ENERGY EFFICIENT LIGHTING

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Abstract: The demand for electrical energy for lighting is bound to reach staggering proportions in the years to come. This would certainly be a hard punch for the developing nations with limited resources. In such a situation it is depressing to see so much electrical energy is also being utilized even for lighting during the day, when there is so much bright sunshine. It is against this backdrop that an attempt is being made to kindle a more frugal attitude towards energy. This article therefore aims at shedding light on the practice of 'Energy Efficient Lighting' through an understanding of the science of light and lighting.

INTRODUCTION

Energy is sometimes referred to as the wasted resource.

The oil crisis of the 1970's saw the birth of a new attitude towards energy; one that developed a global concern about the need for its conservation and efficient use. With an inevitable shift towards an energy related life style and an ever increasing population, there would be a growing demand for more and more energy. Escalating energy cost, dwindling resources and the high cost of development of new resources could seriously aggravate the situation.

Every conceivable effort should therefore be made to effectively implement efficient energy management, without allowing it to rise to the pinnacles of fashion and depths of disregard.

Lighting is one of the applications for which energy is utilised. It is a sizable amount which is rapidly increasing with increasing rural electrification, population, establishment of large commercial and industrial enterprises and the improvements in social standards of the people.

A paper approved by the Editorial Committee of the Sri Lanka Energy Managers Association for publication in the SLEMA Journal.
Paper No. J38804.

It is said that the illuminance levels adopted in a country are directly related to its social standards. This situation is evident in developed countries where the recommended levels of illuminances are higher than those of the lesser developed countries. The proof of this is seen in Sri Lanka, where the preferred brightness levels of domestic lighting in urban areas are higher than those of the rural areas. Therefore we could expect a tremendous increase in demand for energy for lighting in the years to come.

Oil, gas, electricity and solar radiation are some of the sources of energy available for lighting, of which electricity and solar radiation would be the aspects to be dealt within the scope of this article.

Solar radiation is a naturally and freely available source of energy which could be directly applied to interior lighting without the need for any equipment for conversion. The term solar radiation would in this context mean the visible light form the sun, either as sun light or sky light (day light). Countries such as Sri Lanka are blessed with an abundance of bright sunny days all throughout the year which will enable the use of light from the sun for interior lighting during the day.

A lack of awareness of facts concerning light and lighting appear to be the principal cause for the inefficient utilization of energy. A clear understanding of the relevant aspects of the science of light, the methods relating to its application, the science of natural light, the characteristics of lighting hardware are essential for good lighting practice.

VISION AND COLOUR

Vision

The presence of light is necessary for the process of seeing to take place. The capacity to see clearly depends on the amount of light, contrast offered and the age of the person. When the amount of light is considerably low it would be insufficient to bring about an adequate physiological stimulus for satisfactory vision. Also an excessive amount of light, would give rise to glare, impairing vision substantially.

The terms contrast means, the difference in brightness or colour. The magnitude of difference determines the degree of clarity of vision. If the contrast is great the amount of illuminance needed is less and if the contrast is less, then there is the necessity for more illuminance. There is great contrast in a task involving the separation of black and white objects. This is an instance of contrasts in colour as well.

Age has its effect on vision. There is a general impairment of vision beyond the age of 40 years and such people need more light to see clearly. Children need less light to see clearly than adults. This efficient visual performance of young people could be taken into consideration in the lighting design of interiors exclusively used by them with much saving in energy.

Places of work where the majority are in the older age group or public places such as Post Offices and Banks which are patronised mostly by elderly people, the level of illuminance should be relatively higher.

Having briefly looked into the factors affecting the process of seeing, it would also be useful to study some of the characteristics of light relevant to the subject of lighting.

Colour

Colour is an important characteristic of light in the study of its application in lighting. It is one of the important attributes to the creation of a good visual environment. It is determined by the colour qualities of lamps as well as the colours of many surfaces within an interior.

Visible light is generally composed of a mixture of light of many colours. eg.: Day light, light of electric lamps and oil lamps. There are also light sources which produce light of one colour only. eg. Low Pressure sodium vapour lamps.

Good quality white light has the colours Violet, Indigo, Blue, Green, Yellow, Orange and Red, mixed in a fairly balanced proportion. eg. day light, light of certain fluorescent lamps and incandescent lamps. In the absence, increase or decrease in one or more colours in the mixture, the resultant colour is of poor quality. eg. light of high pressure mercury vapour lamps, high pressure sodium vapour lamps and metal halide lamps. The light of the low pressure sodium lamp has only one colour and therefore the quality of light is extremely poor.

The terms "Colour Appearance" and "Colour Rendering" are commonly used to describe colour qualities of lamps. The term colour appearance is applied to describe, the COOL, WARM, or the INTERMEDIATE apparent quality of a light.

If the light from a lamp is bluish, it is referred to as "Cool" in appearance - eg. High efficiency Fluorescent lamps. If the light is white, it is then termed "Intermediate" in appearance eg. Metal halide lamps. If the light is reddish white it is then termed "Warm" in appearance eg. Incandescent lamps. It is therefore the degree to which the blue and red colours are present in the mixture of light that determines its colour appearance.

All light sources are categorised under three groups of colour appearances - COOL, INTERMEDIATE, WARM.

Colour appearance is no indication of the colour rendering ability of a light. It is only an apparent quality which indicates a coolness or warmness of light. Light sources with cool or warm appearance could also provide a degree of physical coolness or warmness to an interior.

Colour rendering property of a light is attributed to its ability to reveal the true colours of an object illuminated by it. Light with good spectral characteristic, such as day light from a clear blue sky, is an example of such a light.

Colour of a surface is not an inherent property. If there is no light, then colour does not exist. What is characteristic of a surface is its differential reflecting property. Light falling on a surface, depending on its colour composition, would undergo a selective process of absorbing certain colours and reflecting the others, which imparts the colour to the surface and is described by the appearances of the reflected light reaching the eye. The incident light has lost certain colours that are absorbed and the surface now acts as a secondary source emitting the balance colours.

Eg. A surface painted yellow will reflect 70% yellow light, 50% red and green and 10% blue and the surface will appear dark yellow. If the incident light is rich in red the surface will then appear more orange.

The colour of a surface therefore depends on the composition as well as the concentration of each colour in the incident light.

Almost 80% of light of any colour falling on a truly white surface will be reflected. The white surface will then take the appearance of the colour of incident light which is reflected. The amount of light reflected from a surface will contribute to the brightness of the surface. Therefore, the brightness of an interior will depend on the reflecting properties of its surface. Dark surfaces will absorb most of the light falling on them and the interior will look dull and gloomy. Reflectivity of furniture and furnishings too contribute to the brightness of an interior. Pastel shades of emulsified colours have a property of diffusing reflecting light falling on them greatly enhancing the brightness of an interior. Considerable saving is achieved on the requirement of energy for lighting by this method. Wood, granite (dark) are dark surfaces which absorb a considerable amount of light of what ever colour falling on them.

Light of any colour falling on a matt black surface will be completely absorbed and the surface will continue to appear black.

Light has other properties such as refraction, diffusion and glare, relevant to the subject of lighting.

REFRACTION, DIFFUSION AND GLARE

Refraction

Light has a characteristic of deviating from its normal path when going from one medium to another such as from air to glass or to plastic and this property is made use of in controlling the direction of flow of light from lamps. Application of this characteristic in day lighting will be dealt later in this paper.

Diffusion

Diffusion is a process of scattering light either by reflection off a surface or as a result of passage through a translucent medium. Non-specular surfaces such as walls finished in emulsion paints are diffuse reflecting. Diffusion occurs also due to transmission through opal, or frosted glass or opalescent plastic. In diffuse transmission, considerable light is lost due to absorption in the medium. This factor must be considered in the selection of materials for light diffusion.

Glare

Glare is an important characteristic in lighting. It could be described as an embarrassing experience when naked or bright sources of light, such as the view of sky through a window, comes within the field of vision. The magnitude of this is reduced if the difference with the ambient level of illuminance is less. Reflection of light off specular surfaces could also contribute to glare. Glare appears in two forms - as disability glare, which completely impairs vision and discomfort glare - which is an expression of discomfort. Discomfort glare is mostly the result of bad interior lighting design.

Distressing effects of discomfort glare is generally felt by older people and even young people engaged in exacting work such as fine drawing, intricate assembly work, computer operation etc., manifested in the form of visual fatigue and headache at the end of a day's work.

Glare could considerably reduce the efficiency of a lighting scheme produced at much energy cost.

Incorrect seating arrangements and the positioning of equipment within an interior also contribute greatly towards discomfort glare, with lowered efficiency and risk to vision.

MEASUREMENT OF LIGHT

Light is a measurable entity. The amount of light given out from a lamp is measured in lumens. The amount of light falling on a surface is measured in lux(01 lux = 01 lm/m^2).

The amount of light given out from a lamp for a unit of electrical energy supplied to it is referred to as the efficacy or the energy efficiency of the lamp. The maximum degree to which these lumens of light can be effectively utilised is the aspect dealing with efficient application.

NATURAL LIGHTING

Depressingly, much energy is being utilised for day-time interior lighting of most of the multi-storied public buildings accommodating offices, Banks, Educational Institutes, Health care institutes as well as industrial establishments; when natural lighting alone could provide either the total requirement of light during the day or, in a worse situation, be supplemented with only a minimum contribution from artificial lighting. Domestic buildings that consume some electricity for lighting during the day are mostly those that are in crowded locations and certain areas of multi-storied apartments.

The necessity for supplementary artificial lighting should arise only on an overcast day or in a few areas in a building where the building geometry does not permit natural light penetration. Sri Lanka is blessed with an abundant supply of natural light throughout the year with nearly 50% of the day with bright sunshine. This is an enormous amount of energy available for lighting at no cost, except for the cost of providing suitable openings and devices in buildings.

Buildings as well as environments have changed so much and become so complex due to limitations in land availability, site restrictions, the need to build for mass employment, education, living etc. Multi-storied buildings and sometimes a maze of them in one restricted location are a common feature in urban areas. Providing natural lighting to these buildings would be a great step towards a reduction in the use of energy for artificial lighting during the day.

Planning for natural lighting should start at the design stage of a building and should take into consideration all available information regarding illumination, climate and the sun paths, as well as the effective application methods. Attempts should be made to give way to new techniques, replacing the out-moded methods.

It would be useful to know some facts about natural light before proceeding to discuss the methods of its application.

Sun is the primary source of natural light. It's visible radiation is sun light. This sun light diffused in the sky is referred to as sky light and it is the effective source of day light. Therefore, sunlight and day light are distinctly different entities and they are considered separately in natural lighting design.

The nature in which sun light is diffused in the sky gives rise to different brightness patterns in the skies over different parts of the earth. The sky brightness is the condition that determines the degree of illuminance due to day light. The sky over Sri Lanka has a sky brightness pattern, where the brightness of the sky opposite the sun is a maximum and uniform up to 15 degrees from horizon, gradually decreasing to a minimum at the zenith.

Colombo is positioned on the 7 degree latitude North of Equator. When the sun is furthermost in the Northern-hemisphere and over the tropic of Cancer, it is 16 degrees North of Colombo. When the sun is furthermost in the Southern-hemisphere and over the Tropic of Capricorn it is 30 degree South of Colombo. Therefore, Sun's rays reach Colombo at 16 degree North and 30 degree South.

Point Pedro and Dondra Head are approximately 3 degree North and South of Colombo.

The prediction of such light is therefore

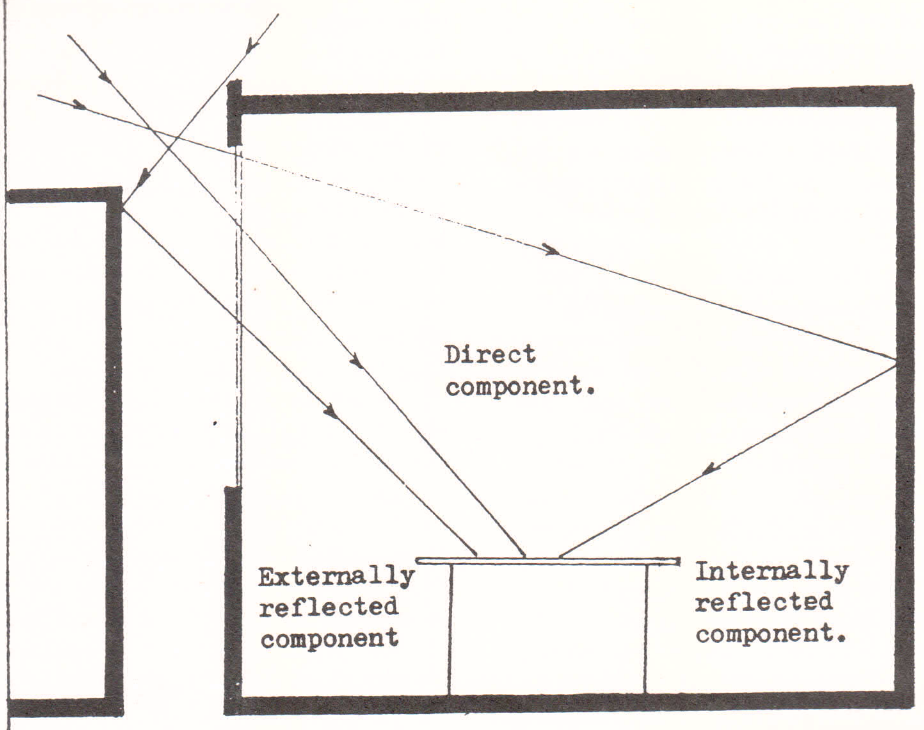


Fig. 1 Components of daylight.

a simple geometrical exercise. This data is useful in preventing glare due to direct sun light and also in an exercise to be discussed later.

In the tropics, sun light is generally regarded as undesirable for the heat and the glare it would bring with it. These aspects are now disregarded and sun light is receiving considerable attention as an extremely useful source of energy for interior lighting. Much of the light we receive in an interior in Sri Lanka is from ground reflected sunlight, unless there are positive external obstructions. Many of us are not aware of this fact. We little realise the difference there is before and after the front lawn came into being.

Illuminance in an interior due to day light is composed of three components -- the sky component, externally reflected component and the internally reflected component. The sky component is what we receive directly from the sky. The externally reflected component comes after reflection off an external surface such as an adjacent building. The internally reflected component is light reflected off internal surfaces see figure 1).

Conventional systems of providing day light into an interior is through side openings referred to as windows. They also serve the useful purpose of providing contact with the outside for psychological benefits. The size, position and orientation of the openings should be considered in relation to the functional requirements of the interior and to provide maximum day light illuminance at the furthest point from the openings, with the least amount of glare from a visible sky and radiant heat from the sun.

Requirements appear to be rather conflicting, but a compromise can be arrived through a good design approach, based on experience and intuition rather than formal analysis, since adequate data on the illuminance climate of Sri Lanka is not available. North - South orientation of windows is the most accepted practice in Sri Lanka, providing maximum illuminance and protection from the direct rays of the morning and afternoon sun. Difficulties arise in urban building planning due to site restrictions. In such a situation, a rational approach based on experience and intuition is again recommended. Sometimes day light and sun light reflected off a nearby building could very satisfactorily be made to penetrate into a room through an unconventionally placed window. Windows should wherever possible be located on more than one wall of a room, to increase illuminance and to prevent the unidirectional quality of light that would give rise to undesirable modeling effects.

Since the brightest area of the sky vault is near the horizon, the direction of maximum intensity day light reaching the window, specially in multi-storied buildings, is at an acute angle to the vertical plain of the window. This fact has an important bearing on the size and shape of the window. When taking into consideration the ground reflected light and the manner in which sky light reaches the window a tall window, reaching up to the ceiling would be more effective than a short window.

As regard shape, rectilinear shapes are more preferable in terms of efficiency.

Primarily the sizes and shapes of windows are related to the size, shape and functional requirement of the interior. Sizes of windows should be optimum, not falling below 20% of wall area, a factor which determines the satisfaction of the user.

If the window could occupy the entire wall length, a number of windows with reasonable separations would be more desirable than one single window to reduce the effect of glare.

The proper seating arrangements with windows to left and right of the occupants is a very practical way of preventing the view of the glare causing sky. The seating arrangement could also provide for day light corridors for more effective penetration of light (see figure 2)

In addition to the conventional methods of admitting light through side openings, there is a practice of roof lighting mostly in the case of large factories, where large floor dimensions make side entry of day light

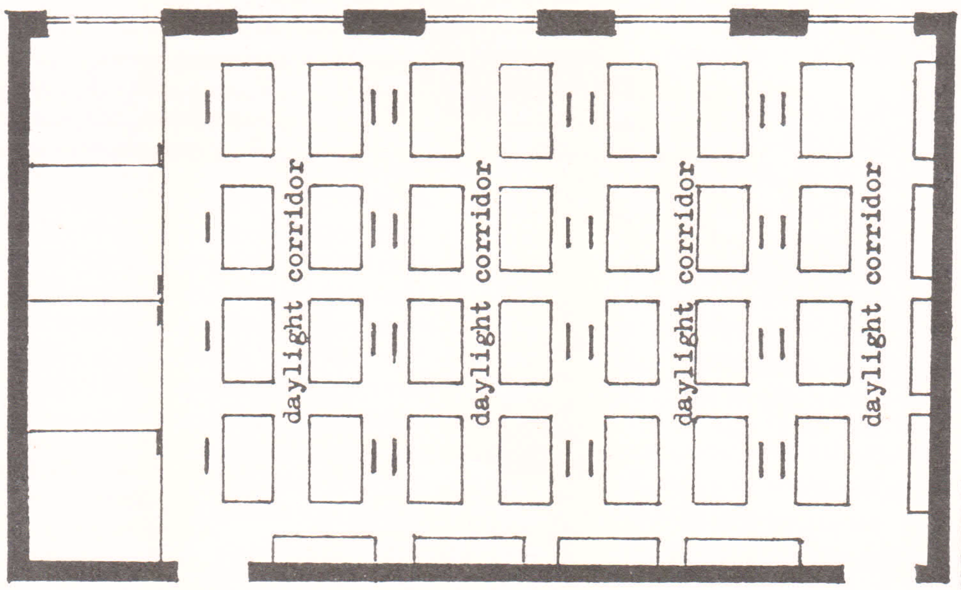


Fig.2 A daylight efficient interior layout design.

ineffective. Light entry should be through a series of well spaced, diffusing roofing materials to provide a uniform illuminance level and also to prevent the disturbing effect of direct sun light.

Sky lights have been very interestingly and effectively employed in some of the dwelling houses in Colombo. In one instance, a sky light has been installed over a stairwell, bringing in plenty of day light and sun light down the stairs into the centre of the building. The stairwell is beautifully illuminated through out the day and the spill over light contributes greatly to the illuminance in the adjoining areas. The designer seems to delighted in the streak of sun light which is constantly moving with the sun. However, if any one considers it a disturbance, a diffusing dome would be the answer.

Window glazing is normally done with clear glass of about 87 - 90% transmittance for light and about 83% for solar radiant heat.

Extensive use of glazing on buildings using many different types of tinted and solar control glasses seem to be gaining popularity in Sri Lanka. It would be interesting to study the merits of this approach.

Consider for example two identical situations A & B where the same level of illuminance is to be achieved using clear glass of 87% light transmittance and 83% solar heat transmittance in situation "A" and tinted glass of 41% light transmittance and 60% solar heat transmittance in situation "B". Situation "B" would require 112% more glass than situation A to achieve the same level of illuminance and this would contribute to an additional 44% heat to situation B.

Looking at these figures one wonders whether much benefits could be achieved through extensive glazing with various types of tinted and solar control glass. Extensive use of glazing in a tropical country such as Sri Lanka will generate an immense amount of heat within a building, which would be an additional load on air-conditioning required to make the interior habitable. Moreover on a bright sunny day light would enter from all over causing excessive glare; curtaining would be the remedy but with the inevitable need to use artificial light again, and we are back in square one, with an additional load on air-conditioning.

Therefore the most advisable approach would be to use good quality clear glass in optimum size windows, with good orientation and in relation to the functional requirements of the interior.

INTERIOR FINISHES

Finishes of internal surfaces such as walls, ceilings and floors and even the furniture and furnishing contribute positively to the effective utilisation of light. Once day light or reflected sun light is made to enter a space within a building, it should meet surfaces that do not absorb them but reflect them. For this purpose the hue of the surfaces should be either white or pastel shades of desirable colours. Reflectances should be high that light entering the space would undergo multiple reflections before it is finally lost through absorption. Shiny and glossy surfaces, though possessing better reflecting properties, would tend to give rise to veiling reflections causing glare. As such diffuse reflecting surfaces are most suitable.

In apartment type dwelling houses, in multi-storied buildings and even in single or two storied houses in cramped urban locations, a problem frequently encountered is the inadequacy of day light in certain areas of the house. It has quite often been observed that the situation is created by the use of dark colours specially on walls and the dark furniture and furnishing. This situation is sometimes further aggravated by extreme untidiness of the interior. Even the little day light that trickles into such a room is immediately absorbed giving it a dull and gloomy appearance. A little extra attention to day light at the design stage and some education on correct interior decoration and maintenance could save considerably on the use of artificial lighting.

Multi-storied buildings with reduced ceiling to floor height and with deep plan interiors have the difficulty of obtaining adequate day light into areas furthest from the window. In situations of this nature, it has always been found that improving the reflectivity of the ceiling, walls and floor help to improve the quality of day light within the space. Successful application of this theory can be seen in a bank building in the city of Colombo. In this particular building even the window glazings have been correctly inclined to allow more reflected sun light to effectively enter the building.

Having provided for adequate day light and reflected sun light penetration, the benefit of the entire exercise is completely nullified by partitioning the entire area into a number of cubicles, with opaque materials or sometimes arranging a series of cubicles along the window wall area. This may help to give the occupants the benefit of a grand stand view of the outside scenery, but the day light and the sun light would stop in the first cubicle itself and the rest of the area once again becomes totally dependent on artificial lighting even on the sunniest day.

This situation can be avoided by siting the cubicles along the windowless wall area and also arranging the tall obstructing objects such as filling cabinets and cupboards well away from windows. A planned seating arrangement, with day light corridors would also assist in the day lighting design (see figure 2)

ARTIFICIAL LIGHTING

Artificial lighting is indispensable from dusk to dawn and sometimes even during the day, for all indoor and outdoor lighting applications. Ill-designed lighting installations consume large amounts of electrical energy, making them wasteful exercises, while serving no useful purpose. It would therefore be worthwhile looking into the various aspects that are relevant to the use of electricity to produce light as well as the techniques concerning application.

Electric lamps are devices that convert electrical energy to light. The amount of light generated per watt of electrical energy put into a lamp goes to describe its efficiency. Since Thomas Alvaa Edison invented the incandescent lamp in 1879, with an efficiency of 3 lm/Watt, there had been large strides in the direction of development, and now we have various types of electric lamps with efficiencies as high as 175 lm/Watt. Developments are continuing and there would certainly be exciting news every now and then.

It would be useful to know the different types of lamps available, and their important characteristics, such as luminous efficacies, life expectancies and the colour rendering properties.

There are two categories of electric lamps.

a) Filament or the incandescent lamps
b) Discharge lamps

All lamps classified under these two Principal categories are shown in figure 3

Electrical energy supplied to an incandescent lamp is converted to light and heat. In the case of discharge lamps, a certain component of the energy is inevitably lost in the control gear, as heat and the rest is converted to light. In well constructed control gear energy losses are kept to a minimum.

Incandescent lamps are less efficient, than Discharge lamps. Amongst discharge lamps too there are the more efficient and the less efficient ones.

Colour rendering property is also an important characteristic of a lamp. Incandescent lamps have excellent colour rendering properties, though warm in appearance.

There are lamps with all degrees of colour rendering properties, among the many different type of discharge lamps.

The important requirement in an energy and cost effective lighting design is to provide lighting without reducing standards. In order to achieve this objective there are a few basic rules to follow.

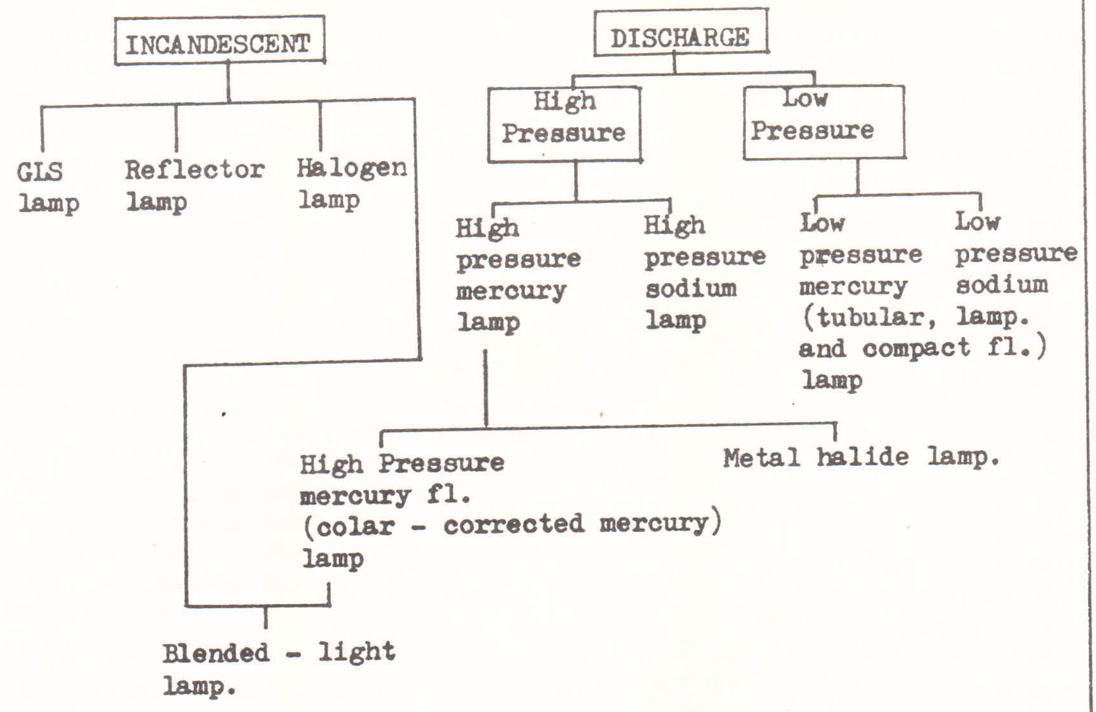


Fig.3 General classification of electric lamps.

LAMP - LIFE & EFFICACY

LAMP	EFFICACY	LIFE HRS
Incandescent (Tungsten)	8-I8 lm/W	I000-2000
Halogen (Tungsten)	I8-24	2000-4000
Tubular Fluorescent	37-90	5000-I0000
High Pressure Mercury Vapour	36-54	5000-I0000
Metal Halide	66-84	5000-I0000
High Pressure Sodium	67-I2I	6000-I2000
Low Pressure Sodium	I0I-I75	6000-I2000
High Pressure Sodium (Built-in Ign)	I05-I50	24,000 hrs.

LIGHT OUT PUT OF COMMENLY USED INCANDESCENT & FLUORESCENT LAMPS

TUNGSTEN FILAMENT LAMPS		26mm LINEAR FLUORESCENT LAMPS	
WATTAGE	LUMENS	WATTAGE	LUMENS
25	230	I8	II50
40	430	36	3000
60	730	58	4800

COMPARATIVE DATA - INCANDESCENT / NEW COMPACT FLUORESCENT

INCANDESCENT		NEW COMPACT FLUORESCENT
WATTAGE	LUMENS	WATTAGE
25	250	5
40	400	7
60	600	9
70	900	II

Fig.4 A comparison of representative lamp types.

1. Choice of most efficient light sources.
2. Choice of "Well designed" lighting fittings.
3. Well designed, energy efficient lighting designs.
4. Maintenance of equipment in good order.
5. Controlled switching systems.
6. Correct interior decor.

A comparison of representative lamp types is shown in figure 4.

A comparison of the energy dissipation from incandescent and fluorescent lamps is also useful when deciding on a lamp for some specific situations.

	100W Energy	
	Fluorescent	Incandescent
Convected and Conducted heat	60%	30%
Radiant Heat	25%	60%
Light	15%	10%

From the above information it can be seen that 60% of the energy supplied to an incandescent lamp is converted to radiant heat, which is what makes an interior physically warm. For this reason, they are extremely unsuitable light sources, where heat is a problem, especially when incorporated in table and bed-head lamp fittings. However, certain technical features incorporated in the luminaire can reduce this undesirable quality to some degree.

CHOICE OF MOST EFFICIENT LIGHT SOURCES

The light source must firstly be appropriate to the situation. This aspect is determined by its colour rendering and colour appearance properties. The efficiency should be the next consideration. A highly efficient low pressure sodium vapour lamp would be a glaring misfit in domestic interior lighting. However, it would be most appropriate for lighting a storage yard or a work site for security purposes, where colour rendering is of no significance.

If a choice is to be made between Incandescent lamps and fluorescent lamps to light a small office, fluorescent should be the obvious choice, because of high efficiency.

Even in a domestic situation, such as a bedroom, fluorescent lamps of 4000 degrees K colour temperature is an ideal substitute for the incandescent lamp at a very much lesser energy consumption and providing a comfortable feeling on a warm day, when one would have been sweltering under the heat of an incandescent lamp.

So, obviously there are energy efficient lamps for every situation. However, other relevant requirements should also be considered for best results.

CHOICE OF "WELL DESIGNED" LIGHTING FITTINGS

A naked lamp hanging in the centre of a room emits light in all directions. If one were to read under this light, he would receive on his reading matter only a fraction of the direct light and some light reflected from the walls, the ceiling, the furniture and furnishings, if those surfaces are conducive to reflection. Therefore, even if the lamp had been efficient, it's light had been abused. The nett lighting concept could be described as bad. The important factor is that the light output from a lamp should be controlled and directed towards where it is needed. For this purpose, the lamp should be included in a Luminaire or a Lighting Fitting, the basic requirements of which are,

(a) The mechanical, electrical and thermal considerations, i.e., sturdy and durable construction, good electrical properties and good ventilation for heat dissipation.

(b) The photometric qualities, i.e. control of direction of distribution of light, and brightness.

Well designed luminaires contribute to energy saving in many ways.

(a) Maximum use is made of the light output of lamps, by being correctly controlled. This helps to minimise the number of Luminaires necessary for an installation.

(b) The light distribution diagrams of

Luminaires help to ascertain the optimum number necessary for an installation.

(c) Use of good electrical materials reduce the energy losses in the electrical circuit, and operate at peak efficiency for a maximum period of time.

(d) Proper ventilation increases the efficiency of fluorescent lamps and prolongs its life and that of control gear.

The choice of a well designed Luminaire should be relevant to the need. Any well designed luminaire will not suit any situation.

ENERGY EFFICIENT LIGHTING DESIGNS

In a well planned lighting design equal importance is attached to the task lighting level, the visual environment, the space details, the occupancy pattern and the lighting fittings:

The three types of lighting systems commonly practiced are,

a) General lighting
b) Localized lighting
c) Local and General lighting

General Lighting

General lighting, is creating an average overall illuminance in the entire working area. Large offices, heavy industrial buildings, packing and storage areas are some of the instances where this system is applied. Since the work involved is not exacting and demanding high visual attention, such a system is practical. The use of a few energy efficient lamps such as high pressure Sodium Vapour lamps or Metal Halide lamps in high bay type luminaires, in place of a whole lot of fluorescent luminaires, in a large industrial building would make a considerable difference in energy requirement. In small offices, where there would be no full occupancy throughout the day, general lighting would not be justifiable. Instead, the system described hereafter would be more desirable in terms of energy consumption. In most of the domestic situations too, general lighting appears to be the rule, rather than the exception, with much demand on energy. Here again the following approach is recommended.

Localized Lighting

In localized lighting, light is provided only at the task and either the spill over light or a very few general lights contribute to ambient lighting.

There are many situations in domestic and public buildings, where a considerable saving in energy can be achieved by designing for localized lighting.

For instance, figure 5 shows a typical situation in an average Sri Lankan home. The required illuminance for studying is obtained from a pendent light in the centre of the room. In a situation such as this, the lamp would also have to be sufficiently powerful to provide at least minimum light to meet minimum visual requirement. It is found, that the approximate illuminance in such a situation is about 30 lux from a 100W lamp, which is about 8 ft away. A 40W lamp in a table lamp fixture (as in figure 6) 18 inches away would provide 200 lux, with a 60% reduction in energy and a 560% increase in illuminance. The situation would be dramatically improved by using a 9W compact fluorescent lamp, which would provide 200 lux illuminance. This is a 91% saving in energy and almost a 600% increase in illuminance. In both situations the "Spill over" light is more than adequate for normal activities in the room.

Figure 7 is another typical domestic situation. Bed-head lighting with a 9W compact fluorescent lamp, would provide 200 lux illuminance on reading matter and 20 lux ambient lighting. Similar energy efficient lighting systems can be introduced to practically every domestic situation.

In small and medium offices as in figure 8 where full occupancy is rarely or never the pattern, individual desk lamps would be more energy efficient than an overall General Lighting system, with a few ceiling lights to provide the ambient lighting. Reference libraries and public reading rooms are specific instance where localized lighting can

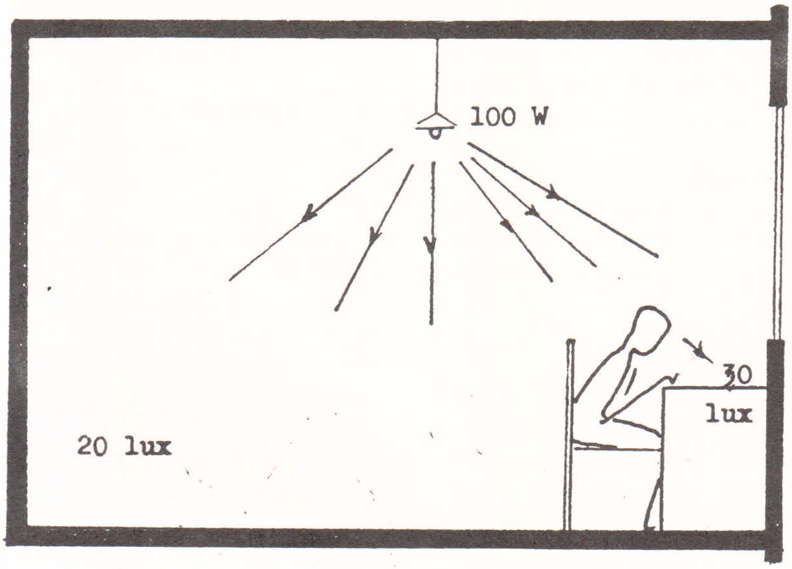


Fig.5 Inefficient general and task lighting.

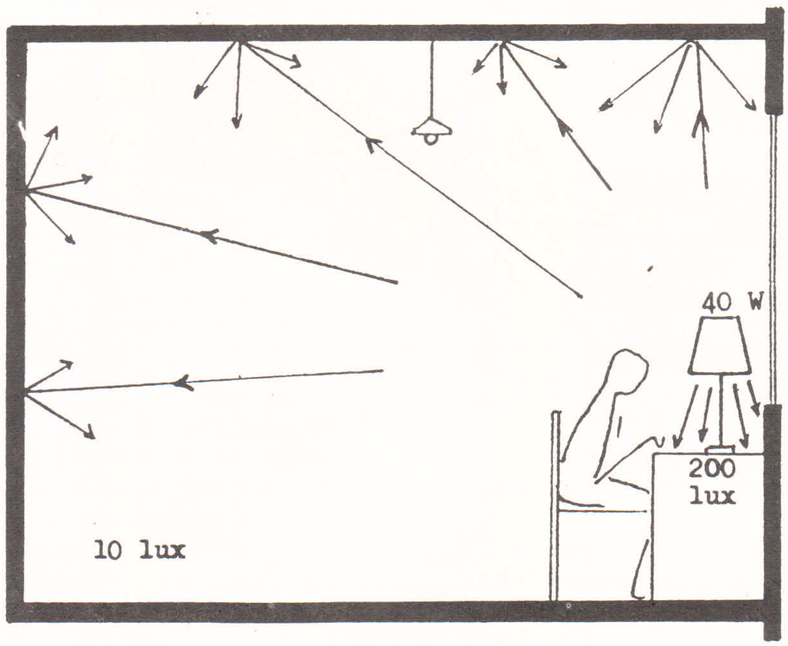


Fig.6 Adequate general lighting from efficient task lighting.

be effectively applied.

It is absolutely wasteful of energy to design for General Lighting of a reference library, where the average occupancy is only about 25 - 30% at any normal time. Individually controlled lights; for example one 40W fluorescent lamp for 4 people, fitted to the desk would be the ideal.

It must be remembered, that distance is very effective in lighting. The amount of light received from a lamp would vary as the inverse of the square of the distance. For e.g. a 60W reflector lamp will provide illuminances of 750 lux, 330 lux and 190 lux at distances 1m, 1.5m and 2m away. The reduction in illuminance for the first 1/2m would be 56% and for the second 1/2m 42% and

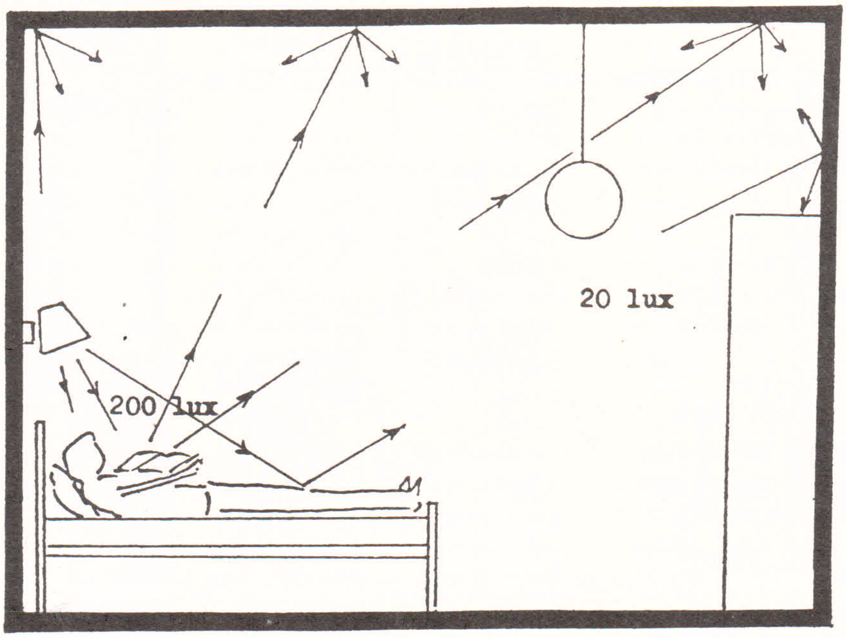


Fig. 7 Ambient lighting from localised bedhead lighting.

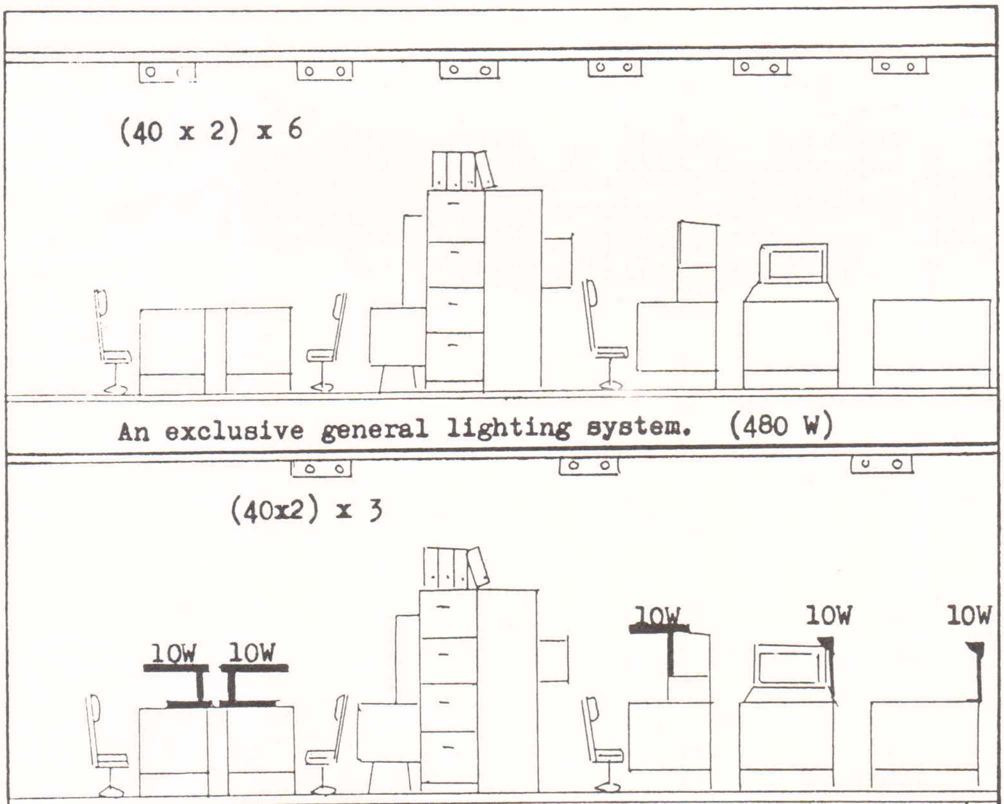


Fig.8 Combined localised and general lighting system. (290 W)

the difference between the first and third is 74%. This alarming decrease in illuminance with distance can only be overcome, either by increasing the lamp wattage or by bringing the lamp closer to the task. The second option would naturally be the most sensible.

Therefore, there is no better alternative to localized lighting, when the demand is for more light for less energy.

Incandescent lamps would be generally unsuitable as they emit a lot of radiant heat. Warm fluorescent lamps, specially the compact series, would be ideal for domestic application. Conventional fluorescent lamps are acceptable for use in localized lighting in offices and other public places.

MAINTENANCE OF EQUIPMENT

Dust and dirt on lamps, reflecting surfaces, and diffusers of Luminaires, reduce the level of lighting considerably. Cleanliness of room surfaces too contribute greatly to the efficiency of a lighting installation. Periodical cleaning is therefore essential. In domestic interiors, tidiness is an important factor affecting effectiveness in lighting.

CONTROLLED SWITCHING SYSTEMS

Manual dimming using electronic dimmers is recommended for domestic interiors such as living rooms and bedrooms. This helps to create the desired mood and also to reduce consumption of energy. However, the colour of incandescent light tends to be unpleasantly affected with dimming.

Use of photoelectric devices to control street and security lighting is desirable, to reduce the incidence of lamps that continue to light even during the day through negligence. The cost and the durability of the equipment should justify their use.

INTERIOR DECOR

Colours of interior surface, and those of furniture and furnishing affect the effectiveness of lighting. Light colours enhance the brightness of interiors even with less light. Dark colours absorb light making interiors gloomy. Light colours therefore, increase the efficiency of the lighting installation. It is also important that the colour appearances of light sources should blend with surface hue. For instance warm lighting would match lighter shades of red and yellow and cool lighting will blend with shades of blue and green. Intermediate lighting will generally blend with shades of all colours.

This should however not be confused with colour rendering which was explained earlier. Other aspects relating to surface colours were discussed previously.

ILLUMINANCE LEVELS

In most of the advanced countries in the world there are recommended levels of illuminances for practically every situation. These illuminance levels have been fixed on what they say is current good practice and they are subject to variation and they are neither minima or maxima. These values are also associated closely with the social standards of the particular country. Where the social standards are high the levels are also relatively high. The primary expectations of a right level of illuminance are that it is adequate to perform the task safely, efficiently and with a sense of well being.

In the light of the foregoing information, would it be necessary to adopt levels of illuminances of advance countries? Should we not operate at lower levels of illuminance in keeping with our levels of Visual efficiency and social standards? Higher levels would mean more light and more energy.

MISCONCEPTIONS REGARDING USE OF FLUORESCENT LIGHT

There are two principal misconceptions regarding the use of fluorescent lighting.

a) Aesthetic unacceptability for domestic lighting
b) Physiological ill effects of fluorescent light.

There is a school of thought that light from a fluorescent lamp is cold, flat, featureless and imparts a commercial appearance and therefore unacceptable for domestic lighting. These are no doubt very correct assessments, but not with regard to all fluorescent lamps. Fluorescent lamps with warm colour appearance, as good as those of incandescent, have been in the market for many years. The commercial appearance too was related to it being mentally associated with cold white light, which too has now been overcome.

The flatness and the featurelessness of the light is associated primarily with the size of the source and the copious amount of diffused light generated by it. The newly developed compact fluorescent lamps, which are even smaller in size than the incandescent lamps, can be more effectively incorporated in luminaires. These lamps offer limitless design possibilities. The conventional fluorescent lamps have also been incorporated in luminaires, designed for domestic application, with aesthetically excellent results.

The ill effects of optical radiation are mostly from ultra violet radiation. Over exposure to strong doses tend to affect skin and eye tissues.

The UV component in solar radiation is stronger than what is in fluorescent light. Therefore the UV component in fluorescent light is not harmful, if used in conventional ways. Also acrylic diffusers and protectors of luminaires tend to filter certain components of UV making it further safe. It is also safer to rely on fluorescent lamps of good quality, conforming to an accepted standards certification.

Headache and eye strain, frequently blamed on fluorescent lighting appear to be more from glare, visual disturbances and fatigue due to bad lighting design. Physiological ill effects of fluorescent light, therefore appears to be a more imaginary hazard than real.

INNOVATIVE NATURAL LIGHTING

This method of interior lighting is somewhat of a recent development, with great potential and merit. It is also sometimes referred to as Innovative sunlighting.

Sunlight was originally considered undesirable to be associated with interior lighting, in the tropics. However, the great potential in sunlighting for interior lighting was realized, when it was found that directing sunlight into a building using various optical devices was far more efficient and easier than directing daylight. Sunlight is more strong in intensity and more directional in quality in contrast to daylight, which is low intensity diffused light that is difficult to concentrate into a strong beam.

The luminous efficacy of sunlight is over 100lm/watt, compared to fluorescent and incandescent lamps which have luminous efficacies of about 60lm/watt and 18 lm/watt respectively.

The choice of innovative sunlighting becomes appropriate when application of daylight for interior lighting becomes ineffective in situations such as:

a) In deep plan offices, when areas beyond a few meters appear to be gloomy.
b) Where there is effective external obstruction that reduces or prevents the entry of daylight.
c) When spaces are geometrically intricate to provide adequate daylight illuminance with conventional windows or other methods.
d) When much sunlight is available.

There are many approaches to the application of sunlight for interior lighting. Some of these are briefly explained in the following section.

LIGHT PIPE SYSTEM

Where an external Heliostat which tracks and collects the sunlight and, after concentrating using a system of lenses and mirrors, directs through either pipes, optical fibres or acrylic rods to wherever the light is needed. This system involves high cost and precise optical alignment when installing, as well as controlling the high temperature that develops when concentrating light.

MIRROR AND PRISM SYSTEM

Application of mirrors is a new approach, which is simple as well. Mirrors are installed in relation to the sun path, below sill level of conventional windows and away from normal view (see figures 9 and 10).

The rays of light recede towards the window when the sun-path moves from one hemisphere to the other over Colombo.

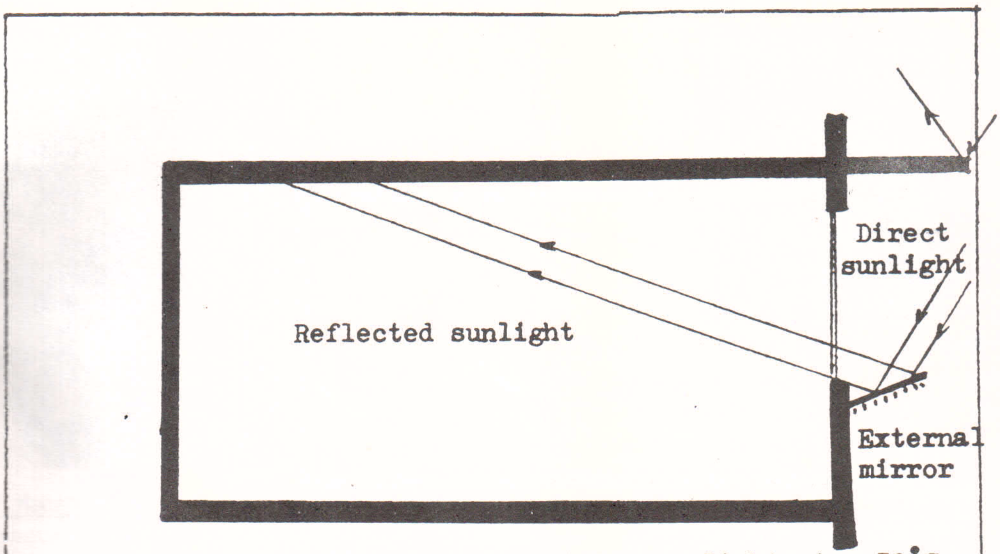


Fig.9 External mirror inclined to reflect snlight at - 30°S.

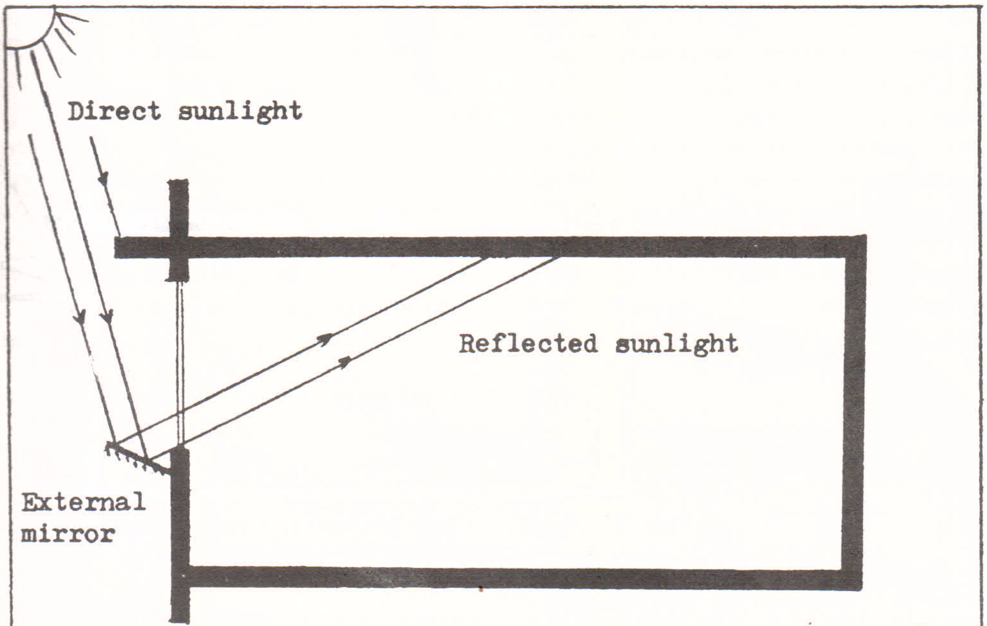


Fig.10 External mirror inclined to reflect sunlight at -16°N.

Mirrors as well as prismatic controllers can be applied to the upper section of a conventional window to guide the rays onto the ceiling as shown in figure 11.

LIGHT SHELF SYSTEM

Sunlight can also be made to reflect off a photometrically designed light shelf, as in figure 12, over the top of a window through a glazed opening. The same device will prevent entry of direct sunlight into the working area.

The reflecting device can also be placed at floor level, as in figure 13 with the glazing correctly inclined to increase light penetration. The convex surface of the reflecting device should be photometrically designed in relation to the sun path, for maximum penetration.

Sunlight directed on to a ceiling as in figure 11, using prismatic controllers have produced illuminances as high as 500 lux at depths of 10m, according to experiments carried out in Australia. Sunlight has been taken underground to a depth of 33.5m in a building at the University of Minnesota in U.S.A. giving an average illuminance of 300 lux at the lowest level. This exciting technology would be quite appropriate to Sri Lanka, with over 60% bright sunshine and conducive light angles.

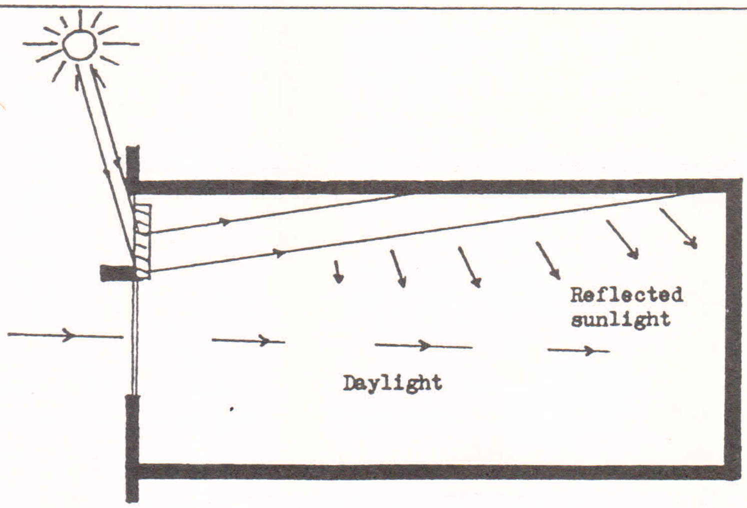


Fig. 11 Sunlight directed from above window with mirrors.

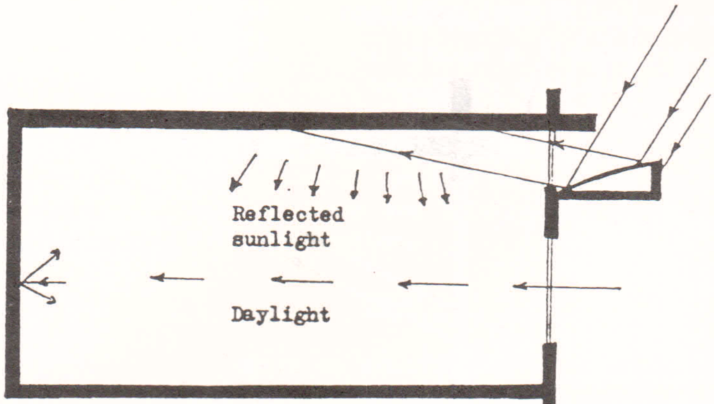


Fig. 12 Combined 'light-shelf' and sun shading device.

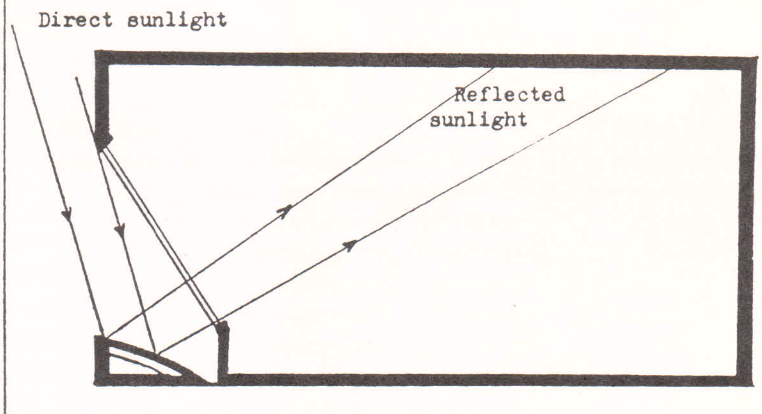
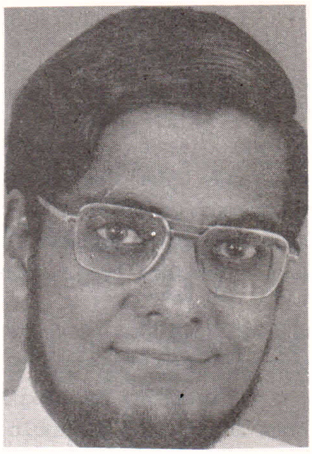


Fig.13 Light-shelf at floor level and inclined window glazing



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Prof Munasinghe, the founder President of SLEMA, is now the President Emeritus of this Association.

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He joined the Ceylon Petroleum Corporation in 1979 and served as a project officer in its Planning and Development Division. In 1983, he was seconded to the Ministry of Power and Energy to work as a Coordinating Officer of its newly formed Energy Coordinating Team. During this assignment, he played a key role in the development and implementation of the Energy Modeling Framework and assisted in the preparation of the National Energy Strategy for Sri Lanka. From 1985 to 1986, he worked as the Personal Assistant to the Chairman of the Computer and Information Technology Council of Sri Lanka, a newly formed Government Upon completion of his assignment at the Ministry of Power and Energy, he returned to the Ceylon Petroleum Corporation in 1987, to take up the post of Assistant Head of the Economics and Scheduling at its Oil Refinery.

Mr Abeywardane is a Corporate Member of SLEMA.

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He joined the Ceylon Petroleum Corporation in 1969 and held positions of the Head of Operations and Operations Manager of the Refinery until he was appointed the Refinery Manager in 1975. He was a participant in the Fuel Conservation Training Course held in New Delhi in 1975 sponsored by the Asian Productivity Organisation, Japan and the Energy Management Training Programme sponsored by the State University of New York and the Brookhaven National Laboratories, New York in 1979.

Mr. Chandrasekera in a founder member of SLEMA and held the post of President in 1987/88.

Mr. S.Ranasinghe has been actively engaged in the designing and manufacture of luminaires and in lighting consultancy for 23 years. He is also a Visiting Lecturer in Lighting Technology at the Department of Architecture of the University of Moratuwa, Sri Lanka.

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