FORMAT FOR SENDING COMMENTS ON THE DOCUMENT

[Please use A4 size sheet of paper only and type within fields indicated. Comments on each clause/sub-clause/ table/figure, etc, be stated on a fresh row. Information/comments should include reasons for comments, technical references and suggestions for modified wordings of the clause. **Comments through e-mail in MS WORD format to eetd@bis.gov.in shall be appreciated.**]

Doc. No.: ETD 49 (25814) WC **BIS Letter Ref:** ETD 49/T **Dated:** 06 June 2024

Title: Draft National Lighting Code of India: Part 10 Installation Aspects for Lighting, Section 1 Mechanical, Section 2 Electrical, Section 3 Coordination with Related Disciplines, Section 4 Installation Guidelines for LED System, Section 5 Lighting Maintenance[First Revision of SP 72 (Part 10/Section 1- Section 5)]

Name of the Commentator/ Organization: ______________________________________

Part 10 /Section 1 Mechanical		
Clause No. with Para No. or Table No. or Figure No. commented (as applicable)	**Comments / Modified Wordings**	**Justification of Proposed Change**
Part 10 /Section 2 Electrical		
Clause No. with Para No. or Table No. or Figure No. commented (as applicable)	**Comments / Modified Wordings**	**Justification of Proposed Change**
Part 10 /Section 3 Coordination with Related Disciplines		
Clause No. with Para No. or Table No. or Figure No. commented (as applicable)	**Comments / Modified Wordings**	**Justification of Proposed Change**
Part 10 /Section 4 Installation Guidelines For LED System		
Clause No. with Para No. or Table No. or Figure	**Comments / Modified Wordings**	**Justification of Proposed Change**

No. commented (as applicable)		
Part 10 /Section 5 Lighting Maintenance		
Clause No. with Para No. or Table No. or Figure No. commented (as applicable)	**Comments / Modified Wordings**	**Justification of Proposed Change**

BUREAU OF INDIAN STANDARDS

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Draft NATIONAL LIGHTING CODE OF INDIA

PART 10 INSTLALLATION ASPECTS FOR LIGHTING

Section 1 Mechanical

[First Revision of SP 72 (Part 10/Section 1)]

Illumination Engineering and Luminaries Sectional Committee, ETD 49	**Last Date for Comments: 06 July 2024**

FOREWORD

The provision of artificial lighting for various applications is achieved through proper design, engineering, installation (erection) and maintenance. Each one of these is important in its own right. While design in this context refers primarily to the design aspects of lighting such as illuminance, glare, uniformity, colour etc. as relevant to the respective application, the other three would include the mechanical and electrical aspects relating to the erection of the lighting equipment and the associated electrical distribution equipment. The work of a lighting installation involves multidisciplinary coordination to correctly transform the design concept to the final installation which is safe and satisfactory functionally as well as aesthetically. The various aspects in respect of these are considered in three sections under this part. This section covers the Mechanical aspects as applicable to a lighting installation work, followed by the Electrical aspects in Section 2, Coordination aspects in Section 3, Installation Guidelines for LED System in Section 4 and Lighting maintenance in Section 5 of this part.

1 SCOPE

1.1 This part and section of the code prescribes the mechanical aspects of any lighting installations.

2 TERMINOLOGY

2.1 The definitions given in part 1 of this code shall apply.

3 STORAGE AND HANDLING

3.1 It is not uncommon that the luminaires are received at site, well ahead of the actual time of installation. Temporary storage thus remains inevitable in most installation works. After verification on receipt, it will be a safe practice to store the luminaires and accessories in the respective packing cases, lest they be damaged in storage or while handling later.

3.2 Luminaires and packed cases (as the case may be) should be stacked so that there is no risk of moisture ingress or exposure to sun or weathering. The storage should be in a covered, lockable space and yet it will be desirable to cover the stored material by an overall polythene sheet especially when stored without the packing cases (where inevitable).

3.3 Packages of the luminaires, lamps and electrical components should be handled with care to avoid mechanical damage or breakage during transportation and installation. The packages should be marked for the purpose in bold letters and symbol.

3.4 Luminaires should be handled with clean hands. They should be held, to the extent possible, symmetrically during installation. Reflectors are generally from thin sheet material and can get easily deformed with slight pressure. Particular care is needed, not to disturb or damage the reflectors.

3.5 The protective layer laid over reflectors in the factory should not be removed till commissioning. Lamp may also be fixed in position only during commissioning.

4 GENERAL INSTALLATION CONSIDERATION

4.1 The interior lighting layouts may not at times indicate the precise distances from walls. The installation at site should, however, be done with due care to see that the functional design concept is not upset, and at the same time aesthetics is kept up, as for example, maintaining symmetry, alignment, relation with other outlets like air conditioning.

4.2 Mechanical integrity is important in the installation of lighting equipment so that its position, alignment, aiming etc. do not get altered under conditions of normal use, maintenance and the environmental conditions at site where it is installed. Supporting and anchoring arrangement to the walls or structure as the case may be, as well as the associated hardware items shall be of adequate strength for taking the load of the luminaire, and control gear where applicable. In the case of outdoor installations, the effect of wind force should also be considered.

4.3 Pendent type luminaire should be installed such that its weight shall not come on to the electrical terminations. Suitable clamp for the cord should be provided in the ceiling rose/suspension box for the purpose. Where possible the cord may be knotted at the luminaire end holder, if the luminaire is suspended by the cord only.

4.4 Where the luminaire is heavy (e.g. chandelier) suitably sized chain or pipe should be provided to take the weight and the cord should be free from the weight of the luminaire. Hooks should be provided as necessary to suspend such heavy luminaires. Alternatively, if the luminaire is to be fixed to the ceiling directly, appropriate fixing arrangements should be employed. It must be ensured that holes drilled in structure for the purpose are of the exactly required size, as otherwise the integrity of fixing thereto may not be able to be assured.

4.5 When luminaire are to be installed as part of a false ceiling, it has to be first confirmed whether the false ceiling can take the load of the luminaire. It is often convenient to suspend the luminaire from the main structure above the false ceiling using chains (in preference to pipes), which will permit easy adjustments at site through a stud of about 25 mm length welded to each end of the chain.

4.6 In installations where site adjustment will be called for (e.g. flood lighting), one or two fixing holes may be elongated instead of being circular. Spring washers and lock nuts should be used with normal bolts and nuts to ensure rigidity of fixing at such locations.

4.7 The likely effect of corrosion should be considered for the hardware items in high humidity areas and coastal areas. Certain chemical and petrochemical industries, chemistry laboratories in educational and research institutions, lead acid battery rooms etc. are likely to introduce corrosive fumes in the atmosphere. The metallic components should be either of corrosion resisting material, or be protected by appropriate coating of anticorrosive material or paint. In most cases, mild steel is used for the hardware, and the same should be derusted, and galvanized before installation or painted with red lead or epoxy paint after installation. Threads in particular are areas highly vulnerable for attack on the base metal. These should be protected by application of anticorrosive material. Depending on the extent of corrosion likely in the area, painted surfaces will need repainting at certain intervals.

4.8 Where heat energy is likely to be generated from a luminaire (e.g. one with incandescent lamp, or from a magnetic ballast), the installation should be such that the heat is readily dissipated away. If this not done (for example, luminaire with an enclosure as part of a false ceiling), it can create heat – traps and may even lead to fire on long time use.

4.9 Magnetic ballasts may cause a disturbing hum. This may not be acceptable in certain locations (e.g. studio, conference halls etc.) It may be then desirable to install the ballasts outside such sensitive area, subject to the limitation of distance (see Section 2 of this part). Here again, necessary provisions need to be made to dissipate the heat effectively.

4.10 Wherever gaskets are used either as part of the luminaire or part of the installation, the material of the gasket should be suitable for the condition of installation, and it should be fixed such that it does not tend to fall out when the cover is opened out.

4.11 In erection of luminaires and electrical distribution conduits/cables, in trusses suitably designed clamps should be used, since quite often drilling holes in the structural members may not be permitted.

5 PARTICULAR CONSIDERATIONS

5.1 Wall mounted luminaire are very common in residential installations. Apart from aesthetics, wall mounting enables easy cleaning of the luminaire and replacement of lamps without seeking assistance from outside. For room depths up to 5 m, a mounting height of about 2.4 m is generally adopted.

Wall mounted luminaire are installed either directly on to a phenolic laminated sheet or to a wooden base which in turn is fixed either to the wall or to the electrical outlet box. The fixing screws should be of adequate length and use of single screw for fixing should not be permitted so that the installed luminaire may not be disturbed from position during maintenance and relamping. Where wood is used, it should be of good quality and be coated with varnish on all sides before installation. Wood screw should be used for screwing on the luminaire to the wooden base.

5.2 Where the floor height is low (e.g. mezzanine; passage below attic; depressed ceiling for toilets etc) luminaire should be installed on wall space to avoid mechanical damage. In areas with normal floor heights, luminaire can be installed at the ceiling level. Where installed directly under the ceiling, round wooden blocks is to be taken on the luminaires is preferable. This improves ventilation of the luminaire and also will not show off any unevenness in the finishing work of the ceiling.

If ceiling fans are used for ventilation, the positioning should be such that the cut off of the luminaire's beam is lower than the ceiling fan so that disturbing shadows are avoided. Where this is not feasible, the luminaire may have to be brought down suitably using down rods. In the case of fluorescent tube luminaires, ball and socket arrangement is provided where the length of down rod is over 300 mm.

Utmost care is needed in such installations in maintaining the alignment of luminaire as well as the uniformity or spacing between the down rods of every luminaire.

5.2.1 Accessibility of the luminaire for maintenance and lamp replacement is very important. No useful purpose is served if any luminaire is installed either for illumination or for decoration; in such a location that relamping/maintenance is not possible. This applies equally where accessories (if any) are installed in a separate box.

5.2.2 In installations with high ceiling such as auditoria, exhibition halls etc. catwalks may be incorporated in the design stage itself for access to the luminaire and control gear.

5.3.3 Access to the luminaire may also be achieved through mechanical / electromechanical raising and lowering mechanism (e.g. high-mast lighting; adjustable indoor pendants). Suitable catwalks of adequate mechanical strength are very essential for initial installation and subsequent maintenance for auditoria and outdoor installations such as sports lighting, arena lighting and hangar lighting.

5.4 It is common to provide the cable terminations/looping and the over current protection of the lamp in a box at the foot of every pole for street lighting and exterior lighting of buildings. It is a safe practice to locate the same at a height of at least 600 mm above ground, and this will also enable easy accessibility. In the interest of safety, such termination boxes should have covers with latches to a fail-safe design.

5.5 In respect of installations for underwater lighting as in swimming pools, the luminaire and cable termination should be in a chamber adjoining the pool, so that relamping and maintenance is conveniently done. There should then be a clear glass of suitable thickness between the luminaire and the pool, with necessary gasket to avoid seepage of water.

5.6 Needless to mention, all safety precautions required for any mechanical installation should be taken in the process of the installation of luminaires and distribution cables. Tools appropriate for the action and size involved should only be used. The installing person should stand on an adequate and reliable support, since the installation work will be done on some height. Wherever necessary, safety belts should be used.

5.7 “As fitted” drawings should be prepared on completion of the installation. In the case of flood lighting/sports lighting installations, the record of aiming angles should be maintained immediately after the initial installation for reference during maintenance.

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Draft NATIONAL LIGHTING CODE OF INDIA

PART 10 INSTLALLATION ASPECTS FOR LIGHTING

Section 2 Electrical

[First Revision of SP 72 (Part 10/Section 2)]

Illumination Engineering and Luminaries Sectional Committee, ETD 49	**Last Date for Comments: 06 July 2024**

FOREWORD

Electricity is the main source of energy for modern lighting. While the lamps and luminaries are selected to provide the required illumination to satisfy the functional requirements, electrical energy should be made available safely to the lamps at the desired supply parameters of voltage and frequency. The electrical system should be designed, installed and maintained as per relevant standards so as to ensure supplying electricity at the required supply parameters to operate the lamps through their control gear (wherever applicable). This section is devoted to aspects relevant to electric supply and distribution to lighting installations.

1 SCOPE

1.1 This part and section of the code prescribes the electrical aspects of any lighting installations.

2 TERMINOLOGY

2.1 The definitions given in part 1 of this code shall apply

3 NORMATIVE REFRENCES

Following Indian standards are necessary adjunct to this standard

IS No.	*Title*
732:2019	Code of practice for electrical wiring installations
694:2010	Polyvinyl chloride insulated unsheathed and sheathed cables/cords with rigid and flexible conductor for rated voltages up to and including 1100 V (Fourth Revision)
371:1999	Ceiling roses - Specification (Third Revision)
1293:2019	Plugs and Socket-Outlets for Household and Similar Purposes of Rated Voltage up to and Including 250 V and Rated Current up to and Including 16 A - Specification (Fourth Revision)
3854:1997	Switches for domestic and similar purposes Switches for domestic and similar purposes - Specification (Second Revision)
9537(Part 2):1981	Specification for conduits for electrical installations: Part 2 rigid steel conduits
9537(Part 3):1983	Specification for conduits for electrical installations: Part 3 rigid plain conduits of insulating materials
14927(Part2): 2001	Cable trunking and ducting system for electrical installations: part 2 Cable trunking and ducting systems intended for mounting on walls and ceilings
SP 30: 2023	National Electrical Code of India

4 STANDARDS

4.1 There are Indian Standard Specifications for all important components of the electrical installation in the form of product standards, for example, wiring accessories, cables, switchgear, lamps). There are also codes of practices (COP) to indicate the best engineering practices with regard to the installation. A list of most commonly applicable Indian Standards is given in clause 3 of this part and section.

4.2 In order to ensure quality and safety, it is always the proper practice to invariably use certified products. Where it is not possible to do so for any reason, conformity to relevant Indian standards shall be insisted upon supported with test certificates. Out of the many standards, IS 732 relates to wiring installation. Electrical installations for lighting circuits shall need to comply with this standard.

4.3 The National Electrical Code brings out the various important aspects as applicable to all types of electrical installations works. References to the respective Standards and Codes applicable have also been made therein at appropriate places. Compliance to the NEC will ensure an electrically safe installation.

5 WORKMANSHIP

5.1 The workmanship of the electrical installation must be of a high order, so as to ensure integrity (security grade) of service and safety from shock hazard and fire hazard. No short cut procedure should be adopted anywhere in the installation work (e.g. twisting wire terminations instead of screwed connections).

5.2 The contractor (agency) responsible for the work of electrical installation should be licensed by the State Government concerned for the type of work to be executed. The skilled workers should also possess the necessary license for the trade involved.

6 ASPECTS PERTAINING TO DESIGN

6.1 It is a fundamental requirement that every part of the electrical system shall be capable of carrying the currents involved for the period of current flow, safely. Every conductor carrying current will produce heat energy equivalent to I^2Rt (where I is the current, R is the resistance of the conductor and t is the time of current flow) and the consequent rise in temperature should be such that the insulation material over the conductor will not be adversely affected by the resultant final temperature of the conductor. The current may be continuous operating current for a long time, or be a large in-rush current for a short time during switching on, or a be a fault current due to an earth fault or short circuit fault for a period which will be governed by the operating time of the protective device concerned. In the case of discharge lamp circuits, the continuous current will correspond to the lamp load plus the losses in the control gear.

The cabling and wiring material selected for lamp circuits should take into consideration, not only the load current but also conditions of installation such as in conduits open bunching, hot or cold environment around the wiring etc. Oversizing may be required to compensate for any likely reduction in the permissible temperature rise due to any such adverse condition. In fact this will apply even to the wiring cables forming part of the luminaries.

6.2 Every part of the electrical system shall have the required level of insulation. Normally lighting circuits operate on single phase 240 V AC supply and the voltage grade of the materials as per Standards will be 650V. In larger installations, the supply is 3 phase 415 V Ac and the insulation will be to 1100 V grade. In certain discharge lamps on electronic device is used to give high voltage pulses to the lamp to strike. The insulation material used for the wiring cabling should be capable of withstanding this voltage.

6.2.1 Every luminaire should be controlled by a switch. There can, however, be group control of more than one luminaire by a switch or a single luminaire may be controlled by 2 switches. The switching arrangement is designed on case to case basis for the best functional utility. As far as possible discharge lamps may have individual controls due to the reason that such loads are predominantly inductive and there can be sparking at the switches during on off operations thereby reducing the life of the switch it is good to oversize the switches in such circuits to (say) at least double the normal operating current of the circuit, considering the effect of sparking during switching where group switching is involved.

6.2.2 A semiconductor device may be used for switching circuits for certain lighting installations. This is not suitable for disconnection under over current conditions and should always be backed up by necessary current protective device.

6.2.3 Group dimming facilities should be available in auditorium and multi purpose hall. The grouping of luminaries for switching/ dimming should be decided at design stage. Dimming facility should be available in all areas where projection of transparencies/ slides etc are likely, such as selected lecture halls, seminar halls, conference rooms etc. The dimmers may be auto transformer type or electronic type.

6.2.4 Discharge lamps operating on voltage higher than 1000 volts (like neon signs) will need fireman emergency switch located in an easily accessible place and be marked accordingly.

6.3 As far as possible the control gear should be placed near the lamp as part of the luminaire. Where the control gear is proposed to be located away from the lamp the distance limitation between them should not be excessive. Lamps manufacturers may be consulted in individual cases. It must also be ensured that there is proper dissipation of heat from the control gear.

6.4 It is a common practice not to mix lighting circuits with circuits for appliances (socket outlet circuits). This is because lighting service is likely to be adversely affected if any defective appliance is connected in a lighting circuit.

6.4.1 The luminaries should be distributed in different circuits each circuit controlled by a 6A fuses Miniature Circuit Breakers (MCB) not exceeding 800W. The switches and MCB's should be rated for switching low pf load. The circuits may be distributed in all the phases where 3 phase supply is used.

6.4.2 Lighting of corridors and common areas of public buildings should be connected in a separate circuit preferably fed from standby supply.

6.4.3 It is a safety requirement that exit lighting foot lights fire escape route lighting and security lighting are all connected to essential circuits so that these could be supplied from standby generator, where provided. These are wired in circuits independent of the general lighting circuits and other loads.

6.5 Where the lighting installation is very close to the substation (e.g. substation lighting) the switches and distribution boards shall be selected with a high fault rating as may be encountered in such situations.

6.6 A rotating object in a space illuminated by discharge lamps will appear to be revolving at a speed lower than the actual speed due to 'Stroboscopic Effect'. IN the extreme case, the object may appear stationary or even revolving in opposite direction. The electrical distribution should be done in 3 phase to avoid this problem. For example, where the lamps are installed in a row, the first one may be connected to R phase, the second to Y phase and the third to B phase and so on. This will be a simple and economical method. Alternatively, fluorescent lamps with electronic choke, which feeds supply t lamp at a very high frequency, can be used.

6.7 Lighting in exhibition areas are designed for flexibility. The types of exhibits and the internal layout of exhibition stalls will be different for each event. The task lighting is provided examining the requirements on case to case basis. The flexibility in the electrical distribution is affected by providing light track or by providing a number of socket outlets on walls in suitable spacing so that the luminaries can be connected as required. In large exhibition halls different floor areas are allotted to different exhibitors, who in turn provide accent lighting for the exhibits. Most of the wiring for lighting in stalls is temporary in nature, with the electric supply drawn from bus ducts. In the interest of safety from electrical leakages in such cases, it will be necessary to provide earth leakage protection at the circuit level. This will also avoid major disruption of lighting service if there is a fault in any luminaire circuit.

6.8 In the case of outdoor lighting such as street lighting and compound lighting, it is desirable to provide earth leakage circuit breakers (ELCB) in the circuits so as to reduce shock risk. From the point of view of energy conservation, luminaries may be divided in two circuits so that one circuit can be switched off late at night without compromise to security. It is also essential to provide a protection for every light outlet in the form of a fuse or MCB at each pole to improve the integrity of service. The distribution may be from properly designed feeder pillars which may accommodate the control gear also.

6.9 Protection against earth leakage/ fault is necessary from safety point of view in accordance with the provisions contained in IS 732. Basically this code calls for bonding to earth “Exposed” and “Extraneous” conducting parts (like metallic body of equipments conduits etc) in an equipotential zone and coordinating the characteristics of the disconnecting (protective) device so as to disconnect the faulty circuit within a time period safe for life. Earthing is an extremely important aspect of electrical installation in this regard. The metallic body of all luminaires are looped and connected to each as per earthing scheme to be prepared in accordance with IS 732 so that the “touch potential” does not exceed 50 volts anywhere in the system. This applies equally to the outdoor installations as well. ELCB shall be provided at the level of distribution boards if the over current device is not likely to operate in a safe time by earth leakage (fault) current.

6.10 Electromagnetic radiation may emanate at Radio Frequency (RF) from discharge lamp operations in the form of radiation in space around and/or through the electrical wiring. The latter is called conducted electromagnetic interference. This may be suppressed by suitable filters in the lighting circuits. These are particularly important in installations having equipment sensitive to RF. The effect of radiated EMI can be controlled by providing necessary shielding over the radiating body.

6.11 Harmonic currents are very common in discharge lamp circuits due to nonlinear voltage current relationship in the discharge and consequent drawl of non-sinusoidal currents. The odd harmonics especially the 3^{rd} harmonic add to cause heating of neutrals and also distort the supply voltage wave form (dictated by the source impedance and circuit parameters) in the installation and this may not be desirable for certain other equipment connected to the same source of supply. Corrective actions to filter out harmonics may be called for near the main switch board, where the number of discharge lamps connected is large.

6.12 Since the content of harmonic current in the neutral conductor becomes a high proportion of the load current in discharge lamp circuits a balanced 3 phase distribution is a common practice not to size the neutral to half the cross sectional area of phase conductors especially upto about 35 mm^2.

6.13 All discharge lamp circuits employ an inductive ballast (choke) or stabilizer. This result in drawing a certain lagging (reactive) component of current i.e. the total current drawn from the mains is more than the active component of current to deliver the required amount of power to the lamp. This low power factor situation results in unnecessary over sizing the wiring. Though power factor improving capacitor is usually provided with individual luminaire for discharge lamps, yet this may be required for the complete installation especially for large installations (such as industries multistoried building etc)

7 ASPECTS PERTAINING TO INSTALLATION AT SITE.

7.1 Intermediate joints in wiring should be avoided from fire safety point of view. Where such joints are unavoidable, the joints shall not be permitted in any location which in inaccessible for inspection such as the space above false ceiling. The joint shall never be of twisted type, but be of crimped type with proper crimping accessories and sleeving and or insulation so that a fault may not develop there from.

7.2 The wiring should invariably be terminated in an outlet in the form of ceiling rose, or connector or switch all of which have proper screwed termination. Twisting of conductors at terminations shall be permitted at all.

7.3 Wherever possible, the terminations should be with crimped lugs. Where the termination arrangement is other than with screws (such as pressure type connections) the type of accessory used with the wiring at the termination shall be suitable for the same. These precautions are necessary to avoid any local heating at terminations.

7.4 Earth conductor connections are as important as phase and neutral conductor connections. The integrity of loop earth in conductor terminations at the metallic body of luminaries box containing the accessories and the distribution equipment, should be very high by proper screwed connections with metallic washers. Twisting of conductors should not be permitted either at terminations or in the runs. Where the integrity of mechanical connections of metallic conduits is likely to be affected (example flexible metallic conduit) independent earth continuity conductor must be run with such wiring, terminated on screws on both ends.

7.5 The arrangement of connection of luminaries and any box containing their accessories should be such that removal of any of them for the purpose of maintenance/ repair/ replacement, there shall not be any disturbance to the loop earthing system as well as electrical distribution to other luminaries, nor there any possibility of causing a fault.

7.6 Where luminaries are to be installed in a false ceiling, it will be preferable to run the electrical wiring, suitably fixed to the false ceiling framework depending on the type of false ceiling in preference to laying conduits in the ceiling and taking the working to the luminaries by either rigid or flexible conduits, so that the wiring is easy for inspection and maintenance. If the wiring is to be necessarily taken from the ceiling level, the same should as far as possible be extended to the luminaire in false ceiling without a joint. Also the same should be taken in a conduit and not be left naked. If the same is terminated on the ceiling, it must be readily accessible for inspection and maintenance.

7.7 PVC cables should not be installed exposed to a sun as a permanent installation, since PVC turns brittle over a period of time on exposure to ultra violet radiation from sun unless specially protected against the same.

7.8 The luminaries shall be connected on the neutral side only. The controlling switches of the luminaries shall be placed on the phase side of the circuit. If this is reversed there is a risk of full electric potential being available at the luminaire terminal even if the switch is in off position and this will be quite unsafe.

7.9 Where Edison screw lamp holders are used, the center of the same should be connected to the phase and the outer screw to neutral as part of precaution against shock protection during changing the lamp.

7.10 The location of controls of lighting in different areas should be arranged to suit the functionality and ease of operation, for example, the positions of the control switches are very important in wards and operation theatres. In operation theatre each luminaire should be independently controlled to enable individual requirements for special operation to be met. In ICUs and recovery rooms dimming of individual bed lights is also desirable.

7.11 Control switch positions and the type of control switches should match with the décor of the interior, especially in hotel guest rooms, lounges, conference rooms etc.

7.12 In outdoor lighting installations the loop in box should preferably located at a height of 1 meter above ground level fro the point of view of easy maintenance. This is subject to approval by the Architect from aesthetic considerations. In any case, such boxes shall not be placed at a location near the ground level since this not only cause maintenance problems but also are unsafe both from the point of view of flooding during monsoon and also from the point of view of probability of any one (like children) coming in contact with live box.

7.13 Lamp holders within a distance, of 2.5 meter from the bathtub, shower, cubicle shall be of such design as not to cause shock hazard.

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PART 10 INSTLALLATION ASPECTS FOR LIGHTING

Section 3 Coordination with Related Disciplines

[First Revision of SP 72 (Part 10/Section 3)]

Illumination Engineering and Luminaries Sectional Committee, ETD 49	**Last Date for Comments: 06 July 2024**

FOREWORD

Lighting is an important service element in a building, Lighting is used not merely at nights enabling normal movements and activities and assisting in security, but is also extensively used even during day times especially in non-residential buildings, for various reasons such as conduct of normal activities (for example, office), security (for example office, hotels), decoration (example hotel lounges), accents (example exhibition areas and shopping malls), special functional needs (for examples operation theatre, auditoria, indoor sports halls) and so on. A good lighting installation indeed provides life to a building.

The luminaire and control switches are the only visible items of the system and these should get integrated with the environment and should be able to be installed for case in their maintenance. Electric supply should be able to be given to the lamps safely without any difficulty. Coordination of the Lighting Engineer is essential with the Architect, the Electrical Engineer and the Civil Engineer to achieve a satisfactory lighting installation. This section is devoted to the aspects relating to such inter disciplinary coordination.

1 SCOPE

1.1 This part and section of the code gives a broad outline about the coordination with various agencies and authorities in the execution of lighting installations.

2 TERMINOLOGY

2.1 The definitions given in part 1 of this code shall apply.

3 DESIGN AND EXECUTION

3.1 While there can be no compromise on the functional requirements of lighting, the lighting system should necessarily merge with the surroundings, whether it is internal or external installation. This calls for detailed interaction by the Lighting Engineer with the Architects and Structural Engineers concerned.

3.2 The Lighting Engineer should study the architectural drawings and understand the basic parameters such as space dimensions, space utilities, provision of false ceiling and its type, provision of central air-conditioning service, availability of wall space for control switches etc. The lighting engineer should also interact to ascertain the type of structure, beam position and sizes, the user should be consulted for special requirements if any and also in regard to the acceptability of the final design viz. the layout as well as selection of luminaries.

3.3 Lighting layouts in buildings should be designed such that the luminaries are symmetrically placed within the bays formed by beams. In a structure without any false ceiling, where the beams will be visible, any asymmetry within the bays will spoil the aesthetics.

Where the ceiling is with waffles, the dimensions should be such that the desired luminaire is able to be installed conveniently within.

3.4 The layout of luminaries, air-conditioning system, fire protection system etc should be coordinated so that all the outlets are integrated for the best aesthetics without loss of functionality for any of the services. As far as possible, luminaries below duct should be is avoided, so that any condensation on duct work may not drip over the luminaires.

It will be also necessary to check the space available above the luminaires for recessed installation in false ceiling, taking into account the layout of other services like ducts, pipes etc. While doing so, dissipation of heat produced at the luminaires should be considered.

3.5 The method of installation of luminaires direct to the ceiling with or without round blocks, provision of chains or down rods and their sizes is to be decided in consultation with the architect. Where false ceiling is proposed, the decision on the method of installation may be taken only after consultation with the civil engineer on the ability of the false ceiling to carry the weight of the luminaries and the wiring.

Where the luminaries is heavy and needs suitable provision like hooks to suspend the same or where a cluster of luminaries needs to be installed as in an outdoor installation, interaction with all discipline is extremely important.

3.6 Close coordination with the electrical engineer is required in regard to the switching and distribution arrangements, control positions, dimming facilities, wiring needs etc.

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PART 10 INSTLALLATION ASPECTS FOR LIGHTING

Section 4 Installation Guidelines for LED System

[First Revision of SP 72 (Part 10/Section 4)]

Illumination Engineering and Luminaries Sectional Committee, ETD 49	**Last Date for Comments: 06 July 2024**

FOREWORD

LED lighting reflects a transition from electrical based lighting products to electronic systems. It is a fast-developing technology that is becoming getting more popular considering its advantages such as energy efficiency, controllability and reliability. However, poor quality installation of LED lighting systems could reduce the advantages and result in inadequate lighting, failure to meet lifetime performance expectations, potential public health and safety issues or even interference with other technology due to poor systems integration.

1 SCOPE

This section gives the installation guidelines for LED Lighting system.

2 NORMATIVE REFERENCES

1. Energy Efficiency Guidelines for Street Lighting in the Pacific © 2015 International Institute for Energy Conservation (IIEC)

3 LIFE AND RELIABILITY OF LED SYSTEM

This mostly depends on power distribution of the system. LED lighting systems comprise many components made from delicate silicon chips. Such products can become easily damaged by transient voltages such as power surges and spikes. The distribution equipment (panel boards, switchgears, circuit connections etc.) are determined from site plans and from the location and grouping of loads. The type of premises and location can influence their immunity to external disturbances.

4 RISKS

In the field of street lighting, LED luminaries are directly exposed to close and distant lightning strikes and surge voltages, on account of their exposed position. In SMPS power supplies connected to luminaries in buildings, there is the risk of damage or premature ageing on account of the high switching surge voltages of up to 5,000 volts. These loads can lead to a reduction in the luminous intensity or to the destruction of the electronic ballasts. There is the risk of failure and of high repair costs, which extend the amortisation time. Accordingly, suitable surge protection should be used as protection against damage from lightning or surge voltages.

The surges and spikes can cause permanent damage, like how a nearby lightning strike can burn electronics and wires. They may also cause small latent failures that erode equipment and cause permanent damage over time. These small latent failures are the most troublesome failures to diagnose because it appears as if the electronics just simply failed one day, when in fact the system had been subjected to continuous intermittent power surges and spikes, continually eroding its performance.

These power surges and spikes are most commonly caused by:

a) Lightning
b) Other Electrical Systems
c) Electrostatic discharge (ESD)

4.1 Lightning

Lightning is the most commonly thought of power surge or spike that damages electronic devices.

Lightning can damage a system in two ways: a direct strike, or through transient voltage surges that travel from the direct strike into nearby areas. Nothing can prevent damage from a direct lightning strike. When installing systems in lightning prone areas or where telemetry poles or antennas are located at higher elevations than their surroundings, lightning rods should be installed. Lightning rods do not attract lightning; they simply divert lightning strikes from causing direct-strike damage to nearby areas. Surge protection devices can then protect against the damaging surges traveling from the direct strike. As with all surge devices, lightning rods must be properly grounded to be effective. More information is detailed below in the installation section.

While it may seem rare that a lightning strike would occur, it is more common than one would think. Even a lightning strike within 1.5 km generates a surge voltage which hits the lighting via the supply cable. These surge voltages have less energy than the direct lightning strike, but can still destroy electronic components. Additionally, surges can cause latent unexpected failures that bring down the system at a later time.

Electrical devices of surge voltage category I, e.g. LED drivers, must normally be created with a surge voltage resistance of 1,500 volts and, in the case of surge voltage category II, of 2,500 volts. However, interference from lightning and switching operations cause surge voltages of up to several 10,000s of volts, which are considerably above the named rated surge voltage resistances. LED luminaires therefore require external surge protection against surge voltages.

4.2 Other Electrical Systems

Surges can come from within a building or facility from such things as fax machines, copiers, air conditioners, elevators, and/or motors/pumps, to name a few. Welding equipment and switching on and off of heavy loads can also generate large surges.

4.3 Electrostatic Discharge (ESD)

Electrostatic discharge, called ESD, is caused by rubbing two non-conducting materials together. This causes electrons to transfer from one non-conducting material to another. ESD is the shock caused by touching a doorknob after shuffling across a carpet. This ESD is typically in excess of 10kV (10,000 Volts) and can be very damaging to sensitive electronics. Additionally it is rare that a circuit board will have to be handled directly when installing and maintaining an environmental data logging system. However, care should always be taken when handling electronic circuitry to avoid discharge. This can be achieved by using a grounding strap and touching a metal object to discharge any built up electrons before handling circuitry.

5 CREATION OF THE EARTHING SYSTEMS

Electrical grounding is a commonly misunderstood and improperly implemented component of environmental monitoring systems. Systems that do not use electrical grounding components can experience either complete system failures or intermittent problems that are hard to diagnose.

Implementing proper grounding techniques not only protects from damaging surges and spikes, but more importantly keeps a system from experiencing the ill effects of latent system failures. However, just using grounding devices is not enough. Improper installation of electrical grounding components can render the components ineffective. Installing a system with the proper grounding equipment and following proper installation guidelines can reduce potential down time as well as costly repairs to system electronics.

In a new installation, the supply cable can be protected against destruction from lightning currents in the earth by an optional earthing line above it.

The system earthing is one protective measure commonly used for the protection against electric shocks. These systems earthings have a major impact on the LV electrical installation architecture and they need to be analysed as early as possible. Advantages and drawbacks are to be analysed for a correct selection.

5.1 Analysis of External Influences

Another aspect needing to be considered at the earlier stage is the external influences. In large electrical installation, different external influences may be encountered and need to be considered independently. As a result of these external influences proper selection of equipment according to their IP or IK codes has to be made.

5.2 Protection against Electric Shocks and Electric Fires

Protection against electric shock consists in providing provision for basic protection (protection against direct contact) with provision for fault protection (protection against indirect contact). Coordinated provisions result in a protective measure. One of the most common protective measures consists in “automatic disconnection of supply” where the provision for fault protection consists in the implementation of a system earthing.

Electrical fires are caused by overloads, short circuits and earth leakage currents, but also by electric arcs in cables and connections. These dangerous electric arcs are not detected by residual current devices nor by circuit breakers or fuses. The arc fault detector technology makes it possible to detect dangerous arcs and thus provide additional protection of installations.

5.3 Installation

As mentioned before, the connection to a ground plane is as important as the surge protection device itself. Following proper installation techniques and attaching to proper grounding planes is required for a workable electrical grounding system.

5.4 Grounding Material Selection

There are three main parts to any grounding system after the protection device: The grounding plane, the grounding wire, and the bond between them.

5.4.1 *The Grounding Plane*

a) The best grounding planes are:

i) Copper or copper clad ground rods driven into the earth.
ii) Copper water pipes or other building grounds, such as metal structural frame.
iii) Metal enclosures and casings (which in turn should be grounded to earth ground)

b) Grounding rods should be either copper or galvanized steel, and have a minimum diameter of 15mm.

c) Aluminium should not be used in direct soil burial as a grounding rod since the alkalinity of the soil will etch the metal. This causes disconnection and an increase in impendence between the grounding system and earth ground.

5.4.2 *The Grounding Wire*

a) Use heavy wire gauges (12 SWG or larger) for running the grounding wire. This is important as a thicker wire gauge, along with a short cable, runs the impendence of the grounding wire lower, keeping voltage drops during surges to a minimum.

b) The cable can be either solid or stranded (just as long as it is a heavy-enough wire gauge). The wire can be either bare or insulated.

5.4.3 *The Bond between Them*

a) The use of dissimilar metals for connection from the surge protection device to the grounding plane should be avoided. Over time the connection can wear down and cause undesirable effects on the grounding system as the connection will degrade due to the oxidized layers that form between them.

b) Ground wires should be bonded to the grounding plane (such as grounding rod or copper water pipes) using grounding clamps. Be sure to pick a clamp that matches the size of either the rod or pipe.

c) Both copper and aluminum are approved for use in grounding protection systems. However, copper is a better conductor of electricity and can be used in smaller gauges.

5.4.4 *Proper Installation Guidelines*

a) Do not sharply bend the surge protection wires during termination. Offer a straight path to ground.

b) Keep the surge protection wires as short as possible to improve effectiveness and response time.

c) Keep the surge protection device a few feet away from the protected equipment to allow enough response time for the transient voltage to be suppressed.

d) Ensure all systems connect to the same grounding point only once. Multi paths to a ground plan create different voltage potentials on the system that can result in transient surges. This simply means only pound one copper rod in the earth for grounding.

5.5 Sizing and Protection of Conductors

Selection of cross-sectional-areas of cables or isolated conductors for line conductors is certainly one of the most important tasks of the design process of an electrical installation as this greatly influences the selection of over current protective devices, the voltage drop along these conductors and the estimation of the prospective short-circuit currents: the maximum value relates to the over current protection and the minimum value relates to the fault protection by automatic disconnection of supply. This has to be done for each circuit of the installation. Similar task is to be done for the neutral conductor and for the Protective Earth (PE) conductor.

5.6 LV Switchgear: Functions and Selection

Once the short-circuit current are estimated, protective devices can be selected for the over current protection. Circuit breakers have also other possible functions such as switching and isolation. A complete understanding of the functionalities offered by all switchgear and control gear within the installation is necessary. Correct selection of all devices can now be done. A comprehensive understanding of all functionalities offered by the circuit breakers is of prime importance as this is the device offering the largest variety of functions.

6 OVERVOLTAGE PROTECTION

Direct or indirect lightning strokes can damage electrical equipment at a distance of several kilometres. Operating voltage surges, transient and industrial frequency over-voltage can also produce the same consequences. All protective measures against overvoltage need to be assessed. One of the most used corresponds to the use of Surge Protective Devices (SPD). Their selection; installation and protection within the electrical installation request some particular attention.

6.1 How Surge Protection Devices (SPDs) Work

Lightning and surge protection devices work by routing voltage surges and spikes away from the electrical components they are protecting and dispersing it to a ground plane, such as the earth or a copper pipe inside of a building. Every grounding system therefore consists of two main components: the protection device that routes the damaging signals and the ground connection the signals are routed to. It is important that both components are in place and properly utilized. One without the other, or one properly implemented with the other improperly implemented, is the same as no surge protection system at all.

6.2 Types of Protection Devices

There are several areas of protection for environmental monitoring devices such as:

– The incoming power from a battery or DC voltage source
– AC surge protection
– Sensor input protection

An AC surge protection device will limit the effect of surges through the AC power lines on expensive monitoring equipment. An AC surge protection device can be as simple as ones purchased at department stores for use in homes. Note that power supplies are much wider than a simple AC power cable and can cover more than one slot on a typical surge protector.

Protection can also be obtained from AC to DC power supplies or AC battery chargers. AC to DC power supplies come in two varieties: switching and transforming power supplies. Switching power supplies are small, lightweight and inexpensive as they use integrated circuits to convert AC to DC power. Transforming power supplies are typically bulkier, heavier, and more expensive than switching power supplies since they use a large coil of wire called a transformer to convert AC to DC power. However, transforming power supplies are usually more rugged and offer good protection to monitoring systems. If the AC power spikes, it would cause damage to equipment connected to it, but a transforming power supply will short and only damage itself, protecting the equipment it is powering. A switching power supply on the other hand, unless listed as a specification, may send damaging voltages onto the system it is powering.

SPD is designed to limit transient over voltages of atmospheric origin and divert current waves to earth, so as to limit the amplitude of this overvoltage to a value that is not hazardous for the electrical installation and electric switchgear and control gear.

6.3 Connection

The protection devices can be installed in series with or parallel to the luminaries. The differing connection can be used to maximise availability (parallel connection) or to switch off the luminair if there is a defect on the protection device (serial connection).

6.3.1 *Parallel Connection*

Below Fig. 1 illustrate the parallel connection:

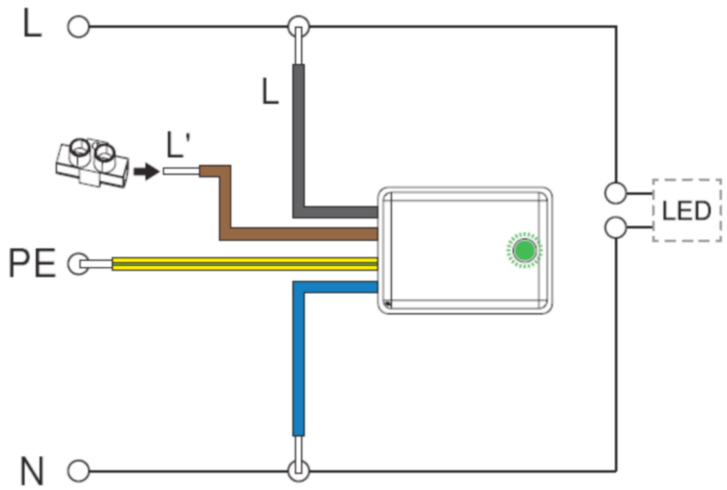

Fig. 1 Parallel Connection

The surge protection device is located upstream of the LED luminaire.

During the failure, the display on the LED goes out. The surge protection is disconnected. The LED luminaire remains lit without protection.

6.3.2 *Serial Connection*

Below Fig. 2 illustrate series connection:

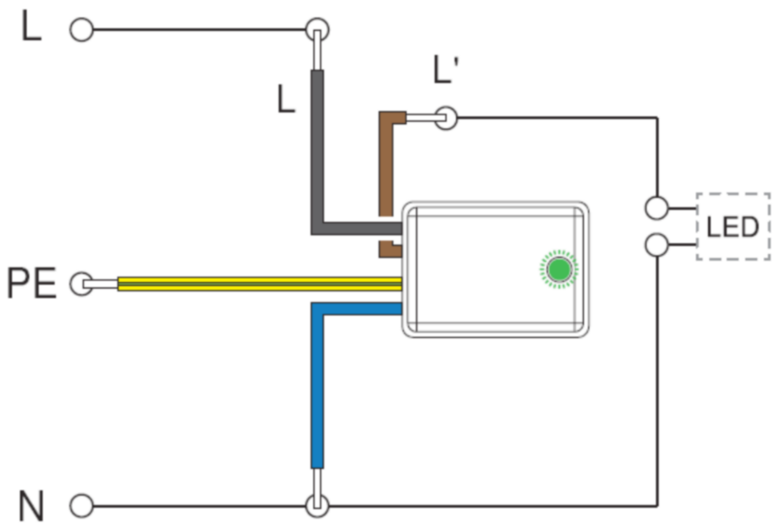

Fig. 2 Series Connection

The surge protection is switched in series to the LED luminary.

During the failure behavior the display on the ÜSM-LED goes out. The surge protection and the circuit (L') are disconnected. The failure is signaled by the luminary going out.

6.3.3 *Power Line Protection*

Fuses are typically one-time-use devices that protect from voltage or current overloads as well as short circuits from an environmental monitoring system power source. Fuses consist of a housing containing a metal wire that will melt when heated by a preset electrical current, called the breaking capacity. This prevents the electrical surge from reaching sensitive electronics to which the fuse is connected.

Fuses should be selected based on —

a) The breaking capacity rating, which for any fuse should be selected just above the maximum expected current of the system.

b) The voltage level of the system and the voltage rating of the fuse

c) Fuse packaging— Fuses come in many standard sizes and types such as glass cartridges, plug-in, etc. Pick the packaging that is supported by your equipment

Other fuse-type protections such as circuit breakers or resettable fuses exist but are not commonly used. Circuit breakers are better for large currents as found in AC power, as opposed to the DC voltages in environmental systems. Resettable fuses are several times more expensive than standard fuses, which are common in environmental monitoring systems.

SPD eliminates over voltages—

a) in common mode, between phase and neutral or earth;
b) in differential mode, between phase and neutral.

In the event of an overvoltage exceeding the operating threshold, the SPD

a) conducts the energy to earth, in common mode;
b) distributes the energy to the other live conductors, in differential mode.

7 ENERGY EFFICIENCY IN ELECTRICAL DISTRIBUTION

Implementation of active energy efficiency measures within the electrical installation can produce high benefits for the user or owner— reduced power consumption, reduced cost of energy, better use of electrical equipment. These measures will most of the time request specific design for the installation as measuring electricity consumption either per application (lighting, heating, process) or per area (floor, workshop) present particular interest for reducing the electricity consumption still keeping the same level of service provided to the user.

8 QUALITY AND SAFETY OF AN ELECTRICAL INSTALLATION

In so far as control procedures are respected, quality and safety will be assured only if:

a) The design has been done according to the latest edition of the appropriate wiring rules.

b) The electrical equipment comply with relevant product standards.

c) The initial checking of conformity of the electrical installation with the standard and regulation has been achieved.

d) The periodic checking of the installation recommended is respected.

9 DESIGN COMPONENTS TO CONSIDER

Achieving desired lighting quality is largely dependent on the luminaries selected; however, their placement and configuration along the roadway are also of major importance to lighting appearance, and in turn to public safety below is a list of the key parameters to be considered by the project designer in order to meet the desired lighting quality recommendations:

a) *Mounting height* —The greater the height the more light/power will be needed to achieve a given luminance, but a more uniform glare free result will be obtained. However, this needs to be balanced out based on road type – width or traffic.
b) *Layout*— Lighting poles can be on just one side of the road or both; pairs of lighting poles can be either opposite each other or staggered.

c) Spacing— The longer the spacing between luminaries, the lower the level of luminance and the more uneven/patchy; however, small spacing result in greater cost and is not always practical.

d) *Lamp type*— These guidelines recommend the use of long service life LED lights. The lighting design based on road type would determine the lighting parameters and should be correlated with the lamp type data to determine suitability of the lamp.

e) *Luminaire*— The actual luminaries chosen have to be suitable for the lamp type and power; the detailed information provided by commercial suppliers can be relied upon for this supported by test reports from NABL accredited Labs.

Fig. 3 illustrate street lighting geometry:

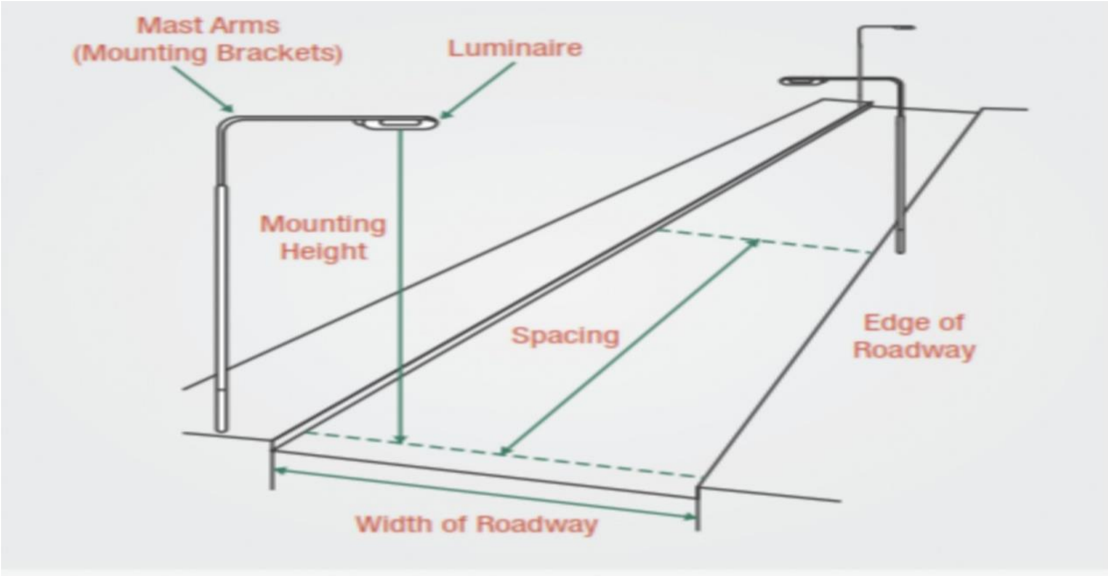

Fig. 3 Street Lighting Geometry

9.1 Electrical Wiring Inspection

All internal and external wiring installations should be inspected to check for broken or cracked terminal lugs, frayed or deteriorated conductor insulations, and the tightness of screws and loose Connections. Loose electrical connection may cause overheating and damaged to the lighting system.

9.2 Measurement of Voltage Input

Measurement should be conducted to determine input voltage to the luminaire. Phase to Neutral, Neutral to Earth voltages be recorded. It is recommended that Neutral to Earth voltage should be greater than 1V and less than 5V.

9.3 Bases and Foundations for Lighting Pole

The base or foundation of a lighting system is its central point of contact with the ground. These structures can have various designs (see Fig 4) but must always be capable of supporting the weight of luminaire, while remaining resistant to wind, vibrations, and other local variables.

Below Fig. 4a illustrate steel base, Fig. 4b illustrated tower type base and Fig. 4c illustrated concrete base. Among the above three, tower type base is most popular.

(4 a) (4 b) (4 c)

Steel Base **Tower Type Base** **Concrete Base**

Fig. 4 Different Types of Base and Foundation

9.4 Electrical Systems

9.4.1 *Grounding*

The metal ground box lids, exposed metal conduit, metal poles, and supplemental ground rods at pole foundations should be connected to the grounding conductor.

9.4.2 *Voltage Drop*

Voltage drop due to resistance in electric wires and cables is an important consideration when installing new or retrofitting street lighting systems because it helps ensure that voltage at all luminaries is sufficient for proper operation. High voltage drop also indicates inefficient operation of the electrical system, resulting from excessive losses over distribution lines.

Street lighting systems should be organized to account for all components, ensuring that even the furthest luminaries in the lighting circuit are able to receive their minimum required level of voltage supply. The amount of voltage drop between the power supply connection point (or feed point) and the furthest luminaries should not excess 3% of the system voltage.

9.4.3 *Service Cabinets*

There are two primary kinds of service cabinets – pad, and pole mounted. These cabinets serve as the electrical service point (feed point) from electric utility to lighting systems. These service cabinets should be sized to accommodate the number of lights as desired, provided that the voltage drop does not exceed 3%.

Street lighting service cabinets should include the following accessories and features:

a) Circuit breaker for mains and branch circuits
b) A concrete foundation and wooden pole for mounting
c) Electrical connections to the power company service conductors

d) Provisions for grounding
e) A meter and meter socket when necessary
f) A photoelectric control socket.

Service cabinet structures should be rain-tight enclosures with a pad-mounting gasket. The cabinet's roof should extend beyond the outer edge of the front door and back wall of the cabinet in order to reduce water build-up in and around sealed areas, such as the cabinet's door.

Below Fig. 5a illustrate pad mounted service cabinet and Fig. 5b illustrate pole mounted service cabinet.

Fig 5 a Pad Mounted Service Cabinet **Fig. 5 b Pole Mounted Service Cabinet**

10 CONFORMITY ASSESSMENT (WITH STANDARDS AND SPECIFICATIONS) OF EQUIPMENT USED IN THE INSTALLATION

The conformity assessment of equipment with the relevant standards can be attested:

a) By a declaration of conformity given by the manufacturer.
b) By a certificate of conformity issued by a certification body, or
c) By mark of conformity granted by the certification body concerned, or

10.1 Declaration of Conformity

The declaration of conformity, including the technical documentation, is generally used for high voltage equipments or for specific products having ISI mark.

10.2 Certificate of Conformity

A certificate of conformity can reinforce the manufacturer's declaration and boost customer confidence. Customers should request this certificate, and it should be mandatory to ensure the maintenance and consistency of the equipment.

10.3 Mark of Conformity

Mark of conformity is a strong tool to verify that the product complies with a specific requirements.

10.4 Initial Testing of an Installation

Before a utility will connect an installation to its supply network, strict pre-commissioning electrical tests and visual inspections by the authority, or by its appointed agent, must be satisfied. These tests are made according to local (governmental and/or institutional) regulations. The principles of all such regulations are based on the observance of rigorous safety rules in the design and realization of the installation.

BUREAU OF INDIAN STANDARDS

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Draft NATIONAL LIGHTING CODE OF INDIA

PART 10 INSTLALLATION ASPECTS FOR LIGHTING

Section 5 Lighting Maintenance

[First Revision of SP 72 (Part 10/Section 5)]

Illumination Engineering and Luminaries Sectional Committee, ETD 49 **Last Date for Comments: 06 July 2024**

FOREWORD

During the life of a lighting installation, the light available for the task progressively decreases due to accumulation of dirt on surface and aging of equipment. The rate of reduction is influenced by the equipment choice and the environmental and operating conditions. In lighting scheme design we must take account of the fall by the use of a maintenance factor and plan suitable maintenance schedules to limit the decay. The lighting scheme should be designed with overall maintenance factor calculated for the selected lighting equipment, space environment and specified maintenance schedule. High maintenance factor with effective maintenance programme promotes energy efficiency design of lighting schemes and limits the installed lighting power requirements.

This section describes the parameters influencing the depreciation process and develops the procedure for estimating the maintenance factor for indoor electric lighting systems. It provides information on the selection of equipment estimation of economic maintenance cycles and gives advice on servicing techniques. It shows some examples of data but for accurate data it recommends that data should be obtained from the manufacturers.

The light has an effect on the physiology and psychology of human being, and it enables him to perceive what is going on around him. There exists a close relationship between the way the visual scene is presented to us and the ability of the eye to fulfill its task properly.

Maintenance activities includes the replacement of failed or deteriorated light sources, control gear, the cleaning of luminaires.

This section of the code is based on CIE 97 (2005) ‘Guide on the Maintenance of indoor electric lighting systems’ and CIE 154 (2003) ‘Guide on the Maintenance of outdoor electric lighting systems’.

1 SCOPE

This chapter specifies the maintenance guidelines of indoor and outdoor lighting installations including a calculation for maintenance factors specific to LED light sources.

2 TERMINOLOGY

For the purpose of definitions, following definitions in additions to those given in Part 1 of this code shall apply.

2.1 Cleaning Agent —Material used to aid the removal of dirt.

2.2 Group Replacement (Lamps) — replacement of a large number of lamps at one chosen time in an installation

2.3 Initial Illuminance — The average illuminance on the reference surface based on initial lamp lumens when the installation is new and the room surfaces are clean.

2.4 Initial Luminous Flux —The luminous flux (lumens) measured after an initial aging period in reference conditions

2.5 IP Code — Ingress Protection Code of enclosures against the entry of dust and moisture.

2.6 Maintained Luminance/ Illuminance — The average luminance/illuminance on the reference surface below which an installation is not allowed to fall. It is the luminance/illuminance at which maintenance must be carried out.

2.7 Maintenance Cycle — repetition of relamping and/or cleaning intervals

2.8 Rated Average Lamp Life — the period over which the lamp survival factor falls to 50% in reference conditions.

2.9 Spot Replacement (Lamps) — replacement of individual lamps as they fail

2.10 Abbreviations

2.10.1 *Lamp Lumen Maintenance Factor (LLMF)* — Ratio of luminous flux of lamp at a given time in the life to the initial luminous flux. Initial luminous flux of lamps is usually declared at 100 hours for discharge lamps.

2.10.2 *Lamp Survival Factor (LSF)* — Fraction of the total number of lamps which continue to operate at a given time under defined conditions and switching frequency.

2.10.3 *Luminaire Maintenance Fact r (LMF)* — Ratio of efficiency of luminaire at a given time to the initial efficiency value.

2.10.4 *Maintenance Factor (MF)* — Ratio of maintained luminance/illuminance to initial luminance / illuminance.

2.10.5 *Surface Maintenance Factor (SMF)* — Ratio of surface reflectance at a given time to the initial reflectance value.

2.10.6 *Room Surface Maintenance Factor (RSMF)* — Ratio of surface reflectance at a given time to the initial reflectance value.

3 NORMATIVE REFRENCES

The following Indian standards are necessary adjunct to this Part of the code.

IS No. / Other Standards	*Title*
12063: 1987	Classification of degree of protection by enclosures of electrical equipment
CIE 97: 2005	Guide on the maintenance of indoor electric lighting systems
CIE 154:2003	Guide on the maintenance of outdoor lighting systems
CIE S 008:2001	Lighting of Indoor Workplaces

4 INDOOR LIGHTING SYSTEMS

4.1 General

Maintenance of all lighting installations is essential as it keeps the performance of the system within the design limits and promotes safety and efficient use of energy. It is a fact that the lighting level provided by a lighting installation will decrease gradually throughout the life of the installation. Several terms have been used to describe the factor the accounts for this reduction but in this guide throughout the term "Maintenance Factor" is used.

Maintenance factor is defined as the ratio of the average illuminance on the working plane after a certain period of use of a lighting installation to the initial average illuminance obtained under the same conditions for the installation therefore taking account of all losses including lamp lumen maintenance.

NOTE—

1. The term "light loss factor", having the same definition as maintenance factor, has been used in the past.
2. term "depreciation factor" has been formerly used to designate the reciprocal of the above ratio.
3. The The light losses take into account dirt accumulation on Luminaire and room surfaces and lamp depreciation.
4. The CIE S 008-2001 Standard on "Lighting of Indoor Workplaces" recommends that the designer of the lighting scheme states the maintenance factor, assumptions and the required maintenance schedule.

The recommended illuminance for lighting design is now based on "maintained illuminance" which is the average illuminance at a "certain period" of use when maintenance has to be carried out and is given by,

$$E_{maintained} = E_{initial} \times MF$$

Lighting systems have different maintenance characteristics and this should be one of the important assessments made in the early stages of project design.

This guide discusses the various influencing factors and gives data based on practical solutions that enable the maintenance factor for types of systems, buildings and locations to be derived. The derived maintenance factor should be applied to all formulae used for lighting scheme calculations, such as illuminance, luminance on areas or at points. Methods for estimating economic maintenance periods and advice on cleaning techniques are also given.

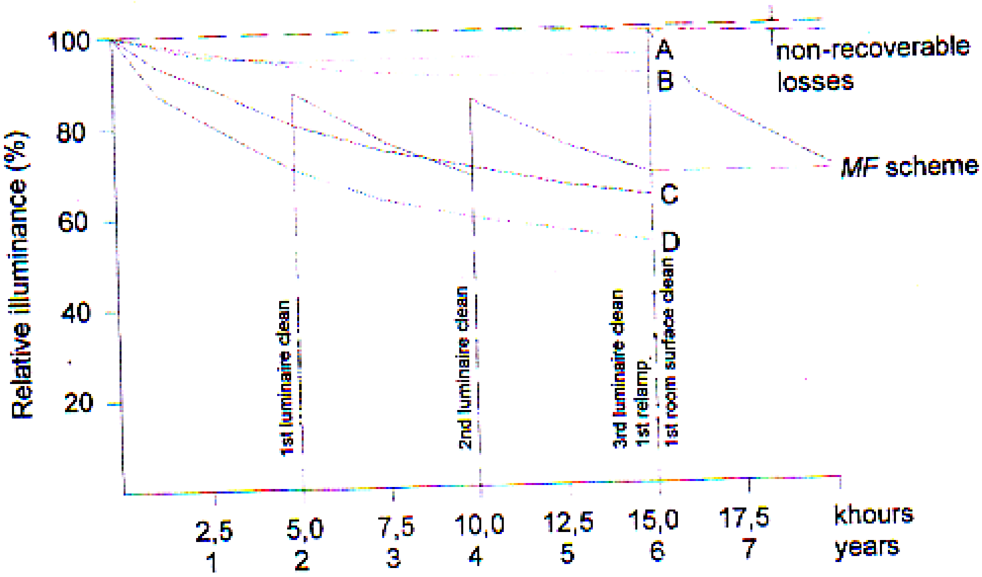
The guide also provides a limited selection of typical current data to allow the calculation methods to be explained. The examples of data have been updated with new lamp types, Luminaire types and improvements in the interior cleanliness. A "very clean" environment category has been added and a new method with data extending to 6 years is proposed for the room surface maintenance factor. However, to take advantage of the continuing developments of lighting products and techniques, "up-to-date" data should be obtained from manufacturers.

4.2 Need for Maintenance

All lighting schemes within a building will deteriorate progressively from the moment they are put into use. The losses are due to the accumulation of dust and dirt on all exposed surfaces of lamps, luminaries and room surfaces, reducing the transmittance or reflectance and to the decay in lamp lumen output, failing lamps and aging of surfaces. If this process is unchecked, it will result in the illuminance falling to very low values as shown in Fig. 1, and the scheme could become very energy inefficient, unsightly and dangerous. As the decay in illuminance is gradual, the workers may not notice the loss immediately. But over a period this gradual reduction will cause increased visual strain, more errors and mistakes in the work; the task will take longer to complete and accidents may occur.

Regular maintenance is, therefore, most important for an effective lighting installation. The lighting system should not only be cleaned correctly and thoroughly but the cleaning should be carried out at regular intervals. A well-designed maintenance schedule and programme will yield a higher maintenance factor and will maintain the required illuminance, reduce capital and operating costs, reduce the installed power requirements and run the system safely. It will ensure satisfactory appearance and comfort for the occupants.

However, even with a well-designed and operated maintenance programme some loss of illuminance is inevitable. This loss has to be estimated, at the time the lighting scheme is planned, and an allowance in the form of maintenance factor should be included in the scheme design calculations.



A — Room surface maintenance curve (reflectance 70/50/20. *DFF* 0.0 in clean environment);

B — Lamp lumen maintenance curve (HF linear tri-phosphor fluorescent lamp);

C — Luminaire maintenance curve (type C luminaire in clean environment);

D — Un-maintained system output;

MF scheme – is the design maintenance factor and indicates the relative maintained illuminance.

NOTE — The lamp survival rate is not included as in this case between bulk re-lamping spot replacement is assumed.

Fig. 1 Variation of Illuminance through Life (Linear Fluorescent Lamp in Industrial Reflector Luminaire Operated with Spot Lamp Replacement Programme)

4.3 Influencing Factors

There are several factors that can reduce the light output. These are grouped under non-recoverable and recoverable depreciations.

4.3.1 *Non-Recoverable Factors*

Non-recoverable factors (NRF), such as ageing/fading of materials, operating temperature and voltage are inherent in the installation and its environment and cannot be improved during normal maintenance or are uneconomical to overcome. These factors in general are small (< 3 %) but should be taken into account together with the planning of a maintenance programme at the design stage of the lighting scheme and the right equipment for the environment should be selected.

Once the non-recoverable reductions, by ageing or soiling, have occurred they cannot be brought back to their original condition and replacement of the luminaire may be necessary. This is the case with luminaires if they are in, say, dusty or oily atmospheres so that dust or oil particles become burnt onto the reflector. In such cases it is not economically viable to bring the reflector back to its original condition and, therefore, it is advisable (sometimes essential) to replace the reflector. If this is not done the lighting installation will not provide the maintained illuminance.

If the influence of other factors such as voltage, frequency, temperature and ballast, are permanent and significant then at the design stage the magnitude of these effects should be estimated and an allowance similar to the maintenance factor should be made in the calculations. These factors although important are not part of this publication and are not used in the described methods. However, it is worth stating that the influence of random occurrences may be ignored, provided they do not harm the operation of the lighting system.

4.3.2 *Recoverable Factors*

Recoverable factors, of lamp lumen maintenance, lamp survival, luminaire maintenance, room surface maintenance can be made good during service and routine maintenance. These should be defined in the maintenance schedule and implemented by re-lamping, cleaning, replacing failed components or painting of the surfaces.

The value of such maintenance programme is indicated by an example in Fig. 1. This clearly shows that the illuminance in the un-serviced scheme will fall to 50 % of the initial value within 6 years and will continue to decline albeit at reduced rate. But by implementing a programme of bi-annual luminaire cleaning and 6 yearly bulk re-lamping and room surface cleaning the decline is checked and can be restored to over 98 % of the initial value. At this time the maintained scheme provides double of the illuminance of that given by the unmaintained system. The maintenance programme will yield a Maintenance Factor of 0.70 for the scheme.

4.4 Inspection Intervals and Cleanliness Category

Regular inspection of lighting installations is advisable. In some countries the provision of adequate illuminance for working is required by law. Independent inspectors enforce the task illuminance.

As a guide for those who have their lighting inspected and/or measured. Table 1 shows maximum time intervals between inspections of various areas. Table 1 also indicates the cleanliness category of typical places of work.

> NOTE— There may be cases, particularly in certain industrial processes area, where the environment is exceedingly dirty which are outside the scope of the above classification.

Table 1

Recommended Inspection Intervals of Lighting Systems in Different Working Environments.

(*Clause* 4.4 *and* 4.10.1)

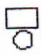
Sl. No	**Inspection Interval**	**Environment**	**Activity or task area**
(1)	(2)	(3)	(4)
i)	3 years	Very Clean (VC)	Clean rooms, semi conductor plants, hospitals clinical areas *, computer centres
		Clean (C)	Offices, schools, hospital wards
ii)	2 years	Normal (N)	Shops, laboratories, restaurants, warehouses, assembly areas, workshops
iii)	1 year	Dirty (D)	Steelworks, chemical works, foundries, welding, polishing, woodwork

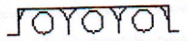
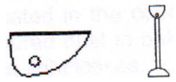
* For reason of hygiene control, more frequent inspection may be required.

4.5 Cleaning Schedule

To assist operators of maintenance schedules Table 2 gives a quick indication of the cleaning intervals for different luminaire types used in the various environments. As far as maintenance is concerned Table 2 and Table 3 can also be used as a guide for the selection of luminaires for the particular environments. The data are typical for the luminaires using any lamp types with the exception of those using high-pressure discharge reflector lamps. These reflector lamp luminaires will have characteristics similar to type B luminaire.

Table 2 Approximate Cleaning Intervals (marked by X) for Luminaires Used in Various Environments
(*Clause* 4.5, 4.10.1 *and* 4.15)

Sl. No	**Cleaning Intervals**	**3 years**			**2 years**			**1 year**		
(1)	(2)	(3)			(4)			(5)		
	Environment /Luminaire type	VC C	N	D	VC C	N	D	VC C	N	D
i)	Bare batten	X				X				X
ii)	 B. Open top housing (natural ventilated) 	X				X				X

iii)	C. Closed top housing (unventilated) 	X			(X)				X
iv)	D. Enclosed IP2X 	X			(X)				X
v)	E. Dust proof IP5X 	X	X				X		
vi)	F. Enclosed indirect (uplight) 				X			(X)	X
vii)	G. IP 65 LED closed luminiares 	x	x				x		

Where VC is very clean, C is clean, N is normal and D is dirty atmosphere in the environment (*see* Table 2)

The selection of intervals is based on having a luminaire maintenance factor (*LMF*) of over 0.80.

Table 3 Examples of Luminaire Types
(*Clause* 4.5)

Sl. No (1)	**Type** (2)	**Luminaire Types** (3)	**Luminaire Descriptions** (4)
i)	A	Bare batten	Bare lamp luminaires
ii)	B	Open top housing (natural ventilated and so called “self cleaning” types)	Direct-indirect luminaires without cover Direct-indirect luminaires with indirect reflector and closed optical device Wall washing luminaires (vertical opening) Wall mounted luminaires open top and base Downlights with open top
iii)	C	Closed top housing (unventilated)	Recessed and surface mounted luminaires (e.g. with louvers) Downlights, spotlights
iv)	D	Enclosed IP2X	General purpose luminaires with closed covers and optics
v)	E	Dust proof IP5X	Dust proof IP5X (protected, clean room luminaires)
vi)	F	Indirect lighting and uplight	Free standing, pendent, wall mounted uplighters with closed base, cove lights.

vii)	G	Closed integrated or modular LED fittings	Used for street and flood lighting

Luminaires C, D and F are not recommended for dirty environments.

4.6 Analysis of Depreciation

Several factors contribute to light losses and the effect and magnitude vary with the type of activity and the location. For example, areas vary as to the amount and type of dirt in the air; the amount of dirt in a foundry is greater than that found in an air-conditioned office. But the amount and type of dirt in an office located near an industrial area is different to that for an office located in the country. The black dirt found in steel mills is most unlike the relatively light coloured dust in bakeries. It is important to be able to recognize these variations when assessing light losses.

4.6.1 *Lamp Lumen Maintenance Factor*

Lamp lumen maintenance factor is the relative light output during the lifetime of a burning lamp to the initial output. The light output of all lamp types decreases with burning hours. Table 4 gives examples of lamp operating hours (burning hours) for a range of activity areas. The exact rate, however, depends on the specific lamp type and for discharge lamps also on the ballasting system. The losses due to this effect can be reduced by more frequent lamp replacement, perhaps by group replacement. Table 5 shows typical examples of lamp lumen maintenance factors. It is therefore very important to obtain up-to-date data from the manufacturers for estimating the maintenance factor and the maintenance programme, particularly when using a new type of lamp.

For accurate data always consult the manufacturer.

Table 4
Typical Annual Operating Hours (Burning Hours)
(*Clause* 4.6.1 *and* 4.14.1)

Sl. No	**Activity**	**Period of occupancy**		**Daylight link controls**	**Operating hours**
	Include shifts	**No. of days**	**Hours/day**	**Yes/No ***	**Hours/year**
(1)	(2)	(3)	(4)	(5)	(6)
i)	**Industrial**				
ii)	Continuous	365	24	no	8760
iii)	Process	365	24	yes	7300
iv)	Two shifts	310	16	no	4960
v)	Six days/week	310	16	yes	3720
vi)	Single shift	310	10	no	3100
vii)	Six days/week	310	10	yes	1760
viii)	Single shift	258	10	no	2580
ix)	Five days/week	258	10	yes	1550
x)	**Retail**				
xi)	Six days/week	310	10	no	3100

xii)	**Offices**				
xiii)	Five days/week	258	10	no	2580
xiv)		258	10	yes	1550
xv)	**Schools**				
xvi)	Five days/week	190	10	no	1900
xvii)		190	10	yes	1140
xviii)	**Hospitals**				
xix)	7days/week	365	16	no	5840
xx)		365	16	yes	3504

* Assuming adequate daylight is available during daytime for about half the working days. As daylight penetration varies across the areas the switching or dimming arrangements will need to be organized accordingly.

NOTE—Frequent switching of the lamps will reduce the lamp life, *see* Fig. 2.

4.6.2 *Lamp Survival*

Lamp survival factor is the probability of lamps continuing to operate for a given time. It indicates the percentage of a large representative group of a type of lamp remaining operational after a certain period. The survival rate depends on lamp type and particularly, in the case of discharge lamps, the frequency of switching and the ballasting system. Traditionally the lamp life is the declared time in hours when 50 % of the lamps in test batch have survived (see Fig.2). Failed lamps in schemes will cause reduction in illuminance and uniformity, but the effect can be minimized by spot replacement of lamps. Table 5 shows typical examples of lamp survival data. The *LSF* value should be used in conjunction with the *LLMF* value to establish an economic working life for the lamp as the declared life is often much longer than the economic light output lamp life.

For accurate data manufacturer may be contacted.

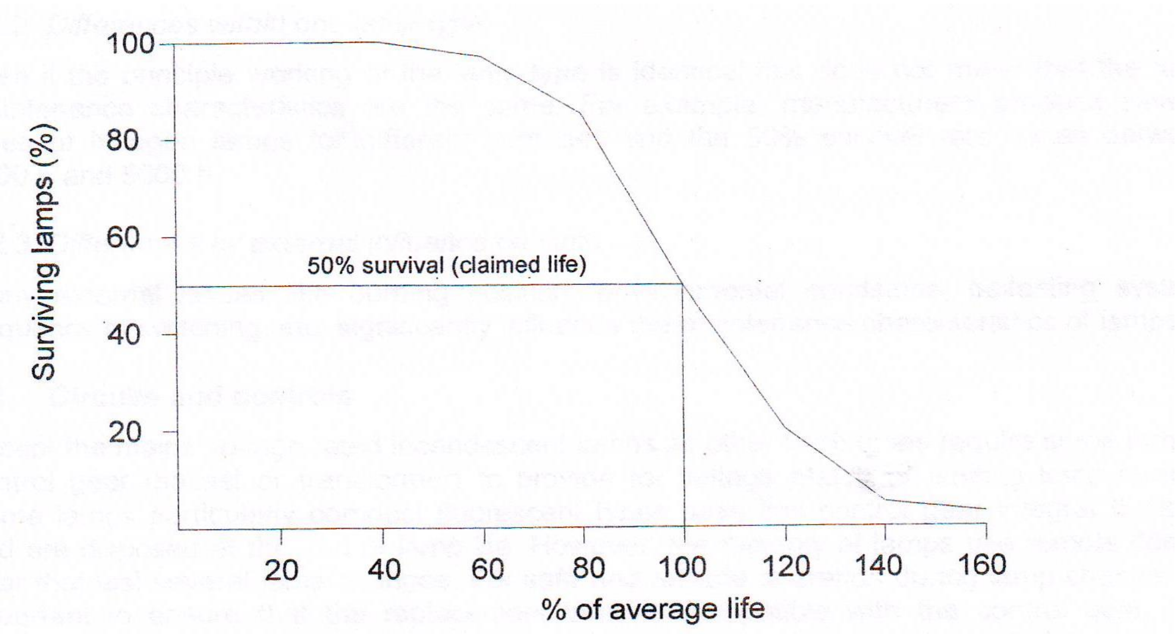


Fig. 2 Typical Lamp Mortality Curves
(Statistical group of linear fluorescent lamps on 8 switch cycles per 24 hours)

Table 5 Typical Examples of the Lamp Lumen Maintenance Factor (*LLMF*) and the Lamp Survival Factor (*LSF*) Data

(*Clause* 4.6.1 *and* 4.6.2)

Sl. No.			differences[1]	Burning hours in thousand hours											
				1.0	5.0	1	2	4	6	8	10	12	15	20	30
(1)	(2)		(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
i)	**Incandescent**	*LLMF*	moderate	1.00	0.97	0.93									
		LSF	big	1.00	0.98	0.50									
ii)	**Halogen**	*LLMF*	big	1.00	0.99	0.97	0.95								
		LSF	big	1.00	1.00	0.78	0.50								
iii)	**Fluorescent Tri-phosphor**	*LLMF*	moderate	1.00	0.99	0.98	0.97	0.93	0.92	0.90	0.90	0.90	0.90	0.90	
		LSF	moderate	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.98	0.97	0.94	0.50	
iv)	**Fluorescent Tri-phosphor**	*LLMF*	moderate	1.00	0.99	0.98	0.97	0.93	0.92	0.90	0.90	0.90	0.90		
		LSF	moderate	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.98	0.92	0.50		
v)	**Fluorescent halo phosphate**	*LLMF*	moderate	1.00	0.98	0.96	0.95	0.87	0.84	0.81	0.79	0.77	0.75		
		LSF	moderate	1.00	1.00	1.00	1.00	1.00	0.99	0.98	0.98	0.92	0.50		
vi)	**Compact fluorescent**	*LLMF*	big	1.00	0.98	0.97	0.94	0.91	0.89	0.87	0.85				
		LSF	big	1.00	0.99	0.99	0.98	0.97	0.94	0.86	0.50				
vii)	**Mercury**	*LLMF*	moderate	1.00	0.99	0.97	0.93	0.85	0.82	0.80	0.79	0.78	0.77	0.76	
		LSF	moderate	1.00	1.00	0.99	0.98	0.97	0.94	0.90	0.86	0.79	0.69	0.50	
viii)	**Metal halide (250/400 W)**[2]	*LLMF*	big	1.00	0.98	0.95	0.90	0.87	0.83	0.79	0.65	0.63	0.58	0.50	
		LSF	big	1.00	0.99	0.99	0.98	0.97	0.92	0.86	0.80	0.73	0.66	0.50	
ix)	**Ceramic metal halide (50/150 W)**	*LLMF*	big	1.00	0.95	0.87	0.75	0.72	0.68	0.64	0.60	0.56			
		LSF	big	1.00	0.99	0.99	0.98	0.98	0.98	0.95	0.80	0.50			
x)	**High pressure sodium (250/400 W)**	*LLMF*	moderate	1.00	1.00	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.96	0.94	0.90
		LSF	moderate	1.00	1.00	1.00	1.00	0.99	0.99	0.99	0.99	0.97	0.95	0.92	0.50
xi)	**LED**[3]	*LLMF*	big	Manufacturer data to be taken into account. Ref Cl 5 for LED system											
		LSF	big & moderate	Manufacturer data to be taken into account. Ref Cl 5 for LED system											

[1]Indicates differences in *LLMF* and *LSF* among lamps, which belong to the same lamp type category

[2]Differences in group of metal halides are extremely remarkable. Very high and very low wattage lamps live significantly shorter than values given here.

[3]Data of LED's varies on many accounts of design parameters. Ref Cl 5 for LED.

It is always advisable to consult manufacturers for detailed and up-to date lamp data.

4.6.2.1 *Differences between lamp types*

Different lamp types behave differently. For example the working principles of an incandescent lamp are a glowing filament whilst a fluorescent lamp is by arc discharge combined with phosphor emission.

4.6.2.2 *Differences within one lamp type*

Even if the principle working of the lamp type is identical this does not mean that the lamp maintenance characteristics are the same. For example, manufacturers produce several types of halogen lamps for different purposes and the 50% survival rate varies between 1000 h and 5000 h.

4.6.2.3 *Differences by external influence on lamp*

Many external issues like burning position, environmental conditions, ballasting system, frequency of switching, etc. significantly influence the maintenance characteristics of lamps.

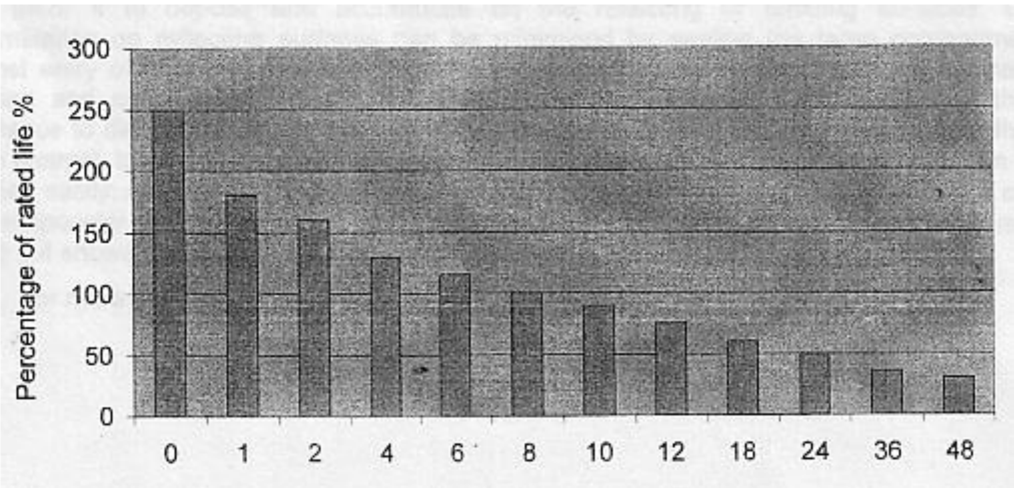
4.7 Circuits and Controls

Except the mains voltage rated incandescent lamps all other lamp types require some form of control gear (ballast or transformer) to provide for voltage match or limiting lamp current. Some lamps particularly compact fluorescent types have this control gear integral (built in) and are disposed at the end of lamp life. However, the majority of lamps use remote control gear that last several lamp changes.

For safe and reliable operation during lamp change it is important to ensure that the replacement lamp is compatible with the control gear. The manufacturers of luminaires use both magnetic and electronic control gear and they should be consulted on the choice. The control gear may be fixed or variable (dim) output and can be coupled with lighting management systems. These systems can be linked to timed control or people presence detection and/or daylight sensing to switch or dim the lamps accordingly.

The lamp life is based on defined frequency of switching with a 24 hour period. Frequent switching will reduce lamp life (*see* Fig. 3). Studies have shown that correct dimming of lamps has no adverse effect on lamp life, in fact incandescent lamps can benefit. Fig. 3 and Table 6 give examples of how ballasting system and switching frequency influence the lifetime of linear fluorescent lamps.

The effect of switching on lamp life



Number of switching in 24 hrs.

Fig. 3 Example of the Effect of Switching on Lamp Life for Fluorescent Lamp on Lagging Switch Start Circuit.

NOTE— The glow switch in a switch start circuit should be changed with each lamp change

Table 6 Examples of Switching Frequency and Ballast Influence on Lamp Life (50 % survivor) of the TLD and T5 Linear Fluorescent Lamps.
(*Clause* 4.7)

		High frequency Electronic ballast		**Conventional (magnetic) ballast**	
Sl. No	**Switching Cycle**	**Programmed Start (Preheat)**	**Instant Start (Non-Preheat)**	**Inductive Circuit**	**Lead Lag Circuit (50 % Capacitive, 50% Inductive)**
(1)	(2)	(3)	(4)	(5)	(6)
i)	12 h	23 000 h	19 000 h	18 000 h	15 000 h
ii)	8 h	22 000 h	17 000 h	16 000 h	14 000 h
iii)	3 h	20 000 h	Not available	15 000 h	12 000 h
iv)	1 h	16 000 h	Not available	12 000 h	9 000 h

NOTE: T5 lamps use only electronic ballasts.

For accurate data the luminaire manufacturer may be consulted.

4.8 Luminaire Maintenance Factor

Luminaire maintenance factor is the relative output of the luminaire due to dirt deposited on lamps and on or in the luminaires over a period. The rate of reduction depends on the construction of the luminaire and on the nature and density of airborne dirt present in the atmosphere. Black dirt or dust will generally cause the greatest loss of light. It is not uncommon to find 50 % loss, due to dirt, from industrial lighting systems between long cleaning intervals. The amount of light loss depends on the nature and density of airborne dirt, luminaire design, luminaire material and finish and lamp type. Ventilated luminaires collect less dirt if the location of openings is arranged so that convention air currents can carry dust and dirt, pass the optic and lamp (sometimes referred to as self-cleaning action) rather than allow it to deposit and accumulate on the reflecting or emitting surfaces. Dirt accumulation on reflecting surfaces can be minimized by sealing the lamp compartment against entry of dust and moisture. Significant benefits can be obtained with the luminaire housing and optic sealed to at least IP 54 protection. Luminaire finishes differ in their resistance to dirt accumulation. For example, anodized aluminium will stay clean longer than white enamel, but the former will have slightly lower initial reflectance whilst the latter can be cleaned easily. Also the dirt deposit can affect the intensity distribution of the luminaire. It can turn a specular surface reflector into a matt finish or a prismatic controller into a diffuser. Table 7 shows typical data for a range of luminaires.

For more accurate data, the luminaire manufacturer may be consulted.

Table 7
Examples of Luminaire Maintenance Factors (*LMF*)
(*Clause* 4.8)

Elapsed time between cleanings in years	0	0.5				1.0				1.5				2.0				2.5				3.0			
Luminaire type (see Table 2)	Environment																								
	Any	VC	C	N	D	VC	C	N	D	VC	C	N	D	VC	C	N	D	VC	C	N	D	VC	C	N	D
A	1	0.98	0.95	0.92	0.88	0.96	0.93	0.89	0.83	0.95	0.91	0.87	0.80	0.94	0.89	0.84	0.78	0.93	0.87	0.82	0.75	0.92	0.85	0.79	0.73
B	1	0.96	0.95	0.91	0.88	0.95	0.90	0.86	0.83	0.94	0.87	0.83	0.79	0.92	0.84	0.80	0.75	0.91	0.82	0.76	0.71	0.89	0.79	0.74	0.68
C	1	0.95	0.93	0.89	0.85	0.94	0.89	0.81	0.75	0.93	0.84	0.74	0.66	0.91	0.80	0.69	0.59	0.89	0.77	0.64	0.54	0.87	0.74	0.61	0.52
D	1	0.94	0.92	0.87	0.83	0.94	0.88	0.82	0.77	0.93	0.85	0.79	0.73	0.91	0.83	0.77	0.71	0.90	0.81	0.75	0.68	0.89	0.79	0.73	0.65
E	1	0.94	0.96	0.93	0.91	0.96	0.94	0.90	0.86	0.92	0.92	0.88	0.83	0.93	0.91	0.86	0.81	0.92	0.90	0.85	0.80	0.92	0.90	0.84	0.79
F	1	0.94	0.92	0.89	0.85	0.93	0.86	0.81	0.74	0.91	0.81	0.73	0.65	0.88	0.77	0.66	0.57	0.86	0.73	0.60	0.51	0.85	0.70	0.55	0.45
G	1	1.00	1.00	0.99	0.98	1.00	0.99	0.96	0.93	0.99	0.97	0.94	0.89	0.99	0.96	0.92	0.87	0.98	0.95	0.91	0.86	0.98	0.95	0.90	0.85

4.9 Room Surface Maintenance Factor (*RSMF*)

Room Surface Maintenance Factor (*RSMF*) is the relative proportion of the initial inter-reflected component of illuminance from the installation after a certain period due to dirt on room surfaces. Tables 9, 10 and 11 provide examples of *RMSF* data. The room surface maintenance factor can also be regarded as the ratio of the utilance of a given installation after a specified time to the utilance of the same installation (without a change of the relative distribution of the direct fluxes onto all reflecting surfaces) when new or after the last cleaning. The room surface maintenance factor depends on the room proportion, on the reflectance of all surfaces and on the direct flux distribution of the installed luminaires. The room surface maintenance factor also depends on the nature and density of dust present or generated in the room. This buildup of dirt on the room surfaces over a period of time will reduce the available amount of inter-reflected light. While periodic cleaning and painting of walls and ceilings is advisable in all installations it should be done more frequently in areas where a large proportion of light arrives on the task by reflection from the room surfaces or curtains, pictures and furniture. Clean room surfaces will help the luminance balance in the environment. In some countries redecoration of the room surfaces is required at regular intervals set out in hygiene regulations.

Under the assumption that the decrease of the reflectance of any particular room surface over time can be expressed by using the formula shown below, the room surface maintenance factor can be evaluated for any maintenance intervals. For a set of realistic values of c and t the room surface maintenance factor values can be calculated for very clean, clean, normal and dirty environment conditions and the results presented for different reflectance conditions in tables just like utilization factors. For practical reasons it is sufficient to generate tables for only one medium proportion room size (k = 2.5) but for at least 3 flux distributions [Downward Flux Fraction (DFF) of 0.0, 0.5 and 1.0] for maintenance intervals of up to 6 years. Table 8 provides values for the constants c and t and Tables 9, 10 and 11 gives *RSMF* values for cosine distribution type luminaire having flux fraction of 0.0 or 0.5 or 1.0 for a set of reflectance and environment. Clearly *RSMF* values can be generated for other luminous intensity and flux distribution type luminaires.

NOTE— The Downward Flux Fraction (DFF) is the ration of the Downward Light Output Ratio (DLOR) and the Light Output Ration (LOR) of the luminaire.

$$DFF = DLOR/LOR$$

$$p\,(t) = p_o \cdot [c + (1-c).\, e^{-t/}\, \tau]$$

where $p\,(t)$ is the reflectance at a specified time t in years;

p_o is the initial reflectance;
c, τ are constants of the dust accumulation process.

Table 8
Table of Values for Constants c and τ
(*Clause* 4.9)

Sl.No	Environment	Ceiling cc	Walls cw	Floor cf	τ (applied to time in years)
(1)	(2)	(3)	(4)	(5)	(6)
i)	Very clean	0.96	0.92	0.85	6/12
ii)	Clean	0.92	0.84	0.70	5/12
iii)	Normal	0.83	0.70	0.50	4/12

iv)	Dirty	0.70	0.45	0.30	3/12

NOTE — Maintenance data is usually provided in tabular form. However, it is often convenient to present the data in graphical forms.

Some examples for fluorescent lamps/luminaires and room surface are shown in Fig. 4

Table 9
Table of Room Surface Maintenance Factor (*RSMF*) for Direct Flux Distribution (DFF = 0.0)
(*Clause* 4.9)

Sl. No	**Reflectances ceiling/wall/ floor**	**Time / yrs**	0.00	0.50	1.00	1,50	2,00	2,50	3,00	3,50	4,00	4,50	5,00	5,50	6,00
		environment	**Room surface maintenance factors – utilization plane**												
(1)	(2)	(3)	(4)												
i)	0.80/0.70/0.20	very clean	1.00	0.97	0.96	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
ii)		clean	1.00	0.93	0.92	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
iii)		normal	1.00	0.88	0.86	0.86	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
iv)		dirty	1.00	0.81	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
v)	0.80/0.50/0.20	very clean	1.00	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
vi)		clean	1.00	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
vii)		normal	1.00	0.91	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
viii)		dirty	1.00	0.86	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
ix)	0.80/0.30/0.20	very clean	1.00	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
x)		clean	1.00	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
xi)		normal	1.00	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
xii)		dirty	1.00	0.91	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
xiii)	0.70/0.70/0.20	very clean	1.00	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
xiv)		clean	1.00	0.94	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
xv)		normal	1.00	0.89	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
xvi)		dirty	1.00	0.83	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
xvii)	0.70/0.50/0.20	very clean	1.00	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
xviii)		clean	1.00	0.96	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
xix)		normal	1.00	0.92	0.91	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
xx)		dirty	1.00	0.87	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
xxi)	0.70/0.30/0.20	very clean	1.00	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
xxii)		clean	1.00	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
xxiii)		normal	1.00	0.95	0.94	0.94	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
xxiv)		dirty	1.00	0.92	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
xxv)	0.50/0.70/0.20	very clean	1.00	0.98	0.97	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
xxvi)		clean	1.00	0.95	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
xxvii)		normal	1.00	0.91	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89	0.89
xxviii)		dirty	1.00	0.85	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
xxix)	0.50/0.50/0.20	very clean	1.00	0.98	0.98	0.98	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
xxx)		clean	1.00	0.97	0.96	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95

xxxi)		normal	1.00	0.94	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
xxxii)		dirty	1.00	0.89	0.89	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
xxxiii)	0.50/0.30/0.20	very clean	1.00	0.99	0.99	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98	0.98
xxxiv)		clean	1.00	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
xxxv)		normal	1.00	0.96	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
xxxvi)		dirty	1.00	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92

Table 10
Table of Room Surface Maintenance Factor (*RSMF*) for Direct/Indirect Flux Distribution (DFF = 0.5).

(*Clause* 4.9)

Sl. No	Reflectances ceiling/walls/floor	Time / yrs	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
		environment	Room surface maintenance factors – utilization plane												
(1)	(2)	(3)	(4)												
i)	0.80/0.70/0.20	very clean	1.00	0.95	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
ii)		clean	1.00	0.90	0.88	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
iii)		normal	1.00	0.81	0.78	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
iv)		dirty	1.00	0.70	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
v)	0.80/0.50/0.20	very clean	1.00	0.96	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
vi)		clean	1.00	0.93	0.91	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
vii)		normal	1.00	0.85	0.83	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82	0.82
viii)		dirty	1.00	0.76	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
ix)	0.80/0.30/0.20	very clean	1.00	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
x)		clean	1.00	0.94	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
xi)		normal	1.00	0.89	0.87	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
xii)		dirty	1.00	0.81	0.79	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78	0.78
xiii)	0.70/0.70/0.20	very clean	1.00	0.96	0.94	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
xiv)		clean	1.00	0.91	0.89	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
xv)		normal	1.00	0.83	0.80	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
xvi)		dirty	1.00	0.72	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
xvii)	0.70/0.50/0.20	very clean	1.00	0.97	0.96	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
xviii)		clean	1.00	0.93	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
xix)		normal	1.00	0.87	0.84	0.84	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
xx)		dirty	1.00	0.77	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
xxi)	0.70/0.30/0.20	very clean	1.00	0.98	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
xxii)		clean	1.00	0.95	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
xxiii)		normal	1.00	0.90	0.88	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87

xxiv)		dirty	1.00	0.82	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
xxv)	0.50/0.70/0.20	very clean	1.00	0.97	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95	0.95
xxvi)		clean	1.00	0.93	0.91	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
xxvii)		normal	1.00	0.86	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
xxviii)		dirty	1.00	0.76	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74
xxix)	0.50/0.50/0.20	very clean	1.00	0.97	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96	0.96
xxx)		clean	1.00	0.94	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
xxxi)		normal	1.00	0.89	0.87	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86	0.86
xxxii)		dirty	1.00	0.81	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79	0.79
xxxiii)	0.50/0.30/0.20	very clean	1.00	0.98	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97	0.97
xxxiv)		clean	1.00	0.96	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
xxxv)		normal	1.00	0.92	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
xxxvi)		dirty	1.00	0.85	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84

Table 11
Table of Room Surface Maintenance Factor (*RSMF*) for Indirect Flux Distribution (DFF) = 1.0

(*Clause* 4.9)

Sl. No	Reflectances ceiling/walls/floor	Time / yrs	0.00	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	5.50	6.00
		environment	Room surface maintenance factors – utilization plane												
(1)	(2)	(3)	(4)												
i)	0.80/0.70/0.20	very clean	1.00	0.93	0.91	0.90	0.90	0.90	0.90	0.89	0.89	0.89	0.89	0.89	0.89
ii)		clean	1.00	0.86	0.82	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81
iii)		normal	1.00	0.72	0.67	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
iv)		dirty	1.00	0.54	0.50	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49	0.49
v)	0.80/0.50/0.20	very clean	1.00	0.94	0.93	0.92	0.92	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
vi)		clean	1.00	0.88	0.85	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
vii)		normal	1.00	0.76	0.72	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
viii)		dirty	1.00	0.59	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
ix)	0.80/0.30/0.20	very clean	1.00	0.96	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
x)		clean	1.00	0.90	0.88	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
xi)		normal	1.00	0.80	0.76	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75	0.75
xii)		dirty	1.00	0.64	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
xiii)	0.70/0.70/0.20	very clean	1.00	0.93	0.91	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90	0.90
xiv)		clean	1.00	0.86	0.83	0.82	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81	0.81

xv)		normal	1.00	0.73	0.68	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67	0.67
xvi)		dirty	1.00	0.55	0.51	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
xvii)	0.70/0.50/0.20	very clean	1.00	0.95	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
xviii)		clean	1.00	0.89	0.86	0.85	0.85	0.84	0.84	0.84	0.84	0.84	0.84	0.84	0.84
xix)		normal	1.00	0.77	0.73	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72	0.72
xx)		dirty	1.00	0.60	0.56	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
xxi)	0.70/0.30/0.20	very clean	1.00	0.96	0.94	0.94	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93	0.93
xxii)		clean	1.00	0.91	0.88	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87	0.87
xxiii)		normal	1.00	0.80	0.77	0.76	0.76	0.76	0.76	0.76	0.75	0.75	0.75	0.75	0.75
xxiv)		dirty	1.00	0.65	0.61	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
xxv)	0.50/0.70/0.20	very clean	1.00	0.94	0.92	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91	0.91
xxvi)		clean	1.00	0.87	0.84	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83	0.83
xxvii)		normal	1.00	0.75	0.70	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69	0.69
xxviii)		dirty	1.00	0.57	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52	0.52
xxix)	0.50/0.50/0.20	very clean	1.00	0.95	0.93	0.93	0.93	0.92	0.92	0.92	0.92	0.92	0.92	0.92	0.92
xxx)		clean	1.00	0.90	0.87	0.86	0.86	0.85	0.85	0.85	0.85	0.85	0.85	0.85	0.85
xxxi)		normal	1.00	0.78	0.74	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73	0.73
xxxii)		dirty	1.00	0.61	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57	0.57
xxxiii)	0.50/0.30/0.20	very clean	1.00	0.96	0.95	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94	0.94
xxxiv)		clean	1.00	0.91	0.89	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
xxxv)		normal	1.00	0.87	0.78	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77	0.77
xxxvi)		dirty	1.00	0.66	0.62	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61	0.61

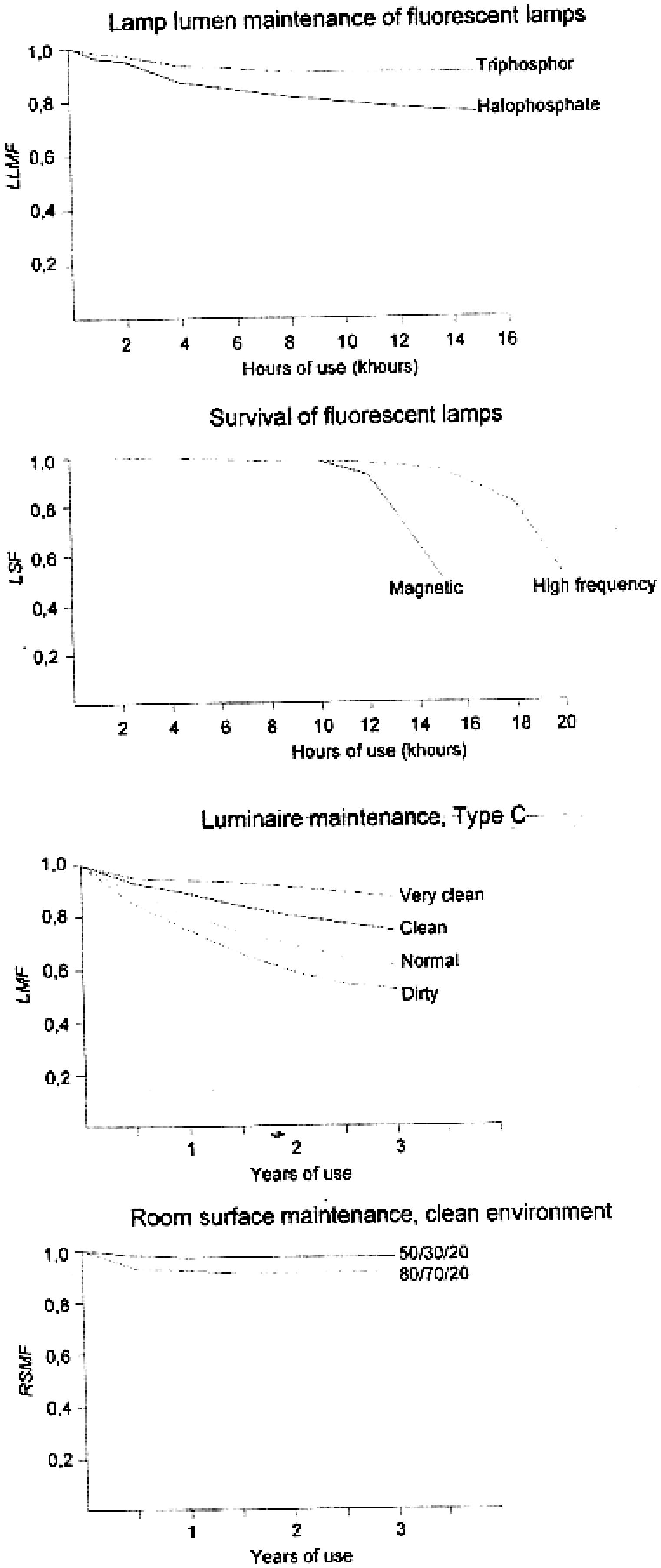


Fig. 4 Examples of Recoverable Maintenance Factor Data

Table 12 Typical Set of *MF* Values For a Medium Sized Room and the Various Lamp And Luminaire Type Combinations
(*Clause* 4.11)

Sl. No	Lamp type		Incandescent halogen				Compact fluorescent				HF with pre-heat fluorescent linear tri-phosphor				Metal halide (250/40 W)				High pressure sodium (250/400 W)			
(1)	(2)		(3)				(4)				(5)				(6)				(7)			
i)	Environment Luminaire		VC	C	N	D	VC	C	N	D	VC	C	N	D	VC	C	N	D	VC	C	N	D
	Type	*DFF*																				
ii)	A	0.5	0.87	0.80	0.70	0.59	0.87	0.75	0.66	0.55	0.82	0.76	0.66	0.56	0.79	0.74	0.64	0.54	0.86	0.80	0.69	0.59
iii)	B	0.5	0.86	0.78	0.73	0.59	0.80	0.73	0.64	0.55	0.81	74	0.64	0.56	0.79	0.71	0.62	0.54	0.85	0.77	0.67	0.59
iv)	C	0.0	0.87	0.79	0.69	061	0.81	0.74	0.65	0.57	0.82	0.75	0.66	0.58	0.79	0.73	0.63	0.56	0.86	0.79	0.69	0.60
v)	D	0.0	0.87	0.79	0.70	0.63	0.81	0.74	0.65	0.59	0.82	0.74	0.66	0.60	0.79	0.72	0.64	0.58	0.86	0.78	0.69	0.62
vi)	E	0.0	0.88	0.84	0.77	0.70	0.83	0.79	0.72	0.66	084	0.80	0.73	0.67	0.81	0.77	0.70	0.64	0.88	0.83	0.76	0.70
vii)	F	1,0	0.81	0.69	0.55	0.39	0.76	0.64	0.52	0.36	0.77	0.65	0.52	0.37	0.74	0.63	0.51	0.35	0.80	0.68	0.55	0.38
viii)	G	0.0	0.92	0.88	0.82	0.76	0.86	0.83	0.77	0.71	0.87	0.84	0.78	0.72	0.84	0.81	0.75	0.70	0.91	0.87	0.81	0.75

This table is based on the following assumptions
Medium sized room (k 2.5) with reflectance 70/50/20 for ceiling, walls and floor respectively
Cleaning intervals of lamps and luminaires – 1 year
Cleaning intervals of room surfaces – 6 years
Failed lamps are spot replaced
Bulk re-lamping intervals (burning hours)

Incandescent halogen	2000 hours	(*LLMF* 0.95)
Compact fluorescent	6000 hours	(*LLMF 0.89)*
HF fluorescent linear	15000 hours	(*LLMF* 0.90)
Metal halide	4000 hours	(*LLMF 0.87)*
High pressure sodium	20000 hours	*(LLMF* 0.94)

4.10 Maintenance Factor

Maintenance factor is defined as the ratio of illuminance produced by the lighting system after a certain period to the illuminance produced by the system when new.

$$\text{Maintenance Factor} \qquad MF = \frac{E_m}{E_{in}} \tag{1}$$

where E_m = maintained illuminance;
E_{in} = initial illuminance.

By calculating the maintenance factor for different times and taking into account the proposed maintenance schedule, it is possible to predict the pattern of illuminance in an installation over a period of time.

The maintenance factor is a multiple of factors.

$$\text{Maintenance factor } MF = LLMF \text{ x } LSF \text{ x } LMF \text{ x } RSMF \tag{2}$$

where *LLMF* = lamp lumen maintenance factor;
LSF = lamp survival factor (used only for group replacement programmes);
LMF = luminaire maintenance factor;
RSMF = room surface maintenance factor.

4.10.1 *Determination of Maintenance Factor*

The magnitude of each of these factors varies with lamp, luminaire, environment, interior and time.

For accurate assessment the manufacturer's data should be used. However, some typical data are shown in Tables 5 and 7.

The maintenance factor can be determined by the following step-by-step procedure.

Step 1. Select lamp and luminaire for the interior application (*see* Table 2).

Step 2 Determine group replacement intervals of lamps (if practical).

Step 3 Obtain *LLMF* and *LSF* from Table 3.2 for period established in Step 2.
If spot lamp replacement procedure is followed then *LSF* will be 1.

Step 4 Assess the cleanliness category of the interior (*see* Table 1).

Step 5 Determine cleaning interval of luminaires and room surfaces.

Step 6 Obtain *LMF* from Table 3.4 for period established in Step 5.

Step 7 Obtain *RSMF* from Table 3.6 - 3.8 for period established in Step 5.

Step 8 Calculate *MF* = *LLMF* x *LSF* x *RSMF (*x *NRF*).
Calculate maintenance factor to not more than two significant figures.

NOTE — If there are significant non-recoverable losses (*NRF*) than these should be included in the final *MF* value.

Step 9 It is advisable to repeat Steps 1 to 8, by adjusting the various components, so that a range of maintenance programme options are considered at the initial design stage.

4.11 Use of Maintenance Factor (*MF*)

In any lighting design calculations an appropriate maintenance factor has to be included to allow for depreciation. The magnitude of the maintenance factor significantly affects the number of luminaires needed to produce the specified illuminance. High maintenance factors are beneficial and can be achieved by careful choice of equipment and electing to clean the installation more frequently. CIE S 008 recommends selecting solutions so that the maintenance factor does not fall below 0.7. Typical values are shown in Table 12.

The maintenance factor can be used in the lumen method of illuminance calculation to estimate the average illuminance of the installation at a particular stage in its life. This is achieved by using the following formula:

$$E_m = \frac{\Phi_{in} \times n \times N \times UF \times \mathrm{MF}}{A} \quad (3)$$

where E_m = maintained illuminance (lux);
Φ_{in} = initial luminous flux of the light source (lumen);
n = the number of lamps per luminaire;
N = the number of luminaires;
A = area to be illuminated (m^2)
UF = utilization factor for the luminaire in the room;
MF = maintenance factor.

NOTE — This expression does not allow for the depreciation caused by non-recoverable losses.

The maintenance factor can and should be applied to all formulae used for lighting scheme calculations, e.g. luminance patterns and point-by-point illuminance plots.

It should be noted that the maintenance factor discussed here and the variation of illuminance shown in Fig.1 and Fig.5 are from fixed power schemes. There is increasing use of controllable electronic ballasts that allows a lighting scheme to provide constant illuminance. In these schemes the depreciation is compensated for by increased power supply to the lamps and thereby increasing the light output. Experience on maintenance of these recently introduced controllable installations is still being gathered and precise advice cannot be offered. It is recommended that maintenance be carried out when about 50% of the lamps are operating at full power.

4.12 Designing Scheme for Optimal Maintenance

During the design of lighting installations it is often possible to choose components, systems and finishes that will result in the maintenance being kept to a minimum:

a) Choosing luminaires in which the lamp is in a dust-proof enclosure having a suitable gasket to allow the luminaire to breathe without sucking in dust;

b) Adopting open luminaires (self-cleaning type) where the convection currents from the heat produced by the lamp are directed to flow over the reflecting surfaces to prevent airborne dry dust settling;

c) Using air-handling luminaires where the forced ventilation assists in the removal of dust and dirt;

d) Only recommending optical systems that are fit for the prevailing environmental conditions, e.g. plastic louvers not suitable for dusty locations;

e) Reducing the number of variants on a scheme;

f) Using luminaires having few components, this, when requiring service, can be easily handled or removed for off-site servicing;

g) Recommending surface finishes that remain clean for long periods and are easily cleanable;

h) Using reflector lamp or bare batten luminaires where the dirt is oily or "sticky".

Other ways the designer can help the maintenance and thus improve the effectiveness of maintenance are:

a) Planning for ease of maintenance – consider access, types of tools needed for servicing, ensuring availability of spare lamps, optics or even luminaires. Early liaison with maintainer to ensure understanding of requirements and procedures is also advantageous.

b) Preparing a comprehensive maintenance schedule with instructions;

c) Organizing effective information feedback of mistakes, failures or difficulties and use these to avoid a repetition in future projects.

4.13 Sustainability

More and more nations in the world are introducing legislations that are supporting sustainability and these rules will impact the choice of electric lighting solutions and their operation.

This section gives a brief insight to consideration of sustainability as applied to electric lighting systems.

An electric lighting system has a major impact on sustainability. Sustainability, as is light, is essential for the conservation of life and resource on our planet. A sustainability approach will ensure that the needs of the present generation are met without loss or compromising the ability of future generations to meet their needs. Sustainability can be practiced through product design and by the selection and use of sustainable lighting solutions. These techniques can also be described as eco-design or design for the environment.

The ideal sustainable design is designing a lighting solution that can continue forever. This can be by products, processes or systems that can be manufactured, used and disposed indefinitely. The ideal arrangement is perpetual reuse without waste of energy, materials or emissions.

Eco-design is designing the lighting solution with the entire lifecycle in mind. The lifecycle covers the whole life of the product or system from material acquisition, material refining, manufacture, installation, use, maintenance and disposal. Employing life-cycle assessment will check the environmental impact of a solution through life including all the materials, energy and environmentally significant releases used and created during the lifecycle.

Design for environment is mainly concerned with the design for disassembly and recycling at the end of the useful life of the lighting product or solution.

Observing these three elements of design will yield the highest sustainability of the selected, installed and operated lighting solutions.

4.14 Economics of Servicing

4.14.1 *Lamp Replacement*

The total lamp replacement costs comprise the cost of lamps and the cost of labour involved including cost of ordering, stocking, installation, disposal, etc. The labour cost depends on the lamp change system adopted and on the inconvenience involved. The alternatives are "Spot" replacement where each failed lamp is changed or "Group" replacement where all the lamps (failed or good) are changed at some time that is less than the rated average lamp life. However, in some projects a combined spot/group lamp replacement programme is practiced. It is very important that in places where loss of a lamp may lead to dangerous working conditions or unsafe movements the failed lamp is replaced immediately. Installation of luminaires with more than one lamp is least affected by random lamp failures.

The most economical system can be assessed as follows:

Cost of spot replacement per lamp C_s is:

$$C_s = L + S \qquad (4)$$

where L = cost of lamp;
S = cost of labour.

Cost of group replacement per lamp C_g

$$C_g = L + B \qquad (5)$$

where L = cost of lamp;
B = cost of labour for group replacement per lamp.

Cost of combined group and spot replacement per lamp C_t

$$C_t = \frac{100 \times C_g + F \times C_s}{l} \qquad (6)$$

where F = percentage of lamps failed at re-lamping interval;
l = percentage of rated lamp life at group re-lamping interval.

NOTE— Lamps may be bulk purchased and stored for spot replacement. Also spares can be part of initial scheme purchase.

If the good lamps (kept after group replacement) are used for subsequent spot replacement, then FC_s/l simplifies to FS/l.

The economy of group replacement heavily depends on lamp survival rate. The more lamps survive the replacement interval the fewer costly spot replacements are needed.

It is important to note that lamp replacement interval very much depends on the lamp burning hours. These vary according to working hours, shifts and lighting management operating in the premises. Examples of annual burning hours are given in Table 4.

4.15 Cleaning of Luminaires

The optimum interval between cleaning *T* of a luminaire is reached when the cost of the lost light output equals the cost of cleaning.

The optimum cleaning interval *T* can be determined from the expression:

$$T = \frac{-C_c}{C_a} + \sqrt{\frac{2C_c}{\Delta C_a} years} \quad (7)$$

where

T = optimum cleaning interval;

C_c = cost of cleaning the luminaire once;

C_a = annual cost of owning and operating the luminaire without cleaning;

Δ = annual average rate of luminaire dirt depreciation. Values are given in Table 13.

NOTE —

C_c — cost of cleaning includes the cost of any cleaning agent, special tool, platforms or equipment and the labour. The labour costs are also affected by the timing at which the cleaning is done; during normal working hours or in unsociable hours.

C_c — cost of operating includes the amortized installation cost (proportion of capital written off per year), the annual energy cost (derived from energy used in kWh x cost of energy per unit) and re-lamping cost (cost of lamps and replacement labour per annum).

Table 13
Typical Rate of Luminaire Dirt Depreciation the First Year
(*Clause* 4.15 *and* Annex A)

Sl. No	Environment	Luminaires (*see* Table 2)						
		A	B	C	D	E	F	G
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
i)	Very clean	0.03	0.05	0.06	0.07	0.02	0.09	0.01
ii)	Clean	0.07	0.10	0.11	0.12	0.06	0.14	0.03
iii)	Normal	0.11	0.14	0.19	0.18	0.10	0.19	0.06
iv)	Dirty	0.17	0.17	0.28	0.23	0.14	0.26	0.09

4.16 Maintenance Programmes

Each lighting scheme should be designed with an overall maintenance factor calculated for the selected lighting equipment, space environment and specified maintenance programme or schedule. The maintenance programme should include the lamp, luminaire and room surface cleaning intervals, the frequency of lamp replacement and the cleaning method. The maintenance can be set for Equi or Variable interval programme. The equi interval programme defines a regular pattern for cleaning and servicing (*see* Fig. 5) whilst in the variable interval maintenance programme the cleaning is carried out at uneven intervals (*see* Fig. 6). The variable interval programme is particularly advantageous where the initial and the energy cost of the lighting installation is high but the maintenance costs are low as it yields a slightly higher maintenance factor than obtained with the equi intervals method.

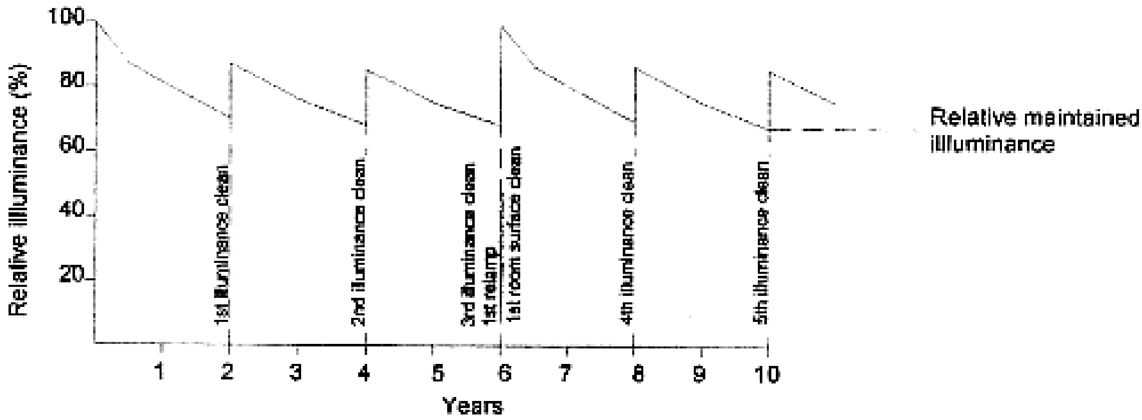


Fig. 5 Equi Interval Maintenance Programme

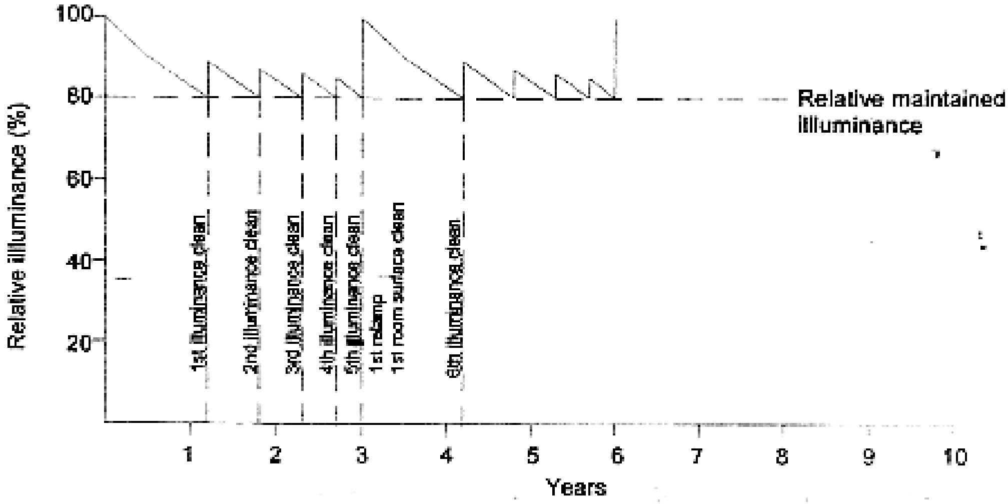


Fig. 6 Variable Interval Maintenance Program

4.17 Equipment and Installation

In some situations leaving failed lamps in the circuit may cause failure of other components. The replacement of these components must be judged on the potential hazard to the safe operation of the installation. As lighting technology is constantly advancing there are many instances where old installations, although operating safely, will benefit from new types of lamps or optical systems or even from changing the whole installation. In these cases the investment can be estimated against the potential savings in energy cost and service cost. Another benefit could be the improvements in the visual environment, well-being and productivity.

4.18 Servicing Lighting Systems

It is important to schedule and plan in detail the access to site, type of cleaning equipment required and times when servicing of the lighting installations may be made to cause least interruption in the workplace. However, servicing of live lighting equipment should be avoided.

4.19 Access

It is important that provision is made for access to luminaires for re-lamping and cleaning. Equipment to help in servicing is discussed in Annex A.

The maintainer will need to determine how to reach the luminaire, i.e., what equipment will be needed, platforms, ladders, bridging, etc. and what furniture will have to be moved or protected, such as desks, machinery and display cases. It is vital to ensure that access equipment is so located that the operators can work comfortably (avoid over reach) and safely on the luminaires (work inside safety barriers), and have space for temporary placement of parts and lamps.

4.19.1 *Cleaning Luminaires*

Extreme caution should be exercised when cleaning all surfaces. Some surfaces are very susceptible to abrasion for example; polished (un-anodized) aluminium is very sensitive, as are some plastics, acrylic in particular. It is vital to consult or read the manufacturer’s instructions to ensure that the correct methods are used for handling and cleaning the products.

The maintainer should experiment on a small test area with a method before starting the whole job.

The maintainer should take care in handling plastic components, as with age they tend to get brittle and break easily. Depending on the environment and on the UV emission of the light source some plastics can yellow badly and there is no successful way of cleaning this and replacement of the part should be recommended.

Aluminium reflectors should be washed with a warm, soapy solution and rinsed thoroughly before being air-dried. Plastic opal or prismatic lenses should be cleaned with a damp cloth (using non-ionic detergent and water) and treated with antistatic polish or spray and allowed to dry.

Vitreous enamel, stove enamel and glass optics should be wiped with a damp cloth using a light concentration of detergent in water.

Plastic or metal louver (rectangular or square cell) optics should be dipped in a warm water and non-ionic detergent solution and rinsed. Specula finished (particularly plastic) louvers are very difficult to clean and their appearance deteriorate over years of use. Therefore, they should only be used where air quality is very clean, such as new office buildings, banks, etc.

4.19.2 *Cleaning Agents*

Choice of cleaning materials and methods is determined by the type of dirt to be removed and the type of material to be cleaned. In some countries certain procedures and cleaning agents may not be permitted for use under environmental health regulations. It is always advisable to consult the authorities.

The first and most commonly used is a dry chemical detergent with additives in different concentration levels and is used for general cleaning. It is an advantage to use compounds that require no rinsing after the wash. For plastic materials a final treatment with antistatic substance is recommended.

The second type of cleaner is a heavy-duty liquid cleaner that may contain detergents, solvents and abrasives. It is useful for the removal of oily dirt found for example in auto garages, oily factories, etc. The cleaning agent must be tested on a sample surface to ensure that it does not damage materials or leave deposits.

In some very heavy oily applications the use of a high-pressure steam cleaner is recommended for schemes that have been designed with this cleaning technique in mind.

The above process of cleaning methodology can be tabulated form as describe in Table 14

Table 14 Materials and its Cleaning Guide Line
(*Clause* 4.19.2)

Sl. No (1)	**Material** (2)	**Cleaning Methods** (3)
i)	Anodized Aluminium	Surfaces should be cleaned with a non-abrasive cloth or sponge using a neutral detergent in warm water that does not leave a residue and then allowed to air dry. Ultrasonic cleaning techniques. Severe staining or contamination should be removed first by metal polish
ii)	Stainless Steel	Surfaces should be cleaned with a non-abrasive cloth or sponge using a neutral detergent in warm water and then the surface dried with a clean cloth, following the grain of brushed finishes where applicable. Surface lustre may be restored by applying an oil-based cleaning compound with a cloth and wiping off all surplus
iii)	Galvanized steel, natural aluminium	Surfaces should be cleaned with a neutral-based detergent and wiped dry.
iv)	Enamel paint finish, polyester powder coat	Surfaces should be cleaned with a non-abrasive cloth or sponge using a neutral detergent in warm water and the surface dried with a clean cloth. Solvent-based cleaners should not be used.
v)	Glass	Surfaces should be cleaned with a non-abrasive cloth or sponge using a neutral detergent in warm water that does not leave a residue, then wiped and allowed to air dry.
vi)	Acrylic, polycarbonate, glass-polyester, reinforced plastic	Remove loose dirt and dust with a vacuum cleaner. Surfaces should be cleaned with a non-abrasive cloth or sponge using a neutral-based detergent that does not leave any residue, then rinsed and wiped dry with warm water containing an anti-static solution. Solvent-based cleaners should not

	be used under any circumstances. Ultrasonic cleaning techniques.

4.19.3 *Re-lamping*

Lamps may be replaced by a variety of skilled people therefore clear instruction will be needed on how to remove the lamps so as not to damage the lamp holders or any other components of the luminaire.

When new lamps are not being put in the luminaires after the cleaning process, the old lamps should be carefully examined and any lamp showing age should be replaced at that time with the lamp specified by the designer. It is also advisable to replace the glow starter switch in switch start fluorescent lamp circuits, as aged starters may stay stuck in pre-start position and continue to draw cathode-heating current that over a short period of time can damage the ballast.

Re-lamping with new lamps should be done after the luminaire is clean and dry. Generally the replacement lamps should be only those that are recommended by the designer of the scheme. However, consideration should be given to the use of improved lamps provided they are suitable for the luminaire and application and are compatible with the circuit. Always check with the luminaire manufacturer or the scheme designer.

5 OUTDOOR LIGHTING SYSTEMS

5.1 General

The luminance/illuminance initially provided by a lighting installation will decrease gradually throughout the life of the installation. Several terms to describe the factor which accounts for this reduction have been used. The term "Maintenance factor" which is the more commonly used and understood term is ratio of the average luminance/illuminance on the working plane after a certain period of use of a lighting installation to the average luminance/illuminance obtained under the same conditions for the installation considered conventionally as new.

NOT E—The term depreciation factor has been formerly used to designate the reciprocal of the above ratio.

The recommended parameters for lighting design are now generally based on "maintained" values which are the average luminance/illuminance at the "certain period" of the above definition when maintenance has to be carried out.

Lighting systems have different maintenance characteristics and this should be one of the important assessments made in the early stages of project design.

This technical report discusses the various influencing factors and gives data based on practical solutions which enable the maintenance factor for types of systems and environments to be derived. The derived maintenance factor should be applied to all formulae used for lighting scheme calculations. Such as luminance/illuminance on areas or at points. Methods for estimating economic maintenance periods and advice on cleaning techniques are also given.

The maintenance of the mechanical fixtures supporting the luminaires is also covered. This is because in most outdoor situations this is of considerable importance to the overall installation performance and quite often has major safety factors of its own. Correct luminaire alignment is also an important factor in this aspect regarding both task and environmental considerations.

The technical report also provides a limited selection of typical data to allow the calculation methods to be explained. However to take advantage of the continuing development of lighting products, up-to-date data should be obtained from manufacturers.

The bibliography contains a list of publications used as the basis for this guide where further information may be obtained.

5.2 Need for Maintenance

All lighting schemes will deteriorate progressively from the moment they are put into use. The losses are due to the accumulation of dust and dirt on all exposed surfaces of lamps and luminaries, reducing the transparency or reflecting power and to the decay in lamp lumen output and failing lamps.

For the luminaires within the installation if this process is unchecked, it will result in their light output falling to very low values as shown in Fig.7 and the scheme becomes poor and dangerous. As the decay in light output is gradual, the loss may not be noticed immediately. But over a period this gradual reduction will cause problems relevant to the tasks at hand.

Regular maintenance is therefore most important for an effective lighting installation. The lighting system should not only be cleaned correctly and thoroughly but the cleaning should be carried out at regular intervals. A well-designed maintenance programme will maintain the required luminance/illuminance, reduce capital and operating costs and run the system safely. It will ensure satisfactory appearance, security and safety for the users.

However, even with a well-designed and operated maintenance programme some loss of light level is inevitable through equipment deterioration. This loss has to be estimated. at the time the lighting scheme is planned and an allowance in the form of maintenance factor should be included in the scheme design calculations.

In outdoor lighting situations, surfaces other than the walls and ceilings of pedestrian or vehicular tunnels or underpasses. are not normally within the control of the lighting maintenance engineer. This guide will therefore concentrate on that part of the installation which is under control.

5.2.1 *Influencing Factors*

There are several factors which can reduce the light output. These are grouped under non-recoverable and recoverable depreciation.

Non-recoverable factors, such as ageing, are inherent in the installation and its environment and cannot be improved during normal maintenance or are uneconomical to overcome. At the specification stage of a lighting installation, these factors should be taken into account together with the planning of a maintenance programme.

If the influence of other factors such as voltage, frequency, temperature and ballast are permanent and significant then at the design stage the magnitude of these effects should be estimated and an allowance similar to the maintenance factor should be made in the calculations. The influence of random occurrences may be ignored, provided they do not harm the operation of the lighting system.

Recoverable factors of lamp lumen maintenance, lamp survival and luminaire maintenance can be made good during routine maintenance by relamping, cleaning and replacement of components.

The value of such maintenance programme is indicated as an example in Fig. 7. Clearly the depreciation in the un-maintained scheme will fall by around 65 % of the initial value within 3 years and will continue to decline. But by comprehensive cleaning the decline is checked at under 40 % depreciation.

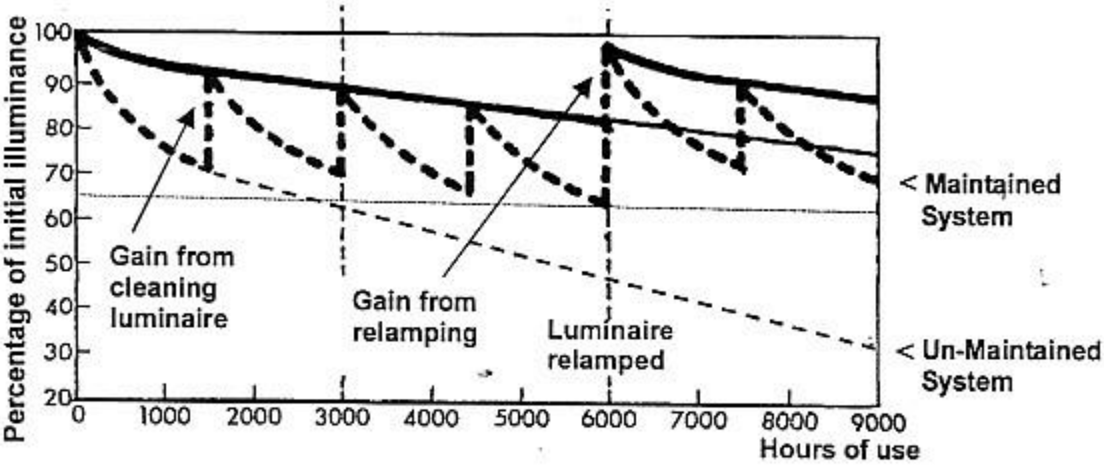


Fig. 7 Effect of Maintenance Program

Once the non-recoverable reductions by ageing or soiling have occurred they cannot be brought back to their original condition and replacement of the outer glazing or complete luminaire may be necessary. This is the case with luminaires if they are in. say, dusty or oily atmospheres. In such cases it is well worth considering at the design stage, the use of sealed luminaires of high IP ratings, e.g. IP 6X.

5.2.2 *Inspection and Recording Intervals*

A regular inspection and performance recording of lighting installations is advisable and is discussed further in 5.4.1 and 5.4.2. While having cost, it may well eventually bring cost savings due to a more refined maintenance requirement for the environment concerned. While having a cost, such inspections may lead to required adjustments in the maintenance procedures, in order to ensure that minimum required lighting performance is maintained at all times.

5.2.3 *Cleaning Schedules and Environmental Pollution Categories*

A regular cleaning schedule of lighting installations, of both internal and external surfaces, is advisable, the frequency of which will depend on:

a) Type of environment;
b) Equipment used;
c) Design parameters.

Within many countries luminaires are classified by IP ratings as per IS 12063, against their ability to deter the ingress of moisture and water. The first integer indicates the particle size i.e. fine dust or large grit, the higher the number the smaller the particle. The second integer indicates the degree of protection to moisture from indirect spray through high pressure jet to total immersion. The higher the number, the higher the seal.

The optical compartments of luminaires used in medium/high pollution environments should be of a rating IP4X or higher.

5.3 Analysis of Depreciation

Several factors contribute to light losses and the effect and magnitude vary with the type of lamp, luminaire, its installation geometry and the environment. For example, areas vary as to the amount and type of dirt in the air; the amount of dirt in a center of an industrial city is greater than that found in a rural village. But the type of dirt is also important.

The dry dust from a stone quarry is very different from the crop spray and insects on a rural traffic route. It is important to be able to recognize these variations when assessing luminaire types and cleaning requirements.

5.3.1 *Lamp Lumen maintenance (LLMF)*

The output of all lamp decreases during use. The exact rate, however, depends on the lamp type and ballasting system. The losses due to this effect can be reduced by more frequent lamp replacement, perhaps by group replacement.

Table 15 shows typical examples. It is therefore very important to obtain up-to-date data from the manufacturers for estimating the maintenance factor and the maintenance programme, particularly when using a new type of lamp.

Table 15 Lamp Lumen Maintenance Factors (LLMF)
(*Clause* 5.3.1)

Sl.No.	Lamp type	Operating time (thousands of hours)				
(1)	(2)	(3)	(4)	(5)	(6)	(7)
i)		4	6	8	10	12
ii)	HPSV	0.98	0.97	0.94	0.91	0.90
iii)	MH	0.82	0.78	0.76	0.74	0.73
iv)	HPMV	0.87	0.83	0.80	0.78	0.76
v)	LPSV	0.98	0.96	0.93	0.90	0.87
vi)	FTL (Tph)	0.95	0.94	0.93	0.92	0.91
	(Hph)	0.82	0.78	0.74	0.72	0.71
vii)	CFL	0.91	0.88	0.86	0.85	0.84

* relates to value at an ambient temperature of 25°C, therefore check location.

NOTE — The lamp abbreviations given in the table relate to the following lamps

HPSV High Pressure Sodium
FTL Tubular fluorescent
MH Metal Halide
CFL Compact fluorescent
HPMV High Pressure Mercury
LPSV Low Pressure Sodium
Tph Triphosphor
Hph Halophosphate

For specific lamp data, the manufacturers may be consulted.

LLMF for LED system need to be taken from manufactures data as stated in LED section Clause No. 6.

5.3.2 *Lamp Survival*

Lamp survival factor is the probability of lamps continuing to operate for a given time. The survival rate depends on lamp type and particularly, in the case of discharge lamps, the wattage, frequency of switching and the ballasting system. Failed lamps cause reduction in illuminance and uniformity, but the effect can be minimized by spot replacement of lamps. Table 16 shows typical examples.

Table 16 Lamp Survival Factors (LSF)
(*Clause* 5.3.2)

Sl. No	**Lamp type**	**Operating time (thousands of hours)**				
(1)	(2)	(3)	(4)	(5)	(6)	(7)
		4	6	8	10	12
i)	HPSV	0.98	0.96	0.94	0.92	0.89
ii)	MH	0.98	0.97	0.94	0.92	0.88
iii)	HPMV	0.93	0.91	0.87	0.82	0.76
iv)	LPSV	0.92	0.86	0.80	0.74	0.62
v)	FTL (Tph)	0.99	0.99	0.99	0.98	0.96
	(Hph)	0.99	0.98	0.93	0.86	0.70
vi)	CFL	0.98	0.94	0.90	0.78	0.50

NOTE — The lamp abbreviations given in the table relate to the following lamps.

HPSV High Pressure Sodium
FTL Tubular fluorescent
MH Metal Halide
CFL Compact fluorescent
HPMV High Pressure Mercury
LPSV Low Pressure Sodium
Tph Triphosphor
Hph Halophosphate

For specific lamp data, the manufacturers may be consulted.

In the case of LED this data has be taken from manufacture and in the agreement with manufacturer/supplier for the SPOT replacement in the maintenance schedule LLF can be taken for LED is 1.0

5.3.3 *Dirt on lamps and Luminaires*

Dirt on lamps and luminaires will generally cause the greatest loss of light. The amount of light loss depends on the nature and density of airborne dirt, luminaire design and lamp type. Dirt accumulation on reflecting surfaces can be minimized by sealing the lamp compartment against entry of dust and moisture. Significant benefits can be obtained with the luminaire optical compartment sealed to at least IP5X protection. Table 17 shows typical data for a range of luminaires.

Table 17 Luminaire Maintenance Factors (LMF)

(*Clause* 5.3.3)

Sl. No	**Optical compartment IP Rating**	**Pollution Category**	**Exposure time (years)**				
			1.0	1.5	2.0	2.5	3.0
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
i)	IP2X	High	0.53	0.48	0.45	0.43	0.42
		Medium	0.62	0.58	0.56	0.54	0.53
		Low	0.82	0.80	0.79	0.78	0.78
ii)	IP5X	High	0.89	0.87	0.84	0.80	0.76
		Medium	0.90	0.88	0.86	0.84	0.82
		Low	0.92	0.91	0.90	0.89	0.88
iii)	IP6X	High	0.91	0.90	0.88	0.85	0.83
		Medium	0.92	0.91	0.89	0.88	0.87
		Low	0.93	0.92	0.91	0.90	0.90

5.3.3.1 *Definition of pollution categories*

a) Low— No nearby smoke or dust generating activities and a low ambient contaminant level. Light traffic. Generally limited to residential or rural areas. The ambient particulate level is no more than 150 micrograms per cubic metre.

b) Medium—Moderate smoke or dust generating activities nearby. Moderate to heavy traffic. The ambient particulate level is no more than 600 micrograms per cubic metre.

c) High— Smoke or dust plumes generated by nearby activities are commonly enveloping the luminaires.

5.3.4 *Long term Depreciation of Reflector and Diffuser Materials*

5.3.4.1 *Outer Glazing — refractors and diffusers*

a) Glass

Glass is easily cleaned to restore the original finish.

A lack of long term cleaning can lead to surfaces being more difficult to restore. Especially prismatic. Or in extreme cases surface damage may result (e.g. etching).

Lack of cleaning leads to reduced light output and change in the light distribution by diffusion of the light, resulting in reduced lighting levels and degraded distribution.

b) Plastics — Acrylic (PMMA – Polymethyl Methacrylate) and Polycarbonate (PC)

Degradation is generally from dirt and atmospheric contaminants, and material ageing. Inappropriate use of, or exposure to solvents can produce rapid degradation as the plastic structure is attacked.

Regular cleaning with mild detergent and water will restore clarity. Remove intense grime with white spirit or other cleaners specifically formulated for PMMA or PC, and rinse will. Abrasives and scourers will damage the surface and add diffusion.

Adhesives used in construction or fixings must be compatible otherwise degradation (short to long term) may occur.

c) Acrylic

Performs well with UV present. Over the long term (of the order 10 years +) the plastic will have begun to deteriorate by crazing with gradual loss of strength; the component should be regarded as a replaceable item.

Its principal drawback is its relative brittleness, lack of impact resistance, where vandalism, for example, may be a problem, although toughened versions are available that improve this characteristic.

d) Polycarbonate

Its principal advantage over PMMA is its (initially) higher strength and resistance to impact. However, the material degrades in the presence of UV, daylight, and UV emitting lamps. The effect is accelerated by temperature. It is important therefore to keep the material service temperature below around 90°C to 100°C, particularly when UV is present (e.g. by ensuring the lamp wattage used in the luminaire is limited appropriately). The degradation can be rapid. so the material is normally protected by UV absorbers, either additives integral with the raw material or applied as a surface treatment. These absorbers are used up gradually and only delay degradation, but normally allow a service life of several years.

Degradation results in embrittlement, loss of strength and impact resistance, yellowing, and loss of light transmission. The component should be regarded as a replaceable component.

Opal polycarbonate is usually more susceptible to UV as the diffusing additive can increase the radiation absorbed. Surface UV absorber treatment is particularly recommended.

Cleaning is as above, but PC is softer than acrylic and has a poor resistance to abrasion.

5.3.4.2 *Reflectors*

a) Aluminium

The reflecting surface of aluminium will degrade by oxidation unless protected. The usual method is by anodizing (a controlled sealed oxide surface), either performed as a separate operation after the reflector is formed, or as a treatment during the production of the aluminium sheet. The film thickness can typically be from 1 µ to 25 µ thick, the thicker the film the more protection it gives, but the more it diffuses the finish. Lighting grades have anodic films of typically around 2 µ to 3 µ to balance corrosion resistance with a wide range of high-reflectance surface finishes.

Exposure to a moist atmosphere will lead to surface pitting and a gradual reduction in reflectance/secularity. Dirt ingress will lead to significant loss of reflectance and secularity with consequent loss of light output and degradation of the shape of the light distribution, leading to poorer light levels and uniformity for example. Protection inside a sealed enclosure is necessary for an acceptable life. Cleaning is then largely unnecessary. If cleaning is necessary, low surface tension water with a special bonded fibre fabric cloth, or chamois leather, can be used.

b) Metallised plastic

Protection is usually by lacquering the aluminium surface, applying the lacquer by spraying and then curing it by heat. The lacquer may eventually degrade to some extent by yellowing. Operating at too high a temperature (by excessive lamp wattage for example) will accelerate degradation. and may also damage the bond between the metallized coating and the substrate.

Cleaning, if necessary, should be gentle without abrasives or solvents to avoid damaging the protective lacquer. In a sealed fitting this should be unnecessary.

c) Glass

Silvered glass is little used now except in specialist applications. The backing on the reflecting surface protects the silver from oxidation; the edges are vulnerable to degradation from moisture, particularly marine and using such reflectors within a sealed luminaire is appropriate. Cleaning the glass will maintain the reflective properties providing care is taken not to damage the protective backing.

5.3.5 *Dirt on Light Reflecting Surfaces; Arcades. Tunnels and Underpasses*

Dirt on structural surfaces tends to reduce the amount of inter-reflected light which in both pedestrian and vehicular tunnels and underpasses, plays an important part in the visual scene. Structural proportions and the distribution of light from luminaires determines the amount of light which strikes the walls and ceiling. Regular maintenance of all reflecting surfaces is advisable in all such installations. Clean surfaces will also maintain the luminance balance in the environment.

5.3.6 *Corrosion of Luminaire Supports*

While recognizing that most supports are chosen for their design strengths, aesthetic factors and overall suitability, it must be recognized that during the life of a structure, periodic maintenance may be necessary.

In general, modern supports have generally been protected from the date of manufacture against corrosion. However, the problems of environmental degradation and accidental damage can significantly affect the life and therefore their structural integrity.

A regular programme of inspections should be made where visual and possibly electronic studies are recorded to ensure that appropriate remedial action is taken in advance of any structural decay. Particular attention should be paid to welded steel structures and to planted steel structures and to internal surfaces where corrosion may go undetected. Wooden supports can equally be susceptible to damage from vehicles and inspections should be made at frequencies which coincide with electrical and luminaire maintenance visits and corrective action taken where appropriate.

5.4 Economics of Servicing

During the design of a lighting installation it is often possible to choose components, systems and finishes that will result in the maintenance being kept to a minimum.

a) Choosing luminaires in which the optical compartment is easy to clean and/or has a high IP rating;

b) Reducing the number of variants on a scheme;

c) Using luminaires having few components, when requiring service, can be easily handled or removed for off-site servicing; and

d) Where applicable, recommending surface finishes that remain clean for long periods and are easily cleanable.

Other ways the designer can help the maintenance and thus improve the effectiveness of maintenance are:

a) Planning for ease of maintenance, consider access, types of tools needed for servicing, ensuring availability of spare lamps, optics or even luminaires. Early liaison with maintenance engineers to ensure understanding of requirements and procedures is also advantageous;

b) Preparing a comprehensive maintenance schedule with instructions;

c) Organizing effective information feedback of mistakes, failures or difficulties and use these to avoid a repetition in future projects; and

d) Concrete plinths that keep steel structures away from the corrosive effects of the ground.

5.4.1 *Lamp Replacement*

The total lamp replacement costs comprise the cost of lamps and the cost of labour involved, including cost of ordering. Stocking, installation, disposal, etc. The labour cost depends on the lamp change system adopted and on the accessibility of the luminaire. The alternatives are "Spot" replacement where each failed lamp is changed or "Group" replacement where all the lamps (failed or good) are changed at some time which is less than the rated average lamp life. In most projects a combined spot/group lamp replacement programme is practiced. It is very important that in places where loss of a lamp may lead to unsafe movements the failed lamp is replaced immediately. Installation of multi lamp luminaires are least affected by random lamp failures.

With lamp lumen depreciation, it can also become a waste of energy resources to operate lamps well past their most efficient life cycle.

Costs can be assessed as follows:

Cost of spot replacement per socket C_s is:

$$C_s = L + S + E + D \qquad (8)$$

where L = cost of lamp;
S = cost of labour (incl. initial sighting costs);
E = cost of access equipment;
D = cost of disposal

Cost of group replacement per socket C_g

$$C_g = L + B + E + D \qquad (9)$$

where L= cost of lamp.
B = cost of labour for group replacement per lamp.
E = cost of access equipment;
D = cost of disposal.

Cost of combined group and spot replacement per socket. C_t is:

$$C_t = C_g + FC_s \qquad (10)$$

Where, F = fraction of lamps failed and replaced prior to the re-lamping interval.

NOTE — Lamps may be bulk purchased and stored for spot replacement. Also spares can be part of initial scheme purchase.

If the good lamps (i.e. those which were recovered during group replacement) are used for subsequent spot replacement, then FC_s simplifies to FS.

The economy of group replacement depends on lamp lumen depreciation and heavily on survival rates. The more lamps survive the replacement interval the fewer costly spot replacements are needed.

It is important to note that lamp replacement intervals very much depend on the lamp operating hours. Examples of annual burning hours are given in Table 18.

Table 18
Examples of Typical Annual Lamp Operating Hours
(*Clause* 5.4.1)

Sl. No (1)	**Installation** (2)	**Hours/year** (3)
i)	Continuous	8760
ii)	All Night (Sunset to sunrise)	4200
iii)	Sunset to 24:00 hr	2600
iv)	Sunset to 22: (5 nights/week)	1300
v)	4 hrs/week	208

5.4.2 *Cleaning of Luminaires*

The optimum cleaning interval T for a luminaire is reached when the cost of the lost light output equals the cost of cleaning.

The optimum cleaning interval T can be determined from the expression:

$$T = \frac{-C_c}{C_a} + \frac{2C_c}{LMF^{(1)}C_a} years \qquad (11)$$

where T = optimum cleaning interval;
C_c = cost of cleaning the luminaire once;
C_a = annual cost of owning and operating the luminaire without cleaning;
$LMF^{(1)}$ = first year rate of luminance maintenance factor. Values are given in Table 17 Column 3.

NOTES —

1. C_c — cost of cleaning includes the cost of any cleaning agent, special tool, platforms or equipment and the labour. The labour costs may also be affected by the timing at which the cleaning is done (during normal working hours or not).

2. C_a — cost of operating includes the amortization installation cost (proportion of capital written off per year), the annual energy cost (derived from energy used in kWh x cost of energy per unit) and relamping cost (cost of lamps and replacement labour per annum).

5.4.3 *Luminaire Supports*

In many outdoor lighting installations, particularly road lighting, the care and maintenance of the luminaire supports is an important part of the overall maintenance responsibility.

For fixed poles, towers or wall brackets, frequent inspections and painting will be necessary, together with occasional monitoring of below ground conditions.

For structures over 20 years old, thought should be given to overall structural stability and to eventual, planned replacement.

Where hinged or winched poles or masts are installed, regular inspection of the ropes and pulleys by a special competent person should be included. The cleaning and lubrication of all moving parts should be a part of the routing maintenance schedule.

Where the accurate alignment of luminaires is of task and/or environmental importance, this too should be checked and corrected as necessary.

5.4.4 *Electrical Components*

Any electrical installation is a potential safety hazard and its regular inspection, maintenance and testing is of great importance, which in many countries is required by law.

The replacement of any components must be judged on the potential hazard to the safe operation of the installation. As lighting technology is constantly making advancements there are many instances where old installations, although operating safety, will benefit from new types of lamps or control systems or even the change of the whole installation. In these cases the investment can be estimated against the potential savings in energy cost and service cost. Another benefit could be in the improvements in the visual environment.

In some situations the group replacement of Photo-electric control units (PECU's) may be considered beneficial, especially when combined with a group lamp change.

5.4.5 *Monitoring/Patrolling for Lighting Defects*

As forms of "Remote Monitoring" of lighting schemes become more practicable, and their relative expense more cost effective, simple patrolling is likely to decline in use.

However, the cost benefit of remote monitoring or direct patrolling for lighting defects is difficult to assess. In cases where non illumination is a major safety risk then routing monitoring or patrolling is a necessity. In other cases where it could be interpreted as more of a public relations exercise, then other factors must be considered such as encouraging the public to notify the authority concerned. A very effective method is to establish a toll-free telephone number or pre-paid postcard for the public to use. The local police and/or security forces can also be asked to help in this respect. However for this to work it is even more important to have a clear and simple identification system for the various lighting points.

An example of how to establish the optimum frequency of professional patrolling for lighting defects in road lighting installations is given in Annex B.

5.4.6 *Obstruction of Light by Trees*

Tree branches and foliage can pose a continuing problem in achieving proper outdoor lighting. Periodic trimming of trees becomes essential to keep up with growth. Field personnel must work closely with forestry organizations and properly owners to achieve lighting requirements with minimum visual and horticultural damage to the trees.

In road lighting, the presence of low overhanging foliage may seriously obstruct the light delivered to road as well as impede traffic movement. Judicious pruning can reduce of eliminate the screening effect. There are instances where pruning increases the average lighting effectiveness approximately one third, and approximately doubled the lighting effectiveness in the critical areas of low visibility.

5.5 Maintenance Factor

In any lighting design calculation an appropriate maintenance factor has to be included to allow for depreciation. The magnitude of the maintenance factor can significantly affect the lamp wattage and number of luminaires needed to produce the specified luminance/illuminance. High maintenance factors are beneficial for achieving the best safety levels. and can be achieved by careful choice of equipment and electing to clean the installation more frequently.

Maintenance factor is defined as the ratio of luminance/illuminance produced by the lighting system after a certain period to the luminance/illuminance produced by the system when new.

Maintenance factor:

$$MF = E_m / E_{in} \qquad (12)$$

where E_m = maintained luminance/illuminance;
E_{in} = initial luminance/illuminance.

By calculating the maintenance factor for different luminaires and environmental conditions, and taking into account the proposed maintenance schedule, it is possible to predict the pattern of illuminance in an installation over a period of time.

The maintenance factor is a multiple of factors.

$$\text{Maintenance factor } MF = \text{LLMF} \times LSF \times LMF\ (\times\ SMF)^* \qquad (13)$$

* Where appropriate (e.g. pedestrian subways);

where *LLMF* = lamp lumen maintenance factor;
LSF = lamp survival factor;
LMF = luminaire maintenance factor;
SMF = surface maintenance factor.

5.5.1 *Determination of Maintenance Factor*

The magnitude of each of these factors varies with lamp, luminaire, environment and time.

For an accurate assessment of *LLMF,* the manufacturer's data should be used. However, some typical data is shown in Table 14.

For an accurate assessment of *LS,* the manufacturer's data should be used. However, some typical data is shown in Table 15.

For *LMF,* considerable research has been done with reference to the degree of sealing (i.e. IP rating) of luminaires which is shown in Table 16.

The total maintenance factor can be determined by the following step-by-step procedure.

Step 1 Select lamp and luminaire for the application.

Step 2 Determine group replacement interval of lamps (if applicable). (*See* Table 17)

Step 3 Obtain *LLMF* from Table 14 for period established in Step 2.

Step 4 Obtain *LSF* from Table 15 (if applicable)

Step 5 Determine cleaning interval of luminaires and surrounding surfaces if applicable (s*ee* clause 3).

Step 6 From an assessment of the luminaire IP rating, environmental pollution category and cleaning interval from step 5, obtain the LMF from Table 16.

Step 7 Obtain *RSMF* from Table 9 to 11 for period established in Step 5 (if applicable).

Step 8 Calculate *MF* = *LLMF* x *LMF* (*RSMF*)*.
* If applicable. Calculate maintenance factor to not more than two significant figures.

Step 9 It is advisable to repeat Steps 1 to 7, by adjusting the various components. so that a range of maintenance programme options are considered at the initial design stage.

5.6 Servicing Lighting Systems

5.6.1 *Safety of Personnel*

Certain procedures and cleaning agents may not be permitted for use under environmental health regulations. It is always advisable to consult the authorities.

Servicing live lighting equipment should be avoided if possible and if necessary only carried out by well-trained persons.

5.6.2 *Access*

It is important that provision is made for access to luminaires for relamping and cleaning. Equipment to help in servicing is discussed in **B-4**.

The maintenance engineers will need to determine how to get at the luminaire, i.e. what equipment will be needed, hydraulic platforms, staging, ladders, safety harnesses, etc. and whether the general public will have to be protected. It is vital to ensure that access equipment is so located that the operators can work comfortably and safely on the luminaires. Their arms should not be fully stretched and all vehicles should have suitable safety coning arrangements.

5.6.3 *Cleaning Luminaires*

Extreme caution should be exercised when cleaning all surfaces. Some surfaces are very susceptible to abrasion for example; polished (unanodized) aluminium is very sensitive, as are some plastics, acrylic and polycarbonate in particular.

The maintenance engineers should experiment on a small test area with a method before starting the whole job.

The maintenance engineers should be instructed to take care in handling plastics, as they tend to get brittle with age. Depending on the actual material, the environment and attitude of the site (higher attitudes have an increased ultra-violet content), the light source and the temperature at which the unit operates, plastics may also yellow badly and will need to be replaced.

Aluminium reflectors should be washed with a warm, soapy solution and rinsed thoroughly before being air-dried. Plastic opal or prismatic lenses should be cleaned with a damp cloth (using non-ionic detergent and water) and treated with anti-static polish or spray and allowed to dry. Vitreous enamel, stove enamel and glass optics should be wiped with a damp cloth using a light concentration of detergent in water.

Care should be taken not to seal up luminaires before they are totally dry.

5.6.4 *Cleaning Agents*

Choice of cleaning materials and methods is determined by the type of dirt to be cleaned and the type of material to be cleaned. For plastic materials a final treatment with anti-static substance is recommended.

a) *General* cleaning — The first and most commonly used is a chemical detergent with additives in different concentration levels. It is an advantage to use compounds that require no rinsing after the wash.

b) *Heavy duty cleaning of oil concentrations* — The second type of cleaner is a heavy-duty liquid cleaner which may contain detergents, solvents and abrasives. It is useful for the removal of oily dirt. These must be tested to ensure that they do not damage materials or leave deposits.

c) *Excessive oily industrial* conditions — In some very heavy oily applications, such as road tunnels, the use of a high-pressure steam cleaner is practical provided the installation has been designed with this cleaning technique in mind.

d) *Ultra-sonic cleaning* — this is a system in which the items to be cleaned are normally removed from the site and placed within special tanks containing the cleaning liquid and a series of “transducers”. These “transducers” produce sound waves that in turn create microscopic bubbles that provide an intense cleaning action over a small area. Normal cleaning times are between 2-10 minutes. If the item is extremely dirty a pre clean may be necessary and rinsing afterwards is also required. Its main use is in the cleaning of glass refractor bowls. Care needs to be taken to ensure that this system does not damage the materials being cleaned.

5.6.5 *Relamping*

The maintenance personnel will require instruction on the removal of the lamps so as not to damage the sockets or any components of the luminaire in any way.

If the luminaire's aiming position has to be disturbed, care must be taken to note and/or mark its original position so that this can be reset when the relamping has been carried out.

When new lamps are not being put in the luminaires after the cleaning process, the old lamps should be carefully examined and any lamp showing age should be replaced at that time with the lamp specified by the designer. Lamps must be replaced with care so that no damage is caused to the luminaire.

Relamping with new lamps should be done after the luminaire has been cleaned. Generally the replacement lamps should be only those that are recommended by the design of the scheme. However, consideration should be given to potential use of improved lamps and control gear, but their suitability for the luminaire and application must be checked with the installation designer.

5.6.6 *Equipment Disposal*

5.6.6.1 *Disposal of lamps*

Uncontrolled breakage or crushing should be avoided whenever possible and incineration is not a recommended disposal route. However the producer or subsequent manager of the waste may undertake the crushing of lamps to reduce bulk or allow materials recovery. If recycling is not an option, discarded lamps may be disposed of through landfill at suitably licensed and contained sites.

Low-pressure sodium lamps contain sodium metal, which reacts with water. Hazards to be considered are the potentially corrosive sodium hydroxide solution and the extremely flammable and explosive hydrogen gas, which result from reacting sodium with water. These lamps should be broken and reacted with water under controlled conditions prior to disposal as follows:

Working in a dry atmosphere not more than 20 lamps should be carefully broken into a large dry container. When the container is not more than one quarter full of lamp debris, the operator should fill it with water from a distance, i.e. by the use of a hose. The water will react with the sodium and may be disposed of as a weak caustic soda solution and the glass debris as a normal controlled waste. These instructions are supplied with each individual lamp. Again the breaking of lamps should only be carried out under controlled and approved conditions after carrying out a full risk assessment.

6 MAINTENANCE FACTOR FOR LED

LED lighting systems offer an exceptionally extended lifespan compared to traditional lighting products, making them a distinct consideration. The longevity of LEDs significantly reduces maintenance needs, and, in most cases, the concept of modular LED chip replacement is neither feasible nor practical due to their integrated nature. Nevertheless, this longevity also poses the risk of luminaires going unattended for extended periods. Hence, making informed and practical decisions regarding LED system maintenance is essential, guided by established LLMF (Lumen Maintenance Factor) guidelines.

For instance, LED supplier often declares a lifespan of 50,000 burning hours for their high-quality LED products. The life curve provided indicates that at the L70 point, which signifies the threshold where the light output depreciates significantly, the LED's performance starts to degrade rapidly. As an example, if the supplier provides a life curve like the one below, it means that the LED's longevity is guaranteed for 50,000 burning hours, and the maintenance factor for LLMF (Lumen Maintenance Factor) should begin at 0.7.

Below Fig. 8 shows typical life time curve of installation of a product.

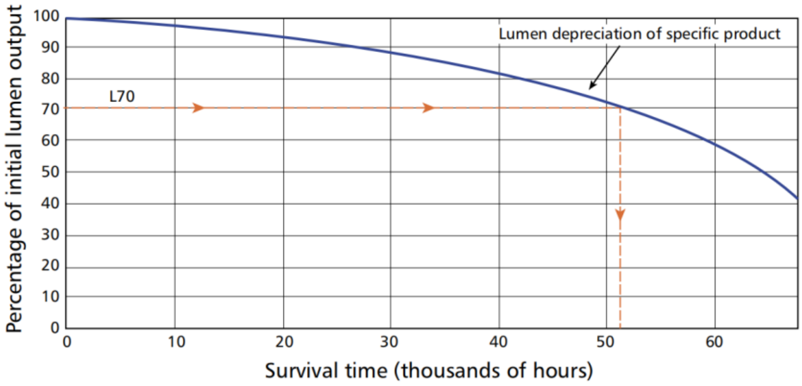


Fig. 8 Typical Life Time Curve of Installation of a Product

In the context of LED systems, it's important to avoid treating 0.7 as a default value, as one should exercise their discretion based on the specific conditions at the installation site. The following example will provide a clearer understanding of this principle.

In an ideal scenario, high-quality LEDs offer an extended lifespan, and they are typically replaced or refurbished before reaching their L70 value. This practice is common in upscale retail shops and some premium commercial office lighting setups.

For instance, in a facility with continuous 24/7 lighting operation, the L70 value of 50,000 burning hours translates to approximately 5.7 years. However, in the case of office lighting with a schedule of 10 hours per day and 5 days a week, the same L70 value of 50,000 hours extends to about 19.2 years, which is generally sufficient before considering a lighting system change.

In situations where a makeover occurs every 15 years, it would be more appropriate to consider the L80 value, which corresponds to a 0.8 factor, rather than L70. This choice is not only practical but also economical in terms of luminaire quantity.

In the context of the Indian working conditions, with a 6-day workweek and 10 hours of daily operation for 52 weeks in a year, the total annual hours of operation amount to 3,120 hours. So, if the proposed designed lifespan of a lighting installation is 10 years, the LLMF may be calculated based on 31,200 hours of the life curve, indicating a factor of 0.9

Point to be noted that this factor calculations is nothing to do with product warranty and guaranty. This is strictly to be followed the life curve ad product supplier have to submit the complete life curve for designed life not that 50, 000 hours.

Lumen depreciation of the luminaire based on many factors like voltage delivered, junction temperature, ambient temperature, deign & type of the driver used etc which has been discussed in Light source chapter in details, therefore the irrespective of the LED chip life curve designer should get the led system /luminaire life curve.

In Indian condition it is observed that led system life is declared in general by the manufacturers is in the range of 8000, 12,000 , 15,000 to 25,000 burning hours in that case the L70 value factor may be very similar to HPSV lamps or tri- phosphor lamps.

The following factors of the LED system:

a) Light output depreciation at 70% of initial value (L value)

b) Failure fraction value for the percentage of LEDs that have gradually fallen below the stated value lumen output percentage. (By)

c) Service life in hours (h)

d) Abrupt failure value percentage I.e when a luminaire or individual chip catastrophically fails & emits no light (Cy)

e) The sum of gradual failure & catastrophic failure values (Fy) - This is basically LSF (Lamp Survical Factor)

f) Manufactured data is at 25 degree centigrade, therefore higher temperature lumen depreciation will vary and designer needs to take account of that .In the case of lower the temperature life normally increased hence factor need to upscale accordingly.

g) Manufacture should definitely intimate the LSF value or factor for designer to achieve the final maintenance factor for LED system.

In the case of LED system replacement for the LED module /modular system, the module can be changed with and luminaire can be cleaned but in the case of integrated system whole LED luminaire to replaced

a) Lamp lumen maintenance factor can be taken as generic value of the technology as it varies with wattage plus in the case of led the variation is too much based on design parameters . So, the specific data for specific product need to considered.

b) Lamp survival factor is very important and manufacture should furnish the value with its operating conditions clearly mentioned to avoid any confusion of the site operating condition. Again no generic value to be taken for LSF also and specific data for specific product line need to be obtained.

ANNEXURE A
EXAMPLE OF MAINTENANCE FACTOR ESTIMATION
(*Clause* 4.19)

A-1 Example of Maintenance Factor Estimation

Site	-	factory assembling television receivers on the outskirts of a large city
Size	-	large open area having normal environment
Finishes	-	70/30/20 % reflectance of ceiling/walls/floor respectively
Lighting system	-	slotted top white metal reflector using tri-phosphor fluorescent lamps

Operation conditions:

Burning hours	-	4000 hrs per year with spot changes of failed lamps
Maintenance schedule	-	cleaning and re-lamp every two years

From:

Table 5	-	*LLMF*	=	0.90 for 8000 hours of replacement time
	-	*LSF*	=	1.00 (as spot change is practiced)
Table 7	-	*LMF*	=	0.80 for two yearly cleaning of type B luminaire
	-	*RSMF*	=	0.93 for 6 yearly clean of surfaces

$$MF = 0.90 \times 1.00 \times 0.80 \times 0.93 = 0.669 = 0.67$$

If cleaning is carried out annually, the *LMF* = 0.90 and *MF* = 0.90 X 1.00 X 0.86 X 0.93 = 0.72

This makes the installation 7% more efficient. This will result in over 7 % saving in the lighting installation size and the energy consumed whilst maintaining the design illuminance.

NOTES —

1. To achieve a specified maintained illuminance various maintenance schedules can be considered and the appropriate factors obtained from the data. All factors relate initial to maintained conditions.

2. It is common practice to carry out lamp change and cleaning at the same time but cleaning of lamp and luminaire between re-lamping may be beneficial in dirty locations or when a longer lamp replacement period is used.

3. Luminaire Maintenance Factor and Room Surface Maintenance Factor are not related to lamp burning hours.

A-2 Example of Luminaire Cleaning Interval Estimation

Lighting system	-	1200 mm x 300 mm low brightness reflector recessed troffer using two T8 1200 mm 36 W nominal rated fluorescent tubes operating on high frequency ballast. (The total luminaire power demand is 72 W.)
Installed luminaire Cost	-	100
Life of luminaire	-	10 years
Lamp cost	-	10 per luminaire
Cleaning cost	-	3 per luminaire
Re-lamp cost	-	0.5 per luminaire
Luminaire power demand	-	72 W (circuit)
Lamp burning hours per year	-	3000
Re-lamping intervals	-	3 years
Unit energy cost	-	0.05 (This should include portion of the maximum demand cost if applicable.)
Dirt depreciation factor for Type B luminaire in normal Environment (Table 13)	-	0.14

NOTE— All costs are in relative terms. It is important to use real costs based on local circumstances.

Cost of cleaning the luminaire once = C_c = 3.

Cost of owning and operating the installation per year = C_a

This includes annual energy cost, amortized installation cost per year (including interest on capital) and total re-lamping cost per year.

$$\textit{Annual energy cost} = \frac{72 \times 300 \times 0.5}{1000} = 10.8$$

$$\textit{Annual installation cost} = \frac{100}{10} = 10$$

$$\textit{Annual re-lamp cost} = \frac{10 + 0.5}{3} = 3.5$$

and $C_a = 10 + 3.5 + 10.8 = 24.3$

The optimized cleaning interval T is given by:

$$T = \frac{-C_c}{C_a} + \sqrt{\frac{2C_c}{\Delta . C_a}} years$$

$$T = \frac{-3}{24.3} + \sqrt{\frac{2x3}{0.14 \ x \ 24.3}}$$

= 0.123+ 1.328
= 1.2 years

These luminaires should be cleaned not later than 14 months intervals. In practice annual cleaning should be practiced with lamps replaced after 3 years.

A-3 Equipment for Maintenance

Time, labour and expense of maintaining a lighting system can be greatly reduced by choosing maintenance equipment with features most suitable to the requirements of each system. Many different kinds of maintenance devices are available to facilitate the cleaning task. The choice of equipment will depend on several factors such as mounting height, size of area, size of doors, lifts and stairs leading to area, accessibility of lighting units and obstacles in the area. Some of the most commonly available maintenance equipments are given in **A-3.1** to **A-3.10**.

A-3.1 *Ladders*

Ladders are often used in lighting maintenance because their low weight, low cost and simplicity make them desirable for simple maintenance tasks. However, safety and mobility restrictions limit their use in some cases.

A-3.2 *Scaffolding*

Portable scaffolding generally has greater safety and mobility than ladders. More equipment can be carried and the maintenance man has a firm platform from which to work. In general, scaffolds should be light, sturdy, adjustable, mobile, and easy to assemble and dismantle.

Special requirements often dictate the type of scaffolding which can be used, for example, for mounting on uneven surfaces or for clearance of obstacles such as tables or machines.

A-3.3 *Telescopic Scaffolding*

The telescopic scaffold provides a quick means for reaching lighting equipment at a variety of mounting heights. This equipment comes in various sizes that have platforms which can be raised and lowered either manually or electrically.

A-3.4 *Lift Truck of Hoist*

Often the quickest and most efficient maintenance device is the lift truck or hoist. Although there are different types available the method of operating is basically the same. The platform can be raised or lowered automatically and, in some types, the truck can be driven from the platform. While the initial investment for such equipment is high, the maintenance savings can be large enough to make this viable. Check that the device can enter the area.

A-3.5 *Disconnecting Hangers (raising and lowering devices)*

Disconnecting hangers lower lighting units to a convenient work level, enabling the worker to maintain them with a minimum of equipment. When a lighting unit is raised into place, the hanger positions the unit and makes the proper electrical circuit connection automatically. An additional safety feature of this type of device is that the electrical circuit is disconnected when the luminaire is lowered. However, installation and maintenance of winches, pullies and line can be a major item.

A-3.6 *Lamp Changers*

Spot lamp replacement can often be simplified by the use of lamp changers. By gripping the lamps either mechanically or with air pressure, as in a vacuum type, the lamp changer can be used to remove and replace lamps.

A-3.7 *Catwalks, Cranes, Cages, etc.*

Lighting maintenance can be incorporated as an integral part of the lighting system. This can be accomplished in many ways. Luminaires can be maintained from catwalks, cranes or maintenance cages. The catwalks and maintenance cages can be installed alongside each row of lighting units so that maintenance can be performed from them with safety, speed and efficiency.

A-3.8 *Vacuum Cleaners and Blowers*

A blower or vacuum cleaner is sometimes used to remove dust from lighting units. While some of the dirt can be removed in this way, the units still have to be washed at sometime. The periodic use of a vacuum cleaner or blower can, however, prolong the cleaning interval.

A-3.9 *Wash Tanks*

It is desirable to have a wash tank specifically designed for lighting maintenance. Tanks should have both wash and rinse sections and be the proper size for the luminaire parts to be washed. Heating units, mounted in each section, are generally desirable. Louvers or reflectors can be set on a rack to drip dry after washing and rinsing while another unit is being cleaned. Special cleaning tanks have been designed for fluorescent luminaire parts and for flexible types of ceiling panels.

NOTE **—** After cleaning plastic luminaires or optics they will need antistatic treatment to avoid build up of static charges.

A-3.10 *Ultrasonic Cleaning*

This method removes foreign matter from metals, plastics, glass, etc., by the use of high frequency sound waves. Basic equipment consists of a generator, a transducer, and a suitable tank. The generator produces high frequency electrical energy which the tank mounted transducer converts to high frequency sound waves that travel through the cleaning solutions. These waves cause a cavitations effect, that is, the formation of bubbles that grow in size and then violently collapse – thus creating a scrubbing action. This effectively removes dirt from the material immersed in the solution.

A-3.11 *Terminology*

Cleaning agent	material used to aid the removal of dirt
Group replacement (lamps)	replacement of a large number of lamps at one chosen time in an installation
Initial illuminance	average illuminance on the reference surface, based on initial lamp flux, when the installation is new and the room surfaces are clean
Initial lamp flux	luminous flux (lumens) of the lamp measured after an initial aging period in reference conditions
Lamp lumen maintenance factor	ratio of luminous flux of lamp at a given time in the life to the initial luminous flux Initial luminous flux of lamps is usually declared at 1 hour for incandescent and 100 hours for discharge lamps.
Lamp survival factor	fraction of the total number of lamps which continue to operate at a given time under defined conditions and switching frequency
Luminaire maintenance factor	ratio of the efficiency of luminaire at a given time to the initial efficiency value
Maintained illuminance	average illuminance on the reference surface below which an installation is not allowed to fall It is the illuminance at which maintenance must be carried out. For general lighting installations the reference surface is taken as the complete area at the working plane, excluding a 0.5 m strip around the perimeter of the room and around major obstructions within the room. For local and localized lighting installations the reference surface is that of defined task areas, such as desks or benches.
Maintenance cycle	repetition of re-lamping and/or cleaning intervals
Maintenance factor	ratio of maintained illuminance to initial illuminance
Rated average lamp life	period over which the lamp survival factor falls to 50% in reference conditions.
Room surface maintenance factor	ratio of room surface reflectance at a given time to the initial reflectance value
Spot replacement (lamps)	replacement of individual lamps as they fail

ANNEX B
PATROL VIABILITY, MAINTENANCE FACTOR, EXAMPLE OF OPTIMUM GROUP MAINTENANCE INTERVAL ESTIMATION AND EQUIPMENT

(*Clause* 5.4.5 *and* 5.6.2)

B-1 PATROL VIABILITY CALCULATIONS

The formulae below have been devised to help calculate the most cost effective patrol intervals for a road lighting installation. They incorporate cost factors not directly associated with. but affected by the frequency of night patrolling.

a) Patrol costs are likely to vary pro-rata to any change in patrol interval.

b) Repair costs are affected by the patrol interval. Extending the interval increases the number of repairs to be carried out in a given area, thus increasing the working/traveling time ratio. In effect an optimum is reached at about 2.5 % outages.

B-1.1 *Social Cost Factor (SCF)*

Patrolling is undertaken primarily to reduce the period of time between failure and subsequent repair of a luminaire. The cost effectiveness of patrolling can, therefore, only be assessed when a value is assigned to the cost of a luminaire being inoperative. The cost is equal to the sum of the costs of providing, financing, energizing and maintaining the luminaire. The cost has been termed the Social Cost Factor (SCF).

B-1.2 *Out of Schedule Repair (OSR)*

Much of the theoretical saving achieved by prolonged patrol intervals is, in practice, absorbed by response to sporadic, individual public complaints. Such Out of Schedule Repairs (OSR) increase administration and operational costs and reduce the number of repairs available for the routine repair visit. The cost effectiveness of that visit is, therefore, reduced.

B-1.3 *Patrol Interval Viability Formulae*

a) Patrol cost per luminaire per period =

$$\frac{\textit{Cost per hour x No. of patrols}}{\textit{Luminaires patrolled per hour in period}} \qquad (14)$$

b) Repair cost per luminaire per period =

$$\frac{\textit{Cost per day}}{\textit{Luminaires repaired per day}} \times \frac{\textit{\% outage per period}}{100} \qquad (15)$$

c) Social cost factor (SCF)

i) Annual cost =

$$\frac{\textit{Avg. Capital Cost}}{\textit{Anticipated life (Yrs)}} + \textit{Maintenance cost} + \textit{Interest on capital} \qquad (16)$$

ii) Luminaire cost per outage per period =

$$\text{Annual cost} \times \frac{\%\ \text{Burning Hours in period}}{100} \times \frac{\text{Avg. Outage time in weeks}}{\text{No. weeks in period}} \times \frac{\%\ \text{outage in period}}{100} \qquad (17)$$

NOTE—

1. Period usually summer or winter, but could be whole year or any part.
2. Avg. outage time = half patrol interval + Avg. repair time (Avg. repair time includes material and cable fault delays)

d) Average cost of out of schedule repairs (OSR) per outage=

(Cost of each unscheduled repair x percentage of repairs done out of schedule) + (Cost of each schedule repair x percentage of repairs done in schedule).

Subtracting the cost of a schedule repair gives the average increased cost per outage due to undertaking OSR's.

The value can be related to a period of time by multiplying by the relevant total percentage outage over that period.

B-2 EXAMPLE OF MAINTENANCE FACTOR ESTIMATION

Location - Urban motorway on the outskirts of a large industrial city (Medium Pollution)

Lighting system- 12 m twin arm columns equipped with IP65 luminaires utilizing high pressure sodium lamps.

Operation conditions (operating hours) - 4000 hrs (Sunset to Sunrise) per year.

Maintenance schedule - Cleaning and relamp every three years.

From Table 14, *LLMF* = 0.90 for 12000 hours of replacement time

From Table 15, *LMF* = 0.87 for three yearly cleaning of IP 65 luminaire.

Therefore: *MF* = 0.90 x 0.87 = 0.783 = 0.78

If cleaning is carried out annually, the *LMF* = 0.92 and *MF* = 0.90 x 0.92 = 0.828 = 0.83. This makes the installation 5 % more efficient. This could result in over 5 % saving in the lighting installation size and the energy consumed while maintaining the designed illuminance.

NOTE—

1. To achieve a specified maintained illuminance various maintenance schedules can be considered and the appropriate factors obtained from the data. All factors relate initial to maintained conditions.

2. It is common practice to carry out lamp change and cleaning at the same time but cleaning of lamp and luminaire between relamping may be beneficial in dirty locations or when a longer lamp replacement period is used.

3. Luminaire Maintenance Factor is not related to lamp burning hours.

B-3 EXAMPLE OF OPTIMUM GROUP MAINTENANCE INTERVAL ESTIMATION

Worked examples:

(A) *Lamp replacement*

a) Cost of spot replacement per lamp C_s (from formula 8)

$$C_s = L + S + E$$

b) Cost of group replacement per lamp C_g (from formula 9)

$$C_g = L + B + E$$

c) Cost of combined group and spot replacement per lamp per rated lamp life C_t (From formula 10)

$$C_t = \frac{(100\, C_g + F\, C_s)}{l} \qquad F = 20 \quad l = 80$$

Where F = percentage of lamps failed and replaced prior to the re-lamping interval, say 20 %
I = percentage of rated lamp life at group re-lamp interval, say 80 %.

NOTE: It is thus more economical to implement combined group and spot replacement.

(B) *Cleaning of luminaries* (from formula 11)

The optimum cleaning interval T can be determined as follows:

$$T = \frac{C_c}{C_a} + \frac{2C_c}{C_a \text{ DELTA}}$$

C_a = Amortized installation cost for column, wiring, luminaire and lamp + annual energy cost + lamp replacement cost per year

DELTA = Annual average rate of luminaire dirt depreciation (normally taken as 0.2)

B-4 MAINTENANCE EQUIPMENT

Time, labour and expense of maintaining a lighting system can be greatly reduced by choosing maintenance equipment with features most suited to the system requirements. Many different kinds of maintenance devices are available to facilitate the cleaning task. The choice of equipment will depend on several factors such as mounting height, size of area, size of doors, lifts and stairs leading to area, accessibility of lighting units and obstacles in the area.

Varieties of equipment for maintenance are described in **A-3.** Out of those Ladders (**A-3.1**), Scaffolding (**A-3.2**), Telescopic Scaffolding (**A-3.3)** Vac, Catwalks, Cranes, Cages etc **(A-3.7)**,and Vaccum Cleaners and Blowers **(A-3.8)** are relevant for outdoor lighting systems. Additonally, the following equipment is also used.

Hydraulic Truck — Often the quickest and most efficient maintenance device is the hydraulic lift truck or hoist. Although there are different types available the method of operating is basically the same. The platform can be raised or lowered automatically. Where, such equipment is required for off-roadway works, it is important to check that the surface can take the weight of the vehicle.

Hinged Columns (and Other Raising and Lowering Devices) — lowering lighting units to a convenient work level, enabling the worker to maintain them with a minimum of equipment. When a lighting unit is raised into place, the luminaire unit makes the proper electrical circuit connection automatically. An additional safety feature of this type of device is that the electrical circuit is disconnected when the luminaire is lowered. However, installation and maintenance of winches, pullies and line can be a major item.