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COMMISSION INTERNATIONALE DE L'ECLAIRAGE
INTERNATIONAL COMMISSION ON ILLUMINATION
INTERNATIONALE BELEUCHTUNGSKOMMISSION

TECHNICAL REPORT

GUIDE ON THE MAINTENANCE OF INDOOR ELECTRIC LIGHTING SYSTEMS

CIE 97:2005
2nd Edition

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628.987

Descriptor: Interior lighting
Evaluation of lighting installations

THE INTERNATIONAL COMMISSION ON ILLUMINATION

The International Commission on Illumination (CIE) is an organisation devoted to international co-operation and exchange of information among its member countries on all matters relating to the art and science of lighting. Its membership consists of the National Committees in about 40 countries.

The objectives of the CIE are :

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2. To develop basic standards and procedures of metrology in the fields of light and lighting.
3. To provide guidance in the application of principles and procedures in the development of international and national standards in the fields of light and lighting.
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2. D'élaborer des normes et des méthodes de base pour la métrologie dans les domaines de la lumière et de l'éclairage.
3. De donner des directives pour l'application des principes et des méthodes d'élaboration de normes internationales et nationales dans les domaines de la lumière et de l'éclairage.
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5. De maintenir une liaison et une collaboration technique avec les autres organisations internationales concernées par des sujets relatifs à la science, la technologie, la normalisation et l'art dans les domaines de la lumière et de l'éclairage.

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Die Internationale Beleuchtungskommission (CIE) ist eine Organisation, die sich der internationalen Zusammenarbeit und dem Austausch von Informationen zwischen ihren Mitgliedsländern bezüglich der Kunst und Wissenschaft der Lichttechnik widmet. Die Mitgliedschaft besteht aus den Nationalen Komitees in rund 40 Ländern.

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1. Ein internationaler Mittelpunkt für Diskussionen aller Fragen auf dem Gebiet der Wissenschaft, Technik und Kunst der Lichttechnik und für den Informationsaustausch auf diesen Gebieten zwischen den einzelnen Ländern zu sein.
2. Grundnormen und Verfahren der Meßtechnik auf dem Gebiet der Lichttechnik zu entwickeln.
3. Richtlinien für die Anwendung von Prinzipien und Vorgängen in der Entwicklung internationaler und nationaler Normen auf dem Gebiet der Lichttechnik zu erstellen.
4. Normen, Berichte und andere Publikationen zu erstellen und zu veröffentlichen, die alle Fragen auf dem Gebiet der Wissenschaft, Technik und Kunst der Lichttechnik betreffen.
5. Liaison und technische Zusammenarbeit mit anderen internationalen Organisationen zu unterhalten, die mit Fragen der Wissenschaft, Technik, Normung und Kunst auf dem Gebiet der Lichttechnik zu tun haben.

Die Arbeit der CIE wird in 7 Divisionen, jede mit etwa 20 Technischen Komitees, geleistet. Diese Arbeit betrifft Gebiete mit grundlegendem Inhalt bis zu allen Arten der Lichtenwendung. Die Normen und Technischen Berichte, die von diesen international zusammengesetzten Divisionen ausgearbeitet werden, sind von der ganzen Welt anerkannt.

Tagungen werden alle vier Jahre abgehalten, in der die Arbeiten der Divisionen überprüft und berichtet und neue Pläne für die Zukunft ausgearbeitet werden. Die CIE wird als höchste Autorität für alle Aspekte des Lichtes und der Beleuchtung angesehen. Auf diese Weise unterhält sie eine bedeutende Stellung unter den internationalen Organisationen.

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This Technical Report has been prepared by CIE Technical Committee 3-40 of Division 3 "Interior Environment and Lighting Design" and has been approved by the Board of Administration of the Commission Internationale de l'Eclairage for study and application. The document reports on current knowledge and experience within the specific field of light and lighting described, and is intended to be used by the CIE membership and other interested parties. It should be noted, however, that the status of this document is advisory and not mandatory. The latest CIE proceedings or CIE NEWS should be consulted regarding possible subsequent amendments.

Ce rapport technique a été élaboré par le Comité Technique CIE 3-40 de la Division 3 "Environnement intérieur et étude de l'éclairage" et a été approuvé par le Bureau de la Commission Internationale de l'Eclairage, pour étude et emploi. Le document expose les connaissances et l'expérience actuelles dans le domaine particulier de la lumière et de l'éclairage décrit ici. Il est destiné à être utilisé par les membres de la CIE et par tous les intéressés. Il faut cependant noter que ce document est indicatif et non obligatoire. Il faut consulter les plus récents comptes rendus de la CIE, ou le CIE NEWS, en ce qui concerne des amendements nouveaux éventuels.

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The following members of TC 3-40, "Maintenance of indoor electric lighting systems" took part in the preparation of this technical report. The committee comes under Division 3 "Interior Environment and Lighting Design". This guide replaces CIE 97-1992 "Maintenance of indoor electric lighting systems".

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GUIDE ON THE MAINTENANCE OF INDOOR ELECTRIC LIGHTING SYSTEMS

SUMMARY

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 this fall by the use of a maintenance factor and plan suitable maintenance schedules to limit the decay. Lighting standard "ISO 8995/CIE S 008-2001 Lighting of Indoor Workplaces" in Section 4.8, recommends a minimum maintenance factor. It states that "The lighting scheme should be designed with overall maintenance factor calculated for the selected lighting equipment, space environment and specified maintenance schedule". A high maintenance factor together with an effective maintenance programme promotes energy efficient design of lighting schemes and limits the installed lighting power requirements.

This revision of the guide 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 and the 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.

GUIDE SUR LA MAINTENANCE DES INSTALLATIONS D'ÉCLAIRAGE INTÉRIEUR

RESUME

Pendant la durée de vie d'une installation d'éclairage, la lumière disponible sur la tâche visuelle décroît de manière progressive en raison de l'accumulation de poussières sur les surfaces et du vieillissement de l'installation. C'est le choix des équipements, les conditions de fonctionnement et la nature de l'environnement qui ont une incidence sur le taux de réduction de l'éclairage. La prise en compte de cette dépréciation est faite au moyen du facteur de maintenance et du plan de maintenance programmé pour en limiter l'effet. La norme d'éclairage ISO 8995/CIE S 008-2001 - Eclairage intérieur pour des lieux de travail recommande, au paragraphe 4.8, une valeur minimale du facteur de maintenance; le projet d'éclairage doit être conçu sur la base d'un facteur de maintenance global défini suivant l'équipement d'éclairage choisi, les conditions environnementales et le programme de maintenance retenu. Un facteur de maintenance élevé, associé à un programme de maintenance spécifique, contribue à réaliser des projets d'éclairage efficaces sur le plan énergétique et à réduire les exigences de la puissance installée en éclairage.

La révision de ce guide décrit les paramètres qui ont une incidence sur le processus de dépréciation et développe les méthodes d'évaluation du facteur de maintenance des installations d'éclairage intérieur. Il fournit des informations pour la sélection des équipements, l'évaluation économique des cycles de maintenance et les indications sur les techniques d'entretien. Des exemples sont cités, avec la recommandation de consulter les fabricants pour des applications particulières.

LEITFADEN ZUR WARTUNG VON ELEKTRISCHEN BELEUCHTUNGSANLAGEN IM INNENRAUM

ZUSAMMENFASSUNG

Wegen Verschmutzung und Alterung nimmt die für die jeweilige Aufgabe verfügbare Lichtmenge während der Lebensdauer einer Beleuchtungsanlage ständig ab. Die Abnahmerate wird sowohl durch die Wahl der Anlage als auch durch Umwelt- und Betriebsbedingungen beeinflusst. Um diesen Lichtabfall zu begrenzen, ist er bei der Beleuchtungsplanung mittels eines Wartungsfaktors zu berücksichtigen und es müssen geeignete Wartungspläne festgelegt werden. Die Beleuchtungsnorm "ISO 8995/CIE S 008-2001 Beleuchtung von Arbeitsplätzen in Innenräumen" empfiehlt in Abschnitt 4.8 einen minimalen Wartungsfaktor. Es heißt dort: Die Beleuchtungsanlage sollte mit einem alle

Einflüsse berücksichtigenden Wartungsfaktor geplant werden, der für die vorgesehene Beleuchtungseinrichtung, die räumliche Umgebung und den festgelegten Wartungsplan errechnet wurde. Ein hoher Wartungsfaktor zusammen mit einem wirksamen Wartungsprogramm fördert die Planung von energieeffizienten Beleuchtungsanlagen und begrenzt den Bedarf an installierter elektrischer Energie.

Dieser überarbeitete Leitfaden beschreibt die Parameter, welche den Wertminderungsprozess beeinflussen und erschließt das Verfahren zur Schätzung des Wartungsfaktors für elektrische Beleuchtungsanlagen im Innenraum. Er bietet Hilfe bei der Wahl von Geräten und beim Ausarbeiten von wirtschaftlichen Wartungszyklen und gibt Auskunft über Wartungstechniken. Der Leitfaden zeigt zwar einige beispielhafte Daten, empfiehlt aber, für genauere Werte die Herstellerangaben zu verwenden.

1. INTRODUCTION

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 that accounts for this reduction but in this guide throughout the term "Maintenance Factor" is used. The equivalent term in French is "Facteur de dépréciation".

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.

Notes:

1. The term "light loss factor", having the same definition as maintenance factor, has been used in the past.
2. The term "depreciation factor" has been formerly used to designate the reciprocal of the above ratio.
3. The light losses take into account the depreciation caused by dirt accumulation on lamps, luminaires and room surfaces.
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,

$$E_{\text{maintained}} = E_{\text{initial}} \cdot \text{Maintenance Factor}$$

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.

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

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, luminaires 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 Figure 2.1, 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.

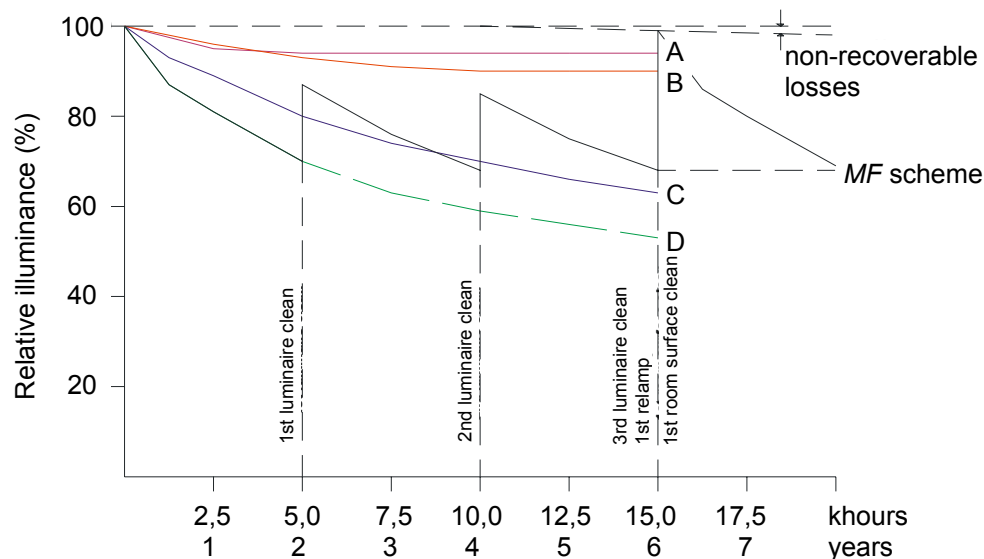


Fig. 2.1. Variation of illuminance through life (Linear fluorescent lamp in industrial reflector luminaire operated with spot lamp replacement programme).

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.

2.1 Influencing factors

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

2.1.1 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.

2.1.2 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 Figure 2.1. 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.

2.2 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 2.1 shows maximum time intervals between inspections of various areas. Table 2.1 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 2.1. Recommended inspection intervals of lighting systems in different working environments.

Inspection interval	Environment	Activity or task area
3 years	Very Clean (VC)	Clean rooms, semi conductor plants, hospital clinical areas*, computer centres
	Clean (C)	Offices, schools, hospital wards
2 years	Normal (N)	Shops, laboratories, restaurants, warehouses, assembly areas, workshops
1 year	Dirty (D)	Steelworks, chemical works, foundries, welding, polishing, woodwork

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