LIGHTING OF OPEN PLAN (AUTOMATED) OFFICES

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

By
Ilkin Oner

January, 1995

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I certify that I have read this thesis and in my own 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

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

Prof. Dr. Mustafa Pultar

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

Assist. Prof. Halime Demirkan

Approved by the Institute of Fine Arts

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ABSTRACT

LIGHTING OF OPEN PLAN (AUTOMATED) OFFICES

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in
Interior Architecture and Environmental Design
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January, 1995

Lighting in Open Plan (Automated) offices is an important factor for the workers performance and productivity. Generally, physiological and psychological requirements of the office lighting are being neglected while designing or relocating of the office environment. Hence, offices become unpleasant places to work in. The aim of this study is to analyze lighting requirements of open plan automated offices and to prepare a set of criteria for the lighting design of these spaces.

Keywords: Lighting, Open Office, Workplace, VDT (Video Display Terminal), Workstation.

ÖZET

AÇIK PLAN OFİS AYDINLATMASI

İlkin Öner

İç Mimarlık ve Çevre Tasarımı Bölümü

Yüksek Lisans

Tez Yöneticisi: Doç. Dr. Cengiz Yener

Ocak, 1995

Yoğun bilgisayar kullanılan açık planlı ofislerde, aydınlatma, çalışanların performansları ve verimlilikleri yönünden önemli bir etkendir. Genellikle ofis tasarlanırken ya da yeniden düzenlenirken, aydınlatmanın fizyolojik ve psikolojik yönden gereksinimleri ihmal edilmektedir. Bu yüzden de ofisler, hoş olmayan çalışma alanları haline gelmektedirler. Bu çalışmanın amacı, elektronik donanımlı açık planlı ofislerdeki aydınlatma gereklerini inceleyerek, bu alanların aydınlatma tasarımında kullanılabilecek kriterleri saptamaktır.

Anahtar Sözcükler: Aydınlatma, Açık Ofis, Çalışma Alanı, Bilgisayar, Çalışma İstasyonu.

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I would like to thank to all precious people who are supported me during this study continuously and patiently. What I know is that I have learned from them a lot. So, for me the word " thanks" is not enough for them. I am not mentioning their names here. But, for those who are interested, they are those who knows the importance of the story about the man, at the seashore, collecting seastars patiently, and throwing them to the sea in order to prevent their dying.

" What is essential is invisible to the eye"

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LIST OF SYMBOLS

CCR	Correlated Color Temperature.
CRT	Cathode Ray Tube.
CW	Cool White
CWX	Deluxe Cool White
DX	Deluxe White
HID	High Intensity Discharge.
IES	Illuminating Engineering Society.
K	Kelvin.
LIL	Lensed-direct Uplighting.
Low-E	Low-emissivity.
MR	Multi-reflector.
PAR	Parabolis Aluminized Reflector.
PBS	Recessed Parabolic Downlighting.
R_a	Color Rendering Index
SPD	Spectral Power Distribution
VDT	Video Display Terminal.
VDU	Video Display Unit.
WWX	Warm White Deluxe

1. INTRODUCTION

Today, computers have become an important part of our work environment, and thus our daily life. In Turkey, the use of computers are steadily infiltrating the office environment. Nowadays, almost in every bank, travel agency and other big business corporation's headquarters these machines are used extensively. As the use of computers in the offices is increasing, at the same time, there is seen a wide preference of designing open-plan type of offices.

In open office planning, initially, free standing screens are utilized. In all cases, the open office utilizes partly-high space dividers. Today, most of the open-plan offices include private and group offices, beside the continuos open plan space. This mix of closed and open plan offices has added a new dimension to design and performance issues. The fundamental distinction between them is simple but meaningful one: partitioning. In the closed system partitions between workplaces are interior walls that extend from floor to ceiling. In the open system, partitions, generally in the form of visual/acoustical screens, do not extend to the ceiling. The screens rarely above 150 cm, and may not be flush with the floor (Harris, et. al., 1991). Open plan office provides facilitated communication between individuals and groups, and stimulated work among workers. In addition, it provides great ease in the distribution of power in the office. Also, because of the rapid changes in the organization systems, flexibility becomes one of the most important requirements in the office planning, and thus, open office seems to be the most appropriate planning for the automated office.

Generally, in the design of new automated offices or while adapting the existing ones to the needs of the newly developed technology, the importance of some factors is overlooked. Most of the time, the workers' visual needs come after the organization's and tools' requirements. Hence, usually offices are not very pleasant spaces to work in. Lighting is an inevitable element in the office design which directly affects the worker's performance and productivity. Thus, it should be considered seriously in the design of any automated office.

In addition, Visual Display Terminals (VDTs) may bring important problems as a consequence of their interrelation with lighting system, since their screens may act as a both light source and a reflecting surface. Glare and veiling reflections can occur on the VDT screen as a result of the careless placement of the VDT screen in relation to the light sources (such as luminaires, windows, etc.) in an environment designed for the paper-based work. As the line of sight for the VDT use is inclined more towards the horizontal than it is for the tasks performed on a desk, light required for each task varies.

On the other hand, it is clear that a pleasant working environment will result in a higher level of productivity. Different lighting patterns draw out various subjective impressions like spaciousness, pleasantness, etc., and affect our visual perception. Especially, in open plan offices light should help to the identification of circulation patterns and activity areas by providing appropriate visual cues. So, psychological requirements are also of important factors that need to be considered. This picture confirms that lighting of an automated office needs to be handled with great care, and with this thesis it is planned to set some criteria related with the lighting design of the open-automated offices.

This study is based upon a literature survey. In the second chapter, mainly the work areas, and to a small extent meeting and adjoining areas like corridors and waiting areas are examined from the lighting point of view. Other areas in the open office are not in the concern of this thesis. Third chapter discusses the lighting systems of open-planned offices (natural and artificial), and the control methods of these systems. The concern of the fourth chapter is physiological lighting requirements such as glare avoidance, quantity of illumination, luminance and factors affecting luminance, and light sources used in office areas. Also, the results of a small investigation that is done in the computer laboratory of the Faculty of Art, Design and Architecture of Bilkent University will be given in this chapter. For the investigation, luminance levels around selected terminals are measured with luminance meter (Minolta, LS 100). These terminals are situated at different areas in the laboratory. Results taken from each terminal are compared with the reference values taken from Grandjean (1987, p.43) in order to decide on whether measured conditions are suitable or not. In the fifth chapter, psychological requirements of open-planned office are discussed, since the lighting design of the environment can be crucial identifier in determining visual meaning by affecting the subjective impressions such as spaciousness, visual clarity, pleasantness, relaxation, etc. A general criteria for the lighting design of open-automated offices that is filtered from the whole dissertation will be given in the sixth chapter.

2. SPECIFIC ACTIVITY AREAS IN OPEN-AUTOMATED OFFICES

Many reasons are presented for using an open-plan type of design approach by the authorities. It provides facilitated communications in between individuals and groups, stimulated work among the workers, and stresses the egalitarian values. On the other hand, there are some reasons for not using an open-plan concept entirely. Generally, highly skilled professionals needed more privacy to perform their work. Besides, private spaces offered security and a place to get away. After careful consideration, a modified closed system was developed. Full-height office spaces were designed for professionals, with one glass partition with vertical shades to close if users needed or desired greater privacy. Also, designing workstations having more enclosure and territory for secretarial employees was also recommended within a modified open-space concept (Harris et.al., 1991). Also, Duffy points out that in Sweden and West Germany, where the open plan was once so popular, many new office buildings are being constructed with private offices and group offices, rather than continuous open plan (Duffy cited in Kleeman et.al., 1991).

In open offices, spaces are generally categorized according to the activities that is going to be performed in this area. In this thesis, only work areas, conference areas, and adjoining areas are going to be considered from lighting point of view.

2.1. Work Areas.

In today's office, whether it be a secretarial or data-processing station or the office of a chief executive of an organization, the workstation is the basic unit of office planning and layout. From ergonomics standpoint, it is considered that the workstation is the domain of the individual and must be planned and designed to meet the varying requirements. The specific placement of components; computer terminals, communication devices, task-support tools, storage facilities, work-display surfaces, book-support facilities, light fixtures, requires a consideration in order to provide the requirements for physical comfort. Manual controls must be designed to accommodate the movements required to perform a given task (Rubin, 1986). In order to satisfy the environmental and ergonomic needs, and because of the varied visual tasks involved, efforts should be concentrated on providing an adjustable visual environment of improved quality, in and around each work station.

Workstations are well-equipped and well-defined working areas. They are generally semi-closed and may accommodate one or more people (Farivarsadri, 1992). In the past, each workstation in a conventional office had a more or less 'fixed' visual task orientation e.g. functions involving reading and writing, reading and typing, audio typing, etc., (Figure 2.1). Today workstations (automated) are required to cover multi-functional aspect such as reading and writing, word processing and typing, computerized data retrieval and filing, face-to-face discussion, etc., (Figure 2.2). Visibility for these tasks varies greatly from excellent to very poor. As much attention needs to be applied to improving the quality of the task as is given to improving the lighting system to adapt the human eye to the various tasks (Harris, et.al.,1991).

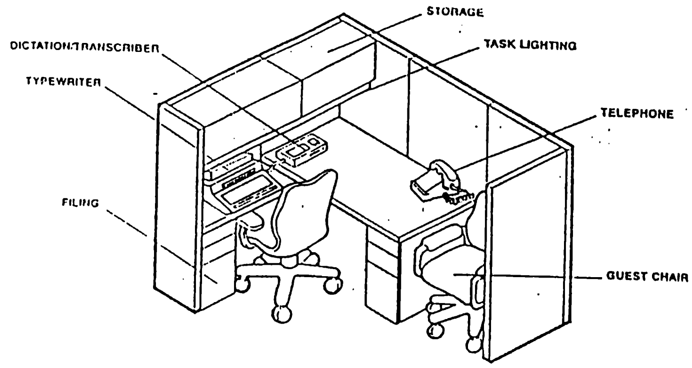


Figure 2.1 Conventional workstation.

(Pulgram and Stonis, 1984, p.125)

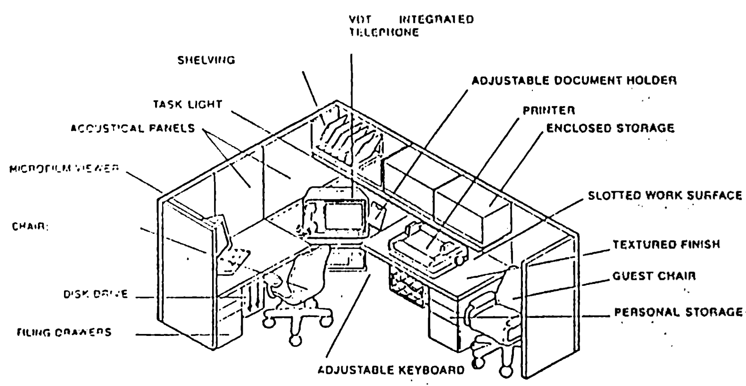


Figure 2.2 Automated workstation.

(Pulgram and Stonis, 1984, p.125)

2.1.1. VDT Work , Reading and Hard copy:

Until recently, terminal use environments were poorly understood. It is identified that there are four basic ways of employing terminals in an organization: namely, regional terminals, satellite terminals, cluster terminals, dedicated terminals. In open offices, usually dedicated type of system is being used. Those terminals are placed in a workstation for the use of only one worker. They can be optimally located for this purpose and normally found when 20 percent or more of a worker's tasks require terminal usage (Galitz, 1984). As the information in today's office move from a paper-based to an electronic-based medium, the characteristics of information are changing in both substance and style. Information displayed on paper is legible and readable, The matte surface of paper diffuses reflected light, scarcely affecting the quality of the material presented. Paper-based information may be read under a variety of lighting conditions. In contrast, VDT characters are luminous and often of a dot-matrix construction. The character image may be blurred by dust on the VDT screen or by reflections from overhead lights or windows. Papers are normally read horizontally, such as resting on a desk top. They may be read vertically, however, by physically raising the paper to a position perpendicular to the eye. Because of the internal mechanics and problems with light reflections VDT's have little flexibility compared to paper, and they are read in a vertical plane. Papers are normally completed by hand, while VDT's through the use of a keyboard. Writing skills are far more than a keying skills. When writing, a person's eyes follow the hands, providing the immediate feedback. When keying, the hands operate in a different visual plane than that of the information display. Therefore, keying is a more complex visual task. Paper can easily be manipulated by moving it into a comfortable viewing position. On the other hand, VDT's are difficult to move and usually viewer modifies his or her viewing angles and distances only by posture changes. A hard copy is perceptually permanent whereas the information on a VDT screen is transient. Display of information on a VDT is limited by the boundaries or size of the display area. Often information must be presented serially as a string of snapshots viewed in sequence. The breadth of display of paper information is only restricted by the physical size of the work area. In general, reading information on a display screen necessitates greater visual requirements than does reading information on a piece of paper (Galitz, 1984). With the introduction of VDT's into the workplace, occupants in offices have become much more aware of the lighting system and its performance. The VDT is very sensitive to veiling reflections, and this directly affects the performance of the worker. Lighting designs with marginal performance are no longer acceptable, and so, the VDT is a very common item that can not be ignored in the design process (Harris, et.al., 1991).

2.1.2. Visual Display Terminals and Their Uses

To understand the problems of correct lighting for VDT's, the available types of VDTs and their applications in the modern working environment should be considered first. Traditional office functions involved working on paper on a flat horizontal desks. The majority of VDTs have brought part of this work task, the reading of text, to a near vertical position. The VDT has a keyboard: separate from the VDT screen, and this is used for writing or controlling the screen. The need to consult with written text, screen text and the keyboard means that the users adapt different postures to those associated with working on a flat desk. The front element of the screen tends to act as a partial mirror. It reflects back to the user an image of what is in front of the screen. If this image is nearly as bright as the screen characters, it starts to compete and thus makes the text difficult to read. Although most modern screens have a anti-reflection finish, which helps to diffuse any sharp images that appear on the screen, the invisibility of the reflected images on the VDT screen becomes important issue that should be considered carefully.

In order to be visible, an object must have a luminous (or color) contrast with its background, that is, the object brightness and the background brightness must be different from each other. There is a need of a minimum contrast that must be exceeded for the perception; contrast values below this threshold are functionally invisible. Contrast threshold depends on a number of factors, including the size of the object, how long the object was seen and the overall adaptation level of the visual system. Contrast threshold can be taken as a representative criterion for defining the visibility, or rather invisibility, of reflected images on the VDT screens (Rea, 1991).

Most VDT screens are self luminous; that is, they produce light by electrically stimulating phosphors on the VDT display. There are two kinds of displays: dark background displays (positive contrast displays) those have an average screen luminance of 5 to 10 cd/m² in the dark, and bright background displays (negative contrast displays) those have a comparable luminance of 100 cd/m² Rea (1991) explains the probability of reflected images occur on each type of display:

> Glass or an untreated VDT screen will reflect about 8 percent of the light incident on it. An object with contrast of, say, 33 percent and a maximum luminance of 100 cd/m² will produce a much more visible reflection in a dark background displays (of 10 cd/m², for example) than in a bright background display (of 100 cd/m²). In both cases, 8 percent of the light from the object is reflected from the screen. The (maximum) luminance of the reflection (8 cd/m²) is close to the luminance of the dark background

display and will clearly seen. For the bright background display, however, this is a small amount of light relative to its self-generated light (p.36).

So it can be said that negative contrast displays work rather well in reducing many distracting reflections from the VDT environment. However, because the upper limit of luminance from this type of display is approximately 100 cd/m^2, they will not be effective for very bright, high contrast objects such as untreated windows. It can be said that the negative contrast displays should have the advantage of reducing the luminance contrast ratio between the screen and source document. Also, as mentioned above, reflections on the glass surface screens should be less disturbing on displays with dark characters and bright background (Figure 2.3). However, because the upper limit of luminance from this type of display is approximately 100 cd/m^2 , they will not be effective for very bright, high contrast objects. Untreated windows and many forms of electric lighting will still have the probability of producing reflections.

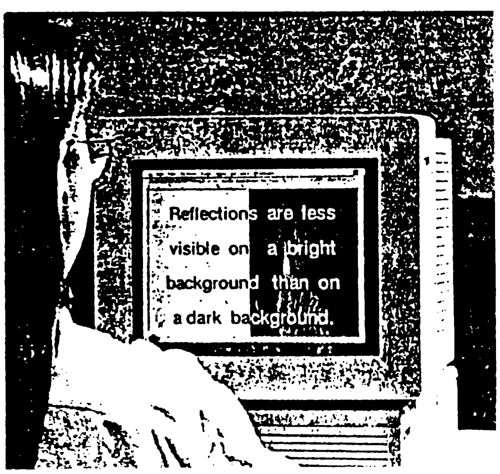


Figure 2.3 Reflections in negative and positive contrast screen

Cathode ray tube is the most common screen type, and used in television sets as well as in micro-computer terminals. It has generally slightly convex screen due to the way the image is produced on it. As the technology improves, these screens become squarer and flatter, in a similar manner to the latest television screens. The introduction of high resolution screens for graphics presentation have made the avoidance of reflections even more difficult, because the screen generally has no anti- reflection treatment so as not to degrade the image. Thus leaving what is in effect a large clear semi-mirror in front of the screen - an image that is required to be the highest quality and resolution (CIBSE, Lighting Guide: Areas for Visual Display Terminals, 1989). Another common type of display is the flat liquid crystal display. It is used mostly on electronic typewriters and portable micro computers. Its screen has a flat shiny surface which makes it particularly difficult to light without causing reflections. Whatever the type of screen, it is generally mounted in a housing that allows some tilt and swivel adjustment. This helps the user to avoid unwanted reflections on the screen.

The keyboard , most frequently, is the means of data entry and control of individual VDT's. Most keyboards are now contained in a low unit, separate from the screen console. This allows the user to move the keyboard to a comfortable operating position. The keyboard can cause distracting reflections, sometimes referred as twinkle, if the key surface is glossy. The better types of keyboard have matte surface keys with the characters in a bold contrasting color. The surrounding of the keys is normally matte, to avoid reflections, and of a similar color and reflectance to the keys, to avoid large luminance contrasts with the keys.

In wide range of applications, from simple display of calculations to complex graphical representations, the terminals are used. The display itself may be used during the day, to check data or receive electronic messages, or may be the entire work task, such as graphics design, data entry or retrieval. For non-critical or occasional use the user may be prepared to accept a slightly degraded image or some postural adjustment to avoid screen images. But where the information on the screen may be of the great importance, such as in control rooms, it is very important to avoid distracting or covering images on the screen (CIBSE, Lighting Guide: Areas for VDTs, 1989).

2.1.3. Problems with the VDT Workstations

In all office automation systems, the VDT is the basic device which is used, and it is therefore not suprising that it has received considerable attention by ergonomics researchers. According to them, it should be considered that the designs of the terminals accommodate the operators miscellaneous needs. Brown and his colleagues (1982), in a symposium conducted by the National Research Council of the National Academy of Sciences, indicate that the most common complaint expressed by the VDT operators is visual fatigue. The term is used to describe symptoms of ocular irritation, burning, blurring of images, and double vision: for the most part of these changes are temporary, according to current research findings (Black et.al., 1986).

The quality of the cathode ray tube (CRT) system, general lighting conditions, workspace design, and job-related factors are the components contribute to visual fatigue. VDT terminals placed in environments designed for desktop work, are the cause of lighting problems because VDT displays create new geometrical relationship between the work surfaces resulting in visual problems. So the reflected images on the VDT screen happens to be the main problem. VDT displays usually provide two competing images for the worker's attention: it provides a view of the electronically generated alphanumeric text, drawings and pictures, and also, a view of the luminous environment surrounding the worker and the VDT, through reflection. These two images are at different optical distances: the electronically generated image is close while the reflected image is usually much further away. So the eye of the worker has to do repetitive focusing (Rea, 1991). In essence all successful design solutions for environments containing VDT's must eliminate or reduce the quality of the reflected image while maintaining the quality of the electronically generated image.

2.2. Committee Rooms.

Committee rooms are the places used for meetings capable of seating up to roughly thirty persons (CIBSE Lighting Guide: The Visual Environment in Lecture, Teaching and Conference Rooms, 1991). To be able to see each other properly, and to see what is going on are important needs for the people gathered for the purposes of discussion. It is possible to see occupants having a grotesque appearance because of a bad lighting, or a well prepared demonstration can be ruined by an uncontrolled ingress of sunlight. It is important that lighting system should allow members to read their papers and take notes properly, and supply a good visibility of wall mounted displays. Committees sometimes have to work under some stress, especially when unpleasant or unpopular decisions have to be made. So lighting is a vital element in such rooms and requirements of lighting should be taken into account from the first stages of the planning.

2.3. Adjoining Spaces

Corridors, lobbies, and waiting areas are known as adjoining spaces. The lighting in such areas is responsible for providing guidance for the visitor from entrance to a destination. In some cases, especially waiting areas and ante-rooms can be used as tea and coffee spaces, so lighting can provide a social atmosphere in these areas and can put users, as they approach, in an appropriate frame of mind for the activity in they are about to take part (CIBSE Lighting Guide: The Visual Environment in Lecture, Teaching and Conference Rooms, 1991)

3. METHODS OF OPEN-AUTOMATED OFFICE LIGHTING

Visible electromagnetic energy (light), when produced by man-made mechanisms is constant in its properties and its hours of availability is controllable. Spectral composition of light produced by electric lamps differs from that of daylight. Daylight varies continuously in its direction, intensity and color properties throughout the day. Its hours of availability changes with season and latitude and the illuminance varies with changing weather. Because of its variability, daylight may produce different visual conditions throughout the day changing from ideal to unsuitable for the working condition in an office. Whereas because of its controllability, electric lighting can be designed to produce excellent visual conditions continuously in any location (Lyons, 1992). Temporal changes in light quality and quantity can be preferred and regarded as stimulating by occupants. Daylight is playing a significant role in the utilitarian as well as the aesthetic qualities of the designed environment in today's offices. However, it can be detrimental to workers visual performance. Therefore, careful analyses of both daylighting and electric lighting are necessary to achieve comfortable, satisfactory, and productive work environment (Steffy, 1990).

3.1. Natural Lighting of Open-Automated Offices

Daylight sources can be categorized as direct (direct sunlight and diffuse sky light) and indirect (light from reflective or translucent diffusers that were originally illuminated by primary or other secondary sources) (Moore, 1985).

Luminances coming to a window from the sun and /or the sky can be much higher than other surfaces' luminances within the room. The intensity of illumination from direct sunlight on a clear day varies with the thickness of the air mass it passes through. It is less intense at sunrise and sunset. Direct sunlight illuminates normal (perpendicular) surfaces with approximately 60000 to 100000 lux, and this is too intense to be used directly for task illumination. So the luminances introduced at any opening from the sun or from the sky, can be much higher than the other surfaces' luminances within the room and that can cause several unwanted troubles like direct glare, reflected glare and veiling reflections (Steffy, 1990). As a result, most illuminating engineers prefer to exclude direct sunlight completely from interiors (Moore, 1985). On the other hand, the movement and sparkle associated with controlled shafts of sunlight add considerably to the visual variety and excitement of a space. Even where visual tasks are fixed in location and subject to direct glare, occupant controls, such as shades and blinds, are preferable to permanent exclusion of direct sunlight. In addition, when the glazing is south-facing and vertical, direct sunlight contributes favorably in winter to workers psychological condition because it evokes positive feelings related to its warmth and brightness as well as thermal comfort (Recommended Practice of Daylighting, 1979). As a result, the interest in using direct sunlight in buildings for both thermal and lighting purposes requires technical complexities.

In its passage through the earth's atmosphere, the light from the sun is scattered by dust and gaseous molecules of the air itself. As a result, sky appears to be more or less bright during the daylight hours, and becomes a major source of usable daylight illumination for building interiors. As compared to sun, the sky has a large visual area and relatively low luminance. The brightness of an overcast sky is approximately three times as bright overhead as it is at the horizon and it provides diffuse light from the clouds and reflected light from the ground. The sky luminance on a clear day is approximately three times as bright as at the horizon than overhead. It consists of direct light from the sun, diffuse light from the sky and reflected light from the ground. A partly cloudy sky provides diffuse light from the ground and direct light from the sun (Recommended Practice of Daylighting, 1979).

When a matte reflective surface is illuminated by a primary source (sunlight or skylight), its resulting luminance makes it an indirect source of illumination. Because it is a distributed source, the quality and distribution of its light is virtually identical to direct sky light admitted through a similar-sized opening. If directly sunlighted, white reflector luminance can be as high as approximately 17000 to 34000 cd/m² substantially more than the luminance of the skydome as approximately 1700 to 7000 cd/m² (Moore, 1985).

Color temperature of daylight is in the range of 4000 Kelvin to 10000 Kelvin. Overcast skies generally associated with low color temperature (4500-7000 Kelvin) and clear skies with high color temperature (10000 Kelvin and upwards). Sunlight has a color temperature in the range of 4000-5000 Kelvin.

3.1.1. Size, Shape and the Treatment of Light Source

The utilization of daylight is a function of fenestration and control mechanisms. Kaufman (1981) defined fenestration as: "any opening or arrangement of openings for the admission of light" (Kaufman cited in Moore, 1985). Walls and the roof could be used as areas for fenestration. The location of fenestration has an effect on the illumination quality and quantity. Regarding the placement of the openings, if the system intended to produce uniform brightness on an interior horizontal surface, moderate-sized openings should be placed so that the center to center spacing does exceed two times the height of the ceiling above the workplane (Flynn et.al., 1992). The size of the opening, characteristics of the glazing material, and control elements are the three important factors that determine the quantity of light admitted from an opening (Moore, 1985).

Windows are one of the daylight media which are used as a permanent way to control interior penetration of light, and they must be examined carefully. The importance of the view-giving properties of windows should not be underestimated. Many studies indicated that, there is a desire of contact with the outside world among the workers. A survey on the windowless offices in U.S. showed that among the reasons for disliking the windowless interior was the lack of daylight (Recommended Practice of Daylighting, 1979). However, a direct view of the sky can cause a feeling of discomfort (discomfort glare). To prevent this, excessive contrasts should be reduced by controlling the direct light sources such as window or skylight and by raising the luminance of the of surrounding surfaces of them. For example, a bright sky seen through a window in an under-lighted or darkly finished room is able to cause discomfort glare (Daylighting in Architecture, 1993). Both large and small windows may appear very bright because of the relatively high luminance of the exterior environment. The high luminance area, as well as direct sunlight, can cause severe problems to VDT users. For this reason, means of shielding or controlling the light from windows are important in any area containing VDT's. Screening the window from VDT screens by adding free standing part-height partitions can be solution, and these allow some adjustment in positioning while permitting some natural daylight to pass over the partition (CIBSE, Lighting Guide: Areas for Visual Display Terminals, 1989). Positioning window as high as possible (preferably 45 degrees or more above the horizontal) locates the offending brightness above the field of view. While high window locations reduce glare from high-brightness exterior areas, they increase the potential of deep sunlight penetration, which can result in glare on interior surfaces. Hopkinson (1966) stated that:

> Daylight from the window in relation to the height of that window depends upon two things, first, that by the operation of the cosine law of illumination, light which reaches a reference plane at a small angle of incidence results in a higher illumination than that which reaches the plane from large angles of incidence, and second, the fact that with an overcast sky the zone near the horizon has the lowest luminance, and therefore the higher the window the brighter the sky which is seen through it (p.434).

It is clear that the higher the fenestration, the greater will be the illumination at a distant point. As a result, room depth, height and daylight quantity are closely related. The level of direct daylight decreases in a considerable manner, as the distance from the window increases. So, higher fenestration provides more uniform distribution than comparable lower locations and controls veiling reflections, while illuminating the vertical surfaces effectively (Moore, 1985). On the other hand, when the sky is too bright, there occurs a greater need to screen high windows than view windows. Hopkinson (1966) indicated that:

> . . . for a work area, a ratio of 1:2 for the height of the window to the depth of the room from the window

usually gives an approach to the optimum daylight distribution (p.435).

Also, high windows (clerestories) can be designed together with the side windows like lightshelves (Figure 3.1). Lightselves are located as low as possible to the floor in order to reflect the most amount of light to the ceiling. The front back of the shelf must be large enough to shelter most area of the room during the sunny days. The reflectance of both inner and outer upper section should be high without specularly reflecting surfaces which creates visual hot spots on the ceiling. Matte surfaces work rather well. The bottom of their surfaces should be finished to balance the room's lighting.

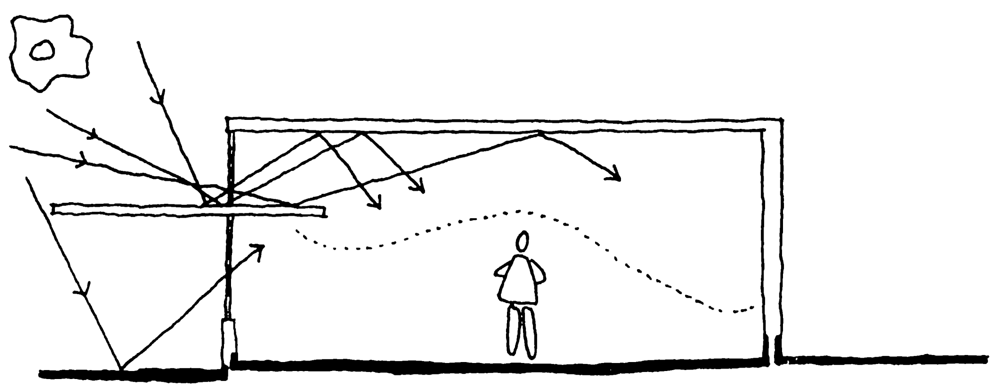


Figure 3.1 Lightshelves.

The effectiveness of the side lighting is limited with a distance into the room away from the windows approximately two and a half times the height of the opening (Recommended Practice of Daylighting, 1979). If the total quantity of light brought into the room is assumed to remain the same, distribution of the fenestration over a large area will (1) reduce shadows, contrast, and texture definition, (2) provide more uniform light distribution, and (3) reduce veiling reflections (Moore, 1985). Strip glazing produces more uniform light level across the room than the individual windows. The surface immediately surrounding the light source (window or skylight) is important in terms of glare. If the luminance of these areas could be kept within an intermediate luminance between the source and the general environment, such contrast differentiation will be helpful. Also the design of the window is an important issue in design. For example, using windows with splayed reveals (Figure 3.2) forms a "soft frame", and it may be helpful to soften the transition of light from the window glass to wall gradually rather than sharply (Daylighting in Architecture, 1993). Also, the sills of clerestory windows should be sloped downwards. However, if not, a deep sill can have a considerable result in reducing the effectiveness of a clerestory window (Hopkinson et.al., 1966).

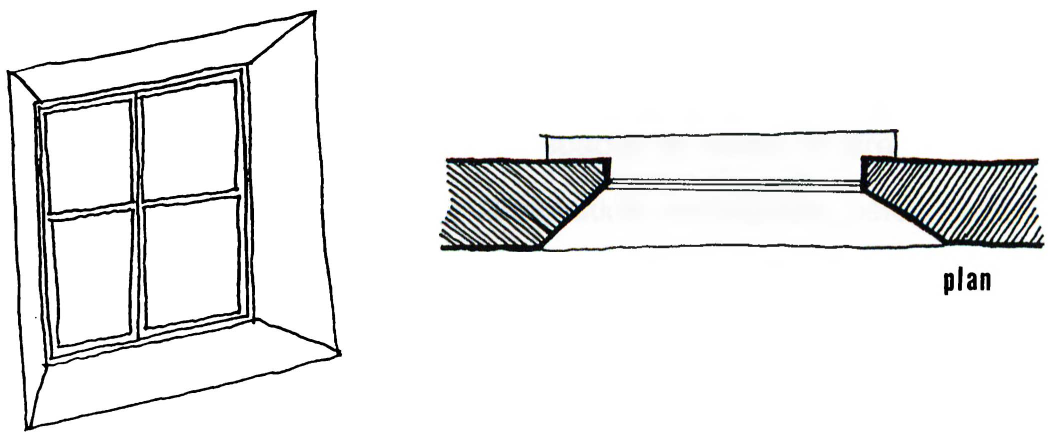


Figure 3.2 Window with splayed reveals

A study which is conducted in 1982, dealt with the daylight as a source of discomfort glare. In this study, the skylight was taken as a reference and direct and reflected sunlight were neglected. The main conclusion of the study is that:

> Discomfort glare from a single window (except for a rather small one) is practically independent on size and distance from the observer, but is critically

dependent on the sky luminance (Daylighting in Architecture, 1993, section 2.17).

Monitors are also daylight media. They are the roof structures that utilize vertical or steeply sloped glazing which allows for the contribution of roof-reflected light and (in the case of south oriented glazing) more direct exposure to winter sunlight (Moore, 1985). North-facing monitors provide the opportunity for daylighting without sun controls and can use clear glazing for maximum transmission since diffusion is inherent in the sky light. Whereas, south-facing monitors have to use translucent glass or white baffles to diffuse direct sunlight (Figure 3.3). In the case of a sawtooth slope monitors (Figure 3.4), when the slope is greater than 45 degrees, the average illuminance is constant, in spite of the increased vertical glazing area. Mazria (1981) described a south monitor with vertical glazing combined with an overhang and interior vertical baffles spaced to shield all direct sunlight. This monitor provides a very high illumination immediately below, with a rapid fall-off at the perimeter (Figure 3.5) (Mazria cited in Moore, 1985).

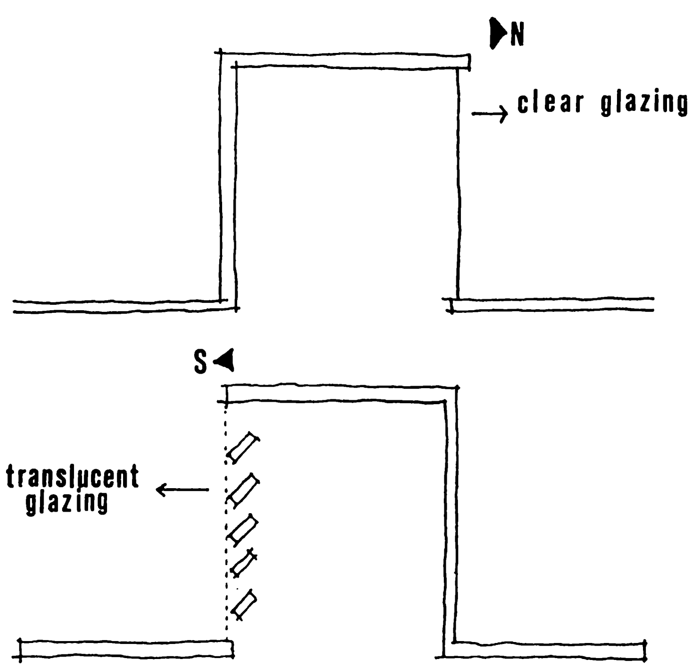


Figure 3.3 North and south facing monitors.

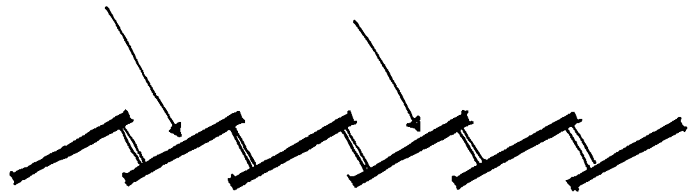


Figure 3.4 Sawtooth monitor.

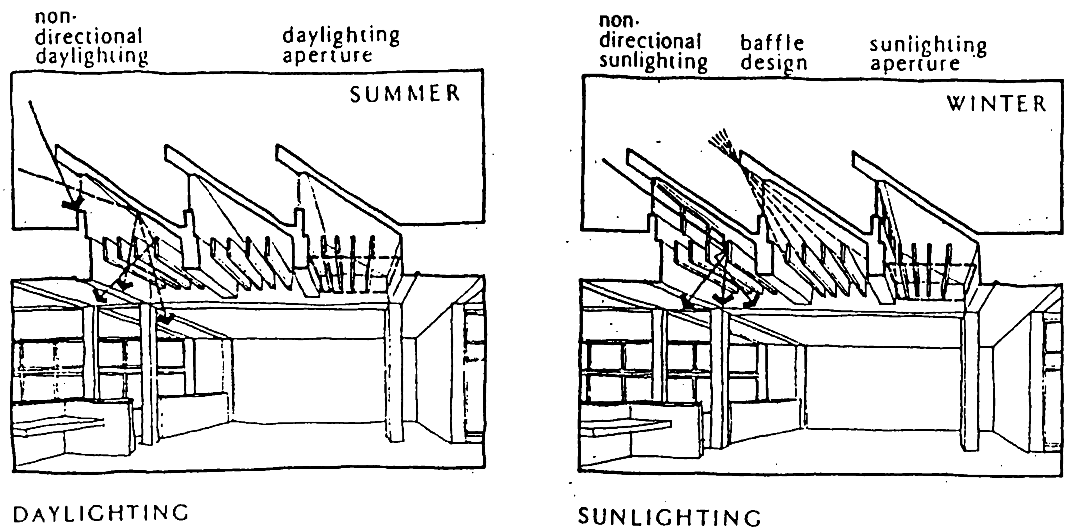


Figure 3.5 Monitor with vertical glazing combined with an overhang (Moore, 1985, p.85).

Admitting daylight through east and west monitors poses a distribution problem because of a daily sun movement problem (Moore, 1985). Most conventional skylight fenestration does not extend below the ceiling plane. Hence the ceiling contributes little to daylight distribution since it is not receiving any direct light transmitted by the skylight (Moore, 1985). To project a translucent skylight diffuser below the ceiling line refracts light onto the ceiling directly, utilizing its reflectance (Figure 3.6). As a result, while ceiling luminance increases, brightness contrast with the skylight itself will tend to reduce.

Figure 3.6 Skylight below ceiling plane

The uneven distribution of illuminance typical with flat, translucent skylights (Figure 3.7) can be improved with sloped reflectors (Figure 3.8), which reflect transmitted light back onto the ceiling surrounding and block out direct light to the room directly below, while allowing light to penetrate directly to the perimeter of the room (Moore, 1985).

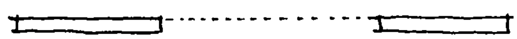


Figure 3.7 A typical flat, translucent skylight.

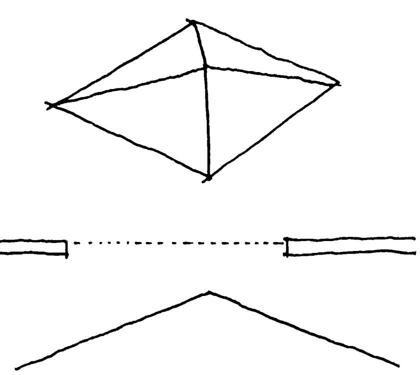


Figure 3.8 Skylight with a sloped reflectors below ceiling plane.

A sloped skylight-well (Figure 3.9) diffuses light admitted through a small roof opening over a larger area before entering the room (Moore, 1985). If clear glazing is used, the sides of the well can shield sunlight from entering the room directly, diffusing it by multiple white-wall reflection (Moore, 1985).

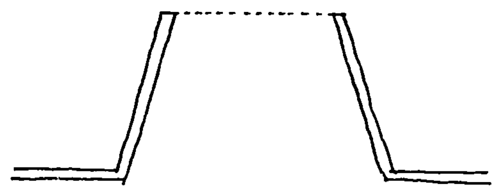


Figure 3.9 A sloped skylight well

Daylighting can be designed as a combination of side-wall fenestration in opposite walls, or a combination of side-wall lighting and toplighting or as a bilateral lighting (Figure 3.10).

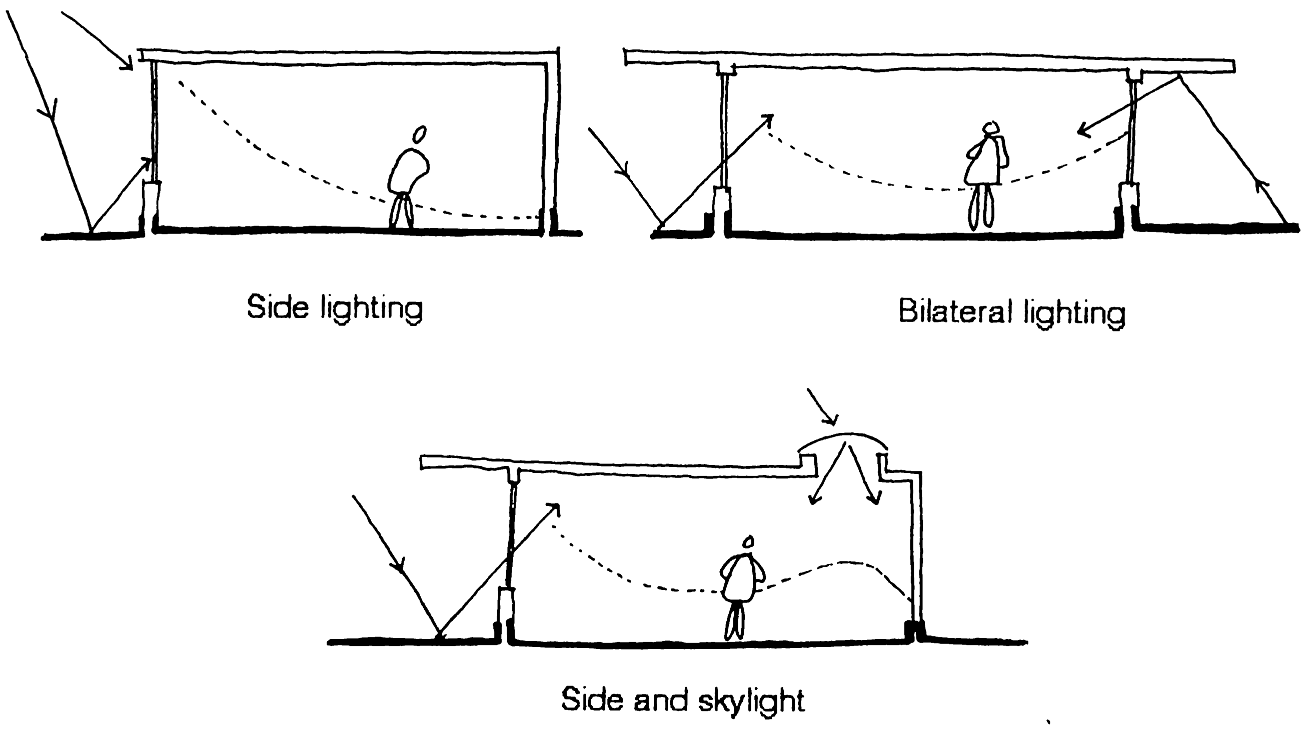


Figure 3.10 Combinations of daylight media; (a) side lighting, (b) bilateral lighting, (c) side and skylight lighting.

In general, people using committee rooms are in the need of having some natural lighting. The occupants in a side-lighted committee room can be faced with different forms of discomfort. Members facing a window may be suffered from glare, and the others seated opposite to them seen in a shadow silhouetted against the bright sky. Also, those having backs to window may cast a shadow on their own papers. So glare from the window should be prevented. This could be achieved by attenuating the light gradient from the window to wall gradually with splayed revealed windows, while using shading devices in interior or exterior, such as baffles or a venetian blinds, as an elements to control direct sunlight entrance. It is highly advisable that the pinboards and flip charts should never be placed next to a window. Although discomfort glare is acceptable, the disability glare will make them harder to read by impairing the vision. Also, they should be placed where there is no possibility for them to reflect a shiny image of the window (CIBSE, Lighting Guide: The visual Environment in Lecture, Teaching and Conference rooms, 1991).

Today, most of the new buildings are using electric lighting systems in conjunction with daylight to light interior areas adequately. Electric light and daylight are compatible and complementary sources, and can be used to produce optimum results in interiors (Figure 3.11)

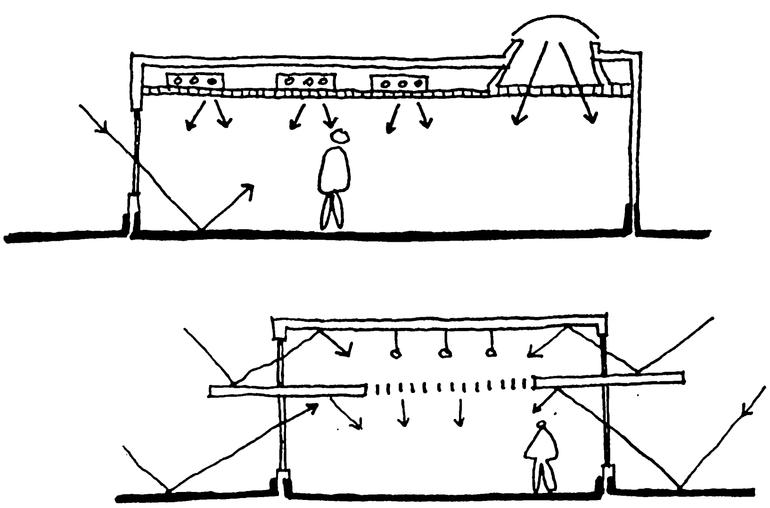


Figure 3.11 Examples of combined system (Daylight and electric lighting).

3.1.2. Control Methods

By control it is meant the control of the intensity and the distribution of daylight in the space. Distribution is affected by the size, shape, location and the orientation of the windows and skylight, and glazing materials. Intensity is controlled by glazing and control devices, such as blinds, drapes, louvers, etc. Other items that affect daylight distribution and intensity are exterior objects such as trees and other buildings, ground reflectances, overhangs and awnings, and interior finishes and configurations. Daylight media (monitors, clerestories, skylights, windows) with appropriate orientation, shading control and room surface finishes along with proper electric lighting is necessary to achieve cost-and occupant- effective daylighting (Steffy, 1990). Many workspaces today involve reading and electronic-based tasks such as VDT's, so daylight quality and quantity requirements differ from the requirements of the recent past. As a result, there arouse a need of controlling the daylight media with appropriate glass and shading, as well as controlling room surface finishes and electric lighting with great care. The daylight media and most appropriate control techniques that might be used in workplaces is summarized in Table 3.1 (Steffy, 1990). The orientation for daylight media depends on the geographic and topographic location. Generally, the more diffuse the daylight is, the less bulky the control technique and the more uniform the brightness of the daylight media (Steffy, 1990). Caution is advised when using daylighting in offices where there are computer screens; direct light creates too many reflections on screens and, even with indirect daylighting, ambient light levels must not be very high (Kleeman et.al., 1991). Brightness uniformity and brightness limits are critical if glare and VDT imaging problems are to be minimized. Nevertheless, diffuse north skylight luminances can still exceed approximately 10000 cd/m², which is more than ten times the luminance limits set for indirect lighting by the Illuminating Engineering Society (IES) VDT Guidelines, and therefore, shade control techniques are advisable even for north-oriented daylight media (Steffy, 1990).

Table 3.1. Daylight media for workspaces (Steffy, 1990, p.78).

Media	Orientation in order of preference	Most appropriate control technique	Surface Finish Tones		More appropriate electric light options[2]
			Walls	Ceiling	
Monitors	North East West South	• Low-transmission glass (30–50%) • Architectural baffles • Architectural set-backs • Overhangs and light shelves	Medium to light (30–55%)	Light (70–80%)	• Indirect • Indirect/direct
Clerestories	North East West South	• Low-transmission glass (30–50%) • Architectural baffles • Architectural set-backs • Overhangs and light shelves	Medium to light (30–55%)	Light (70–80%)	• Indirect • Indirect/direct
Skylights (continuous, relatively large)	North East West South	• Extremely low-transmission glass (around 2%) • Architectural baffles • Frit pattern glass • Blinds • Solar shades • Deep wells	Medium (35%)	Light (70–80%)	• Indirect • Indirect/direct • Direct
Windows (continuous, relatively large)	North East West South	• Very low-transmission glass (around 10%) • Frit pattern glass • Solar shades • Blinds • Significant overhangs with lightly colored ground cover	Light (55%)	Light (70–80%)	• Indirect • Indirect/direct • Direct (wall washing necessary to balance window brightness)

Roof overhangs and window-shading projections can be designed to shield windows from direct sunlight while allowing some skylight entrance. The control techniques exist for either interior or exterior applications, on windows and skylights. Control elements applied to the exterior of buildings are effective from the heat control standpoint. Such elements transmit most of the absorbed heat to the exterior air. However, they can require adequate maintenance as they are revealed to weather and pollution. On the other hand, interior elements are less susceptible to pollution, whereas they tend to absorb and reradiate heat to the interior influencing both the occupants' comfort and the air conditioning load (Recommended Practice of Daylighting, 1979). Usage of low-transmission glass, usually tinted gray or bronze, or solar shades are effective for sunlight control (Steffy, 1990).

Overhangs can be used to diffuse light in two ways. The overhang material itself can be translucent (for example, a white fabric awning), or it can be consisted of series of parallel, opaque white louvers that provide shielding between critical solar angles (Figure 3.12, 3.13). This diffuses all sunlight and most skylight by double reflection before reaching the glazing plane.

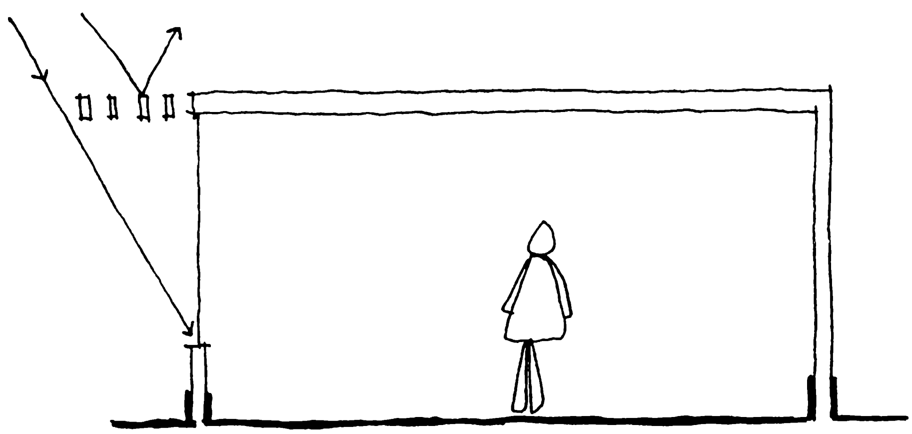


Figure 3.12 Overhang constructed with vertical louvers.

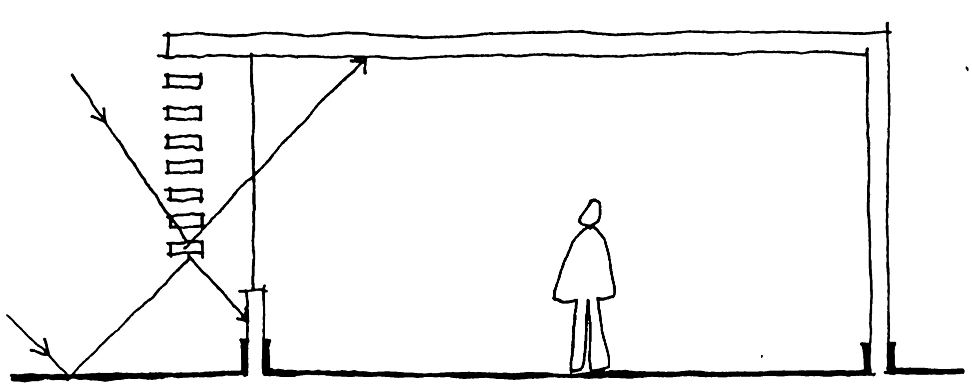


Figure 3.13 Overhang with horizontal louvers

Low-transmission glass allows a clear view of the outdoors, but at the same time, usually changes the color of the view and of the incoming daylight. With gray tinted glass, the exterior view appears grayed and dull, and the sky always looks like cloudy. On the other hand, bronze- tinted glass, while distorting colors seems much more acceptable. It makes the exterior scene looks rather rosy, and incoming light has a warmer color. Newer, low-emissivity (Low-E) glass provides an improved-color view of the exterior and improved-color incoming daylight.

Recently, frit pattern glass usage is showing an increase in the market. Frit is a ceramic coating that actually is part of a glass and thus is permanent. The frit patterns can vary significantly from dot patterns to horizontal lines reminiscent of venetian blinds, and it still has the ability of preserving the image beyond the glass. Charles Linn (1991) states about an example of the usage of frit pattern glass by the lighting designer Garry Steffy, in the design of an office building where the majority of floor space is devoted to open offices, and the VDT's are used extensively. The view requirement was given as a must to lighting designers, hence they were concerned about glare and over lighting from the sloped glazed windows. It's purely an electronic office; everyone in the space has at least one VDT, and some people have two (Figure. 3.14). Steffy says "decreasing the transitive value of the glass was a partial solution", and adds," although the problem might have been solved using louvers or some other interior or exterior movable shading system, Steelcase representatives wanted to avoid the maintenance headaches often associated with such devices. So, frit coated glass was used" (Steffy quoted in Linn, 1991). The appropriate usage of frit color is also very important. When light strikes translucent white frit, it diffuses, and if the source of the light is bright, the translucent white frit can be a source of serious glare. Linn (1991) describes Steffy's solution for an open-planned office building:

> This was solved by applying light gray frit on the glass so that it faced the interior of the space, and applying black frit behind it. As a result the frit essentially becomes opaque to the sun's rays, and no longer diffuses the light striking it (p.26).

This method also may allow to uplight glass. A skylight designed with the light gray frit pattern glass could be uplight with fluorescent luminaires. With this system, it is possible to avoid too extreme luminance contrast and also to provide additional ambient lighting on cloudy days and a during the working hours after dark. Because, normally you can not uplight an ordinary skylight since the light would go through the glass and all you could see is a reflection of the lamp (Linn, 1991).

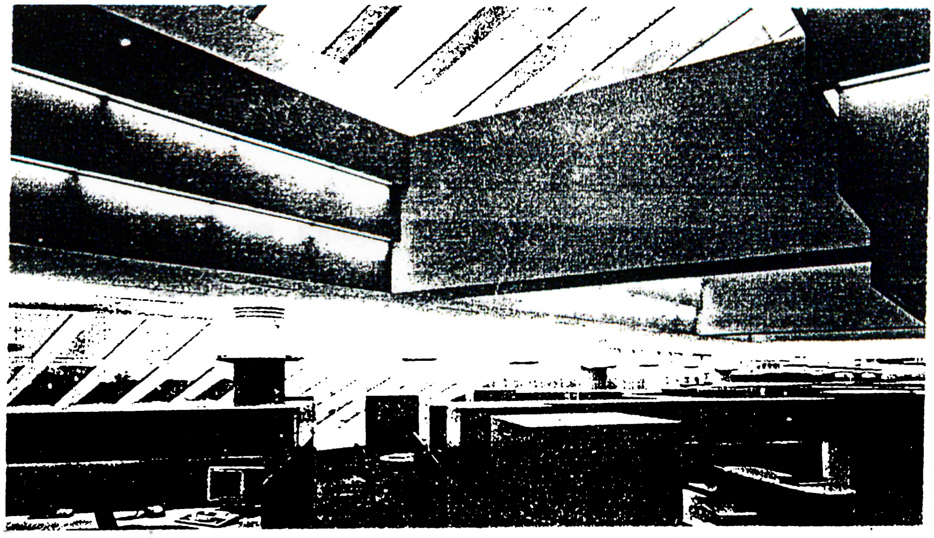


Figure 3.14 Skylight and the loft system of the open-automated office (Steffy, 1990, p.113).

Fixed exterior shading devices such as fins (Figure 3.15), or various types of shade-screen materials are often employed. They shade the window from direct sun penetration but allow the diffuse skylight transmission. Operable shading systems let dynamic control to supply improved thermal and visual comfort, and they work suitably on the west and east elevations (Johnson, 1986). They are generally motor-driven and controlled by photocell, and require cleaning periodically. Low-transmission glass, frit pattern glass, and photocell-controlled shades are very appropriate daylight control techniques for very large areas used by many people (Steffy, 1990).

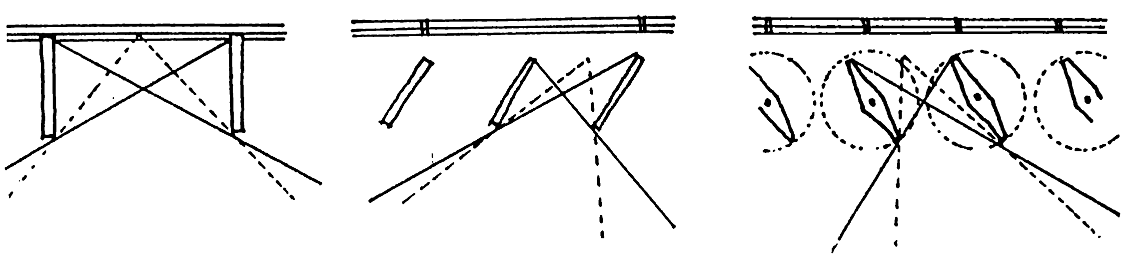


Figure 3.15 Plans of various types of fins

(Olgyay & Olgyay, 1957, p.91)

On the contrary, more independently controlled smaller-scale daylight control techniques such as horizontal or vertical blinds and drapes can be very problematic for large areas used by many individuals. A horizontal blind properly set for one person may cause severe VDT imaging problems for someone working nearby. A vertical blind set properly for one side of a room is inevitably set improperly for the other side, unless set in the closed position. Once the drape is opened just a little bit, there might arise a potential for serious glare and VDT imaging problems. Hence, it is advised to use these two techniques for single occupancy rooms (Steffy, 1990). Also, there is the possibility of placing intermediate screens between the VDT workstation and bright windows. Such a screen should not have reflectance higher than about 50% (Grandjean, 1987). Photocell light sensors and dimmers in conjunction with a programmed computer are usually utilized in systems using daylight as a major component (Kleeman et.al., 1991).

Where daylight media are used extensively in workspaces, finishes of wall and ceiling surfaces should be matte in order avoid harsh, glary reflections of light. The walls should have minimum reflectance of 30 percent, and the ceilings should have a minimum reflectance of 70 percent. These reflectances allow the daylight to inter reflect within the room, providing more efficient use of light source.

For the control of daylight in committee room, one approach is to ensure that the chairman faces the window and can control both the curtains and the electric lighting and this arrangement makes the chairman's face is clearly revealed, that there is no visual discomfort, and the faces of other participants can be seen comfortably (CIBSE, Lighting Guide: The Visual Environment in Lecture, Teaching and Conference rooms, 1991). However, it is stated that in this situation the others will have some trouble in seeing one or another.

3.2. Artificial Lighting of Open-Automated Offices

Perhaps, lighting of an open automated office is the most questionable and least resolved problem. According to Fisher (1986), it is not just the unpredictable location of desks in open offices that makes their lighting problematic, but also the variety and difficulty of the seeing tasks (reading of a computer screen) that are performed there adds considerable to the problem. Existence of veiling reflections on the screen produced by office lighting system makes the seeing task much more difficult to perform. Therefore, the type of lighting system becomes very important. Today direct, indirect or combination of both systems can be used according to the requirements of the spaces. Each of them have both advantages and drawbacks, and differs in their methods of light distribution, light control, and overall appearance.

3.2.1. Direct Lighting

In a direct lighting system, light comes from its source to work space without first being reflected from other room surfaces. Direct lighting is the most commonly used system for offices, and is often applied as a blanket solution, using a grid or row pattern throughout the entire ceiling of an office (Harris et.al.,1991). This system provides equal levels of illumination across large spaces, which is necessary when activity or task location within space is unknown. So, this system emphasizes the ceiling surface and emphasizes work surfaces and floor surfaces.

Task-oriented approach is another application of direct lighting. With this method proper illumination is provided by locating the fixtures only over the work areas. Other areas such as corridors, reception areas, and lobbies, are illuminated to a lower illumination level. Task oriented lighting is a direct response to a need for optimum lighting and energy conservation. A recent application of direct lighting is the system developed for use with high amounts of VDT's in the workplace. With this application, a uniform pattern of a low level of uniform illumination throughout the space (approximately 160-300 lux) which provides illumination for traffic and large, non-critical tasks (Harris et.al.,1991). Task lighting is installed at each workstation in order to provide necessary illumination for local task, and this brings the optimum user comfort and productivity.

Using downlighters means that the luminaires will be ceiling mounted or suspended close to the ceiling. So, the ceiling above and behind a VDT operator normally composes the major part of the area reflected in the screen. To select luminaires with the correct intensity distribution is very important in order to avoid high luminance images appearing on the screen. However, only selection of the correct luminaire is not enough, also sharp contrasts within the interior should be avoided. Therefore it is necessary for the designer to have some influence over the control of daylighting and working plane and wall reflectivity (CIBSE Lighting Guide: Areas for Visual Display Terminals, 1989). Since, in the case of direct lighting, very distracting luminances may be created, low brightness ceiling luminaires are usually chosen to reduce the potential for veiling reflections on the VDT. High luminance reflections on a VDT can be controlled by limiting the luminances of luminaires in appropriate directions because these reflections are a matter of geometry (Figure 3.16). The solution described as:

> If the VDT is assumed to be standing on a desk, viewed by someone sitting in front of it, then limiting luminance of the luminaire above the angle of view from the screen will also limit the luminance of reflections on the screen: the lower the luminance

above this angle, the lower the luminance of the screen reflections(Lighting Guide: Areas for Visual Display Terminals, 1989, p.7).

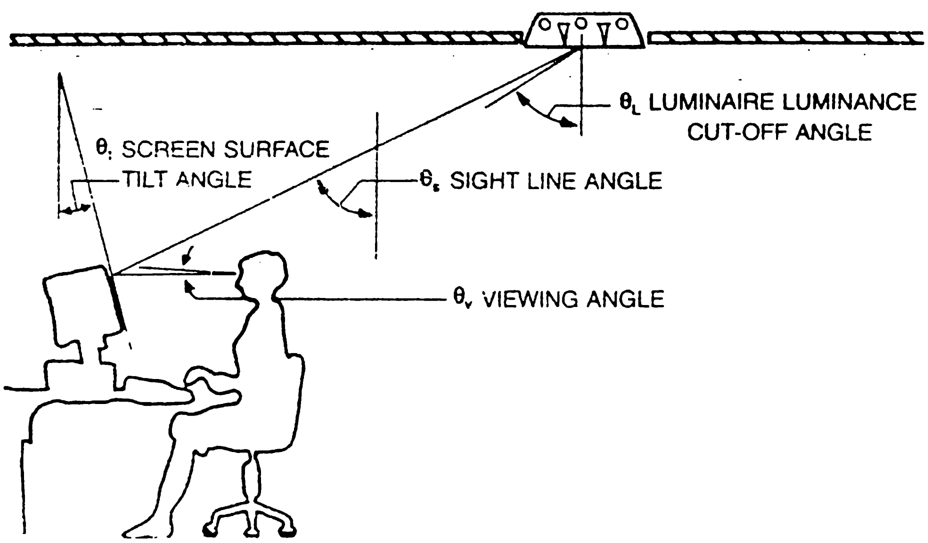


Figure 3.16 Typical geometry for eye, screen and luminaire

(Florence, 1992, p.33).

By examining the geometric relationship of the eye, the VDT and a typical ceiling luminaire, the sight line angle or the luminance limitation angle can be calculated (fig 3.16). Noel Florence (1992) explains this relation as:

> The relationship involves the viewing angle from the eye to the VDT, Qt, and the screen surface tilt angle, Qt, which together control the sight line angle, Qs, and relationship is Qs = Qv + 90 - 2Qt (p.32).

Noel Florance (1992) states that there are 25 luminance limitation angles (angle of sight-line) calculated with the help of 5 realistic viewing and screen tilt angles (Table 3.2).

Table 3.2 Screen to ceiling luminance limitation angle (angle of sight-line) from the vertical (*Os*) in degrees.

Veiwing Angle (Qv) (degrees)	Screen Tilt Angles (Qt) 0	5	10	15	20
0	90	80	70	60	50
5	95	85	75	65	55
10	100	90	80	70	60
15	105	95	85	75	65
20	110	100	90	80	70

From the Table 3.2 it can be seen that there are only two cases in which sight-line angle is 55 degrees or less and only four cases where it is 65 degrees or less (This recommendations related with positive contrast screen having luminous letters on dark background). So, Lighting Guide published by CIBSE (1992) categorized the luminaires as:

> The luminaires are referred the Category 1, 2 or 3. These have luminance limitation above 55 degree, 65 degree and 75 degree to downward vertical respectively. The angles do both infer " cut off " angles but rather sharp run back on the polar curve in all vertical planes. Above these angles the average luminance does not exceed 200 cd/m² (p.11).

If a luminaire had no luminance at 55 degrees or greater, its reflection would hardly ever been seen in the VDT regardless of where it was placed on the ceiling and if it had no luminance at 65 degrees or greater, it would seldom be seen (Florence, 1992). It is advised that more critical the VDT application, or the higher the VDT density in an area then, in general, the lower this angle (luminance limiting angle or sight-line angle) (CIBSE Lighting Guide:

Areas for Visual Display Terminals, 1989). While the angle gets lower then the efficiency of the luminaire also tends to get lower, due to the much better control of the luminaire's distribution. Thus it is preferable to install the light fixtures parallel to and on either side of the operator. Luminance flux angle should not exceed 45 degree to the vertical (Figure 3.17) (Grandjean, 1987).

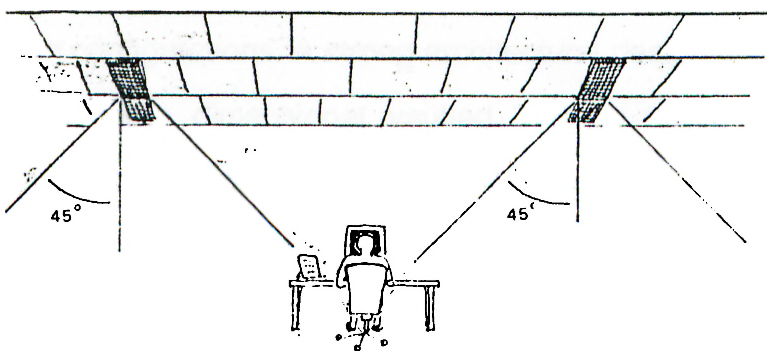


Figure 3.17 Ceiling lighting generating a cone of light with an angle of 45 degree to the vertical (Grandjean, 1987, p.53).

The layout of the perimeter spacing of luminaires and their proximity to walls and columns are very important points needed attention. This is because the luminaires can produce bright scallops on surfaces that they close to (especially likely at the ends of a luminaire). In order to avoid sharp transition from high luminance of the scallop to the lower luminance adjacent, it may be preferable to keep luminaires set back from walls - even if this means offsetting them from a regular array. The careful use of asymmetric luminaires to assist as wall washers could be another approach, because even illumination with slow rate of change is preferable to uncontrolled scalloping. However, it is possible that dimming control will be required to limit the brightness in certain cases (CIBSE Lighting Guide: Areas for Visual Display Terminals, 1989).

So direct lighting which consists of modules with a luminaire in the center and provisions for sprinklers, sound masking systems, and air distribution can give an optimum design choice to a designer (Harris et.al., 1991). These modules can be designed for use with a variety of luminaires in both flat and vaulted ceiling configurations. A strong architectural design can be achieved by the use of three dimensional vaulted system, which also provides improved acoustical control (Figure 3.18) (Harris et.al., 1991).

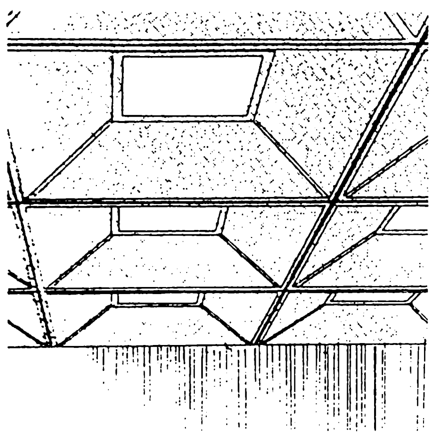


Figure 3.18 Vaulted ceiling system (Harris et.al.,1991, p.126).

It is apparent that a downlighting installation gives a very characteristic appearance to the interior (Figure 3.19). Since the light output from the luminaire is in a downward direction, the luminances of the horizontal surfaces are high where as, the luminances of the vertical surfaces and the ceiling are low. Also, there are strong shadows and there is a possibility of strong ceiling reflections that can occur on keyboards and documents. The overall effect of the created atmosphere by the system appears rather dark (CIBSE Lighting Guide: Areas for Visual Display Terminals, 1989).

Figure 3.19 Open plan office with downlight installation (CIBSE Lighting Guide: Areas for Visual Display Terminals, 1989).

In committee rooms visual tasks change from casual to difficult. So lighting system should be applied according to changing needs. Two or more lighting systems can be applied: a general lighting system which is controlled by switching of lamps, or by dimmer help to vary the illumination, and supplementary lighting system consisting of downlighting with dimmer control can be useful. Also a perimeter wall wash lighting system may be included (IES Lighting Handbook. 1981 Application Volume, 1981). If we consider system in a more detailed way, the geometry of lighting should be match to the conference table, defining the limits of the main activity within the room. However, this does not mean that the table is necessarily the brightest surface. Downlights can be unsuitable because they cast severe shadows and generate shiny reflections in a polished table-top. Also, this can tend to leave walls and ceilings in relative darkness. If there are wall charts or boards, supplementary display lighting will be necessary. In order to keep reflections to a minimum these charts should be mounted vertically on the front wall. They are best lighted by ceiling mounted luminaires and shielded so that the lamps are not visible to the audience. Lighting should be kept within shaded area like in Figure 3.21 (CIBSE, Lighting Guide: The Visual Environment in Lecture, Teaching and Conference Rooms, 1991).

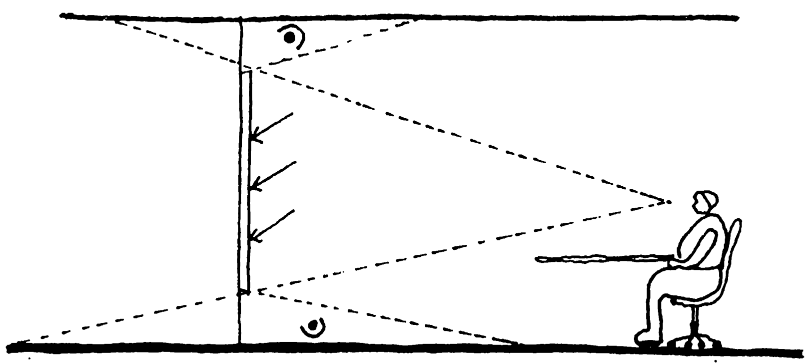


Fig. 3.20 Lighting method of wall mounted charts in conference room (CIBSE, Lighting Guide: The Visual Environment in Lecture, Teaching and Conference Rooms, 1991, p. 9).

The distribution of light should be even on the board without steep fall-off toward the bottom, and display lighting should be dimmer controlled (CIBSE, Lighting Guide: The Visual Environment in Lecture, Teaching and Conference Rooms, 1991).

3.2.2. Indirect Lighting

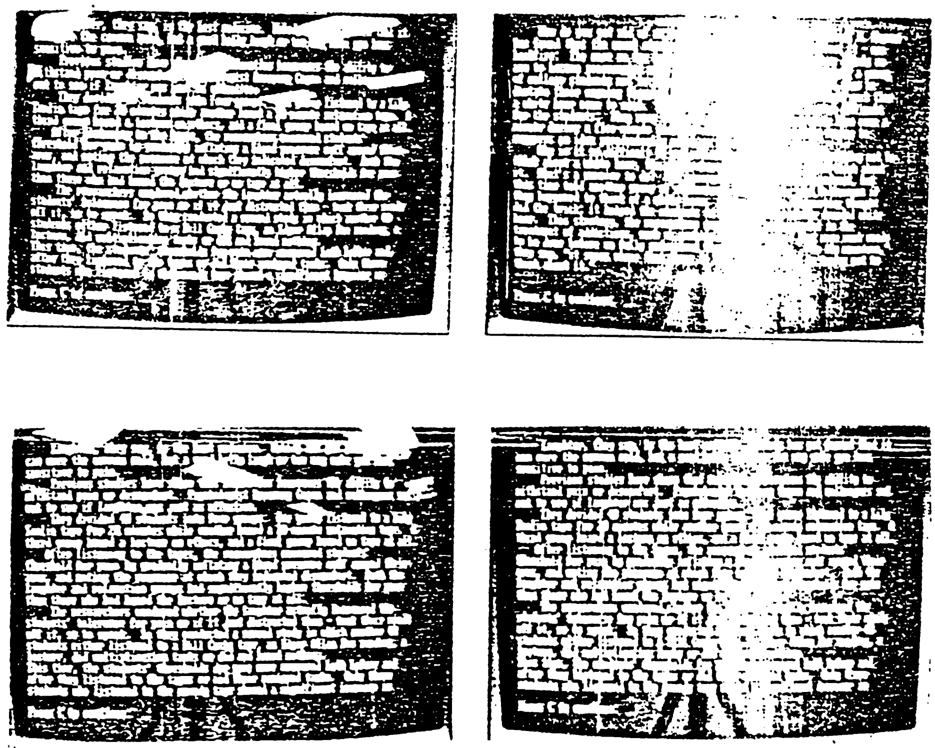
Indirect lighting illuminates the ceiling and walls and the light is reflected from these secondary surfaces to the workplane. As a result, the ceiling appears to be the brightest surface in the visual field, while the objects like partitions and desks tend to loose their definition. So this brightness should be distributed evenly in order to avoid excessive glare. In order to achieve this, indirect luminaires have a restricted light output upwards where the luminaire is closest to the ceiling and a reinforced light output to the sides (IES Lighting Handbook, 1987 Application Volume). The use of totally indirect lighting in the office accommodates a near shadow free environment similar to conditions under an overcast sky (Harris et.al., 1991). Uplighting can be successfully used to light rooms having VDT's because these surfaces act as a large area, with low luminance luminaires. Thus, any reflections which occur from VDT are usually of an even low luminance. As long as the luminance of the screen characters is not unusually low, they will have sufficient contrast with the background wash to be easily visible (CIBSE, Lighting Guide: Areas for VDTs, 1989). So, it is stated that visual clarity aspects of the task are generally greater with the use of indirect lighting system when compared with the use of typical direct lighting systems (Harris et.al., 1991). Some lighting designers discuss that indirect lighting, whether the source is visible or not, can create glare in CRT. Claude Engle says that :

> A level of indirect illumination that is low enough not to reflect in a CRT provides insufficient light for other tasks and if you increase the level of illumination to provide an even approximately 500 lux on the work surface, the ceiling then becomes so bright that its entire surface reflects in the computer screen (Engle quoted in Fisher, 1986, p.100).

Also Ranieri (1991) says:

> In comparison to direct systems, the diffuse distribution of indirect light sources tends to reduce veiling reflections on glossy paper, but increase

veiling reflections on VDT screens (Figure 3.21) (p.37).



A B

Figure 3.21 Comparison of screen reflections from direct (a), and indirect luminaires (b).

Task lights at each desk can resolve this problem by causing a reduction in the amount of indirect illumination, while providing sufficient light on the work surface by direct luminaires located either within the furniture system or in free-standing units (Fisher, 1986). However, the need for task lighting has been increased with the growing trend to open-office planning and modular furniture systems. These systems consist of work surfaces surrounded by acoustical partitions and overhanging shelves and storage units. So, due to the shadows caused by the partitions and shelves, the workstations cannot be illuminated effectively (Harris et.al., 1991). Also, Kleeman et.al. (1991) states that:

> Although there is much disagreement among the lighting authorities about how the VDT office should be lit, there is a definite trend toward the use of indirect uplighting, sometimes incorporated into the systems furniture, along with the adjustable separate lighting on the task with dimmers, also sometimes attached to the furniture (p.119).

On the other hand, large amount of task light can create its own glare but some lighting designers think that it works if properly designed. For example, a fixture that has a low brightness louver on its upper surface and a sliding batwing lens on its lower surface can provide both task and ambient light from a single fluorescent lamp (Figure 3.22) (Fisher, 1986).

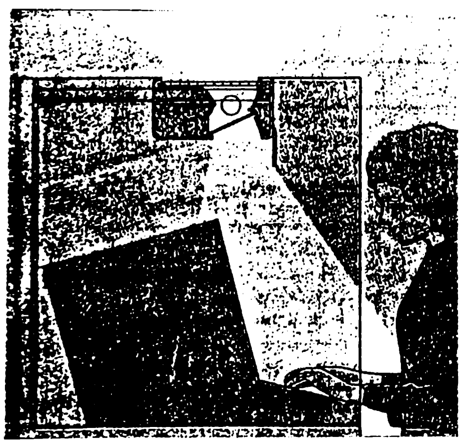


Figure 3.22 Task light with a batwing lens (Fisher, 1986, p.99).

In general, the ambient lighting whether it is achieved by direct, indirect or direct-indirect systems, should be designed to provide the two thirds of the required illuminance, with the task light providing the remainder (CIBSE Lighting Guide: Areas for Visual Display Terminals, 1989). Indirect lighting equipment suspended from the ceiling usually used and advised for the areas having ceiling heights 280 cm or higher and this allows enough suspension distance of the luminaire optics to distribute lighting more uniformly across the ceiling (Ranieri, 1991). Uplighting can be in several forms depending on the way of mounting the uplighter. Free standing floor mounted units (Figure 3.23), wall mounted units (Figure 3.24) and units mounted on furniture and units suspended from the ceiling are used widely (Figure 3.25).

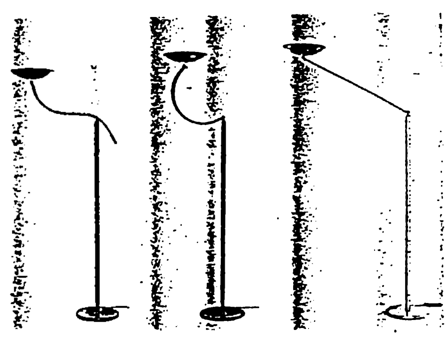


Figure 3.23 Free-standing uplighters

Figure 3.24 Wall mounted uplighters

Figure 3.25 Uplighters suspended from ceiling.

There should not be a very sharp cut-off in the luminous intensity distribution of the uplighter at any angle, as this will provide a steep change in luminance on the ceiling or wall of the interior (CIBSE, Lighting Guide: Areas for VDTs, 1989). Positioning the uplighters over, or close by a desk or work surface is an important thing that should be considered. Large uplighters can themselves obscure the lighted ceiling above and it may reduce the total illumination. When suspended uplighters are used, the reflectance of the under-side of the luminaire becomes an important feature that needs care. Indirect luminaires must have a widespread light distribution On the other hand, a narrow light distribution may cause patches of brightness (Figure 3.26).

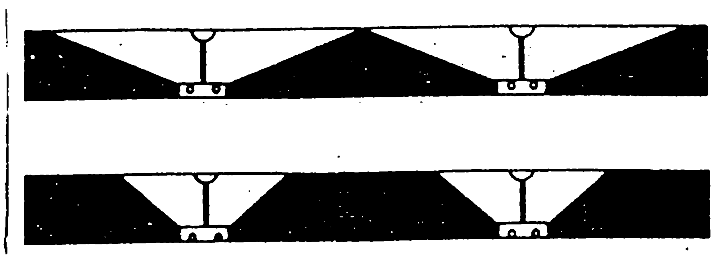


Figure 3.26 Uplighters with a wide and narrow light distribution

Comparisons are being made between the direct and indirect lighting systems for offices (Ranieri, 1991). In recent years, researchers have tried to find out the lighting preferences of office workers. Ranieri states that in 1988 Cornell University conducted a study which intended to make a comparison between the lensed indirect lighting systems and 6 x 6cm recessed standard parabolic system. They found out a preference for the indirect systems. Ranieri also mentions another experiment which have results in contrast to Cornell Universitys'. In this second study, eight direct and two indirect light system examined and results indicated a strong preference for a compound parabolic direct system (Figure 3.27), whereas, acceptance of the indirect systems varied greatly with their application but generally improved as the suspension distance from the ceiling was increased (Ranieri, 1991).

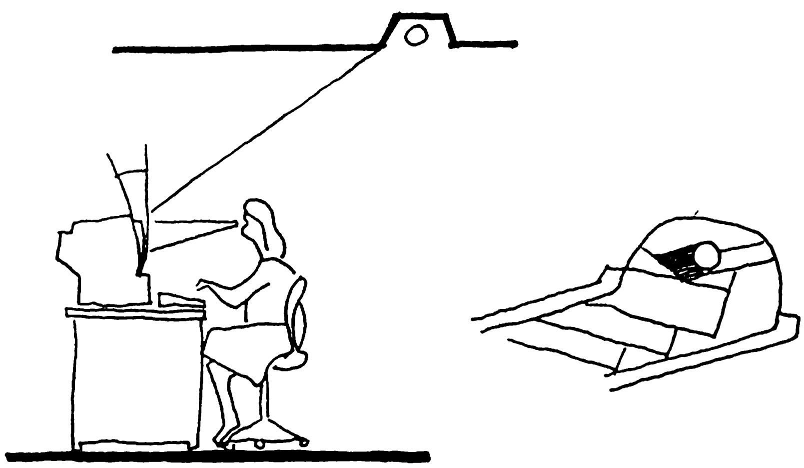


Figure 3.27 Compound parabolic direct lighting system

Conversely, Blatterman (1990) mentions about just-completed another survey conducted by a team from the Department of Design and Environmental Analysis of Cornell University's Department of Human Ecology, which asked office workers what they think of the two lighting systems: recessed parabolic downlighting (PBS) and ceiling-suspended, lensed-direct uplighting (LIL). The study evaluated the impact of both techniques on VDT-intensive work performed. Also, 28 item questionnaire asked about personnel and job related data, work related health problems, and job satisfaction and stress in order to draw out attitudes toward office lighting. The survey area was a single-storey mostly windowless office building divided into interior open-planned partitioned areas, approximately 300 x 450cm windowed, enclosed offices, and 300 x 300cm and 300 × 450cm windowless enclosed offices. Before the survey a baseline is established for thermal and visual comfort of workers in each type of space. Also, measurements of light levels from the existing fluorescent troffers, recessed into approximately 290 cm ceiling and covered with prismatic diffuser. After the remodeling of the entire office with the new furniture and wall finishes, an approximately identical "after" questionnaire was given to employees matched with their "before" location and function. The sample characteristics of the two groups worked under either LIL or PBL systems, were generally similar as to gender, age, and time spend on VDT equipment. According to the statistical analysis ratings notably better for the LIL than the PBL groups for how well the office lighting supported reading/writing and drawing/drafting on the computer, where as, there were no differences between the lighting systems when applied to tasks on paper, which is easy to re-orient for more comfortable viewing (Blatterman, 1990).

Another study performed at the University of Colorado at Boulder by Dilaura and Mistric in 1985, compared a parabolic louver direct lighting system with two indirect systems for VDT workplace. The results showed that there was a three-to-one preference for the two indirect systems over the parabolic because they produce less reflected glare on VDT screen, walls, ceiling and other workplace surfaces. Moreover, it is found that worker felt the indirect lighting produced a pleasant, higher quality visual environment and direct lighting caused the workers to feel more productive (Di Laura and R.G. Mistrick cited in Kleeman et.al., 1991). Also it is indicated that:

> Workers perceive less light in an indirect lighting environment than they perceive in a direct light environment - even though the measured footcandles are identical in both (Kleeman et.al., 1991, p.120).

Indirect lighting particularly when pendant fixtures are used, allows greater flexibility in the arrangement of desks. Besides it can lower the energy consumption in an office, since it uses more efficient high intensity discharge lamps (HID) (Rhiner cited in Fisher, 1986). Uplighting has its drawbacks. Since its like working under an overcast sky, it could be unsuitable for the workers those don't like this condition. However, it gives the impression of light, airy interior but one in which the lighting is very diffuse giving little visual variety to the room surfaces (CIBSE, Lighting Guide: Areas For VDTs, 1989). The decor of interiors those using uplighters should need attention in order to provide visual change. Different textured areas having colored walls or columns can help to add variety to the space.

3.2.3. Direct / Indirect Lighting

Direct / indirect lighting is a method combining downlighting with uplighting. It is possible to design the lighting system by separating the uplight and downlight luminaires or by a single luminaire producing both up and downlight. The characteristic appearance of the environment is associated with the proportion of downlight and uplight emitted by the luminaire. Downlighting provides a good horizontal illumination (i.e. modeling), while uplighting provides good vertical illumination by lighting ceilings and walls with having no harsh shadows. By combining up and downlighting, a well lighted environment can be designed which has a well lighted walls and ceiling, while having some directional element for modeling. Also, the horizontal illumination is good without either creating a gloomy interior or having bright ceilings and walls. It would be advised to keep the proportion of uplight higher than the downlight in areas containing VDTs. In combined system, downlighters still need to be of a low luminance design and the uplighters still need to provide an even wash of light over the ceiling. However, as the ceiling is uniformly lighted, it is acceptable to allow the luminance limiting angle of the downlight to increase so that it is not seen as a dark slot in a brighter ceiling. For a suspended up/downlights, the surface of the luminaire must be light enough to avoid a contrast against a light background, which would be noticeable on VDT. It is important that the luminance of the sides is even and that they do not exceed the design luminance of the ceiling against which they are to be viewed (CIBSE Lighting Guide: Areas for Visual Display terminals, 1989).

3.2.4. Control Methods

Lighting conditions in open office must be adaptable because of each different task calls for an optimized visual condition. Therefore the modern lighting systems requires flexibility at each individual workstation or within a particular zone, such as conference room. This could be achieved by the flexible lighting installation thus offering personal control of the lighting according to the changing needs at a particular time. In order to function lighting installation in a flexible, comfortable and cost saving manner, numerous control technologies are available that meet the specific lighting needs. Also, the greatest developments in advanced office settings in the United States center around the workstation. Loftness (1990) explains this trend as:

> Each individual workstation now contains a very large range of electronic peripherals (phones, mini or personnel computers, printers, fax machines), supported by ergonomic furniture systems, cable management floor systems, and- for the first time in

modern offices- the possibility of individual environmental control systems (p.48).

Also, in the market, it could be possible to find out control products having the ability to duct fresh air to each desk in an open-office, and having dimmer controls for cool air, task light (Loftness, 1990).

According to the characteristics of the office area switching circumstances may change. American National Standard for Office Lighting (1981) states general requirements that should be considered:

> Each separate office or area must have its own control switch(es); in large open spaces, work areas should be grouped and switched independently; when single or 2-lamp luminaires are used, adjacent luminaires must be placed on alternate circuits; when 3-lamp fluorescent luminaires are used, it needs to connect center lamps to a separate circuit from outside lamps; when 4-lamp luminaires are used, this time the inside pair of lamps and the outside ones should be connected separately to different circuits; task areas with special higher levels of lighting should be on separate circuits; luminaires along the window walls should be organized in separately switched groups (p.22-23).

Besides, switches must be as near as possible to the luminaires they control. Also dimming control could be possible. Dimming methods allows smooth and continuos modification of lighting level in each zone to match visual requirements, however, dimming equipment is more expensive than switching equipment (IES Lighting Handbook, 1987 Application Volume, 1987). Switching is suitable for strategies such as scheduling, where switching action can be restricted to unoccupied areas (IES Lighting

Handbook, 1987 Application Volume, 1987). For switching and regulation of incandescent lamps and high voltage halogen lamps, electronic dimmers of various types and qualities can be found. These are known as phase-cutting dimmers. There are two different kind of phase-dimmers: surface mounted and recessed ones, and they can be controlled by rotary push buttons. For the low-wattage halogen lamps, an electronic transformer can be used and it can be controlled by a standard incandescent lamp dimmer. These light-regulating units can be both built in or placed near to the luminaire, however, cable connections can be employed in order to control the lighting points from a certain distance. The automatic switching and regulation of individual lighting points is applied where there is a need for flexibility, safety, cost saving and comfort. Some of the automatic control techniques are: *time switches* to turn off all or portions of the lighting on a predetermined schedule; *presence detectors* that automatically switch the lighting points on and off, depending on a presence of persons in the vicinity; *photosensitive controls* to regulate lighting depending on the level of incoming daylight; *relays* that can be set in luminaires to admit selective operation of individual luminaires or groups of luminaires; *computers or microprocessors* that can be set up to manage a large lighting system and may be designed to respond to a variety of inputs from task locations (American National Standard for Office Lighting, 1981). Photosensitive (photoelectric) controls are two types: on-off control type; switches the lighting off when the illuminance produced by daylight is about to equal to that produced by the lighting system and switches on when the illuminance from the daylight fall below certain level, and top-up control type; is controlled by photoelectric sensor so that as the daylight fades, electric lighting increases, conversely as the daylight gets brighter, the electric lighting is reduced (Wotton cited by Lueder, 1986). Besides, individual remote control can now play an important role in offering many extra benefits. There are several techniques exist in remote control: radio frequency, ultra sonic, and digital infrared control. Compared with others, because that it is similar to the technique employed for radio and television with its many possibilities, digital infrared control technique is seen to be an excellent standard for the future. It consists of a compact transmitter and various types of receivers. This technique gives possibility to flexible control of several switching and regulating channels with a long range (up to 15m), and potentiality to various presets that permitting particular lighting configurations to be programmed under a push button; for example, a preset in offices for reading and writing, a preset for Video Display Unit (VDU) work and a preset for meetings.

For adjoining areas occupation sensors can be used. The primary technologies used in occupancy sensors include passive infrared type; responds to the motion of infrared energy (heat) in a space, ultrasonic; response to the change in reflected sound waves caused by the moving object in a space, and a hybrid type that combines passive infrared and ultrasonic technologies (Maniccia, 1993). These sensors can be wall-mounted and ceiling-mounted.

4. PHYSIOLOGICAL LIGHTING REQUIREMENTS OF OPEN-AUTOMATED OFFICES

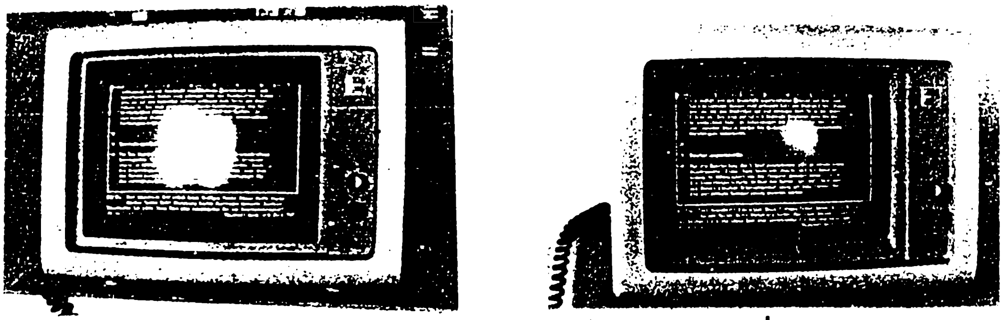
4.1. Glare Avoidance

In offices the use of Visual Display Units and accordingly the length of time spent at the computer screen will clearly continue to grow. Unfortunately, so will the problems related with them like eye strain, change in the ability to see colors, and burning eyes. In the majority of studies, the emphasis is being given on solving the problem of cutting down glare and the reflections, on the glass or plastic-covered VDT, and in areas where there is no VDT usage on the horizontal work surface (Shemitz and Walker, 1983).

Glare is an important trouble to be dealt with. It can be in the forms of direct and reflected. Direct glare takes place when the light source within the sight is much brighter than the objects that are being viewed. It can be resulted in disability and discomfort glare. Former occurs when glare impairs the vision, while latter only causes a feeling of discomfort. Discomfort glare is more likely to induce problems, and by controlling it, the other can be controlled at the same time (de Boer and Fisher, 1981). Reflected glare is the result of a specular surface adjacent to the task. It occurs if the observer sees the reflection of a light source in a glossy surface. If reflected glare is occurring in a task itself that reduce contrasts to give a loss of detail sufficient to impair visibility, it is referred as a veiling reflection. It can be result in discomfort and loss of concentration, because the attention unintentionally is being drawn from the task toward the area of higher brightness (de Boer and

Fisher, 1981). Glare can produce many sensations classified from mild discomfort to temporary blindness. The magnitude of these sensations depends on the size, number, position and luminance of the glare sources, and on the luminance to which the eyes are adapted (De Boer and Fisher, 1981).

Control of glare starts at the luminaire itself by assuring that excessively high luminances of the sources are avoided (Flynn et.al., 1992). The luminance of the luminaires used has to be limited in such a way that the glare produced by the installation as a whole is within acceptable limits. Also, the potentiality of the luminaires yielding reflected glare must be examined. But the measures assigned to control direct glare won't be necessarily support the reflected glare. For instance, a bright light source protected from direct view may still be visible as a reflection in specular surfaces on, or near to, the work task especially positioned badly relative to the source. The most obvious sources of veiling reflections and glare are windows and light sources (Figure 4.1). Alternative installations and designs which cut off from daylight and prevent visual contact with the outside environment create in the end gloomy, isolated, and prisonlike spaces and they do not work (Shemitz, 1983).



a b

Figure 4.1 Reflected image of a window (a), and a light source (b) on screen.

There are two main ergonomic obstacles that necessitate special attention when lighting is designed for offices having VDTs: sharp luminance contrasts between a screen and its surroundings must be avoided, and annoying reflections on the glass surface of screens must be reduced or eliminated. The surface of a screen is made of glass, and reflects the incident light and that is enough to reflect clear images of the office surroundings (lights, the keyboard or the image of the operator). One part is reflected from the glass surface of the screen which produces a mirror-like reflection of the surroundings. The other part is reflected from the phosphor layer, producing a veiled and diffuse reflection of a light source (Grandjean, 1987). Specular and diffuse reflections from a screen is shown in the Figure 4.2.

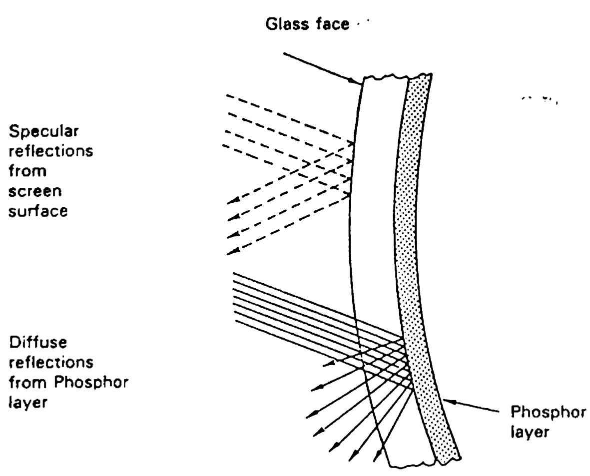


Figure 4.2 Specular and diffuse reflections.

(Grandjean, 1987, p.25)

Bright reflections can be a source of glare and image reflections are annoying since the eye is forced to focus alternately on the text and the reflected image. Thus reflections are also a source of distraction. Grandjean (1987) stated that:

> . . . after many studies it is been observed that bright reflections on the screen are the principal indication of operator's discomfort with the reflected luminances reached figures of between 3 and 50 cd/m² in the positive-contrast screens (p.50).

So the main problem with the visibility of displays appears to be as solving the occurrence of reflections on the screen. There are two strategies that can be offered: reducing brightness and subjective contrast (Rea, 1991). If reduction in brightness is considered as a design solution, the first thing that should be done is to reduce absolute brightness of the reflected image, and this also will tend to reduce the contrast of the image reflected in the screen. Reflections of ceiling luminaires and windows are of primary concern. There are some design measures that should be considered.

First of all, VDTs should be located in a position that eliminates reflections from windows and luminaires. This is difficult to achieve with curved screens since they have a wide-angle view of the interior and reflections can not be completely eliminated (Rea, 1991). In offices windows play a role similar to lights: a window in front of the operator produces a direct glare, behind it creates reflected glare. It is advised that the VDT workstation must be placed at the right angles to the window (Grandjean, 1987). Also, at night, uncovered windows can cause glare because of reflections of interior office lights. However, it is difficult to achieve permanent solutions because VDT workstations are frequently relocated. As a general rule, the design solution should not be considered by depending entirely on an presumed VDT location (Rea, 1991). Turning the electric lights off or obscuring light from windows, could help to eliminate bright reflected images in the screen. Kleinschrod (1986) states that to encounter the effects of glare upon screens, many companies simply reduced the lighting levels in their offices. This is not a design solution, but it is possibly the most common treatment applied by the operators where VDT work environment did not designed properly (Rea, 1991).

Positioning lighting fixtures out of the area (out of the offending zone) where they reflect in the screen eliminates the image problem. However, in a large area with many computers, most configurations end up with images in the screen. With the help of optical controls, screen can be shielded from the reflections. One of the most preferred shielding approach is to provide sharp cut-off louvers for direct lighting ceiling luminaires. Both " egg-crate " (Figure 4.3) and parabolic louvers are available for direct lighting luminaires. The blades of a parabolic louver provide a physical cut-off in the same way as an "egg-crate" louver; however, a parabolic louver with a specular finish reflects all light from its curved blades at an angle equal to or less than the louver cut-off angle (Figure 4.4). The luminance values of these louvers change depending on the type and finish of the louver material as well as the angle of view (Rea, 1991). Moreover, using both the parabolic wedge unit and the polarizing overlay together, is possible to reduce lamp images while maintaining the low brightness of the luminaire (Jones, 1992).

However, sharp-cut-off luminaires are not cure-all. Strongly directional down lighting will create very dark areas along the ceiling-wall juncture (Figure 4.5). Also, they produce strong shadows under shelves and bright horizontal surfaces. As a result, they can create high contrast images in the screens. In order to surmount the dissatisfaction of workers in the VDT environments screen treatments and supplemental lighting (wall washing and task lighting) may be needed (Rea, 1991).

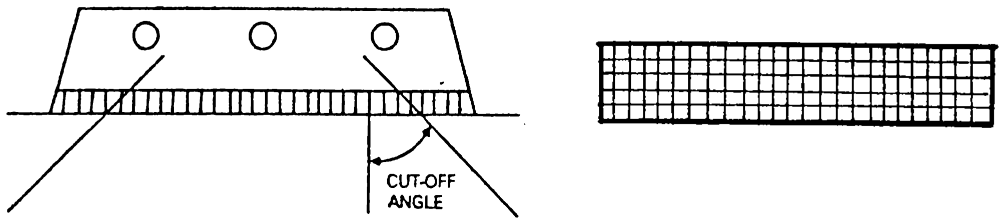


Figure 4.3 Egg-crate louver

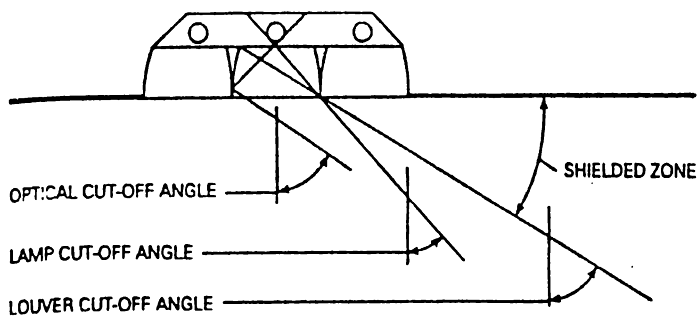


Figure 4.4 Parabolic louver

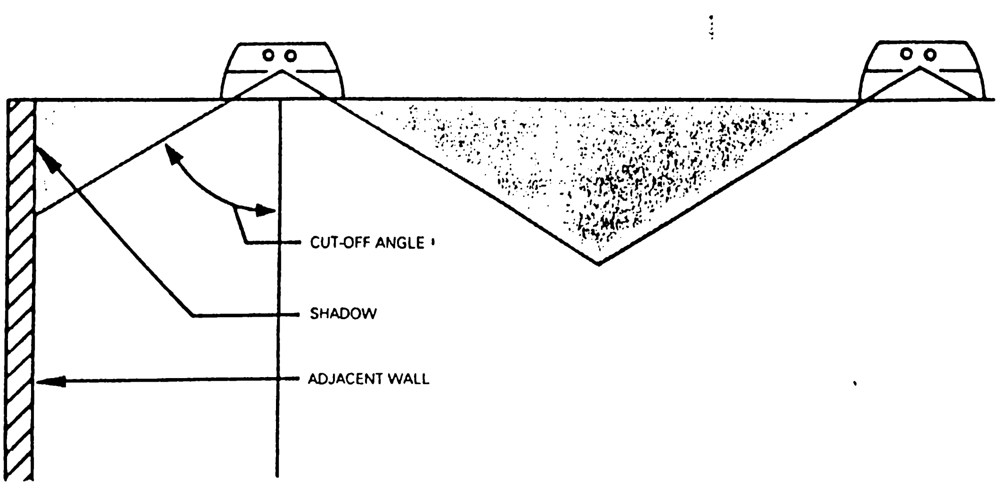


Figure 4.5 Shadows from sharp cut-off luminaires

Attachments to the screen can also eliminate a direct view of the luminaires. A screen mesh will shade the screen from high angle illumination from ceiling luminaires, while still providing a view of display directly through the mesh. Micromeshes are materials situated directly onto the glass surface or hung in front of the display screen. It permits the passage of only the light coming perpendicularly on it, while absorbs the part of the light which is not falling directly. This reduces both specular and diffuse reflections. However, it also reduces the luminance of the characters, too and this could be perceived if screen is not viewed head-on position. Neutral density fibers also reduce the amount of light that passes through them while allowing the passage of the light emitted by the characters without reduction. Thus, the brightness of the characters is reduced less than that of the reflected background and the characters stand out more distinctly. These filters are able to support the damage and cleaning which can expeditiously lessen the character resolution. Colored filters function the same way as neutral density filters except they change the color of the light passes through them (Grandjean, 1987). Grandjean stated about the report of the panel of experts of the US Academy of Sciences (1983) which investigates one neutral and several colored filters and this study determines that:

> In general, filters are more effective in reducing diffuse reflections than reducing specular reflections. This is unfortunate because specular reflections cause the greater loss of contrast and probably contribute more to problems encountered in viewing VDT's (1987, p.83).

Roughening the front glass surface is another procedure which is utilized frequently. By a chemical or mechanical treatment, the outer surface of the front glass roughened in order to have irregular surface. The reflection of light to all directions causes a reduction in brightness of the reflected images, and renders the borders more less distinct. So the reflected image becomes softer. On the other hand, this procedure deteriorates the good character sharpness.

Using circular polarizing filters with an anti-reflective coating is another approach to blocking reflections. In essence, the circular polarizer works like a key hole in a lock. Light passing through the circular polarizer oriented in one direction, as a key has to be oriented to pass through a key hole. Reflection from the screen causes the light to be reoriented and, in doing so, prevents the light from passing back through the circular polarizer " key hole " again (Rea, 1991). This type of filter reduces specular reflections from the filter itself through the use of anti-reflective coating and by eliminating specular reflection from the screen through the use of the circular polarizer. Whereas, circular polarizer filters without anti reflective coatings can cause double images. All anti-reflective techniques have important drawbacks. Grandjean recommends that:

> If efficiency is weighed against drawbacks, the roughening procedure is preferable, whereas micromesh, polarization and colored filters cannot be recommended. The adequate positioning of lights and appropriate positioning of the screen with respect to windows remain the most efficient preventive measures (1987, p.86).

Second approach as a design solution to reflected images on the screen is making reduction in the subjective contrast. Reducing the prominence of sharp edges in the image will reduce subjective contrast. Although lighting techniques can also be partly effective, primary concentration should be kept on the display (Rea, 1991). Screens with matte finishes will diffuse the reflected light and reduce the brightness of the reflected image. They work well in reduction of the subjective contrast by eliminating well defined edges in reflected images. The matte finish can lessen the quality of electronically generated images to a small extent, but the visual advantages outbalance the disadvantages. Moreover, VDT with a bright background display (negative contrast displays) will also reduce the contrast of the reflected images. Furthermore, indirect and direct-indirect lighting can be effective. Diffuse light created by indirect luminaires reduces the subjective contrast as well by diverting the sharp shadows in the environment into softened ones. The light reflected from the ceiling is typically of lower luminance than that produced by direct luminaires, and the distribution of the luminance pattern on the ceiling is less sharply defined. Nevertheless, the dark underside of a totally indirect luminaire can produce a high contrast, distinct, reflected image in the screen. Luminaires that combine direct and indirect optical control can often balance the brightness of the ceiling and the underside of the fixture, thereby reducing the contrast between the bright and dark. Direct-indirect luminaires are ideal for producing a relatively high level of ambient brightness without producing a high contrast image of the fixture in the VDT screen. The distance between the luminaire and the ceiling, the materials and finishes are all important factors that need careful consideration.

4.2. Factors Affecting Luminance

The distribution of the luminances in the visual environment plays an important role for both visual comfort and visibility. If the difference in luminance levels becomes higher, the loss of visibility will be greater (Grandjean, 1987). Whereas, areas with having no luminance differences, for example an all white interior, can be found disturbing and disorienting since it is too hard to understand the configuration of an area (IES Lighting

Handbook, 1987 Application Volume). Especially in the areas having VDTs luminance differences affect the workers work performances and visibility. Some studies that have measured the luminances (cd/m²) at VDT workstations showed nearly all workstations according to their contrast ratios are exceeding the general rules for offices (Figure 4.6).

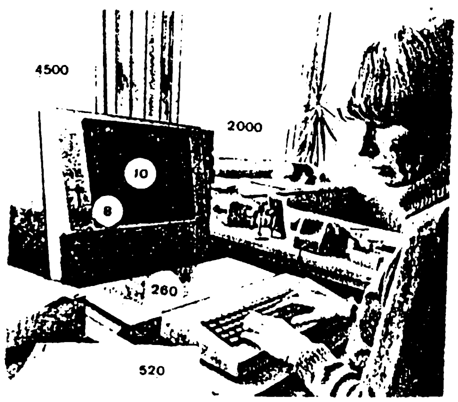


Figure 4.6 Excessive luminance contrasts in the visual environment of a VDT operator (Grandjean, 1987, p.43).

According to the various guidelines the contrast ratio between the dark background of a screen and an illuminated source document should not exceed 1:3. Whereas this suggestion cannot be accomplished at the most VDT workstations with bright characters and a dark background (Grandjean, 1987). According to Grandjean (1987):

> The luminance contrast between dark screen (with bright characters) and source document should not exceed the ratio of 1:10. All other surfaces in the visual environment should have luminances lying between those of the screen and the source document (p.45).
> . . . VDTs with reversed presentation have a screen luminance ranging between 50 and 100cd/m² . It is obvious that such bright screens do not raise the problem of excessive contrast ratios with source

documents or other bright surfaces in the visual environment (p.46).

For the effective luminance distribution large areas and major surfaces in the visual field must be equally bright, the work area should be brighter in the middle and darker in the surrounding field, contrast of light sources with their background should not exceed 20:1 ratio, maximum luminance contrast of 40:1 within the entire space must not be passed, and it should be considered that excessive contrasts are more destructive at the sides than at the top of the visual field . Luminance contrast ratios of different surfaces in the middle of the visual field should be 3:1, within the outer field 10:1 (Figure 4.7). Besides, contrasts between the central and the marginal areas of the visual field should not exceed 10:1 (Figure 4.7) (Grandjean, 1987). In balancing the preferred luminance ratios attention should be given to the surface textures, reflectances and color variations.

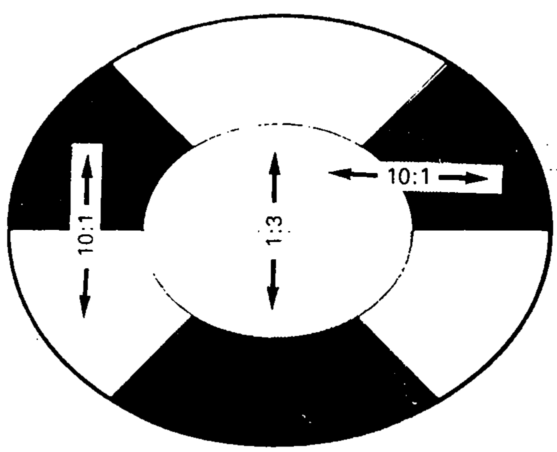


Figure 4.7 Acceptable contrast ratios of brightness between different area of the visual field (Grandjean, 1987, p.42).

The points mentioned above are very important for the lighting design of open-automated office. But unfortunately, most of the time this fact is neglected in the design of the work environments, or is done without using scientific results. A small investigation in the computer laboratory of the Faculty of Art, Design and Architecture of Bilkent University reinforces this statement. As an experiment two computer terminals are chosen which are situated in two different parts of the same lab. One is located in an area which is surrounded with partitions and far from the windows (a), and the other in an area near to the windows (b). The location of these two terminals are shown in the plan in Figure 4.8.

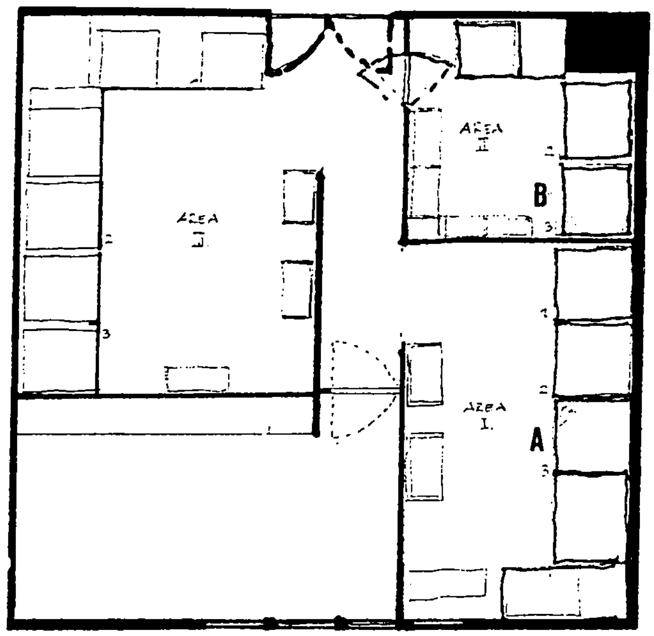


Figure 4.8 Plan of the laboratory and the location of the computers

The measurements were taken in the afternoon when the sky was partly cloudy. The luminance values for each computer were taken from the middle of the screen, and from the near surrounds with the luminance meter (Minolta, LS 100) (Figure 4.9). The values found for each computer is shown in Table 4.1.

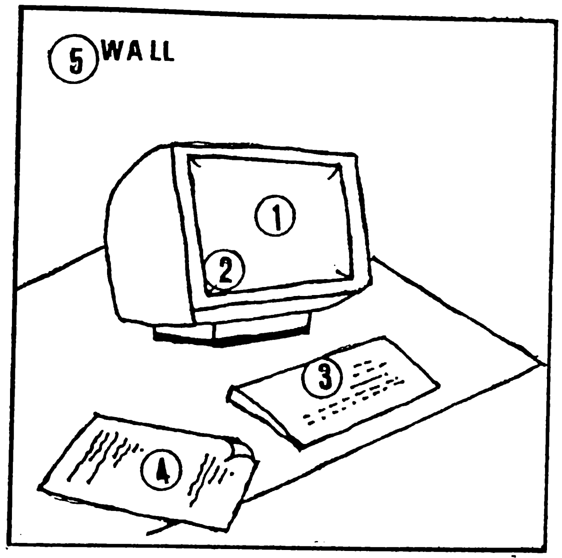


Figure 4. 9 The points of measurements on and around the VDTs.

Table 4.1 Luminance values for the experimented computers:

Luminance Values for Computer A (cd/m²)		Luminance Values for Computer B (cd/m²)
1	7.43	2.24
2	4.90	2.45
3	52	14.74
4	139	44.88
5	273	28.51

Comparing these values with those given above by Grandjean as accepted luminance contrast levels, it can be seen that the luminance contrasts existing on and around both of the computers (a) and (b) are not within the accepted range. However, the differences in the luminance levels of the measured points for the computer (a) are so high that cause an excessive glare and it is even harder to work with this computer. This experiment shows that even within the same space, just the location of the computers according to the light sources may create completely different working conditions.

4.2.1. Texture and Finishes

Treatment of the room and furniture surfaces are important in determining the luminous ratios between the light source and its surroundings as well as between the task and its remote surroundings. Luminance and perception of brightness depend on the surface reflectance since the luminance is changing according with the incident illuminance on a surface times the percentage reflected (IES Lighting Handbook 1987 Application Volume, 1987).

In office areas reflectance of the surfaces (Figure 4.10) and VDT workstation (Figure 4.11) should be designed according to the recommended values. The reflectances for the office surroundings containing VDTs should be slightly lower than that of the traditional office (Figure 4.11) The reason for low reflectances is the risk of reflections from bright ceilings, walls and windows (Table 4.2). Also, texture of the surfaces should be treated properly. For example, smooth and glossy work surfaces can produce troubles. They will reflect the ceiling lighting installation as a mirror image, so that the downward light distribution of direct luminaires will cause reflected glare, and also, it will make the appearance of color brighter (Shoshkes, 1976). So matte finish is recommended for all surfaces in the office area.

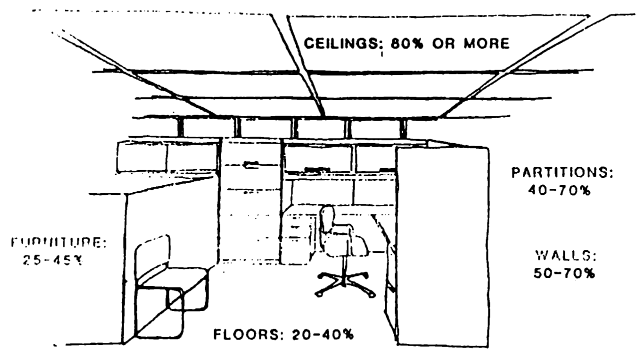


Figure 4.10 Recommended reflectances for open offices (IES Lighting Handbook, Application Volume, 1981, section 5.6)

Table 4.2 Recommended reflections for VDT environments (Grandjean, 1987, p.46).

Surfaces	Reflectances (%)
Ceilings	70
Windows, blinds or curtains	50
Walls behind the screen	40-50
Walls opposite the screen	30-40
Flooring	20-40
Work surface	30

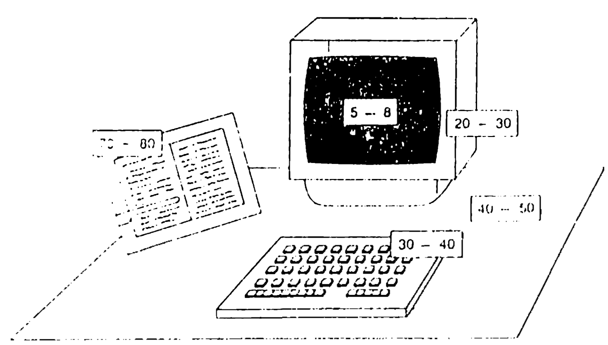


Figure 4.11 Recommended reflectances for VDT workstation with a positive contrast screen (Grandjean, 1987, p.45)

If shiny surface can not be avoided, utilization of low luminance uplighting system having luminaires with a broad light distribution is advisable for general ambient lighting. By this method the lumianance of the reflections on the glossy surfaces could be kept within low levels, whereas, matte finished ceiling with having an uplighting installation illuminates areas having VDTs much better. If supplementary task light is used, they should be placed to the sides in order to keep away reflected glare which is caused by the shiny surfaces, from the eyes when viewing in a forward direction (CIBSE, Lighting Guide: Areas for VDTs, 1987).

4.2.2. Color variations

Color is another factor affecting luminance. Workers are affected by the colors in their surroundings. Color can affect workers performance, positively or negatively, consciously or unconsciously. In the offices colors should be balanced by using dominantly neutral colors while having a high chroma touches in some part of the surroundings. Color is distinguished with the help of three factors: hue, chroma and value. Hue is the name of the color like green, red, blue, etc. Chroma (saturation, strength or intensity) shows the purity of a given color; the quality that distinguishes it from a grayed color. Value (brightness or lightness) is the quality that differentiates a dark color from a light one is the degree to which color varies along the white -black continium. Available color systems can specify color according to these dimensions. The Munsell Color System is the most cited system in the literature since it has an ease of usage (Farrel and Booth cited in Clearwater, 1986). In Table 4.3 a color specification is given for the office environments.

Table 4.3 Color Specifications for the Offices by Munsell Notation (Mahnke and Mahnke, 1993).

General Offices		Corridors: Two-Wall Effect	
Walls:	5Y9/4	Wall 1:	10YR9/2
	10YR9/2	Wall 2:	7.5YR9/4
	7.5YR9/2		
	10YR8/2	Accent:	2.5YR7/8
	10GY9/2	or:	2.5PB6/6
	2.5BG9/2		

Private Offices With Endwall Treatments		
Walls: 10YR9/	Endwall:	7.5R7/4
	or	5YR8/4
	or	5BG7/4
	or	7.5B6/6

Manhke and Mahnke (1993) states that violet, purple, vivid yellows or yellow- green, bright red, and dark brown (except wood) should not be used in the office environments. Moreover, for offices where high concentration is very important, cool hues are advisable. In general the choice of cool or warm colors depends on preference. The colors like soft yellow, sandstone, pale gold, pale orange, pale green, and olive tones are appropriate. If corridors are considered, one side of it could be beige, the other light orange, and with an accent wall at the end in a medium tone blue (Mahnke and Mahnke, 1993). Besides, de Boer and Fisher (1981) stated some general rules formulated by Helson and Lunsford (1970):

- Warm colors surfaces viewed under the warm colored light, are judged as being more pleasant to look than viewed under the cool light.

- The most preferred surface color for the background (walls, ceiling, and objects having a large area) is either white, or pale colors with very low saturation (i.e. pastel shades).

> Very dark background surface colors can be acceptable if there is an attempt of creating contrasts, but wall colors of medium lightness and saturation are rated lowest of all. The widely preferred object colors are blues, blue-greens, and greens. In order of preference red and orange takes the second degree, while yellow ranking lowest of all. Whereas the best colors of large areas are light but desaturated, the best liked colors for small objects are highly saturated (p.112).

4.3. Quantity of Illuminance

In open-automated offices, the illumination level is becoming more technical and complicated consideration the as usage of VDTs emerged. So, the level of illumination should correspond with the needs of the task being performed. Lighting levels required for VDT usage are considerably different from those required for traditional office task, however, the lighting of most VDT workplaces was originally designed for traditional office tasks. Wierenga (1985) states that the American National Standards Institute recommendation for minimum illumination levels in a general office environment is nearly twice that recommended by some experts for offices using VDTs. In several studies, it is observed that with higher illumination levels (illumination above 1000 lux) there was an occurrence of eye troubles. Hence, for the areas which do not use VDTs, illumination levels between 500 and 700 lux can be recommended for most office jobs (Grandjean, 1987). Whereas these recommendations are not valid for areas having VDTs. It is recommended that the illuminance should not exceed 750 lux on the horizontal work-plane. If there are tasks which requires higher illumination levels, supplementary lighting should be used to accommodate the necessary illuminance (IES Lighting Handbook, Application Volume, 1987). Cushman states that if a computer is used with accompanying paperwork set side by side at a desk level, a bit more illumination is needed than if the computer is used by itself (Cushman cited in Birren, 1988). Mahnke and Mahnke (1993) states Cushmans' (1982) proposal of 160 to 380 lux for tasks not involving paper documents, and 380 to 540 lux for tasks requiring information transfer from paper documents to VDT. Also, Mahnke and Mahnke cites another figure from a technical report of Human Factors of Workstations with Visual Displays, that is tending to confirm these illumination levels. In this report an average light level of about 400 lux is given as an optimum illumination level for visual satisfaction in office environments. Grandjean (1987) mentioned about the study conducted by Benz et.al.(1983) which is carried on in order to find out the illumination level preferences of the VDT operators. In this study, it is observed that 40 percent of VDT operators preferred levels between 200 and 400 lux, and 45 percent levels between 400 and 600 lux. However, low illuminance levels (for example 200 lux) generally cause the office to appear dimly lighted, and also it is inadequate for reading hard-copy documents. On the other hand, high levels of illumination, particularly on the vertical surfaces, were found to produce degradation of the contrast on the computer screen, and images of the luminaires themselves were very apparent on the screen. In an open office, vertical obstructions (partitions, filing cabinets) play an significant role in determining the lighting condition within and surrounding a workstation.

For instance, an average density of 1.65m high partitions may reduce illuminance levels on a work surface by 10 to 50 percent (Depending on reflectance and luminaire distribution characteristics) (IES Lighting Handbook ,Application Volume, 1987).

It can be concluded that to suggest exactly one value for illuminance level is not appropriate, since the working conditions can differ from one job to another. Miscellaneous practice as well as several field studies lead to the recommendations given in Table 4.4.

Table 4.4. Recommended illumination levels at VDT workstations (The lux values refer to measures taken on a horizontal plane) (Grandjean, 1987, p.40).

Working Conditions	Illumination Levels (Lx)
Conversational tasks with well printed source documents	300
Conversational tasks with reduced readability of source documents	400-500
Data entry tasks	500-700

For committee rooms, the illuminance on the table is recommended as approximately 300 lux (CIBSE Lighting Guide: The Visual Environment in Lecture, Teaching and Conference Rooms, 1991). It would be more appropriate to design a flexible lighting system which enables to satisfy changing illumination requirements by dimming. For circulation areas generally 100-200 lux of illumination is recommended (de Boer and Fisher, 1981). The level of illumination affects the accommodation. When the lighting is poor the far point moves nearer and the near point recedes. The speed and the accuracy of the accommodation starts to reduce as well as luminance contrast and sharpness of printed texts, because accommodation occurs quicker and precise when the object or character stands out sharply against its background. The speed as well as the precision of accommodation decreases with age. So illumination levels must be increased with age to provide a constant visual performance. Grandjean (1987) states that according to Fortuin (1957) the lighting levels required for reading a well-printed book must be multiplied by the following factors:

20-25 years old	1.0
40 years old	1.17
50 years old	1.58
65 years old	2.66

On the other hand, corridor illumination should not be less than one-fifth of the illumination of the adjacent areas. If not, the level of illumination of a corridor can create discomfort while entering the corridor from other areas, since it causes an uncomfortable level eye adaptation upon occupant (IES Lighting Handbook, Application Volume, 1987).

4.4. Artificial Light Sources

Office work is offering some of the most troublesome seeing tasks. Manufacturers have begun to respond to the lighting needs of the enlarging automated office. Lamp companies have enhanced the energy efficiency , beam control, and color rendering of light sources, while shaping lamps more compact. Lighting control producers have improved the performance of ballasts, controllers, and sensors. And fixture manufacturers have improved the optics and reduced the dimensions of their products to minimize glare and simplify placement. According to some producers lamps are possibly the most important part of a lighting system (Fisher, 1986).

Incandescent or tungsten halogen lamps (quartz lamp), while used in the office mainly as task or accent light, produce what most people still consider as the best light. They are also used to provide additional lighting in uplighters in the offices with either metal halide or high pressure sodium discharge lamps (CIBSE Lighting Guide: Areas for Visual Display Terminals, 1989) Their drawbacks, at least until recently, have included a relatively short life, poor beam control, and inefficient light output. Some incandescent sources now have twice the life expectancy they once had. Their optics, too, has greatly improved with the incorporation of reflectors. That in parabolic aluminized reflector (PAR) lamps prevents the spill of light out its sides. Today, reflectors in lamps become even more sophisticated. MR-16 lamps, for instance, have multifaceted, mirrored- glass, dichroic coated reflector. The facets produce a brighter beam of light than other reflector lamps with the same wattage, while the dichroic coating produces a cooler beam by letting some of the heat given off by the 5 cm halogen lamp escape out his back (Fisher, 1986). Coatings on the inside of halogen lamps also have improved the energy efficiency of these light sources. Low-emissivity coatings, for example, allow visible light to escape the lamp, but reflect the infrared energy back on to the filament. Less energy is thus required to achieve a given output of light.

Fluorescent lamps, too, have undergone major changes in their design and coating. One of their most important design change is the reduction in their size. Straight fluorescent tubes, now available in one-inch diameters, have effected the development of slimmer fixtures. Even more compact lamp shapes have been obtained turning or joining the glass tubes and arraying them in single or double pairs. These compact fluorescent tubes can produce the same light output as standard 40-watt fluorescent tubes at one third to half the size. Another important change among fluorescent lamps has been the improvement of their efficiency and color rendering. Good color rendering and high efficiency used to be mutually exclusive properties, but with smaller, double-coated lamps, manufacturers can afford to coat the inside lamps with more expensive rare-earth triphosfhors. Such triphosphor coatings render colors more faithfully, with an efficiency equal to or better than standard fluorescent lamps. They also can produce a range of colors from 3000 Kelvin which allows their use in conjuction with or as a replacement for incandescent sources, to over 5000 Kelvin. Whereas they have also some disadvantages. They canx produce flicker. Flickering light is extremely annoying and causes visual discomfort. In Europe offices never lit with single fluorescent tubes but always with two or more phase shifted tubes inside one lighting unit (Grandjean, 1986).

Metal halides have had the greatest use in offices, mainly in indirect lighting. High efficiency has been the major attraction of metal halide lamps, but the difficulty of controlling their beam, their impartial color rendering, and inconsistency of color from one lamp to another have been traditional drawbacks . Metal halides when they are turned on their sides in an indirect fixture, the lamps create hot spots on ceilings that may people have reasonably criticized. Some of the objections have been disappeared with the recently presented low wattage metal halide lamps, whose smaller size and lower brightness permit their application in direct lighting (Fisher, 1986). Nowadays, some type of metal halides are being used in offices as an indirect light source. Improvements in color consistency of metal halides also may increase their use. Still, few lighting designers show much interest in using these high intensity discharge lamps in offices. Some of the designers have stated the new metal halide and high pressure sodium lamps as the light sources of the next decade (Fisher, 1986).

A new development in lamp technology is the type electrodeless induction lamp. In induction lamp the phosphor powder is irradiated with ultraviolet (UV) to produce visible light (Lyons, 1992). The life of induction lamps is about 60000 hours. They may be dimmed electronically without no change in light output color, and any required color characteristic can be produced by the use of suitable phosphors. Because that they are physically small, some manufacturers expected that by handling together with the appropriate fixtures, they will be used in the artificial lighting systems of the offices (Anonymous, Arredamento-Dekorasyon, 1993, translation mine).

4.4.1 Color Temperature

Since the appearant color of a surface depends on the color characteristics of the light source under which it is viewed, the selection of a light source can be important. One of the main purposes when selecting a light source for the office environment is to make people look attractive in their surroundings. This can be achieved by using a light source that is complementary to skin tones and therefore makes the occupants of the space look healtier (Harris et.al., 1991). Manhke & Mahnke states that Knithof (1941) observed preferences of cool color temperature when illumination is intense and a warmer color temperature when illumination is low. it is reported that objects have a normal color appearance under warm light at low intensity and under cool light at high intensity (Figure 4.12) (Mahnke & Mahnke, 1993).

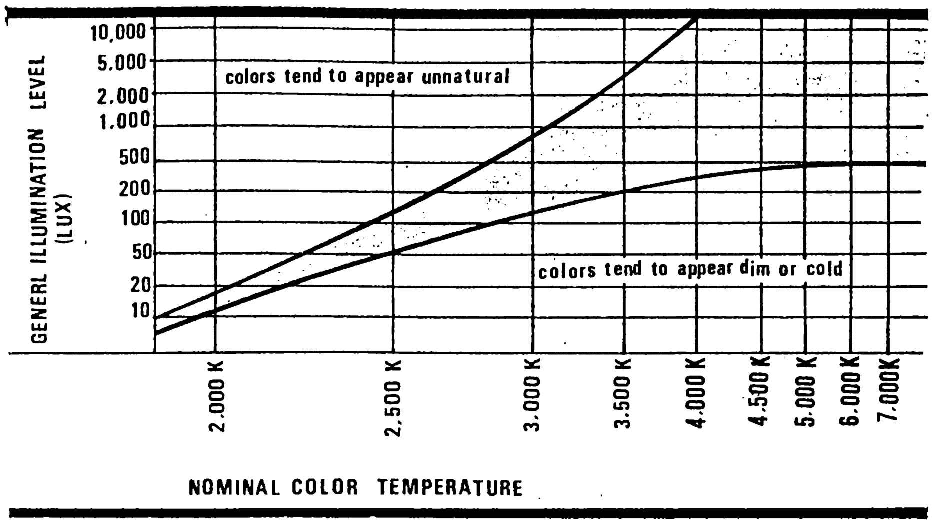


Figure 4.12 Color Apperance (Flynn et.al, 1993, p.44)

Also it is important to make decisions concerning finishes and materials of the office after the selection of the light source. It is necessary to make these selections under the same light source at the correct intensity in order to eliminate improper selection of reflectance values and color distortion. For instanse, if the finishes and colors of the office were selected under 6000 lux of daylight (north sky) for use in an office being lighted with 600 lux of warm white fluorescent, the colors in place would appear darker in intensity and warmer in hue (Harris et.al., 1991).

Technically, color temperature designation can only be assign to sources of continous spectral composition, such as incandescent lamps (IES Education Series, 1988). Electric discharge sources such as fluorescent or high intensity discharge emit uneven spectral distribution. These lamps have mixed energy peaks which give the visual appearance of white light. The color is expressed as " appearent " degrees Kelvin in these types of sources or it can be expressed as correlated color temperature (CCT) (Harris et.al., 1991). It is used to indicate the degree of whiteness of these sources (Figure 4.12).

4.4.2. Color Rendering

The color of the lamp has no indication of how coloured objects will appear under ots light. Moreover, altough two lamps look alike (i.e. their color appearance is the same), they can make the same surfaces look different. For instance, Cool White (CW) and Deluxe Cool White (CWX) fluorescent lamps look approximately the same. However, yellows become particularly vivid and reds are grayed when are viewed under the CW lamp where as under the CWX lamp these effect do not occur. So it is necessary to differentiate between the color appearance of lamps and their color-rendering properties (Wotton, 1986).

Color rendering designates the effect of light on colored objects. Color Redering Index (R_a) is a measure of the degree that gives an indication of how closely a given light source matches the color-rendering ability of a reference source. The reference source has a R_a of 100 and it shows the objects in their "true" colors (IES Education Series, 1988). For example, R_a of a Deluxe Cool White lamp is 89 where as 62 for the Cool White lamp. However, only in the case of a very high R_a value, such as 95, it can be stated that the lamp will very probably give true color rendering for all kinds of object colour. As the R_a decreases, it becomes increasingly difficult to predict the color rendering of specific object colors. It can be said that a lamp with an R_a of 70 or lower can cause a noticeable color distortions for various objects colours (de Boer and Fisher, 1981). On the other hand, a lamp having a R_a 100 does not necessarily mean that it is ideal for all circumstances. The lamp with a lower R_a can be richer than the reference source: it can show the skin color and some other object colors more attractively than the daylight. This is especially true for the de luxe series of fluorescent lamps which do render most colors more vividly than do daylight. It is stated that:

> . . . in the future an additional index will be developed- a Colour Preference Index, or whatever- that has a starting point not the 'true colours' of objects, but the 'preffered colours' for specified fields of lighting (De Boer and Fisher, 1981, p.107)

The distribution of wavelengths emitted by a source known as the Spectral Power Distribution (SPD). SPD of incandescent lamps shows immense amount of red or long wavelengths present. The quartz iodine SPD is similar to that of the incandescent lamp but contains more of the shorter wavelengths (blue). Incandescent lamps have acceptable color rendetion. Fluorescent lamps are not able to render all colors exactly as they are seen under the natural light. The emitted light does not contain all wavelengths as daylight. This is also true for three-phosphor fluorescent lamps (Meyer and Nienhuis, 1988). Of the mercury vapor lamps, deluxe white (DX) is increased in red, has a good color rendetion, and warm white deluxe (WWX) is excellent in reds and has a excellent color rendering. Also, metal halide lamps produces good color rendetion. On the other hand, high pressure sodium lamps while having energy at all wavelengths, they are dominant particularly in the yellow-orange region. The color characteristics of the lamp turn red objects orange and will darken the color appearance of blue and green objects (Helms, 1980).

5. PHSYCOLOGICAL LIGHTING REQUIREMENTS OF OPEN-AUTOMATED OFFICES

As a result of his studies, Martyniuk obtained some results which confirms the two aspects of concern implied at the beginning of his study:

> Lighting can be discussed as a vehicle that alters the information content of the visual field_ and that this intervention has some effect on behavior and on the sensations of well-being. These lighting effects can be evaluated by psychological procedures for the rating and mapping of behavior (Martyniuk et.al., 1973, p.62).

Therefore lighting should be concerned as a complex system having both physiological and psychological aspects. Lighting design of the built environment can be a crucial identifier in determining the visual meaning of interiors by affecting subjective spatial impressions. In the psychology of lighting some of the subjective spatial impressions like perceptual quality, pleasantness, spaciousness, privacy and relaxation accepted as the subject matters (Flynn et.al., 1973, and Steffy, 1990). Environmental lighting provides behavioral impact. In this respect, it would be appropriate to state about two kinds of environmental lighting systems. One of them is a system which illuminates the space indiscriminately. These are behaviorally neutral systems which does not awake a sense of intentional reinforcing on user impression. They may supply some advantages for space such as: unity, flexibility, and general clarity. Sometimes this lighting uniformness creates spaces without much taste like in Figure 5.1 (Flynn et.al., 1992).

Figure 5.1 An uninteresting committee room.

(Flynn et.al., 1992, p.14)

Second lighting system creates specific patterns of light and shade to reinforce selected information or space cues. This system captures user's selective attention and improves the information content of the visual environment. For visual impact, brightness ratios should be well articulated (Table 5.1).

Table 5.1. Brightness Ratios (Flynn et.al, 1993, p.17).

Visual Impact	Brightness Ratio
Barely recognizable contrast; negligible attraction power as a focal point.	2:1
Minimum meaningful contrast as a focal point; marginal attraction power.	10:1
Dominating contrast as a focal point strong attraction power.	100:1

With the help of light patters impressions of somberness, playfulness, tension, etc. can be created. Lighting which advances these impressions is an important tool for affecting human behavior, performance, and productivity. Subjective impressions are influenced by the three brightness parameters: brightness uniformity (uniform vs. nonuniform), brightness position (overhead vs. peripheral), and brightness intensity (dim vs. bright) (Flynn, et.al., 1992).

5.1. Spaciousness

Spaciousness is an important construct on which people often based their descriptions and evaluations of interiors and it is closely related to such variables as size, clutteredness and the general atmosphere of interiors (İmamoğlu, 1975). Large / Small are the two adjectives representing the impression of spaciousness. The impression of spaciousness is represented by the linear combination of uniform / nonuniform and overhead / peripheral dimension (Flynn et.al., 1973). The term "large" describes a luminous environment that perceived as having expanded spatial limits or increased volume. Whereas, " small" refers to a luminous environment that creates impressions of confinement (Flynn et.al., 1992). Confined impressions is evoked when vertical surfaces and/or ceiling are quite dark compared to the horizontal plane while spaciousness is drawn out as a result of relatively bright vertical surfaces (Steffy, 1990).

Martynuik et.al. (1973) and Hendrick et.al.(1977) conducted studies in order to find out effects of environmental lighting on user's spatial impressions. According to them some patterns of light might serve as environmental cues or signals, so that the occupants might tend to respond to these cues in a consistent way. Results showed significant differences in response to the room under six lighting arrangements (Figure 5.2).

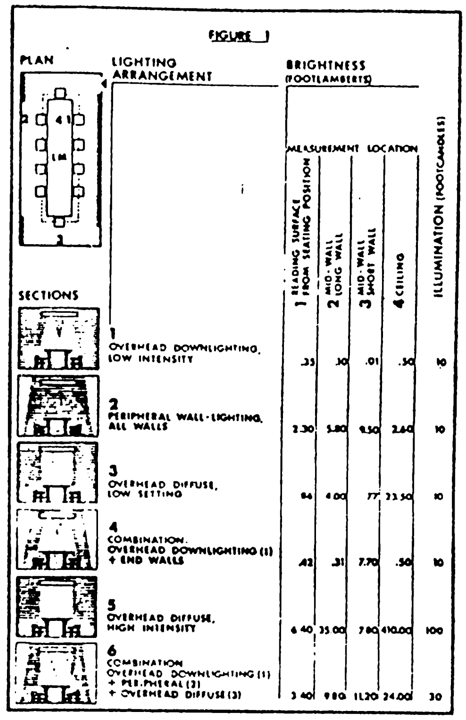


Figure 5.2. Descriptions of setting and lighting arrangement.

(Flynn et.al., 1973, p. 436)

Lighting arrangements 1 and 3 were found less spacious than arrangements 2 and 6. It was seemed that when four walls are lighted (arrangement 2 and 6), the impression of spaciousness advanced in comparison to the low intensity overhead arrangements of 1 and 3 in which wall brightness were subdued. The psychological effect varies according to the changes in the lighting arrangements since the physical dimensions of the room and the furnishing did not vary (Flynn et.al., 1973). They also studied the changes in the impression of pleasantness by changing the distribution characteristics significantly of the overhead lighting system while making no change in the horizontal illumination. In this study, arrangement 4 was evaluated more positively than arrangement 1 (downlights only). It was found that limited wall lighting (peripheral lighting) when added to the different distributions of downlighting system, enhanced spaciousness (Flynn et.al., 1973). Also Sorcar (1987) confirmed this, and stated that:

> An impression of spaciousness can be created with a moderate amount of general ambient lighting and a greater amount of perimeter(wall) lighting. The perimeter must be bright and uncluttered, possibly within light tone. Warm colors appear to advance and cool colors recede characteristics can be adapted to "open-up" space (p.178).

Moreover, Inui and Miyata (1973) had found a strong correlation between the spaciousness and the average horizontal illuminance on the working plane and the vertical illuminance at the eye position at the rear wall. Besides, the effect of light source color on various evaluative dimensions is studied by some researchers. They found very little effect of light color, although cool white fluorescent were perceived more positively in terms of spaciousness and clarity particularly when compared with high pressure sodium . However, they also indicated that this results are not valid in interiors using daylight as supplementary light source (Flynn and Spencer, 1977, and Bennet et.al, 1985 cited in Space Human Factors Office, 1986).

Spaciousness is an important subjective factor that should be considered for both inherently small circulation and assembly spaces, and office spaces which consists of workstations and private offices (Steffy, 1990).

5.2. Pleasantness

Our perceptual judgment of the luminous environment are qualitative rather than quantitative. In order to judge a space as light or dark, the luminance level is not sufficient for giving some visual information about the environment and to the extent that satisfies our needs or meets our expectations (Lam, 1992). Lam stated that :

> Elements in the visual field of vision are judged as to be " too bright " when there is no perceptible reason for them to be brightly illuminated or when they interfere with our ability to perceive information required for the satisfaction of activity or biological needs (1992, p.52).

For example, an evenly overcast sky is considered as unpleasantly bright since it competes with our environmental perception, which has a greater importance and interest than the inside environment. When the largest, brightest and colored objects within the office environment are designed purposely to attract attention, a positive focus is likely to satisfy and please the user. If not, they will be perceived as annoying distractions and the space is evaluated as unpleasant. This often happens in offices when indirect high brightness luminaires are used in a careless manner (Lam, 1992).

Glare is an important stimulus in offices which interferes with the perception of what we want or need to see. Lam stated Hopkinson's conclusion about a study of artificial sources of large areas, such as wide open offices. According to Hopkinson glare is just acceptable at approximately 500 cd/m^2, and that glare sensation is independent from the size of the glare source. Hopkinson also stressed that this conclusion is inappropriate for our everyday experience with daylight. For instance, in an office, it does not cause discomfort to look out of the window (from the lower brightness of the inside to the higher brightness of the outside) (Hopkinson cited in Lam, 1992). So the true determinants of pleasantness in the luminous environment are relevance and appropriateness. For example, for an office, a meaningless, informationless surface such as a translucent diffuser on a fluorescent fixture or a typical luminous ceiling with having luminance lower than 500 cd/m^2 'could be perceived as too bright. On the other hand, a feature of the visual environment which is more relevant but having luminance more than this threshold value might not cause any sensation of discomfort. However, relevance is factor that is difficult to quantify and so, usually is omitted from experimental researches. (Lam, 1992).

The sensation of visual gloom can occur when desirable and expected visual information is absent in the environment. A space can be perceived as "gloomy", if there is an inappropriate or inadequate lighting installation that makes difficult to perform activities and there is obstacles in biological needs. For example, a windowless open-office is perceived as visually gloomy since it cuts the visual contact of the workers from the outside environment. Gloomy appearance can occur as a result of inappropriate focal points which we do not want to see such as a glaring direct light fixture or a luminous ceiling (Figure 5.3). In a space where a gloomy appearance is being perceived, what needed is the improvement of luminance environment which calls for the use of less light, distributed in a more relevant manner to upgrade the overall appearance of a space. Besides, an inherently dull office environment can be more interesting by adding color to it, since people require varying stimuli to remain sensitive and alert to their environments (Birren, 1988).

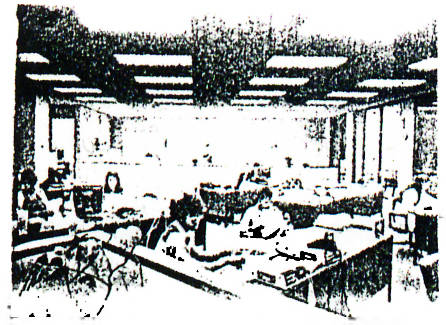


Figure 5.3 Gloomy interior

Studies of Martynuik et.al. (1973) and Hendrick et.al.(1977) had shown results related with impression of pleasantness, too. Intensity of light emission from overhead diffusing systems has relatively little effect on pleasantness than perceptual clarity. Among the lighting arrangements in figure 6.2 arrangement 6 and 4 were generally most preferred, and arrangements 3 and 5 were less preferred. As a result, it was seen that overhead downlighting with limited wall lighting in comparison to downlighting used alone, did enhance the impressions of pleasantness (Flynn et.al, 1973).

However,Sorcar (1987) cited another experiment conducted by Hawks et.al. (1979), in which a study is conducted for a small office illuminated by 18 different lighting combinations which included conventional uniform lighting, downlighting, wall washing, local desk lighting and spot lighting. The most preferred combination had a bright look and a nonuniform pattern of wall lighting with incandescent focused sources (spotlights). The least preferred setting is the fluorescent used as blanket of uniform diffuse light. For the office environment, what kind of nonuniform lighting satisfies pleasantness is an open ended question that varies with application. In general, special effects like wall washing , concentrated light on flowers, paintings and sculptures especially with incandescent sources could be helpful for variations (Sorcar, 1987).

5.3. Visual Clarity

Visual clarity should not be confused with visibility. It is related with the overall visual impression of a given environment; perceived distinctiveness of architectural and human features and environmental details. The term "clear" is used to indicate a luminous environment which creates impressions of distinct space and objects within. However, "hazy" is a term that signifies an environment which creates clouded or fuzzy impression of a space and objects within (Steffy, 1990).

Studies of Martynuik et.al. (1973) and Hendrick et.al.(1977) had also shown results related with impression of visual clarity (spatial brightness). The bright/dim adjective pairs are used as representatives of the visual clarity. The arrangements of 5 and 6 in Figure 5.2 were defined as the clearest, brightest while the others are defined as less bright. Intensity of light emission from overhead diffusing systems may affect the impression of visual clarity (Flynn et.al, 1973). For office environment, visual clarity is an important subjective impression that should be considered, and can be reinforced by uniform brightness, with more peripheral brightness, and relatively high brightness (Flynn et.al., 1992).

5.4 Relaxation

A sense of relaxation could be important for committee rooms, and in adjoining areas like waiting areas, etc. It reflects an environment as both comfortable and highly productive (Steffy, 1990). The terms "tense" and "relaxed" are used for evaluating the impression of relaxation. Steffy states that:

> Tense signifies a luminous environment that promotes impressions of fast-paced visual work. Relaxed on the other hand signifies a luminous environment that promotes impressions of rather comfortably paced activities, including visual work (1992, p.20).

Relaxation signifies a rest for tired body. In areas in the office where this sense is intended to be produced, first of all, glare should be avoided. Low levels of ambient light together with the use of warm-toned light sources, for example in the form of wall wash in a nonuniform patterns stimulate a relaxed environment. Task lights can be used with dimmers (Sorcar,1987).

6. GENERAL CRITERIA FOR LIGHTING OF OPEN-AUTOMATED OFFICES

These criterion were filtered through the whole complete thesis. Detailed information will be found on the pages given at the end of each criteria.

Basic Requirements

1. Lighting in office areas should enable the workers of the office to see their visual task and their environment with ease and accuracy (p.102).

2. Lighting in office areas should enhance the appearance of the interior by supplying appropriate or desired responses for the worker (p.103).

3. In open-automated offices flexibility of lighting is very important since from time to time there can be a possibility of replacement of the working environment. So lighting should serve these changing needs and new requirements (p.102).

4. Lighting should be designed according to each activity that is performed at each place in the office. So each task and its lighting requirement should be analyzed carefully (103)

5. Since the workstations are the places which required to cover multi-functional aspects such as reading, writing, computerized data retrieval and

filing, etc., visibility for these areas is very important. In general, reading information on a display screen necessitates greater visual requirements than does reading information on a piece of paper since the VDT is very sensitive to veiling reflections and this directly affects the performance of the worker (p.5).

Natural Lighting Requirements

1. In offices daylight and artificial lighting should be designed together with careful attention (p.15).

2. Windows, skylights, clerestories, monitors are the daylight media that are used to take daylight into the office areas. They should be designed and controlled in order not to cause direct or reflected glare on the VDT screens (p.18).

3. Room depth, height and daylight quantity are closely related. The level of direct daylight decreases in a considerable manner as the distance from the window increases. So, higher fenestration provides more uniform distribution than comparable lower fenestration and controls veiling reflections while illuminating vertical surface effectively. On the other hand, at times when the sky is too bright, there occurs a need to screen high windows (p.19).

4. A ratio of 1:2 for the height of the window to the depth of the room from the window usually gives the optimum daylight distribution in a space (p.19).

5. If the total quantity of light brought into the room is assumed to remain the same, distribution of the fenestration over a large area will (1) reduce the

shadows, contrast and texture definition, (2) provide more uniform light distribution, (3) reduce veiling reflections. So, strip glazing produces more uniform light level across the room than the individual windows (p.20).

6. Windows with splayed reveals and clerestory windows with sloped downward sills should be used to keep the luminance of these areas within an intermediate level between the source and the general office environment in order to eliminate glare (p.21).

7. North-facing monitors can be used for daylighting without sun controls. However, south-facing monitors should use sun controls such as translucent glass, baffles, etc. When saw-tooth south monitor with vertical glazing is combined with interior vertical baffles spaced to shield all direct sunlight, a high illumination immediately below with a rapid fall-off at the perimeter can be provided (p.22)

8. In committee rooms glare from the window should be prevented by using control methods. Also, wall charts should never be placed next to a window. They should be placed at a place where there is no possibility for them to reflect shiny image of the window (p.26).

9. Caution is advised when using daylighting in open-automated offices since direct light can create too many reflections on VDT screens. So, some control elements could be used for daylight media such as low-transmission glass, frit patterned glass, architectural baffles, louvers, overhangs, blinds, deep-wells, etc. Also the characteristics of these elements should be known. For example, low transmission glass allows a clear view of the outdoors, but at the same time changes the color of the view and of the incoming light. With gray tinted glass, the exterior view appears grayed and dull. However,

bronze tinted glass makes the scene looks rosy, and incoming light has a warmer color (p.26).

10. Horizontal and vertical blinds can be problematic for large areas used by many individuals and their usage is not advisable. For example, a horizontal blind set for one person may cause severe VDT imaging problems for somebody nearby (p.32).

11. Control elements that are applied to the exterior of the buildings, are effective from the heat control standpoint. They emit most of the absorbed heat to the exterior. However, they can require frequent maintenance as they are exposed to weather and pollution. On the other hand, interior control elements are less susceptible to pollution. Whereas, they tend to absorb and reradiate heat to the interior influencing both occupants comfort and air conditioning load (p.32).

12. In open-automated offices where daylight media are used extensively, finishes of wall and ceiling surfaces should be matte in order to avoid harsh, glary reflections of light (p.33).

13. In committee rooms, for daylight control, one approach is to situate the chairman facing the window with having ability to control automatically both curtains and electric lighting (p.33).

Artificial Lighting Requirements

1. Direct artificial lighting if evenly distributed, provides equal levels of illumination across large spaces by emphasizing the ceiling, work and floor

surfaces. Task oriented approach can be used by locating the fixtures only over the work surfaces (p.34).

2. Direct lighting together with the task lighting is advised for areas having high amounts of VDTs (p.34).

3. In direct lighting system, selection of the luminaire with correct intensity and distribution is important. Low brightness ceiling luminaires should be used to reduce the potential for veiling reflections on the VDTs. High luminance reflections on a VDT screen can be controlled by limiting the luminances in appropriate directions. If a luminaire had no luminance at 55 degree or greater with the vertical, its reflection would hardly seen in the VDT screen. If it had no luminance at 65 degree or greater, it would seldom be seen. In general, the higher the intensity in an area, it is advised to lower the luminance limiting angle (p.36).

4. Lighting fixtures should be installed parallel to and on either side of the operator (p.38).

5. it is preferable to keep direct lighting luminaires setback from walls in order to avoid scallops (p.38).

6. Direct lighting which consists of modules can have provisions for sprinkler, sound masking system, and air distribution (p.39).

7. In committee rooms lighting system should serve to the changing needs. It is advised to have both general and supplementary lighting system. The geometry of the lighting system should match to the conference table. Besides, wall charts must be illuminated with supplementary display lighting

and they should be controlled with dimmer. The distribution should be even on the board without steep fall-off toward the bottom (p.40).

8. If only ceiling is lighted with indirect lighting system, it appears to be the brightest surface in the visual field while the objects like desks and partitions tend to loose definition. So, this brightness should be distributed evenly in order to avoid excessive glare (p.42).

9. Task lighting together with the indirect lighting can be used for obtaining better lighting conditions for the VDTs. In general, the ambient lighting whether it is achieved by direct, indirect or direct-indirect systems, should be designed to provide two thirds of the required illuminance and task light providing the remainder (p.43).

10. Indirect lighting system must be used in areas having ceiling heights 280 cm or higher in order to allow enough suspension distance for the luminaire to distribute its light more uniformly across the ceiling (p.44).

11. Uplighters used in indirect lighting systems should be placed over, or close to the desk or work surface (p.46).

12. There should not be a very sharp cut-off in the luminous intensity distribution of the uplighter at any angle. They must have a wide-spread light distribution (p.46).

13. When suspended uplighters are used, the reflectance of the under-side of the luminaire becomes important and it needs care. Sharp luminance differences and glary surfaces should be avoided (p.49).

14. Indirect lighting particularly when pendant fixtures are used allows greater flexibility in the arrangement of desks (p.49).

15. Indirect lighting gives the impression of light, airy interior. However, since the lighting is very diffuse with giving little variety to their room surfaces, the decor of the interiors which are lighted with indirect system should be handled well in order to give variety (p.49).

16. In areas where direct/indirect lighting system is used, the characteristic appearance of the space changes associated with the proportion of downlight and uplight emitted by the luminaire (p.49).

17. It would be advised to keep the proportion of the uplight higher than the downlight in areas containing VDTs. In combined system, downlighters still need to be of a low luminance design and the uplighters still need to provide an even wash of light over the ceiling. Moreover, as the ceiling is uniformly lighted, it is acceptable to allow the luminance limiting angle of the downlight to increase (p.50).

18. Today, in offices each individual workstation contains VDT, and according to the changing needs of the work lighting should be controlled by the occupant of the workstation (p.51).

19. Light can be controlled with switches and dimmers by automatically and manually. Switches must be as near as possible to the luminaires they control. Time switches, presense detectors, photosensitive controls, relays, computers or micro processors are the automatic control techniques that can be used at the office areas (p.51).

Physiological lighting requirements

1. Glare is an important problem that should be eliminated in the open-automated offices. So, excessively high luminances of the sources are avoided. Besides, sharp luminance contrasts between a screen and its surroundings must be avoided and annoying reflections on the glass surface of the screens must be reduced or eliminated (p.54).

2. VDTs should be located in a position that eliminates reflections from windows and luminaires. In another words, luminaires and the windows should be out of the offending zone of the any VDT screen (p.57).

3. With the help of the optical controls VDT screen can be shielded from reflections. Egg-crate and parabolic louvers can be used as a shielding element. (p.58).

4. Attachments to the VDT screen or screen treatments can eliminate reflections. However, the adequate positioning of lights and appropriate positioning of the screen with respect to windows remain the most efficient preventive measures (p.60).

5. VDT screens with matte finishes are preferable since they diffuse the reflected light and reduce the brightness of the reflected images (p:61).

6. It can be advised to use negative contrast displays since they work well in reducing many distracting reflections from the VDT environments (p.62).

7. Luminaires that combine direct and indirect optical control can often balance the brightness of the ceiling and the underside of the fixture,

therefore reducing the contrast between the bright and dark without producing a high contrast image of the fixture in the VDT screen (p.62).

8. In areas containing VDTs, luminance differences affects the workers work performances and visibility. The luminance contrast between dark screen and source document should not exceed the ratio of 1:10. For effective luminance distribution large areas and major surfaces in the visual field must be equally bright. The work surface should be brighter in the middle and darker in the surrounding field. Also, contrast of light sources with their background should not exceed 20:1 ratio and maximum luminance contrast of 40:1 within the entire space must not be passed (p.63).

9. In open-automated areas reflectances should be slightly lower than the traditional office (p.67).

10. Smooth and glossy work surfaces should be eliminated. Instead, matte surfaces are recommended for all surfaces in the open-automated office area.

11. In open-automated offices colors should be balances by using dominantly neutral colors while having high chroma touches in some parts of the surroundings (p.70).

12. Required illumination level for areas having VDTs is nearly half as the required illumination level for the traditional office. For committee rooms, the illuminance on the table is recommended as approximately 300 lux, whereas circulation areas do not need that much of illumination (p.72).

13. Incandescent or tungsten halogen lamps are used in the office mainly as task or accent light. Also, they provide additional lighting in uplighters in the offices with either metal halide or high-pressure sodium discharge lamps. Besides, fluorescent lamps with high efficiency and good color rendering are being used excessively in the offices (p.75).

14. The finishes and the materials of the office should be chosen after the selection of the light source. It is necessary to make these decisions under the same light source at the correct intensity. Also, lamps with different color temperatures should not be used within the same room. Moreover, it is necessary to differentiate between the color appearance of lamps and their color rendering properties (p.77).

Psychological Lighting Requirements

1. Lighting of the office environment can enhance the visual meaning by affecting subjective spatial impressions like perceptual clarity, pleasantness, spaciousness, relaxation, and they are influenced by the three brightness parameters: brightness uniformity, position and intensity (p.81).

2. Spaciousness can be enhanced with a moderate amount of general ambient lighting and a greater amount of perimeter (wall) lighting (p.85).

3. It can be said that overhead downlighting with limited wall lighting in comparison to downlighting used alone can improve the impression of pleasantness (p.86).

4. Visual clarity is an important subjective impression for the offices. It can be reinforced by (1) uniform brightness, (2) more peripheral brightness, and (3) relatively high brightness (p.89).

5. Relaxation is an important concern for the committee and adjoining spaces. Low levels of ambient light together with the use of warm-toned light sources stimulate a relaxed environment (p.90).

7. CONCLUSION

Today's office designers are much more concerned with the quality of work placeand the humanization of work environment than they were in the past. Introduction of computers to the office environment brought about not only speed and ease of work but also some sort of obstacles such as visual and postural problems. In general the problems mentioned above, and in particular visual problems can cause a decrease in the performance and productivity of the office workers. Thus lighting is an important concern that should be dealt with according to the requirements of each task and activity performed in the office. The main areas in the office; namely, work areas, committee areas and adjoining areas each have their own lighting requirements. Thus, the designer of the office space should treat these areas separately and decide about the most suitable lighting system for each.

Methods of lighting are important, especially, in the open-plan automated offices, since they have continuous, unrestricted ceiling and walls. Thus, the treatment of the ceiling as well as the walls, becomes critical from the light sources' (natural and artificial) point of view. Another important consideration in lighting design for an automated office is that the required amount of illumination while using VDT is much less than it is while working on a paper. Sources of light within the visual field can create both direct and reflected glare which make working with VDT very difficult and should be prevented. As mentioned before, there are two general kinds of light sources: natural and artificial. Natural light sources should be treated in a way that they do not compete with luminance contrasts within their near surrounding, while providing good quality (glare free) illumination. The light provided from these sources (windows and skylights) can be controlled by changing the size and the treatment of the openings, by using the light control elements such as buffles, fins, blinds, etc. and by utilizing different types of glasses (low transmission and frit pattern glasses, etc.).

Artificial lighting is also very important in the automated open-plan offices. There are three major artificial lighting systems used in these environments, namely, these are direct, indirect and direct/indirect ones. In order to choose the best alternative for a particular office, these systems should be examined according to the geometrical relationship of the fixtures with the work surfaces. Besides, the luminance contrasts, the glare and reflections on the screen should also be taken in to the consideration. Moreover, the light distribution within the whole office environment needs great care. Another very important point which should not be neglected is that researches have pointed out that workers prefer to control the light in their own work spaces. To obtain this manual and electronic control equipment can be used on walls and ceilings.

It is obvious that light can not be thought of without considering texture and color. In the office spaces, these factors are used to create pleasant environments as well as to answer the functional needs. To reduce reflection, the usage of glossy and shinny surfaces should be avoided and matte surfaces and neutral colors preferred. Lighting design in an office should not only fulfill the functional requirements, but also should consider the psychological needs of the workers. Also, light is an important factor in determining the way people perceive the environment. By using different light patterns, different subjective impressions such as spaciousness, pleasantness, etc. can be obtained. All the points mentioned above are very important, and they should be considered carefully. I hope that the general criteria given in the seventh chapter could be helpfull as basis to interior designers who are dealing with the lighting design of the open-automated offices.

APPENDIX

A

Accommodation: The ability of the eye to bring into ' sharp focus' objects at varying distances from infinity down to the nearest point of distinct vision, called the 'near point'.

Alternating current: It flows in one direction, and reverses. The rate of change is called frequency and is measured in cycles-per-second, or Hertz. Alternating can be stepped up and down by transformers. It can be generated economically and transmitted over long distances.

Altitude angle: It is the angle between the solar ray and its horizontal projection. Altitude angles range from 0 degree at the horizon to 90 degree at the zenith

Ambient light: It is the background light level as distinct from light from a visible source.

Awning: A control element made of opaque or diffusing flexible material placed on the exterior of a pass-through component to protect it against the sun.

Azimuth angle: It is the angle between the solar ray and the south.

B

Baffle: A fixed single opaque or translucent element, which reflects or protects a pass-through component against direct solar radiation at certain angles, mat reflect daylight to the interior.

Ballast: A device used with an electric-discharge lamp to obtain the necessary circuit conditions for starting and operating.

Blind: An exterior or interior element composed of slatted screens placed over the whole of the window. The slats may be fixed or movable. This device can be moved along the opening, grown to the side, or rolled up to the top.

Biological needs for visual information: Not related with conscious activities, but rather related more fundamental aspects of human relation to the environment: orientation, defense, stimulation, sustenance, and survival.

Brightness: Attribute of visual sensation according to which an area appears to emit more or less light.

Bright characters on dark screen: Positive presentation of characters, positive contrast display.

Brightness ratios: Comparison of the measured surface brightnesses or luminances of any two objects in the visual field.

C

Cathode ray tube (CRT): An electronic vacuum tube in which an electron beam is generated and used to energize a phosphor screen which emits visible light.

Clerestory: A vertical plane of glass above the viewing pane, such as high daylighting windows in offices.

Cluster terminals: They are consists of one or terminals placed in a fixed position with in equal reach of two or four people. No one person has optimum access to such a terminal, but all are within seated arm's reach. Cluster use normally evolves when a person's time requirements for using the VDT are in the 10 to 15 percent range.

Color rendering: General expression for the effect of a light source on the color appearance of objects in conscious or subconscious comparison with their color appearance under a reference light source.

Color rendering index (R) : of a light source. Measure of the degree to which the phychophysical colors of objects illuminated by a source conform those of the same objects illuminated by a reference illuminant for specified conditions.

Color temperature: Temperature of the black body that emits radiation of the same chromaticity as the radiation considered. Unit: Kelvin, K. The Kelvin scale has a zero point at - 273 C.

Contrast: Used subjectively, it describes the difference in appearance of two parts of a visual field seen simultaneously or successively. The difference may be one of brightness, color or both. Used objectively, the term expresses the luminance difference ratio in numerical form.

Control element: Particular device specially designed to admit and /or control the entry of light through a pass-through component.

D

Dark characters on a bright screen: Negative presentation of characters, negative contrast display or simply reversed display.

Dimmer: A control that allows the amount light from a fixture to be reduced some percentage. On incandescent fixtures, this may be a simple rheostat that reduces voltage; on fixtures with ballasts, this may be quite complex.

Direct current (dc): Direct current flows in one direction only. It is used in some subways, in automobiles, and in emergency lighting systems.

Downlighter: Luminaire which emits the majority of its light output downwards.

Dull: Uninteresting

F

Fin: A control element placed on the exterior facade of a building and fixed vertically on the sides of the opening. It reflects and redirects natural light which falls laterally upon the fin to the inside.

Fluorescent lamp: Discharge lamp in which most of the light is emitted by a layer of fluorescent material excited by the ultraviolet radiation from the discharge. This term usually applied to low-pressure tubular florescent lamps.

G

Gloomy: A condition in which desirable and expected visual information is absent, producing a sense of depression or disappointment; not necessarily dark or dim.

H

Hue: Hue is the name of the color: red, blue, and so on

I

Illumination: Illumination is the measure of the light falling on a surface. The light may come from the sun, lamps in a room or any other bright source. The unit of measurement is the lux, defined as one lumen per square meter (lm/m^2).

K

Kelvin: see *color temperature*.

L

Light-shelf: A control element usually placed horizontally above the eye level in a vertical pass-through component. It protects the interior zones against direct solar radiation, obstructing and redirecting light to the interior ceiling.

Limiting Angle (shielding or cut-off angle): It refers to the maximum angle that the eye can be raised above the horizontal without seeing through the shielding system.

Louver: A series of baffles used to shield a source from view at certain angles or to absorb unwanted light. The baffles are usually arranged in a geometric pattern.

Low emissivity glass (Low-E): A glazing with a coating that has an emissivity of less than 0.20. Emissivity is a measure of surface's ability to emit long-wave radiation (room temperature radiant heat energy). Emissivity varies from 0 (no emitted infrared to 1 (100 % emitted infrared).

Luminaire: A complete lighting unit consisting of a lamp or lamps together with the parts designed to distribute the light, to position and protect the lamps and to connect the lamps to the power supply.

Luminance: Luminance is the measure of the brightness of a surface; the perception of brightness of a surface is proportional to its luminance. Luminance is therefore a measure of light coming from a surface. In the metric system lumianace is measured in units of candles per square meter (cd/m^2).

Luminance meter: An instrument for the measurement of luminance.

Luminous environment: Lighting considered in relation to its physiological and psychological effects.

Lux (lx): see *Illumination.*

M

Monitor roof: A raised section of a roof, including the ridge, with lateral openings on it.

O

Offending zone: an imaginary area that is seen by the task surface (if task area is excepted as an mirror) where the light sources are forbidden to put in order to eliminate reflections and glare.

Overhang: A control element which is part of the building itself protruding horizontally from the facade above a vertical pass-through component. It protects the zones close to the openings of the building, obstructing direct solar radiation which falls upon the overhang.

P

Perception: It is the process of interpreting sensations. Also, the sensory awareness of external objects, qualities, or relations.

Polarizing panel: It could be both linear or multilayer. The polarizing panel eliminates a part of the light that causes veiling reflections, but retains that portion of the light that is helpful, thus improving contrast on the task.

R

Reflectance: The fraction (usually expressed in as a percentage) of the incoming light energy that is bounced back from a surface.

Regional terminals: They are groups of terminals in one location which support large groups of mostly professional or technical people. A walking distance of 50 to 100 feet (approximately 15 to 30 m) from the workstation to the terminal area is common, as are frequent return trips. One community terminal can support 10 to 20 workers as long as each worker's tasks demand terminal use only about five percent of the time.

S

Satellite terminals: They are consists of terminals placed closer to where people do their work. The processing needs of four to six people may be satisfied by one terminal located just a few feet (approximately 1m) away from their workstations.

Side lighting: Fenestration that is on a vertical surface or the process of using vertical fenestration for daylighting.

Skylight: An opening situated in a horizontal or tilted roof.

Spectrum: A range of electromagnetic radiation usually referring to a portion of what is within the visible range.

Specular reflection: A reflection that retains the original image.

Stimulus: Anything which excites a sensory receptor, causing a response or sensation.

T

Task lighting: Placing luminaires in such a way as to throw most of their light output onto the task or area where the task is performed.

Transient adaptation: The eyes adapt themselves for optimum vision when moving from one luminance level to another by a photochemical reaction within the eye and by a chance in pupil size. This compound effect is termed transient adaptation, and takes a finite time for completion.

U

Uplighter: Luminaire which emits the majority of its light output upwards.

V

Visibility: The quality or state of being perceivable by the eye.

Visual Display Terminal (VDT): Terminal of a computer or self contained system, consisting of a keyboard for input and a display screen.

Visual Display Unit (VDU): As VDT (above).

Visual Task: Conventionally designates those details and objects that must be seen for the performance of a given activity, and includes the immediate background of the details or objects.

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