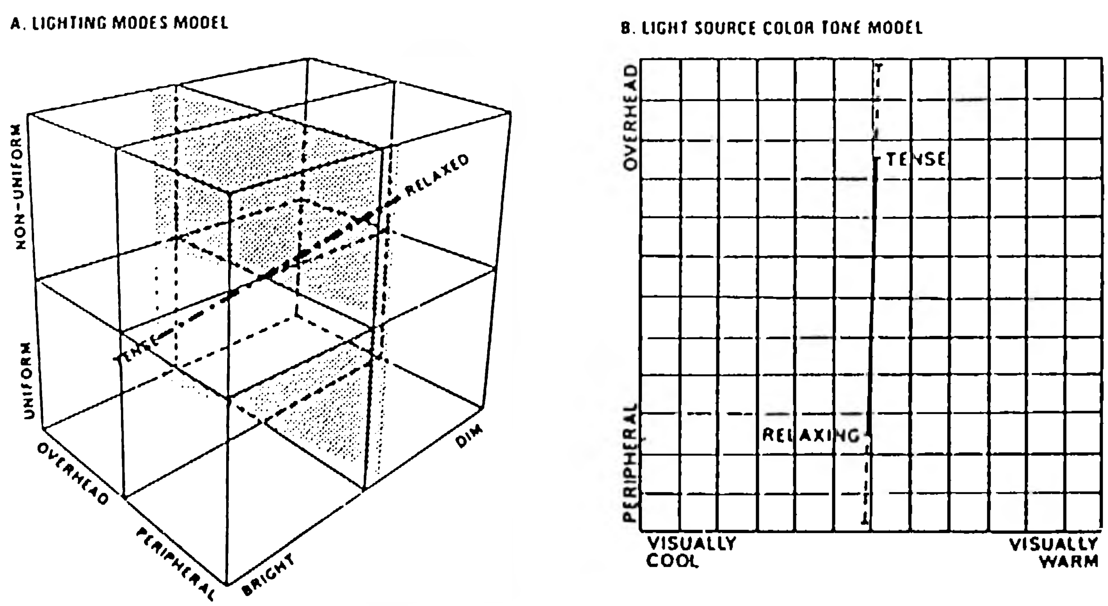


Figure 71. Light structure model for the impression of relaxation,
from Flynn, J. et al., Architectural Interior Systems (New York: Van Nostrand Reinhold Company, 1992) 21.

4.2.1 Achievement of a Relaxing Atmosphere

To be able to achieve a relaxing atmosphere, the daylighting apertures should be designed to obtain a non-uniform wall lighting. This non-uniformity can be achieved by having different sized windows that admit different quantities of daylight into the space.

Colour is an important aspect in the determination of any spatial atmosphere characteristics of an interior. Warm-toned sources of light are said to reinforce the impression of relaxation within a space (Steffy, 1990). Daylight achieves this warm-toned colour at certain times throughout the day, but this is temporary. A permanent application to obtain a warm-toned daylight within an interior can be a treatment on the glazing to provide the warm-coloured daylight. Also, colour of the reflective surfaces which are the sources of reflected light within an interior, affect the apparent colour of the space.

4.2.2 Example of a Relaxing Atmosphere

The Kimbell Art Museum in Fort Worth, Texas constitutes an example for a relaxing atmosphere, achieved through the help of the daylighting. Here, the most noticeable benefits of daylighting are the highly placed windows that minimizes direct competition with displays; and the reflections of sunlight on the ceiling through these openings (Figure 72.).

Reflectors made of aluminium are made opaque just below the opening which is 75cm wide, and the remainder of the reflector is perforated. Although this stops the penetration of direct sunlight at noon, it also "blocks the slice of the sky to be seen" (Meyers, 1979). This reduces the contrast where the edge of the perforated reflector could be seen against the ceiling. Not all the spaces had the same restrictions as to direct sunlight. The public spaces, entry halls, auditoriums, banquet area, bookstore area, and library mezzanine tolerate the fully perforated reflectors. This increases the light intensity within these spaces as well as the hope for the view of the sky above. The holes of the perforations are fine and frequent; and this presents a transparent window to the sky and washes the reflector in a transparent glow. With Kahn's own words, "this light gives a glow of silver to the room without touching the objects directly, yet give the comforting feeling of knowing the time of day" (qtd in Meyers, 1979).

Figure 72. Kimbell Museum, Fort Worth Texas,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 340.

Lam (1986) criticises the Kimbell Museum to have a sound reflector concept in the skylight, which is inefficiently executed. As a reason for this idea of his, he states that the relatively dark coloured surfaces of the unpainted skylight well and ceiling vault "give a pleasant glow" that is not sufficient for lighting the exhibits even at noon on a sunny day in mid-summer. He suggests that the skylight well should be painted white to have more light. However, I think that it is this application which supplies the interior space with a relaxing atmosphere. By the help of the reflectors, daylight is distributed over the ceiling (Figure 73., Figure 74.) of the space free from harmful radiation, which is previously absorbed by the skylight well. The exhibits are lit by artificial lighting, which is designed as a part of daylighting strategy, in such a way that the resultant effect is relaxing.

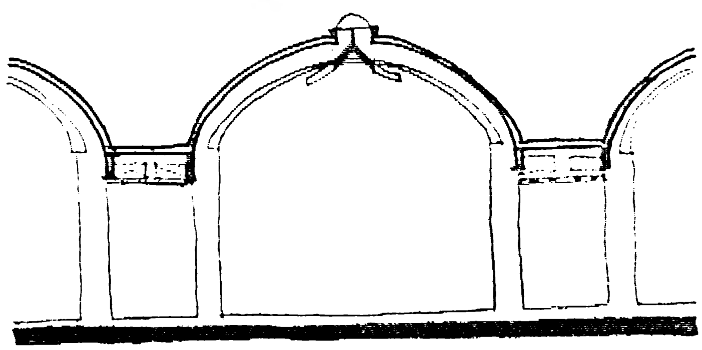


Figure 73. Section of the Kimbell Art Museum which incorporates the reflectors, from Meyers, M., "The Development of the Kimbel's Natural light Fixture."AIA Journal (September 1979) 61.

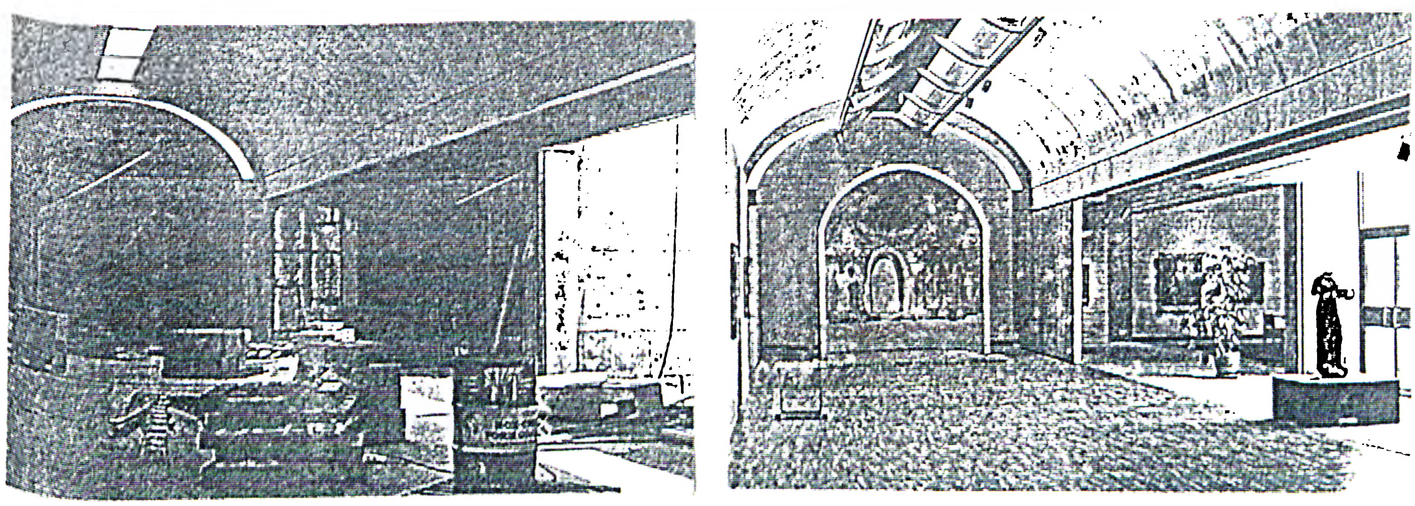


Figure 74. Kimbell Art Museum before and after the reflectors, from Meyers, M., "The Development of the Kimbel's Natural light Fixture."AIA Journal (September 1979) 62.

4.3 Calm Atmosphere

A space having a calm atmosphere can be defined as a space free from excitement, nervous activity, or strong feeling; or in short, a quiet and an untroubled space. A sense of being static (in terms of the space) is introduced within the meaning of a calm atmosphere. This type of a space can be obtained through daylighting, as desired. A calm space acquires that the daylight presented within the space is also calm; and this can be achieved by having a diffused, and a uniform daylight within it. There are many types of daylighting apertures, or certain treatments for these apertures, through which this type of result can be obtained.

4.3.1 Achievement of a Calm Atmosphere

Sidelighting is the most common type of daylighting apertures used for daylight illumination on buildings. To have a calm atmosphere, windows should be oriented or treated in such a way that the illumination obtained within the space is diffused and uniform. A diffused illumination can be directly obtained by orienting the window towards north (the shady side in the northern hemisphere). If the windows are located on the other sides of the building envelope, certain controls should be provided so that the direct rays of sunlight in the space are eliminated.

Toplighting can be the tool through which a calm atmosphere can be achieved. As the requirements for the achievement of a calm atmosphere within a space through daylighting remain the same, independent on the type of the aperture being used, the apertures should be designed to provide these final effects. For the achievement of a calm atmosphere with the use of toplighting apertures, for example, these types of apertures should be designed in such a way that the daylight presented within the interior is diffused and uniform.

To obtain a diffused and a uniform daylight through a clerestory, for the achievement of a calm atmosphere in an interior, there should be no sunlight within the received light; because, the sun changes its position quickly, and this introduces an action and a dynamism into the atmosphere. According to Lam (1986), adding suncatchers to side clerestories oriented East-West, enables the achievement of the steadiest illumination throughout each day and the most uniformity throughout the space (Figure 75.). The suncatchers are devices that increase the illumination at noon, and make the two face-to-face walls equally bright, no matter what the direction of the sun is, but with some deceleration in total efficiency. They are the exterior devices that converts direct sunlight to indirect sunlight. During summer, when the sun is arriving at the building apertures with a greater angle, no direct sunlight is seen on the walls. Also, if a translucent glazing is used, again the result is a diffused daylight.

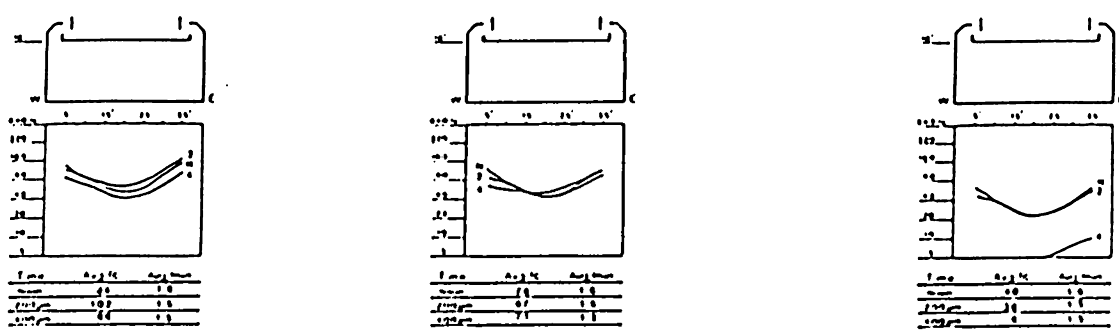


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Figure 75. Suncatcher baffles on east and west exposure clerestories provide the steadiest illumination throughout each day and the most uniformity throughout the room,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 340.

The monitor roof should be designed so that the obtained illumination is kept as constant as possible throughout the hours the daylight can be used, in order to be able to achieve a calm atmosphere. The glazing material can be chosen to be of a translucent medium, which diffuse the daylight falling on it, either direct sunlight or sky light. However, this cannot change the consequence that some surfaces have a higher illumination than the others. Therefore, overcast skies are the sources of daylight through which monitor roofs can act as apertures of achieving a calm space.

The sky conditions are important determinants of the performance of skylights. Under sunny skies, the solar altitude is depended upon from the performance of skylights point of view. On overcast sky conditions, horizontal skylights are exposed to the sky, and collect and distribute this diffuse and overcast sky light. A translucent material of a glazing may help to diffuse the light from a clear sky, but this does not restrict the higher illumination on some surfaces than on others.

Achieving a calm atmosphere within an interior is not the concern with toplit shared spaces, because sunlight is presented within the obtained daylight. Also, as these types of apertures are designed to provide light for surrounding spaces, there may be gradation of light from close to the aperture to further away. Usually, these spaces are said to provide a dramatic effect (Lam,1986). However, certain treatments can be done to shape the received daylight as desired. Some control elements may diffuse the light and direct the light towards specified directions (Figure 76.). With these applications, a calm atmosphere can be achieved within the toplit shared spaces.

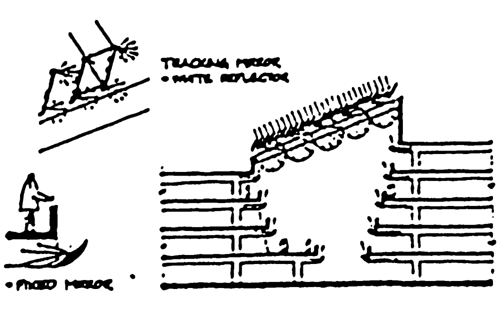

Figure 76. Achieving a calm atmosphere through treatments within a toplit shared space.
from Lam, W. Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 287

4.3.2 Example of a Calm Atmosphere

The Rosenthal Glass Factory in Amberg, Bavaria is an example of a calm interior, as a space characteristics. It is a design of The Architects Collaborative, Walter Gropius and Alex Cvijanovic. It is oriented with its longer side on the north south axis, and is flanked by courtyards and low service areas on either side. The courtyards can be seen and enjoyed from the interior and visited during rest periods.

Glass blowers need an evenly distributed source of diffuse light to spot bubbles and other imperfections in the molten glass, and since the kilns are operated in a round, the light had to come evenly from all directions, high and low. To accomplish this the building skin is developed as a natural daylight diffuser (Figure 77.).

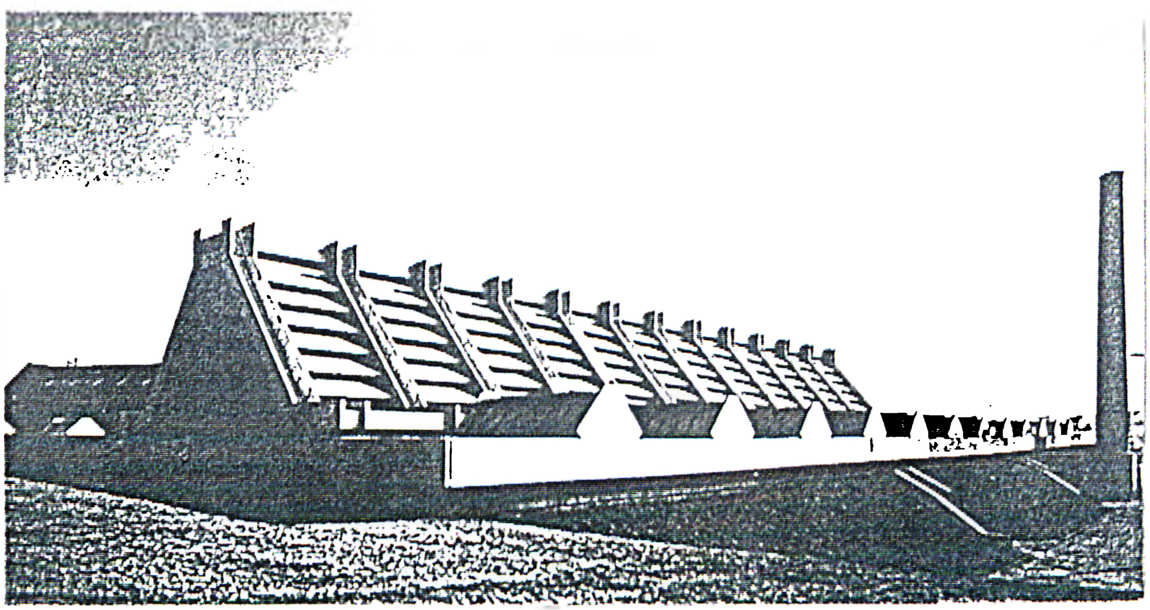

Figure 77. The building skin is developed as a natural daylight diffuser (The Rosenthal Glass Factory, Amberg Bavaria),
from Summers, N., "A Factory in which Light and Air were Formgivers." AIA Journal (September 1979) 78.

On the triangular roof of the main glass hall, they placed a series of sloping baffles. Within this aspect, Royston Daley, TAC associate in charge, states that:

> As you obviously do not want to introduce more solar gain into an already hot space, we introduced a series of sloped concrete fins that are glazed in-between and overhang so no direct sun can enter except of course, at very low angles (Figure 78.). In this way, you get reflected indirect light off the underside of the fins, which helps balance the brightness coming from the glazed north and south ends and the glass doors along the sides (qtd. in Nevin Summers,1979: 78.).

The reflected indirect light which helps balance the brightness within the space creates a calm atmosphere in the space, which eases the occupants' working, and this is shown in the following photograph (Figure 78.).

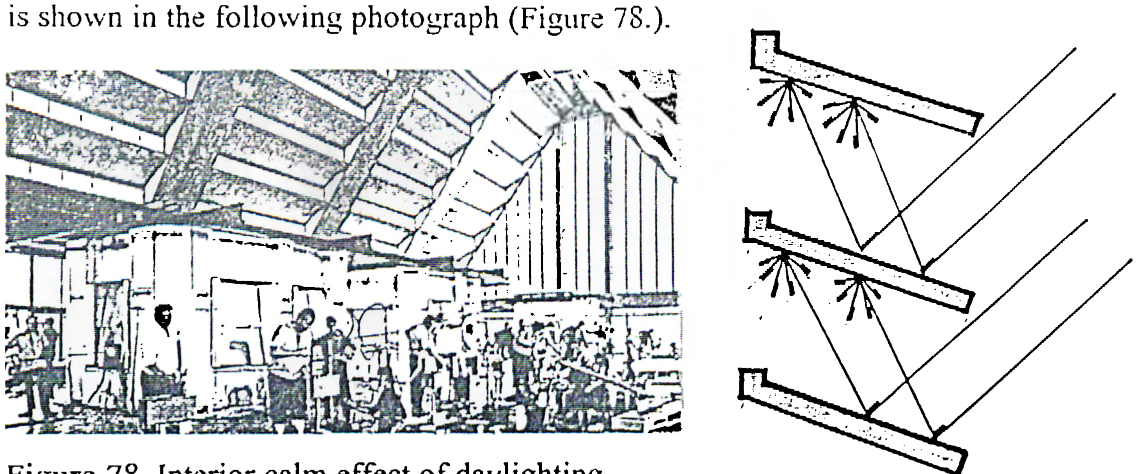

Figure 78. Interior calm effect of daylighting,
from Summers N., "A Factory in which Light and Air were Formgivers." AIA Journal (September 1979) 78.

This factory is the last major work of Gropius, and it is for a client who is concerned for the welfare of the employees and is willing to share the risk with an architect who thought the ordinary solution could be improved. The use of fenestration to better the life of the workers is of major significance.

Another example for a calm interior space is the Türk Tarih Kurumu in Ankara. The library part of the building is illuminated by north-facing roof apertures (Figure 79.). Therefore, the illumination within the space is uniform, and is steady throughout the day. This is achieved by the apertures that face north. This direction receives the already diffuse sky light. At winter time, the direct sunlight that is reflected from the sloped surfaces, does not go into the interior because of the direction of the sunlight. However, it should be kept in mind that during winter, the overcast conditions, where the sky brightness is greater, are more than the clear conditions. Therefore, the illumination received into the space does not decelerate. At summer, the sun comes with a higher angle, and is reflected by the surfaces to achieve the similar results as it would be by the overcast conditions (Figure 80.).

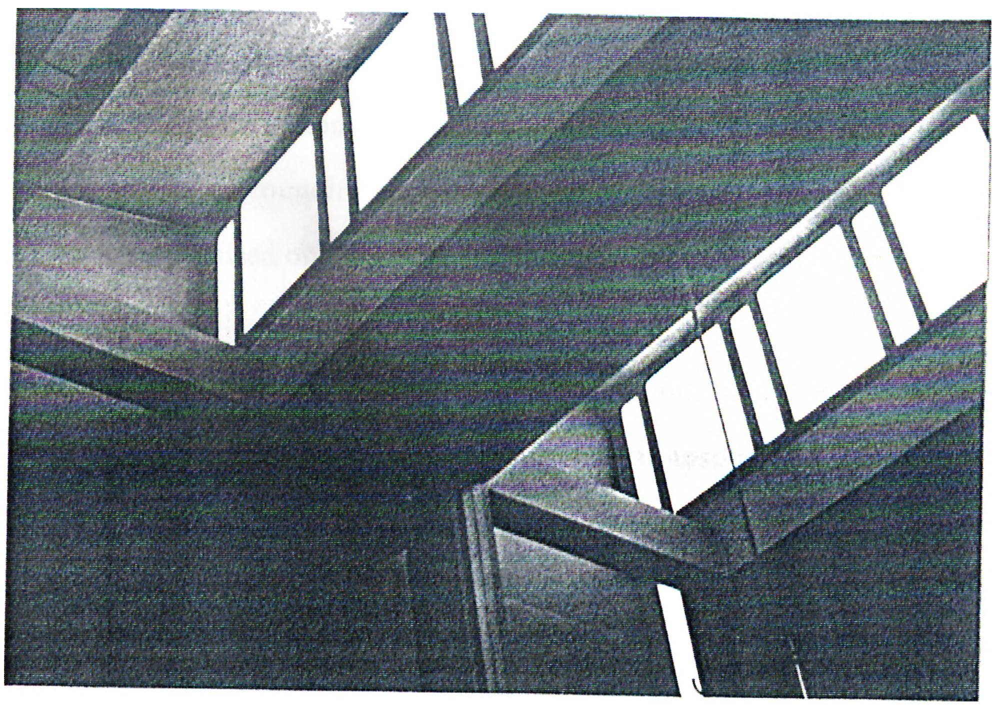

Figure 79. The apertures on the roof facing north creates a calm interior atmosphere

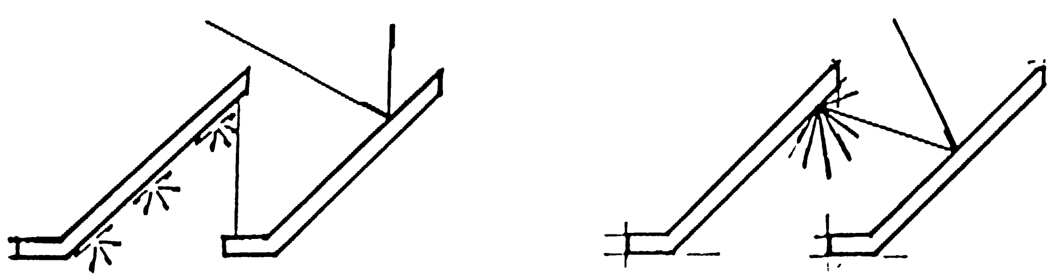

Figure 80. Behaviour of direct sunlight at Türk Tarih Kurumu Building, in different seasons

The reflecting surfaces are left concrete. If they were painted white of high reflecting material, the inside illumination levels would be increased, but this might cause the directly received sunlight to be beamed downwards. This might break the evenly illuminated calmness of the interior atmosphere.

4.4 Private Atmosphere

A space which has a feeling of privacy introduced within it implies that there is a state of being undisturbed. This can be achieved through daylighting, by the correct design of daylighting apertures. Flynn (1977) specified that this type of an atmosphere can be obtained through non-uniform lighting, which is low-intensity in the immediate surrounding of the user and high-intensity away from the user, and which is emphasised on the peripheral boundaries of the space.

First, the spaces should be distinguished according to the activities they serve; in order to point out the ones requiring a private atmosphere. A private atmosphere is acquired when the occupants may want to feel alone within a public space. Some kinds of restaurants are good examples where a privacy is desired. The examples are those kinds that are chosen to celebrate a special event, or have a special meal. It is very disturbing to see other people within this type of a space, as this introduces the feeling of being watched. Steffy (1990) specifies creating a private atmosphere as the opposite of designing for "being on stage for public view" (Figure 81.).

The light structure model for the impression of privacy is presented in Figure 82. It suggests that this impression is reinforced by rather non-uniform, peripheral, and relatively low brightness.

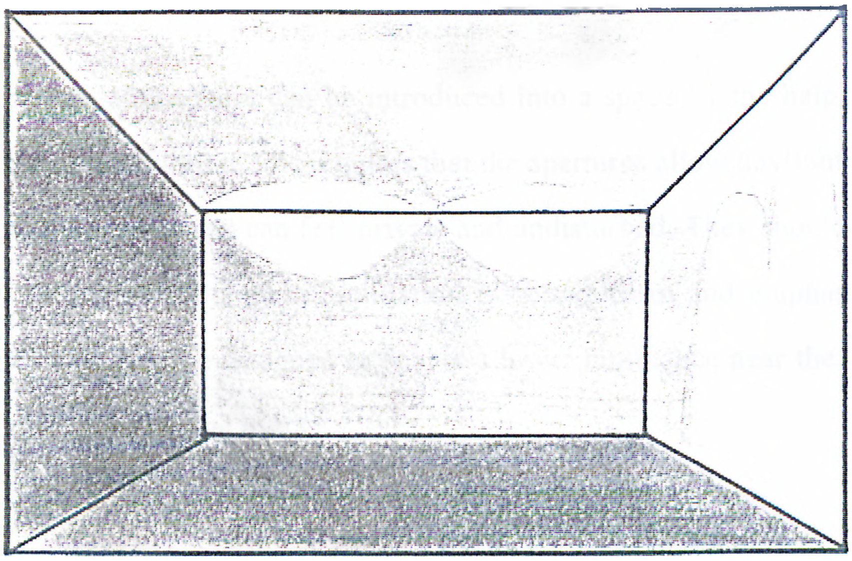

Figure 81. Graphical representation of privacy in terms of lighting,
from Steffy, G., Architectural Lighting Design (New York.Van Nostrand Reinhold Company, 1990) 36.

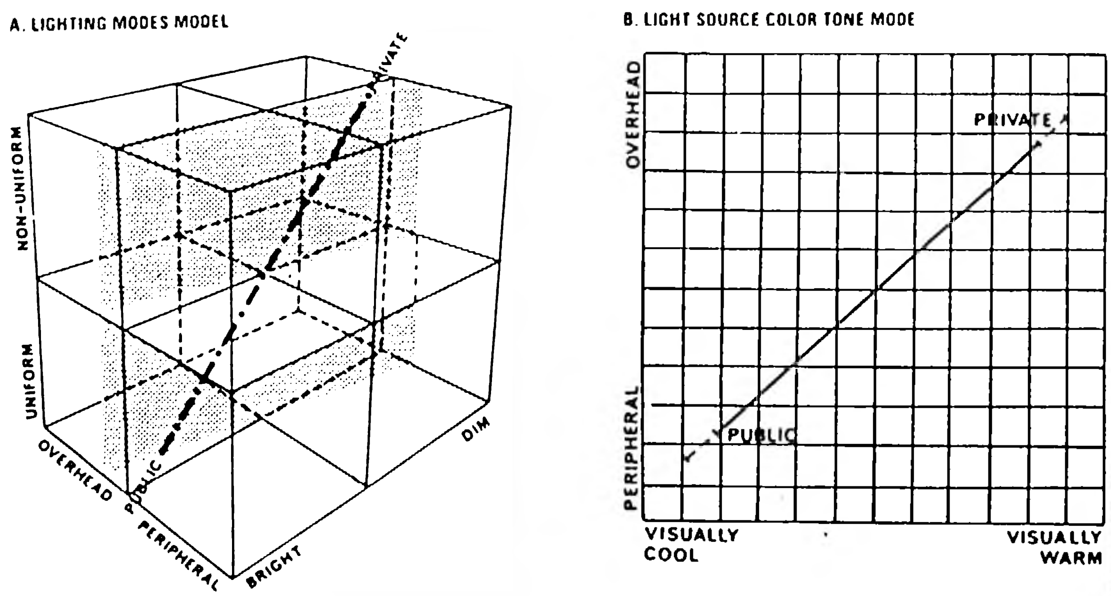

Figure 82. Light structure model for the impression of privacy,
from Flynn, J. et al., Architectural Interior Systems (New York: Van Nostrand Reinhold Company,1992) 23.

4.4.1 Achievement of a Private Atmosphere

A private atmosphere can be introduced into a space by the help of the lighting. In terms of daylighting, this requires that the apertures allow daylight to achieve a space where the occupants can feel private and undisturbed. They should be treated in such a way that the obtained illumination is non-uniform and emphasised on the walls. Also they must be designed to enable a lower luminance near the users and a higher one surrounding the users.

Under the scope of the definition of a private space, in terms of daylighting, the control elements should be in accordance with the achievement of the required results. To be able to obtain a non-uniform lighting within a space, control elements directing the daylight towards varying directions at varying qualities can be used (Figure 83.). While some controls may serve for lighting the top part of a wall, the others may serve for lighting the bottom part. The common property of apertures should be to provide illumination on the walls, which should be non-uniform; and this can be achieved through control elements.

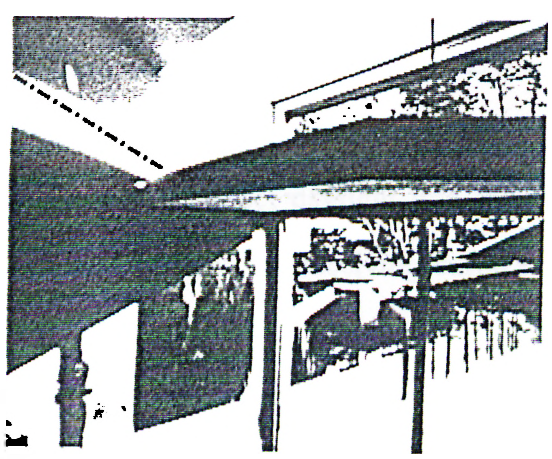

Figure 83. Control elements to achieve a private atmosphere,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 340.

7.4.2 Example of a Private Atmosphere

As stated earlier, some types of restaurants, where special occasions are celebrated, need to provide a private atmosphere for the occupants. One example of such a space is presented in Figure 84. Here, a private atmosphere is achieved through lighting, both natural and artificial; and the furniture layout is done in accordance with the lighting to achieve a private atmosphere within the space. It is a night-time picture, where the lighting is only artificial. However, the same effect is tried to be achieved through daylighting.

At night, the scones are used to illuminate arches above them, which then become the light sources illuminating the dining tables below. The rest of the space is slightly dim, illuminated by these arches and the end walls which are illuminated separately by scones for displaying drink bottles. This ensures the sense of privacy for each table. This is tried to be achieved by daylighting. Windows are placed beneath each arch, and tried to illuminate the tables. Walls between windows are places where the daylight is less intense and thus helps in the achievement of privacy within the space. However, in order to achieve exactly the same results with the artificial one, certain treatments could be done to the apertures (Figure 85.). For example, making an opening at the top of the full-height windows, and putting a lightshelf to reflect daylight into the arch via this opening would produce a similar effect. The receiving surface of the lightshelf, and interior of the arches should be reflective material. The lightshelf should be an adjustable one to redirect the received daylight into the arches, throughout the changing characteristics of daylight. The rest of the ceiling should be a darker color to ensure that a low intensity light is presented as general. This would introduce a feeling of privacy on the occupants where the feeling of not being watched by the others is ensured.

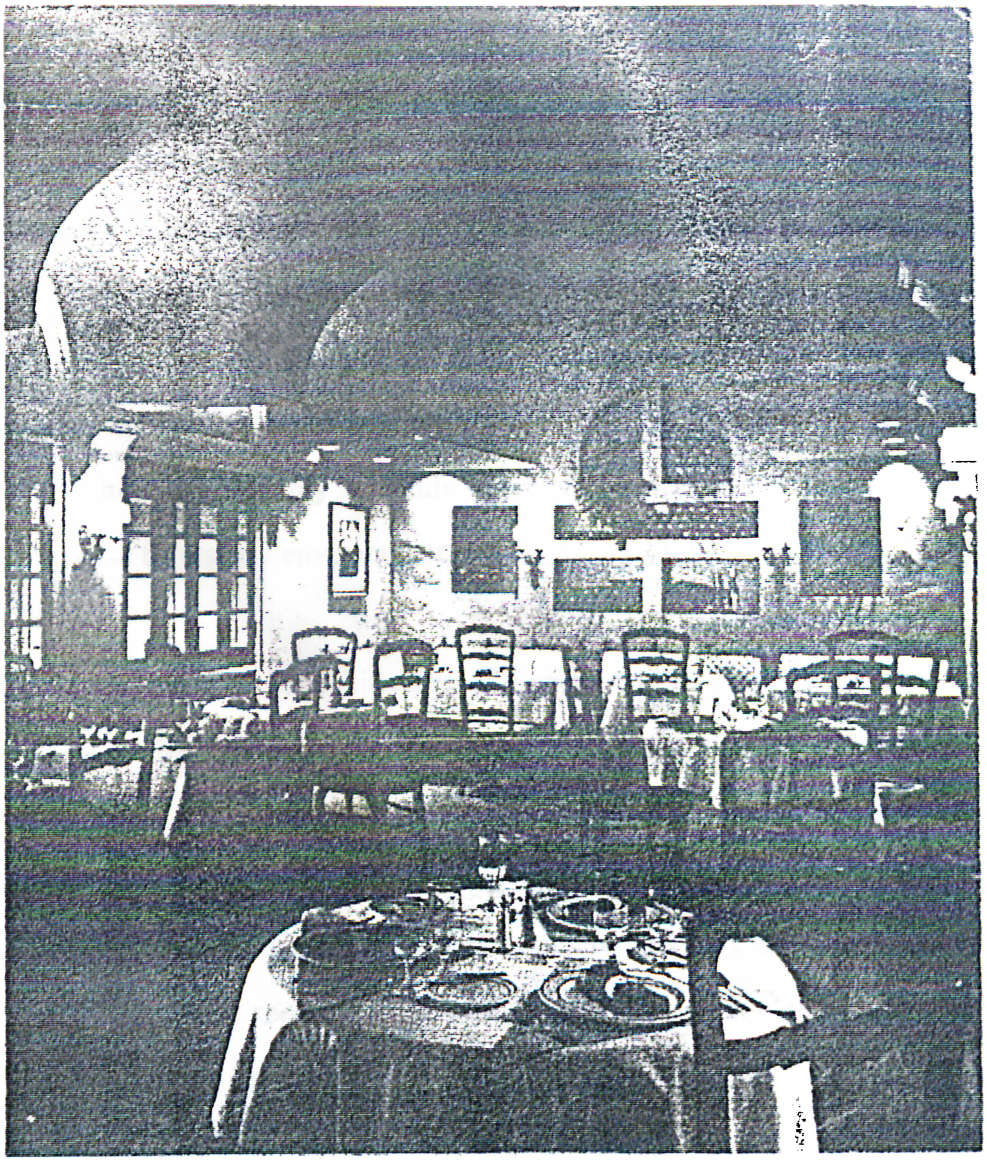

Figure 84. A private atmosphere of a restaurant

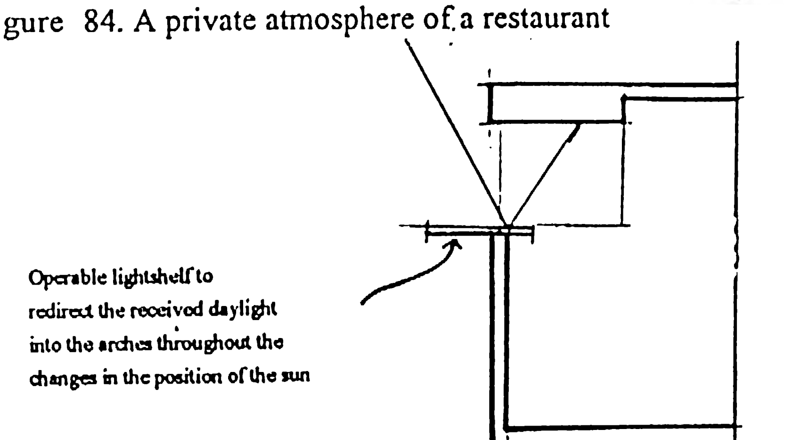

Figure 85. Achievement of feeling of privacy within the space through daylighting

4.5 Dramatic Atmosphere

A dramatic atmosphere is an exciting and unusual space characteristic. It is that type of an atmosphere which is dynamic as well. Again this result is a matter that can be achieved through daylight. A dynamic atmosphere of an interior implies that the space has a moral force that produces activity or change. As Robbins (1986) points out, having sunlight within a space adds variety to a space, and changes the quality of it by introducing changes in colour, contrast, and light, which create a dynamic quality of space that cannot be achieved by any other design element. Such an atmosphere is probably a result obtained by sunlight, transforming what might otherwise be a static environment.

A simple and a plain architecture of a space can be given a dramatic effect by the help of the daylighting. Some paths of direct sunlight on the architectural boundaries of a space can achieve this dramatic effect. The sun is a constantly changing phenomenon. Because of this change, dynamism is introduced into the interior through sunlight. Sunlight is not visible, unless there are some particles of dust in the air. This invisible source can be used as an architectural element in buildings, and it is a very strong determinant of dramatic atmospheres: Although it is not visible on its own, the sunlight can form strong light patches on the built form, in very clear atmospheres. Usually, the dust particles in the space, which are not visible to the naked eye, will be visible under the beams of sunlight or in other words, with the help of the particles, solar beam will be visible in all effectiveness and vividness. These beams and patches introduce a dramatic effect on the interior atmosphere, which is dynamic as well. This dynamism comes from the continuous movement of the sun.

4.5.1 Achievement of a Dramatic Atmosphere

In order to achieve a dramatic atmosphere, the apertures, either sidelighting, toplighting or toplit shared spaces, should be designed to obtain paths of direct sunlight within a space. In other words, beams of sunlight should be observed, bringing light and shadow patterns on the interior surfaces.

Small sized apertures of a building are the effective sources of light for the production of a dramatic atmosphere as a space characteristics. These apertures enable the introduction of beams of sunlight, which changes continuously with the movement of the sun. These small, changing patches of sunlight on dark room surfaces introduce feelings of drama and dynamism into the interior. The excellent examples of such spaces are the traditional Turkish baths. Here, the relatively small openings on the dome were beautifully bringing beams of sunlight into the interior, which in turn, produce a dramatic atmosphere (Figure 86.).

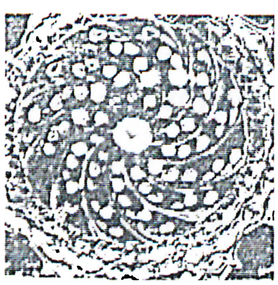

Figure 86. Openings on the dome of the İsmail Bey Hamamı, İznik

Even if some treatments, like putting bottle-like glass pieces into them, were done to the openings, this did not change the resultant atmosphere of a dramatic effect. This time, the beams of direct sunlight were turned to softer, conical, diffused beams, which still produce a similar result.

Use of tracking mirrors is another method through which beams of sunlight, and thus a dramatic effect can be achieved within interiors. The tracking mirrors are automated systems that follow the path of the sun in such a way that the same angle of incidence is kept constant (via the photo-sensors). Thus, they make it possible to continuously obtain beams of sunlight within interior spaces through the continuously changing sun. These tracking mirrors can be seen in Figure 87.

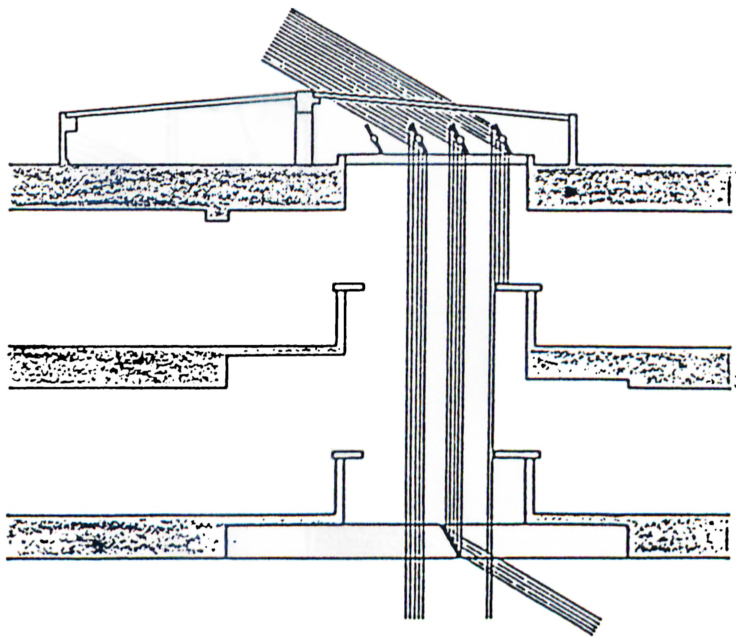

Figure 87. Tracking-mirrors,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 425.

4.5.2 Examples of a Dramatic Atmosphere

Central United Methodist Church at Milwaukee, Wisconsin, is an example in which a dramatic atmosphere is experienced. The bulk of the church is earth-sheltered. The only thing that is visible is the bell tower and entryways cut into a hillside covered with wildflowers. The tower is glazed only on the south. A large shutter is designed to isolate the upper cavity of the tower from the rest of the church. When needed, this shutter can be opened and some of the sunlight is redirected down and into the space. The south facing opening enables maximum light receiving from the sun during winter, when this is most desirable (Figure 88.). In winter, large amounts of solar radiation are admitted and a portion is redirected to the ceiling. In summer, most of the light and heat are rejected, except during services. After passage from the primary mirrors, some sunlight reaching the secondary mirrors are reflected on to the ceiling of the nave (Figure 89.).

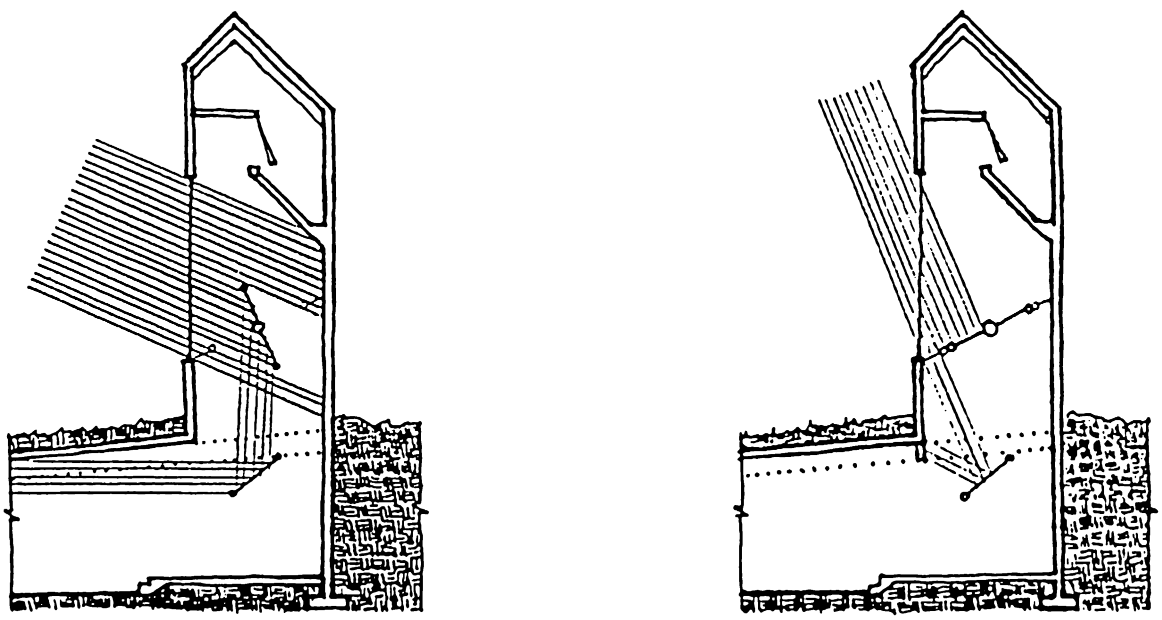

Figure 88. Schematic diagrams of the operation of the lightshaft at the Central United Methodist Church,
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 401.

I fully agree with Lam's suggestion (1986) on the orientation of the building. He states that:

> Unfortunately, most church services have been scheduled for very early morning hours before the sunlight reaches the south exposure and the space can be experienced at its most dramatic. For the earlier events, a more easterly orientation would have been better so that both maximum heat and light control could be experienced (402.).

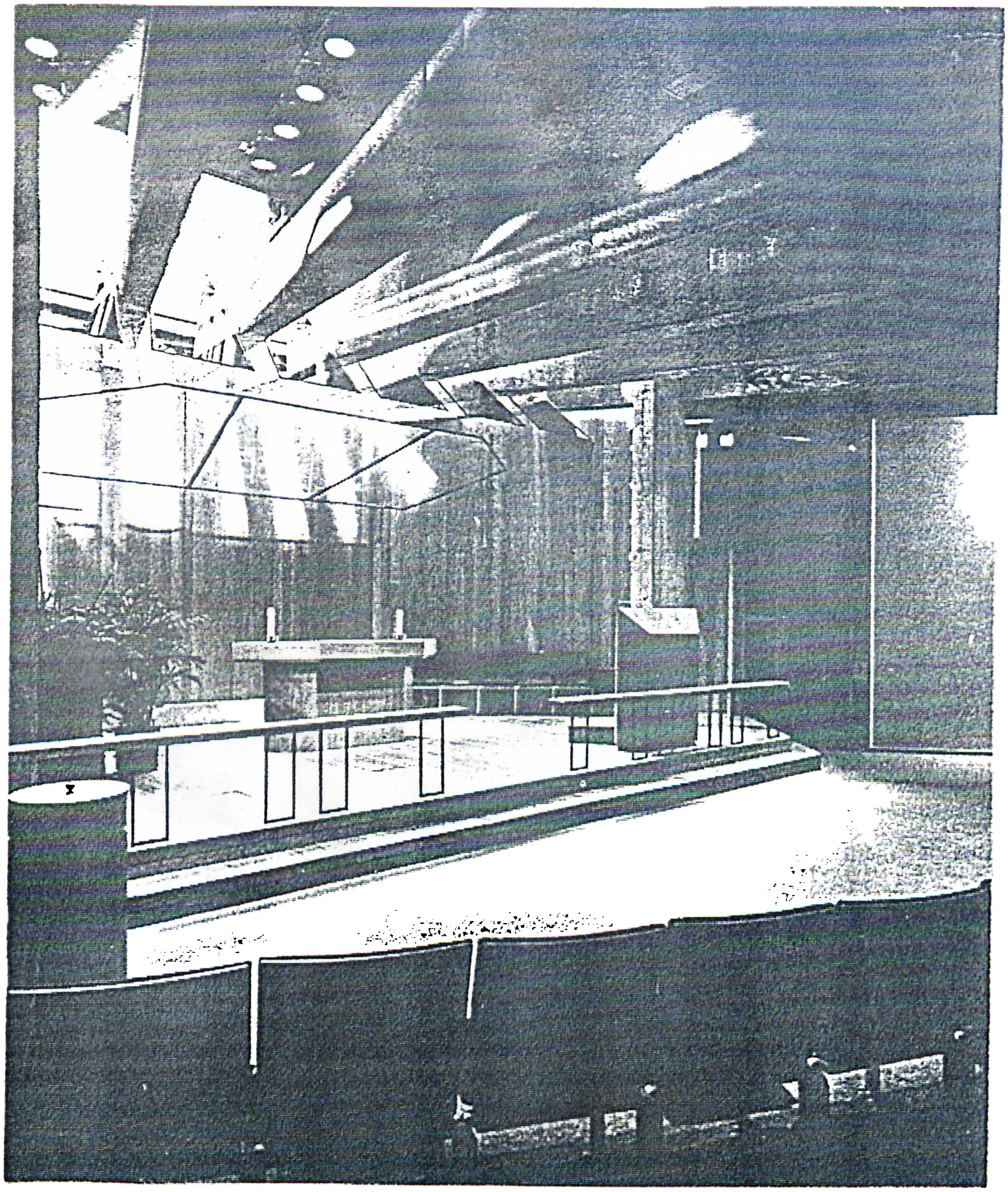

Figure 89. Interior of the Central United Methodist Church.
from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold, 1986) 403.

Another example of a dramatic interior is the Doğramacı Dwelling, at Bilkent, designed by E. Şahinbaş and A. Güleyen. Occupancy (the type of space) is the most important aspect of the building. This huge space of 3500 square meters is a house where the family lives independently; but at the same time, its public use is of a greater importance. Cultural and social facilities are held via meetings at the central spaces, and the impression of these spaces thus becomes very important. The designers stressed this importance through lighting. They created a space where the natural lighting introduces a dramatic feeling. This is intended to be achieved at a central space, because this space was to be perceived first and most, and it is this space that the whole building was to be evaluated by the visitors. In other words, image becomes the dominant aspect that is stressed, and daylighting played the major role within the achievement of this.

An axial vault which is treated so that daylight is received not directly, but as redirected from the side walls, has been employed within the space (Figure 90.). The

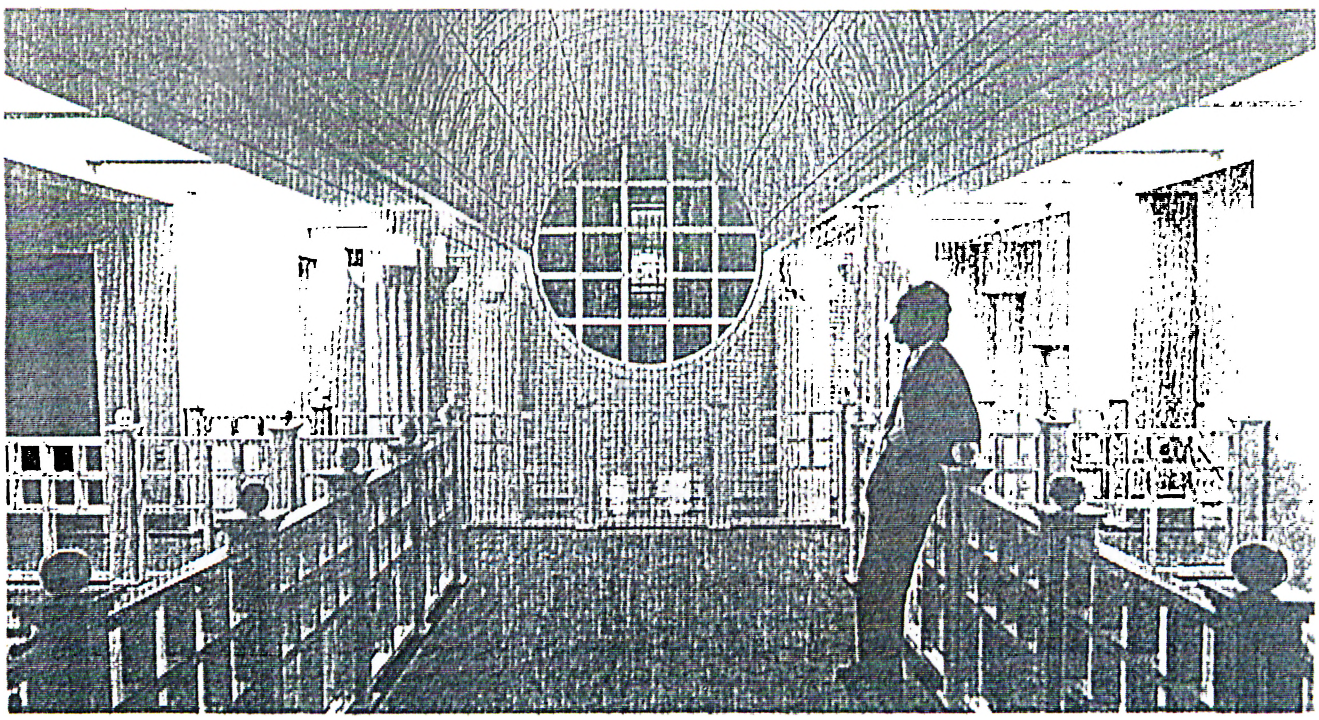

Figure 90. The axial vault supplying daylight that introduces a dramatic feeling into the space.
from Şahinbaş, E., Personal Interview (June, 1996).

shape of the solid stripes connecting the solid vault to the side walls below the transparent one casts light patterns on the walls, which change throughout the day by the changing position of the sun. Besides this application, other features like statue exhibitions are specified by daylighting, and this also introduces a change in modelling and a feeling of drama into the space (Figure 91.).

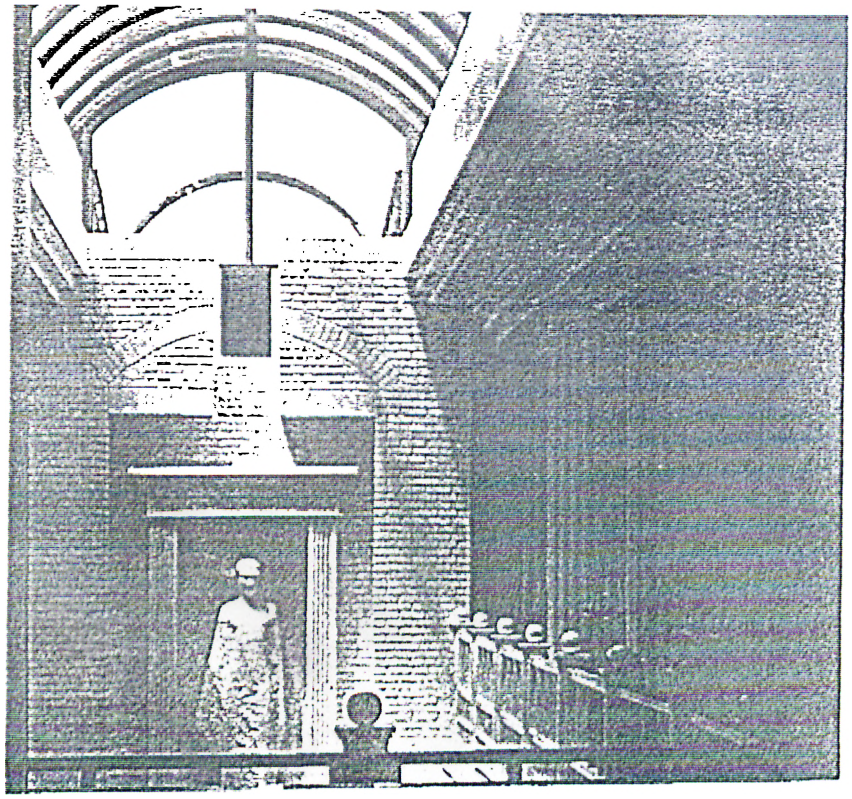

Figure 91. Dramatic effect produced by the exhibits,
from Güzer, A., "Erkut Şahinbaş." Dekorasyon (February 1996) 78.

As a whole, daylighting has been used to produce a dramatic atmosphere within this space. This is felt by the users as soon as they observe the space. This first impression is thought by the designers to be very important in perception of the space as a whole. People evaluate the space by the things they observe. Therefore, putting a dramatic effect for the spaces of public use, as soon as entering in, makes the space to be a striking one. Employing a vault as a dominant element of the space, and getting the required light from that vault is designed in accordance with this idea.

Kapalı Çarşı, İstanbul, is another interior where daylight creates a dramatic interior. The space is made from vaults that are forming a grid. It is illuminated by daylighting through clerestories and small openings on the vaults. For every space left under the vaults, clerestories are employed for illumination, and they supply a uniform lighting for these spaces. The space, made up of vaults that lie laterally and longitudinally, as a whole is seen dim. These intersection spaces of the vaults are important and emphasised by dramatic influence of paths of sunlight. These paths change with the moving sun, and this introduces a dramatic feeling into the space as seen from Figure 92.

Figure 92. Dramatic effect of sunlight paths within the dim interior

4.6 Warm and Cool Atmospheres

Warmth or coolness of the atmosphere of a space is primarily determined by the color of the light the space is exposed to. Here the issue of colour temperature of the light sources becomes important. Colour temperature is a light source characteristics that is related with the colour appearence of the source. Robbins (1986) states that, theoretically, the colour of any object changes with the colour temperature of the light source illuminating it. Colour temperature is measured in degrees Kelvin (K). It is determined by heating a black body until color of the body matches that of the source it is being compared to. In terms of daylighting, for example, early morning or late afternoon lights are warm. The predominant color of the daylight depends on the type of the sky. For the clear sky, without the sun, the color temperature is approximately 5000 K; for the overcast sky, it is approximately 7000K. Figure 93. shows the color temperatures of various light sources.

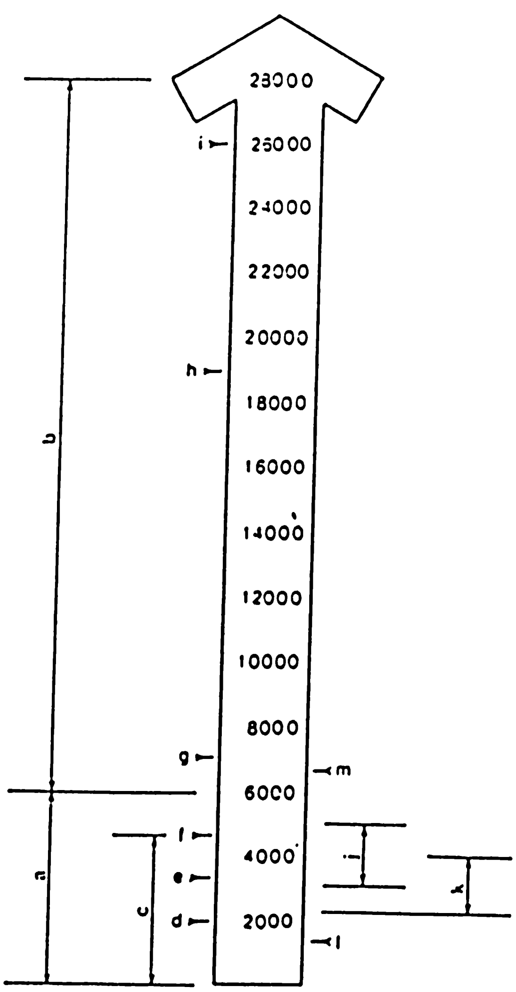

Figure 93. Colour temperatures of various light sources in degrees Kelvin: (a) typical range of sunlight; (b) typical range of skylight; (c) range of sunlight within 2 hours of dawn; (d) dawn + 15 minutes; (e) dawn + 1 hour; (f) dawn + 2 hours; (g) CIE uniform sky; (h) typical north sky; (i) north sky, high altitude, very clear; (j) range of most fluorescent lamps; (k) range of most incandescent lamps; (l) candle light; (m) daylight fluorescent.
from Robbins, C., Daylighting Design and Analysis (New York: Van Nostrand Reinhold Company, 1986) 256.

For a certain illuminance level, particular color temperatures appear natural to the human eye. Kaufman and Haynes (1981) represents these colour temperature/ Illuminance relationships on a graph (qtd. in Robbins, 1986) (Figure 94.). On this graph, the area below the shaded part produces cold, drab environments; and the area above this part produces overly colorful and unnatural-appearing light.

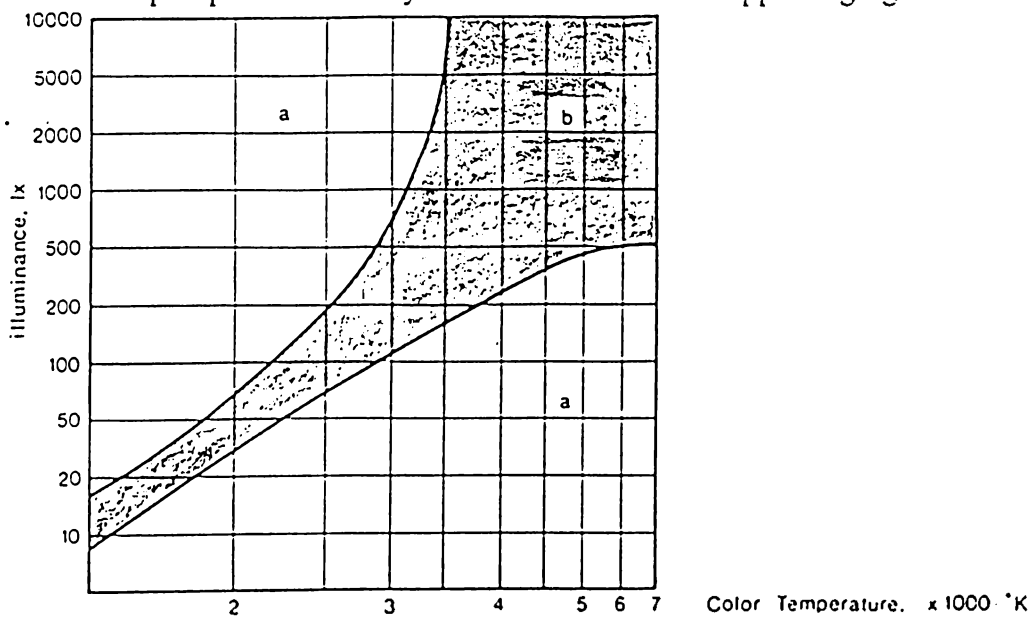

Figure 94. Color amenity curve: (a) colour appears unnatural; (b) colour appears natural,
from Robbins, C., Daylighting Design and Analysis (New York: Van Nostrand Reinhold Company, 1986) 257.

A warm atmosphere of an interior is the one where some emotions of pleasure and sincerity are introduced within the space. The colour of the light the space is exposed to, plays an important role in the achievement of such a space. A warm-colour-dominant light source, which is low-intensity and uniform within a space can produce a warm atmosphere. Actually, a warm atmosphere is a space characteristic that is desired in most of the spaces being used by the human-beings.

A cool atmosphere of a space, on the other hand, can also be obtained through the light source that illuminates the interior. The light sources that are cool color-dominant (according to the color appearence of them), are said to create cool atmospheres.

4.6.1 Achievement of a Warm Atmosphere

A warm atmosphere can be achieved by having a warm-toned lighting source. Daylight achieves this warm-toned color at certain times through the day, as the color temperature of daylight changes throughout the day. However, because of this change, it is a short-time effect, and thus cannot be relied upon for the achievement of a warm atmosphere. There are some cautions that can be taken to pretend as if the apparent colour of daylight is always warm-toned. A warm-colored glazing can be used to obtain this result.

4.6.2 Achievement of a Cool Atmosphere

Because the daylight is a full-spectrum light source, it is not one-color dominant. However, because it achieves different colour appearances at different times throughout the day, it can be one-colour dominant at these different times; but these are short-time consequences. Therefore, it should not be relied solely upon the daylight on the production of a cool interior atmosphere (although it may reach to colour appearances that produce cool atmospheres at certain times). There are glazings with special treatments that filter the daylight into the interior as cool-colored light. Thus the space exposed to such a daylight becomes a cool space. If the apertures are designed so that the redirected daylight is received from a cool-colored surface, this received light also becomes a cool-toned lighting source for the space.

4.6.3 Examples of Warm and Cool Atmospheres

Warm or cool atmospheres can be achieved as long as the colors of daylight which penetrates into the space is in accordance with the above mentioned ones. A warm atmosphere may be achieved if the received daylight is warm-colored, and likewise a cool atmosphere may be achieved if the admitted daylight is cool-colored. The following photographs (Figure 95.) present an effective comparison of the same space with warm and cool atmospheres. This is created by the color of the daylight that enters into the space.

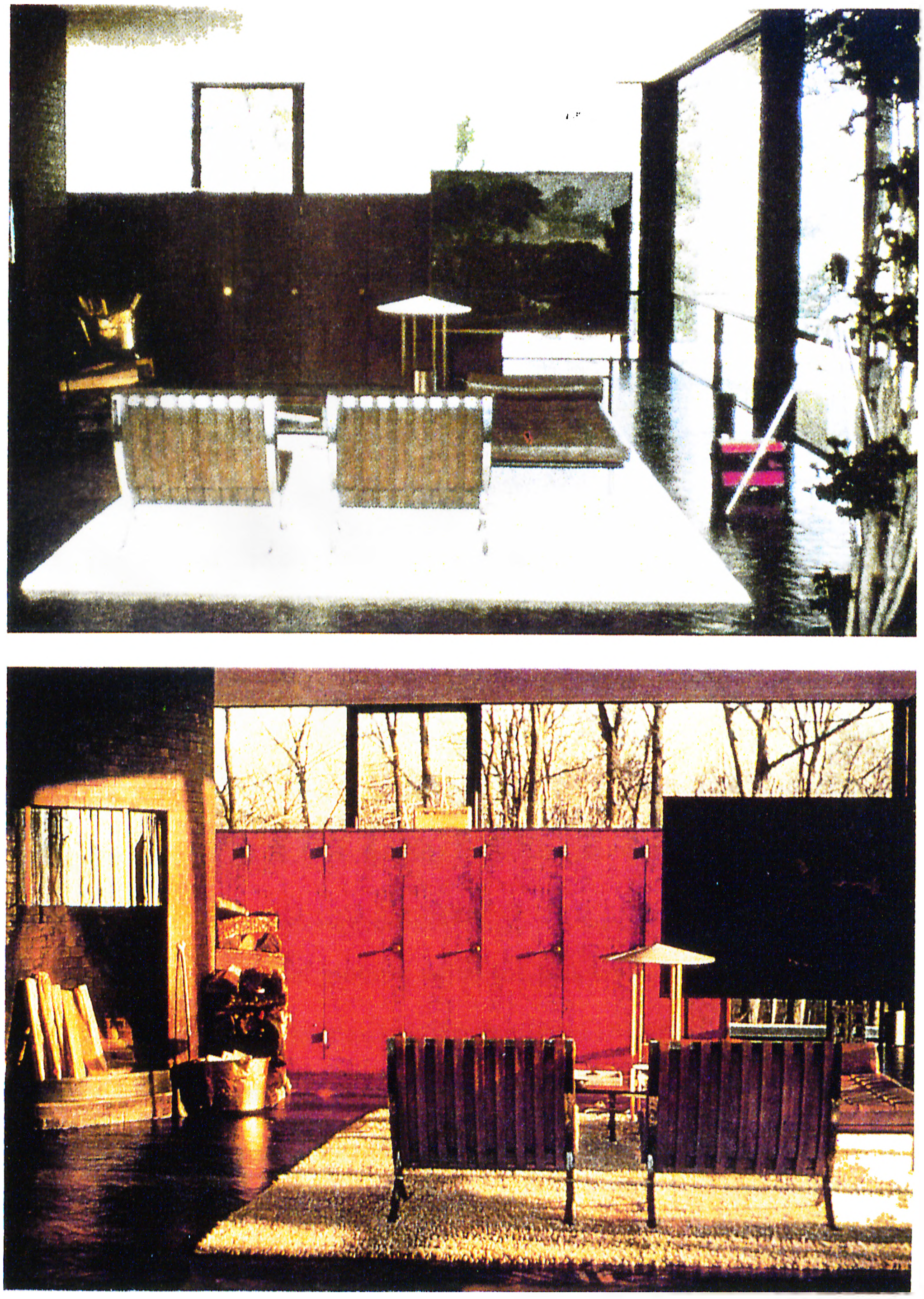

Figure 95. Photographs of the same space being exsposed to warm-colored winter daylight, and a cool-colored **summer** light show the different atmospheres (warm and cool) of the space,
from Bertolone, S., Bringing interiors to light (New York: Whitney Library of Design, 1986) 103.

4.7. Depressing Atmosphere

The depressing atmosphere of a space makes the space unfriendly. Usually this type of space is created by artificial light sources, as a result of the limited color combinations within them. This results in the misrecognition of the colors. Daylight, on the other hand is a full-spectrum light source; and therefore, the objects are seen "true" under daylight. Actually, it should be stated that human beings have been evolved under daylight throughout history, and this daylight has become the norm against which all other sources are evaluated. However, with some daylighting apertures, the interior space having those apertures, may become unfriendly as well. This can be resulted from daylight which is very limited (very low intensity), and also the absence of sunlight within this daylight in the interior may produce such an effect. The size of the daylight apertures are also affecting the atmosphere of the space in terms of being depressing. If the apertures are so small that no information (weather, time, view, etc.) is gained from outside, this ends up in a depressing atmosphere.

During the day, we expect the outside to be brighter than inside, because of time and orientation. Likewise, during night time, we expect the outside to be darker than the inside; and we tend to feel gloomy when the situation is ambiguous, such as on dark overcast days. If low-transmission glass is used, for example, this ambiguous period is elongated. It is unexpected, and thus depressing to see our reflection in the glass when we expect to see the brighter exterior scene through the window at midday. Studies have shown that many people suffer from a short-day syndrome, and are depressed in winter months (Lam, 1986).

Usually, a depressing atmosphere is not wanted to be owned within a space; and therefore, the achievement of it should be avoided by the correct choice of daylighting apertures and control elements.

4.7.1. Ways to Avoid a Depressing Atmosphere

Apertures usually serve for two main purposes: To obtain daylightight into the interior spaces; and to supply exterior view and information into the interior spaces. When the latter is omitted from the function of the sidelighting apertures, the interior space they are serving for becomes depressing or boring. Also, if the windows receive daylight that is insufficient to perform the acquired tasks within the space, then the space can be considered to have a depressing atmosphere.

Depressing atmosphere of an interior space can be resulted from insufficient toplighting apertures. Creation of any atmosphere by daylighting the spaces via toplighting apertures is closely related with the way the aperture admits daylight, and the weather conditions. If the space is only illuminated by a toplighting aperture, there is always a risk of having a depressing atmosphere. There are of course some spaces where this type of apertures are useful, beyond the creation of a depressing atmosphere. Art galleries are examples for these type of spaces. Also, presentation of sunlight paths in the obtained daylight illumination may take away the depressing atmosphere of a space.

A depressing atmosphere can be produced through the use of toplit shared spaces. If these types of daylighting spaces are not sufficient to carry the obtained daylight to the lowest levels, which should be their primary concern, then these spaces may be considered depressing or boring spaces. However, this is not the usual case. These spaces, especially courtyards provide an attractive view outside, especially at the lower levels, which in turn, brings the interior an air free from depression or boredom.

4.7.2. Example of a Depressing Atmosphere

The T.W.A. Terminal of the Kennedy Airport can be regarded as a space having a depressing atmosphere. The sloping floors, non-vertical walls, and the lack of windows produce this result. Visual contact with outside is a basic need for human beings to avoid the sense of depression. Within this terminal, this is omitted. Although the space is illuminated, there are no points of reference. This is illustrated in Figure 96.

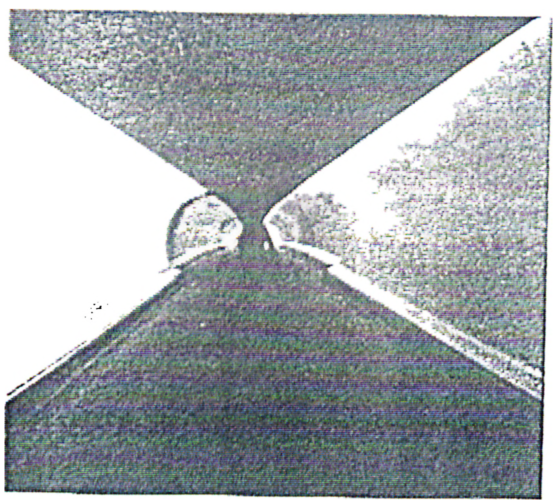

Figure 96. Depressing atmosphere of T.W.A. Terminal of the Kennedy Airport, from Lam, W., Sunlighting as Formgiver for Architecture (New York: Van Nostrand Reinhold Company, 1986) 20.

5. CONCLUSION

The fact that a good daylight design has aims of providing a fully sufficient light for sufficient visual performance; and ensuring a comfortable and pleasing environment appropriate to its purpose, as stated by Hopkinson et al.(1966), has constituted the basis of this study. The latter aim that has been stated is related to the quality and use of daylight. Quality is a subjective phenomenon. It is an expression of one form of visual sensation. Within this aspect, Hopkinson et al. states that a sensation cannot be measured, but that the physical factors which determine sensation can be measured; and that a valid design procedure can be devised with the aid of a "statistically significant" relation between the objective measurement of physical factors and the subjective estimates of the magnitude of the corresponding sensation. Throughout this study, the atmospheres previously defined by others, and validated by statistical processes, are taken as the base data; and it is examined to find out how they could be achieved by using daylight as the lighting source. Applications within this aspect have been searched and examined, and it has been tried to show that every atmosphere can be created by daylight.

Different effects of different daylighting strategies within interior spaces are tried to be stressed. Within this aim, several atmospheres are identified, and literature is searched whether such atmospheres are obtained as effects of daylight. Examples of such atmospheres are found and tried to be examined. The daylighting apertures, control elements, space forms and orientations, and other factors affecting the quality aspect of daylight within interiors are investigated. As a result, it has been found that the atmosphere of a space can be created by daylight, through its conscious use by the designers.

The effects of daylight on the atmosphere of a space is something related with the quality of a space. Quality of most of the things generally is more important for the users than anything. It is the quality that anything is judged for. It is something presented within everything made, either intended or not. It is aimed at stressing the importance of the aspect of quality as a space characteristics. Daylight is considered to be responsible for the achievment of different atmospheres within spaces if designed properly; and with this study, qualitative judgement of spaces from the impression of atmosphere point of view, as a result of daylight is put forward. It should be stated at this point, however, that since these are subjective evaluations, there are not clear-cut boundaries among these impressions of atmospheres. Always one can find overlappings between them.

Design that concerns daylighting consists primarily of planning the geometric relationships of architectural elements to the daylight conditions. The concept of daylight is a changing phenomenon. Therefore, the architecture of buildings should be designed in accordance with the nature of daylight. This implies complete understanding of its nature, and its control, together with the ways through which it can be provided for an interior, to be able to shape the desired atmospheres within spaces. To sum up, it is found out from the examination of the chosen examples that the naturally available daylight may be used as a design element to help the creation of certain moods within interiors. This is found to be a function of the geometry of the apertures and the spaces, control, orientation, and latitude; and it also changes on the daily and the annual basis. These all affect the behaviour, or the presence of daylight within spaces, which in turn gives different atmospheres to them. This is tried to be explored throughout this study. Sketches helped in the presentation of the behaviour of daylight. They also helped show the precautions taken, by the selected examples, for the achievement of the stated atmospheres. Within this aspect, the following summarizing demonstration of the space characteristics employing different daylighting strategies have been prepared. It should be stated at this point that the strategies that are presented to produce the related atmospheres are only certain types of apertures capable of producing those moods, and there may be other solutions achieving the similar results. Figure 97. represents that the previously defined atmospheres which were found to be produced by lighting, can also be produced by daylighting. This is found out by the examination of buildings that employ different daylighting strategies.

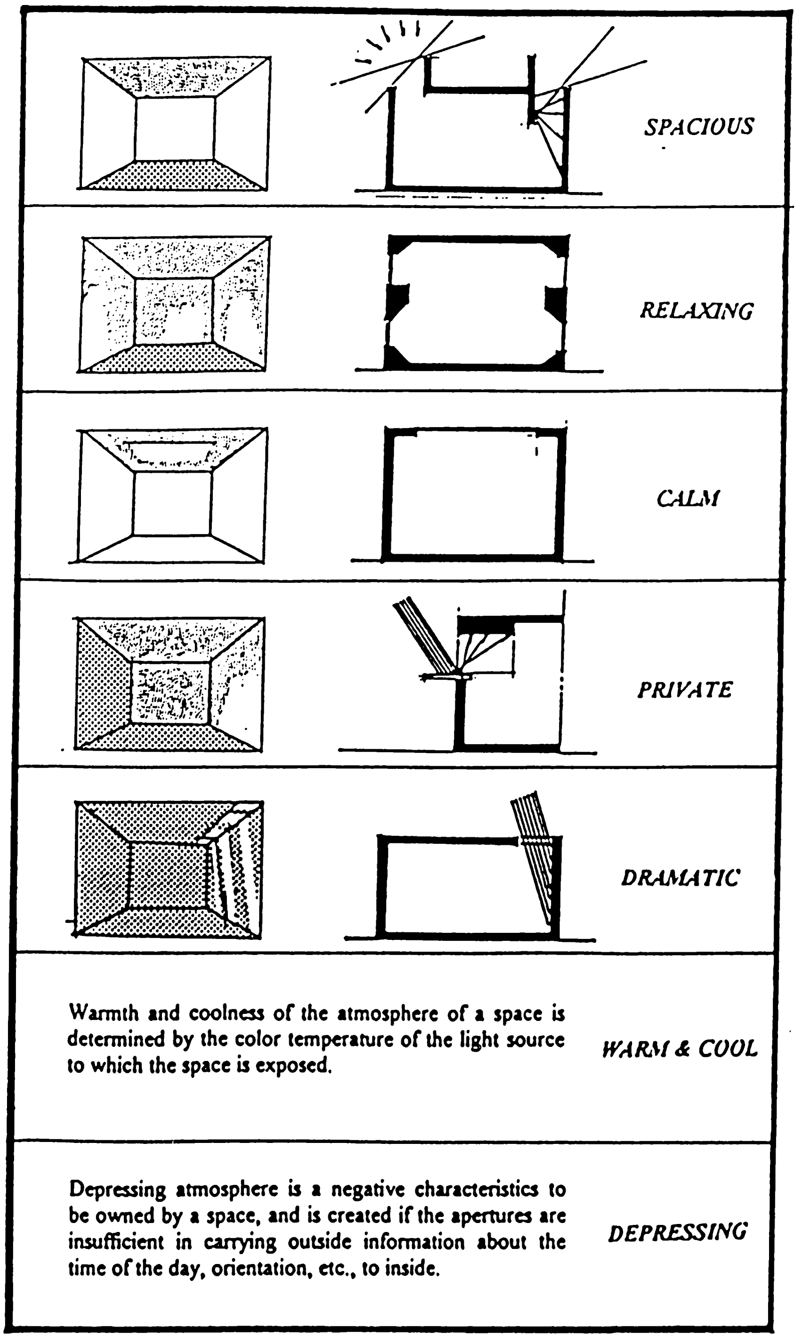

Figure 97. Summary of the defined atmospheres that can be produced by daylighting

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