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

TECHNICAL REPORT

LIGHTING DESIGN METHODS FOR OBSTRUCTED INTERIORS

CIE 161:2004

UDC: 628.931
628.972

Descriptor: Artificial lighting: Design and calculation
Interior lighting

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 38 countries and one geographical area and of 4 associate members.

The objectives of the CIE are :

1. To provide an international forum for the discussion of all matters relating to the science, technology and art in the fields of light and lighting and for the interchange of information in these fields between countries.
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.
4. To prepare and publish standards, reports and other publications concerned with all matters relating to the science, technology and art in the fields of light and lighting.
5. To maintain liaison and technical interaction with other international organisations concerned with matters related to the science, technology, standardisation and art in the fields of light and lighting.

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A plenary session is held every four years at which the work of the Divisions and Technical Committees is reviewed, reported and plans are made for the future. The CIE is recognised as the authority on all aspects of light and lighting. As such it occupies an important position among international organisations.

LA COMMISSION INTERNATIONALE DE L'ECLAIRAGE

La Commission Internationale de l'Eclairage (CIE) est une organisation qui se donne pour but la coopération internationale et l'échange d'informations entre les Pays membres sur toutes les questions relatives à l'art et à la science de l'éclairage. Elle est composée de Comités Nationaux représentant 38 pays plus un territoire géographique, et de 4 membres associés.

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1. De constituer un centre d'étude international pour toute matière relevant de la science, de la technologie et de l'art de la lumière et de l'éclairage et pour l'échange entre pays d'informations dans ces domaines.
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.
4. De préparer et publier des normes, rapports et autres textes, concernant toutes matières relatives à la science, la technologie et l'art dans les domaines de la lumière et de l'éclairage.
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.

Les travaux de la CIE sont effectués par 7 Divisions, ayant chacune environ 20 Comités Techniques. Les sujets d'études s'étendent des questions fondamentales, à tous les types d'applications de l'éclairage. Les normes et les rapports techniques élaborés par ces Divisions Internationales de la CIE sont reconnus dans le monde entier.

Tous les quatre ans, une Session plénière passe en revue le travail des Divisions et des Comités Techniques, en fait rapport et établit les projets de travaux pour l'avenir. La CIE est reconnue comme la plus haute autorité en ce qui concerne tous les aspects de la lumière et de l'éclairage. Elle occupe comme telle une position importante parmi les organisations internationales.

DIE INTERNATIONALE BELEUCHTUNGSKOMMISSION

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 38 Ländern und einem geographischen Gebiet und aus 4 assoziierten Mitgliedern.

Die Ziele der CIE sind :

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 3-31 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 3-31 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 tout 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.

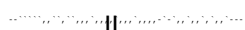
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The following members of TC 3-31, "Electric lighting for real spaces" took part in the preparation of this technical report. The committee comes under Division 3 "Interior Environment and Lighting Design".

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LIGHTING DESIGN METHODS FOR OBSTRUCTED INTERIORS

SUMMARY

Traditional lighting calculation methods assume a clear room volume allowance for the influence of room contents. Objects located between light source and task will act to block direct light and will result in some light being absorbed by the object and some reflected from its surface. This may cause both local and general reductions in planar illuminance over a whole installation. This report draws together design related material on the subject. It is intended as specialist reference for use in conjunction with relevant design guidance. It contains information on the magnitudes of likely losses in different types of building interior and design guidance to ameliorate the effects of these light losses.

A major part of the report is concerned with calculation methods for obstructed interior lit by general lighting systems. Modifications to traditional lighting design calculation methods to acknowledge the influence of room contents, above and below the working plane are described. Advice on the application of computer programs for lighting design and analysis to solution of problems involving obstructed interiors is given.

METHODES DE CONCEPTION D'ECLAIRAGE POUR DES INTERIEURS ENCOMBRES

RESUME

Les méthodes traditionnelles de calcul d'éclairage supposent que la pièce à éclairer soit un espace vide pour tenir compte de l'influence du contenu de la pièce. Les objets situés entre la source lumineuse et l'endroit à éclairer agissent en bloquant la lumière directe. Il en résultera qu'une partie de la lumière sera absorbée par l'objet et une autre partie réfléchi à partir de sa surface. Ceci peut causer des réductions aussi bien locales que générales dans l'éclairage plan de toute l'installation. Ce rapport résume des données sur la conception de l'éclairage. Il est destiné à être utilisé par des experts comme référence, conjointement avec d'autres guides pertinents. Ce document contient des informations sur l'ampleur des pertes probables dans des intérieurs de conception différente et des recommandations pour en réduire les effets.

Une grande partie du rapport traite des méthodes de calcul pour des intérieurs encombrés illuminés par des systèmes d'éclairage général. On y décrit des modifications des méthodes traditionnelles de calcul en conception d'éclairage en considérant l'influence du volume, au-dessus et en-dessous du plan de travail. Des conseils sont également donnés pour l'utilisation des programmes informatiques de conception d'éclairage ainsi qu'une analyse pour régler les problèmes concernant les intérieurs encombrés.

PLANUNGSVERFAHREN FÜR DIE BELEUCHTUNG VON MÖBLIERTEN INNENRÄUMEN

ZUSAMMENFASSUNG

Traditionelle Beleuchtungsberechnungsmethoden gehen im Hinblick auf die Berücksichtigung der Raumeigenschaften von leeren Räumen aus. Objekte zwischen Lichtquelle und Nutzebene blockieren direktes Licht und führen dazu, dass Licht zum Teil vom Objekt absorbiert und zum Teil von seiner Oberfläche reflektiert wird. Dies kann eine örtliche Verringerung der Beleuchtungsstärke zur Folge haben wie auch in der gesamten Anlage eine allgemeine Verringerung der Beleuchtungsstärke in einer Ebene. Dieser Bericht fasst planungsbezogene Unterlagen zu diesem Thema zusammen. Er ist gedacht als grundlegendes Bezugsdokument zur Verwendung in Verbindung mit entsprechenden Planungsanleitungen. Er enthält Informationen über die Größenordnung der zu erwartenden Verluste in verschiedenen Arten von Innenräumen und Planungsempfehlungen, um die Auswirkungen dieser Verluste zu verringern.

Ein wesentlicher Teil des Berichtes behandelt Berechnungsmethoden für möblierte Innenräume, die durch eine Allgemeinbeleuchtung beleuchtet werden. Zur Berücksichtigung der Wirkung der im Raum befindlichen Gegenstände über und unter der Nutzebene werden Korrekturen zu traditionellen Beleuchtungsberechnungsmethoden beschrieben. Es werden Ratschläge für die Benutzung von Computerprogrammen für die Beleuchtungsplanung und eine Analyse zur Lösung der mit möblierten Innenräumen verbundenen Probleme gegeben.

STATUS OF THIS REPORT

Technical Committee 3-31 was set up at the 22nd Session of the CIE in Delhi in November 1995. The terms of reference of the TC are to review current knowledge, gather data on light losses caused by interior contents in offices, commercial and industrial buildings, and propose modifications to methods of measurement and calculation to acknowledge presence of contents in interiors. The target audience is both practitioners and researchers.

1. INTRODUCTION

Lighting is arguably the only major building services subsystem where the design process is undertaken making no allowance for building occupancy. Traditional lighting calculation methods assume a clear room volume without allowance for the influence of room contents. Objects located between light source and task will act to block direct light and will result in some light being absorbed by the object and some reflected from its surface. This may cause both local variations in illuminance (for example over a task area) and a general reduction in planar illuminance over a whole installation. Such reductions in illuminance are not necessarily objectionable. Local shadow may clarify spatial and directional properties of light and can be quantified. On the other hand whilst sophisticated means of calculation of planar illuminance or luminaire spacing exist based on the clear room approximation, few are capable of quantifying the light reductions caused by obstructions.

Recent developments in lighting equipment, prompted by the visual problems of VDTs and the pressure to increase energy efficiency tend to increase the risk of obstruction losses. Much use is now made of mirrored and louvred luminaires, designed for use at wide spacing, whose directional lighting characteristics mean that areas of the working plane remote from luminaires are particularly prone to light reductions caused by room contents. Additionally, changes in lighting design standards involving the specification of "maintained illuminance" at the task - the minimum average illuminance at which maintenance must be carried out - have exposed the deficiencies of current lighting design methods enabling installations to be more easily checked for compliance with a performance specification.

The purpose of this report is to draw together design related material on the subject. It is intended as specialist reference for use in conjunction with relevant design guidance. It contains information on the magnitudes of likely losses in different types of building interior and design guidance to ameliorate the effects of these light losses. A major part of the report is concerned with calculation methods for obstructed interiors lit by general lighting systems. Modifications to traditional lighting design calculation methods which acknowledge the influence of room contents, above and below the working plane are described. Advice on the application of computer programs for lighting design and analysis to solution of problems involving obstructed interiors is given.

2. LIGHT LOSSES IN INTERIORS

This section gives guidance on likely magnitudes of light losses in obstructed interiors and the factors that may influence them.

2.1 Office interiors

Offices and other commercial premises constitute a major part of the world's building stock and good lighting is a factor in the establishment of a safe, comfortable and productive office environment. Lighting design for office interiors usually assumes an "empty room" because of uncertainty about the ultimate contents of the space. The subsequent addition of furniture will cause light loss by, for example, blocking of light by the contents above the notional working plane or absorption of light by the various objects within floor cavities. This will cause the achieved illuminance levels in the room to be lower than those predicted using an "empty room" assumption and result in areas of local light loss and shadow that may influence user visual performance, or in extreme cases, safety. Light losses of this nature can frequently cause contractual disputes between designers and building owners when specified illuminance levels are not achieved at the commissioning stage.

2.1.1 Obstruction light losses above the notional working plane

Relationships between average light loss over the working plane of furnished offices and the various parameters of general lighting installation have been estimated, mainly by measurement of horizontal working plane illuminance in actual office interiors, before and after furnishing (see Appendix B). This enables Obstruction Light Loss (OL), the percentage reduction in average working plane illuminance caused by obstruction to be estimated for office interiors containing evenly distributed furniture layouts. The magnitude of Obstruction Light Loss is related to the following installation variables, in order of importance: obstruction size and density; luminaire type and layout; and the geometry and photometric characteristics of the room. An obstruction for a general lighting installation is an object located between working plane and luminaire plane, or between working plane and floor, that blocks the passage of light from source to task. A convenient and reliable measure of obstruction density is the obstruction **vertical** surface area to **floor** area **ratio** (*VFR*) that is illustrated in Figure 2.1.

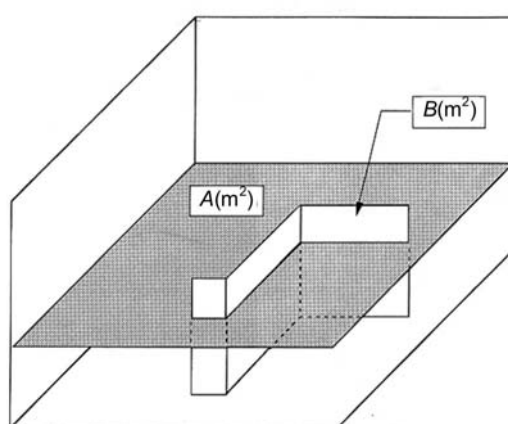


Figure 2.1 The concept of *VFR*.

In Figure 2.1 the *VFR* is numerically the total vertical surface area of room contents above the working plane and below luminaire plane (*B*) divided by the area of the working plane (*A*). Included in this calculation is the area of any surface that may block light. This could include, for example, both sides of a free standing partition or the outer surfaces of a closed object such as a filing cabinet. Table 2.1 shows values of Obstruction Loss for typical office interiors and illustrates the general principle that light loss (*OL*) rises as obstruction density (*VFR*) increases. It is applicable to office interiors having floor to ceiling heights from 2,5 m to 4,0 m, evenly distributed contents (furniture and equipment), typical values of reflectance (ceiling 0,7, walls 0,5, floor cavity 0,2, obstructions 0,4), and lit by regular arrays of ceiling mounted downlighting luminaires. Since combinations of these variables occur in most office interiors the results in Table 2.1 can be considered to have a wide applicability. The derivation of the *OL* data is set out in Appendix D.

Table 2.1 Values of *OL* for installations with luminaires installed at manufacturers recommended spacing to height ratio.

	<i>VFR</i> = 0,15 "Light"	<i>VFR</i> = 0,35 "Medium"	<i>VFR</i> = 0,5 "Heavy"
Diffusing or uplighting luminaire	2,5%	7%	15%
Wide distribution reflector	2%	5%	11%
Narrow distribution reflector	1,5%	5%	10%

Generally office interiors may be described as falling into three categories of obstruction density which may be classified as "light", "medium" and "heavy". Figure 2.2 shows whole room and workstation views of typical examples of each class of obstruction density (the top pair of images are heavy obstruction and the bottom pair are light

obstruction). A typical "light" interior would contain mainly desks equipped with single computer terminals (VDT) but with few partitions and with approximately 12 square metres of floor space per workstation. A "medium" obstructed office may have more than one VDT per workstation and the office as a whole will contain some movable partitions, filing cabinets or drawing boards. A heavily obstructed office would be divided into individual workstations by use of partitions and each user would typically have one or more VDT on each workstation. The ranges of *VFR* into which office furnishings may be classified are: $0 < \text{light} \leq 0,2$; $0,2 < \text{medium} \leq 0,45$; $0,45 < \text{heavy} \leq 0,9$.



Figure 2.2 Whole room and workstation views of typical examples of each class of obstruction density.

Different types of luminaire have varying potential for light loss for similar degrees of obstruction. For purposes of estimating likely light losses luminaires may be considered as generic groups each consisting of luminaires having similar physical and photometric