Abstract: This paper is based on the ‘Energy Management Study’ carried out by the author, in Tata Infotech Ltd’s 12 offices in India. This paper is being put forward to impart a practical approach towards achieving ideal energy management through use of energy efficient technology and proper illumination system design for the Software Industry. Through this paper, an attempt is being made, to provide general guidelines for designing and renovating illumination systems for modern computer offices. The implementation can defer in some aspects for different locations.

1. Introduction :-

Illumination is an art as well as a science. It should fulfil esthetic, emotional as well as economic and functional requirements. Provision of good and efficient illumination system calls for co-ordination between the architect, the consultant and the illumination engineer. The human eye is adaptable to illumination levels from 20 lux to more than 1,00,000 lux. Hence, the quality of lighting is more important than just the illumination level.

Illumination accounts for 20% to 30% of the total energy consumption in software industry. For any typical lighting system, energy cost is about 80% to 90% of the annual cost & 65% to 85 % of the life cycle cost. So while designing the system more emphasize should be on reducing the running & recurring costs as compared to reducing the initial cost. Energy efficient fluorescent tube-lights cost around Rs. 40 more as compared to the conventional tube-lights, at the same time the annual electricity cost of each tube-light can be in the range of Rs. 700 – 1000, depending on the working hours. So more importance should be given to reduce the total number of tubelights by using more efficient lighting technology.
2. Requirements for designing a good Illumination System :-

1) Provide adequate illumination.
2) Provide uniform light distribution all over the working plane.
3) Provide light of suitable colour and avoid glare & hard shadows as far as possible.

A well-designed illumination system adds to the productivity of its occupant, creates lively atmosphere and reduces fatigue. On the other hand, side effects directly related to improper lighting include rapid fatigue, lethargy, headaches, eyestrain, eye burn and overall visual impairment. As per the information given by one of the leading Ophthalmic Surgeons in Mumbai, Dr. (Mrs.) Jayashri Thakore, persons do find difficulty in dark adaptation & the adaptation time may increase due to continuous working in bright light.

The B.I.S. recommends that the values of illumination level should be related to the visual requirements of the task to users’ satisfaction, to practical experience and to the need of cost-effective use of energy.

2.1 Essential factors for designing lighting scheme for modern offices :-

1) **Illumination level** :-
   For each type of work there is a range of brightness most suitable i.e. which causes minimum fatigue and gives maximum output in terms of quality and quantity.

   Degree of illumination necessary, depends upon :-
   a) The size of object and its distance from observer.
   b) Contrast between the colour of the object and background. The human eye is more sensitive to contrast and difference in illumination than to absolute illumination level.

   Earlier the normal office work mainly consisted of writing and reading horizontal documents. In modern offices, the work mainly consists of use of computers with vertical screen. Realisation of these requirements for rooms containing VDUs involve careful planning of brightness and colour pattern within the working areas and the surroundings. This calls for greater importance in creation of a well-balanced luminance distribution in the field of view including vertical surfaces. In addition, due to the need of avoiding direct and indirect glare in the screen of **Visual Display Terminals**, use of antiglare (Category I) mirror optics luminaries is recommended.

   The Indian Standard Code of Practice for Interior Illumination, IS 3646 (Part 1) 1992 gives the general requirements and recommendations for working interiors. Table 1 shows the recommended illumination for modern offices. As the surroundings are different at different locations for same working activity, the ISI standards recommend a range of illumination level. A factor of 1.5 represents the smallest significant difference in subjective effect of illuminance. Hence each range consists of three successive steps of the recommended service illuminance.

   For normal working areas, the middle value of each range represents the recommended service luminance. For the areas where the working environment is below the average standard, higher value should be used and for the areas where the working environment is above the average standard, lower value can be used.
Table 1. Recommended values of Illumination Levels (As per IS - 3646 I : 1992):

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Location</th>
<th>Illumination Level (in Lux)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Computer work area</td>
<td>300 - 500 - 750</td>
</tr>
<tr>
<td>2</td>
<td>Entrance and Hallways</td>
<td>150 - 200 – 300</td>
</tr>
<tr>
<td>3</td>
<td>Reception</td>
<td>200 - 300 – 500</td>
</tr>
<tr>
<td>4</td>
<td>Classroom</td>
<td>200 - 300 – 500</td>
</tr>
<tr>
<td>5</td>
<td>Stairs</td>
<td>50 - 100 - 150</td>
</tr>
<tr>
<td>6</td>
<td>Library (reading area / tables)</td>
<td>200 - 300 - 500</td>
</tr>
<tr>
<td>7</td>
<td>Library (book shelves)</td>
<td>100 - 150 - 200</td>
</tr>
<tr>
<td>8</td>
<td>Bathrooms</td>
<td>50 - 100 - 150</td>
</tr>
</tbody>
</table>

From Table 1, it is clear that the recommended illumination level over the task area in any room containing Visual Display Terminals should be in the range of 300 - 500 lux. This is a compromise between the illuminance necessary for reading working documents, which are frequently of poor quality & the most comfortable illuminance of operating terminals. A much higher illuminance will normally produce difficulties because of the difference in the luminance in document and screen & a much lower illuminance may cause problems in reading documents. When the task is mainly screen based such as data retrieval, lower end of the range should be used. On the other hand, when the task is mainly document based such as data entry, higher ends of illuminance are more appropriate.

2) Uniformity of Illumination :-
Lack of uniformity of illumination, makes the pupil of the eye adjust more frequently. This causes fatigue and productivity is reduced. Modern trend is towards “localised lighting plus general lighting” & towards adaptation of “general lighting oriented towards the working plane” i.e. to keep the ambient lighting at relatively low illumination level and use of task lighting to raise the illumination level at working plane.

Uniformity of illumination is required to create the right visual environment for rooms containing VDTs. Luminance relationships between screen & desk is very important and need to be controlled. Non conformance to this may lead to 3 complaints:-

a) Glare :- It is the high luminance reflection on the screen. It may cause a reduction in the visual performance and adversely affect people’s satisfaction with the display.

b) Static Imbalance :- It occurs when luminances close to the line of sight vary widely. This may contribute to the sensation of discomfort glare.

c) Dynamic Imbalance :- It occurs when there are very large differences in the luminances of objects viewed by the operator in continuation e.g. source document, monitor & keyboard. This may cause difficulties in seeing the text.

3) Type of Screen :-
Distress caused by the glare depends on the type of screen. Screens with antiglare treatment will cause fewer problems as compared to a screen with smooth glass. The magnitude of glare also depends on the polarity of software running on the screen. A negative polarity software (light characters on dark background) makes the glare more noticeable as compared to the positive polarity software (dark characters on a light background). The VDT luminance limitation angle of luminaries should also be considered to avoid glare on the screen. Generally the monitor comes with a housing that allows tilting & swivel adjustment of the screen. This option helps the operator to avoid the annoying glare & to find a relaxed posture.
4) Mounting height & Spacing of luminaries :-
Mounting Height is the height of luminaries above the working plane. It is mainly governed by the type of building and type of lighting scheme employed. The required number of luminaries depends on Mounting Height. Correct spacing of luminaries is very important to provide uniform illumination. The “ratio of horizontal spacing between rows to the mounting height” depends mainly on the choice of luminaries.

5) Colour Rendering Index of the source :-
The appearance of body colour entirely depends upon the colour of the incident light. The composition of light should be such that the colour appears natural. Use of lamps with high C. R. I. improves clarity.

6) Day-lighting :-
Sunlight is available in abundance and is free of cost. Economics, esthetics and health, all these factors favor the practical use of day lighting. Thus a good day-lighting design offers a big energy saving potential and has a positive impact on the occupant satisfaction. The use of advanced day-lighting technologies, such as light guides and improved windows, may increase the amount of daylight available inside buildings. The most effective day-lighting strategies calls for optimized building orientation and form, optimized window size and placement, a light switch, maybe a light shelf.

Natural light should be used as far as possible. Perimeter day-lighting systems, such as windows, bring daylight about 15 feet into a building. Core day-lighting techniques bring daylight deeper into a building. Instead of using blinders to block the sunlight, use of vertical louver drapes should be promoted. This will allow maximum utilisation of day light without causing glare.

2. Designing the Illumination System for software offices :-
The scope of lighting design can differ widely from installation to installation. Various methods can be used for lighting design like lumen method, point by point method and software developed by luminaries’ manufacturers of lighting luminaries. Out of these methods, lumen method is one of the most commonly used. Here, an attempt is being made to give steps involved in illumination design by the lumen method.

1) Study the plan and requirements of the work environment.
2) Determine the illuminance level required from ISI specifications (IS : 3646 Part 1 – 1992) and the user requirements.
3) Calculate the Room Index (RI), the Utilisation Factor (UF) from the COU table and Maintenance Factor (MF).
4) Calculate the number of luminaries required depending on the choice of luminaries.
5) Determine the effective Spacing to Mounting Height Ratio and draw the layout.
6) For a renovation project calculate the energy savings and cash savings.

While designing the illumination system, care should be taken so as the lights in each area can be switched off partially when not in use. (e.g., The illumination level required for working on computers is 300 - 500 lux, but when the area is not used for work illumination level of 150 lux is sufficient. This can be achieved by switching off some of the lights. Also proper naming or numbering of the switches will facilitate the use of them by occupants or security staff.
4. MODERN CONTROL SYSTEMS

Many office buildings are designed to have guards & maintenance staff to switch on the lights very early in the morning and switch them off again very late at night. At the same time occupants don’t have access to controls, most of the areas are over lighted and thus may consume up to 100% more energy than needed. A sophisticated Direct Digital Control system using fuzzy logic can dynamically adjust schedules according to the occupancy pattern.

A building automation system (BAS) offers advantages such as interoperability (capability of sharing information such as temperature, security, and lighting among building systems) and extendibility, over even the most sophisticated lighting control system. For example, an occupancy sensor connected to a BAS can control lights, and it can also control temperature and airflow, operate security & fire alarms, help rescue crews locate occupants in an emergency, and even determine the floors at which empty elevators should wait to pick up passengers.

Experiments conducted by the Lighting Research Center at Rensselaer Polytechnic Institute suggest that auto restore motion sensors and manual switching & dimming controls maximizes occupant satisfaction and minimizes the energy wastage up to 60% in private offices. The occupancy sensors can save up to 40% of electricity. Manual controls can further reduce the energy consumption by 10% to 15%, by providing opportunity for occupants to tailor lighting conditions to their individual needs and satisfaction. This may also increase productivity due to optimization of their work environment.
4.1 Control Strategies :-
Various control strategies can be used to minimize the wastage of energy in offices.

1) **Scheduling** :- This involves turning the lighting systems on or off according to need of program. Manual scheduling involves switching by occupants and automatic scheduling can be achieved by use of time switches, occupancy sensors, photo-sensors, temperature sensors and other automatic control devices.

2) **Tuning** :- This involves reducing power supplied to the electrical systems as per the requirement. For lighting, this involves use of dimming controls.

3) **Zoning** :- Control zones are defined depending on the existing wiring methods & occupancy pattern. Smaller the area of zone, the greater the potential for energy saving. Each zone contains at least one switch or other control device easily accessible to the occupant & can have a separate schedule for weekdays, weekends or special events.

4) **Duty Cycling** :- Special care can be taken to minimise the peak demand & electricity bills. For large complexes the power supplied to the illumination systems can be reduced by 10% in order to reduce the peak demand without causing a significant drop in illumination level.

4.2 Types of Sensors :-
Various types of sensors are currently available for use in control systems. These controls offer a variety of operations that include automatic-on / automatic-off, manual-on / manual-off / automatic-off, 2-level-on / automatic-off, manual-on / automatic-off / dimmer controls. Sensor economics depends upon occupancy pattern and tariff rates. Performance and reliability depends upon design of rooms, installer’s experience, maintenance and compatibility with building components like ballasts and lamps. Occupancy loggers can be used to determine the occupancy pattern.

A) **Occupancy Sensors** :- These are basically motion detectors which react to variables like heat &/or sound by turning equipment on or off. These can further divided in 3 types.

1) **Passive Infrared Sensor** :-
   It works on the infrared heat energy emitted by people. It’s a strictly ‘line of sight’ device and can’t see around the corners and through partition. It’s quite resistant to false triggering.

2) **Ultrasonic Sensor** :- It emits a high frequency sound (25 KHz to 40 KHz) and listen for a change in frequency of reflected sound. It covers large volume and is more sensitive but more prone to false triggering. There are no blind spots in the area of coverage.

![Various Control Strategies Diagram]

- Lumen Control
- Automatic
- Timer Control
- Automation System
- Manual
- Multiple level switching

A simple diagram showing various control strategies.
3) **Hybrid Sensors** :- Use both technologies and combines the sensitivity of ultrasonic sensors with the infrared sensor’s resistance to false triggering. They switch on lamps when both sensors detect motion, keep the lamps on if either sensor detects motion & turns them off, after a delay, if neither sensor detects motion.

**B) Daylight & lumen maintenance sensor** :- It use photo-sensors to send a signal to main dimming module, which controls the power supplied to luminaries in control zone either by solid state device or by auto transformer dimming.

5. **CONCLUSION**

A good energy efficient lighting system employs optimum mix of energy, equipment and operations that result in not only long term energy savings but also increased productivity. This involves proper design of illumination system and regular maintenance along with the use of energy efficient equipment & procedures. Involvement of various departments like engineering, finance, administration and commitment of top management is necessary for any energy management project to succeed. Employee participation and awareness should be promoted to maximize the benefits from Energy Management. Properly planned and executed energy efficient upgrades can have a pay back period between 2 years to 3 years. An additional push to energy efficiency can be provided by strengthening energy standards & providing energy labels for energy efficient products.

**Success Plan for Energy Efficiency**

![Success Plan for Energy Efficiency](image)

**References :-**