Electric Luminaires

# ZVEI Guide to DIN EN 12464-1

## DIN EN 12464-1

Lighting of work places
Part 1:
Indoor work places

## Contents

## 1 Foreword

This Guide is designed to facilitate the application of DIN EN 12464-1 "Lighting of work places – Indoor work places" for lighting system planning and design. European standard EN 12464-1 is a product of detailed discussion. It covers all the relevant applications of the current German standard DIN 5035 "Artificial lighting of interiors". Published in March 2003, DIN EN 12464-1 documents the state of the art. EN 12464-1 applies throughout Europe and – like ISO 8995/CIE S 008 – as an ISO standard worldwide.

The terms and definitions used in the European standard are explained here in plain language. Designs can be crafted on the basis of DIN EN 12464-1 but because of varying assumptions they are not necessarily comparable. This ZVEI Guide helps permit comparability by making recommendations and presenting examples of maintenance factors, rating areas, etc.. The recommendations and examples are largely compliant with the office lighting information sheet BGI 856 "Beleuchtung im Büro" (April 2003), which in turn builds on DIN 5035 Part 7 "Lighting of interiors with visual display work stations" (August 2004) and was specifically developed for office lighting applications.

The legal reference has been agreed with the Commission for Occupational Health and Safety and Standardization (KAN) and the German federation of institutions for statutory accident insurance and prevention (HVBG).

## 2 Legal reference to the Arbeitsstättenverordnung, workplace regulation ASR 7/3, work safety regulation BGR 131 and DIN 5035

In Germany, occupational health and safety requirements for workplace lighting are set out in the Arbeitsstättenverordnung (workplace ordinance), workplace regulation ASR 7/3 and current BG regulations (BGR 131 for workplaces with artificial lighting and safety control systems).

Where ASR 7/3 and/or BGR 131 are applied – along with DIN 5035 Parts 1 and 2, to which they refer – it is safe to assume that the requirements of the Arbeitsstättenverordnung are met. In the wake of the August 2004 amendment of the Arbeitsstättenverordnung, ASR 7/3 is to be revised. BGR 131 is currently being updated to reflect the state of the art.

Since some parts of DIN 5035 have now been superseded by DIN EN 12464-1, uncertainties have arisen for planners/designers. For the transitional period until ASR 7/3 and BGR 131 are revised, the ZVEI recommends proceeding as follows:

For lighting design work, planners/designers should – in consultation with the client – refer to DIN EN 12464-1 and not to DIN 5035 Parts 1 and 2, to which the above regulations refer. Reference surfaces for lighting quality features (working areas) should be defined with the help of this guide.

As a general rule, where the standards set out in DIN EN 12464-1 are met, the law referring to DIN 5035 Parts 1 and 2 is broadly satisfied (see 9.1 for exceptions).

## 3 What is new in DIN EN 12464-1

Both lighting quality features and factors determining the difficulty of the visual task are defined in the new standard in the same way as in DIN 5035 Part 1.

What has changed are a number of basic concepts and methods of assessing individual quality features. Particularly significant changes are:

- introduction of the task area and the immediate surrounding area
- introduction of maintained illuminance
- introduction of a new method of rating direct glare (UGR)
- introduction of new reflected glare rating limits for workstations with display screen equipment (DSE).

DIN EN 12464-1 lists the lighting criteria still required for lighting quality:
- agreeable luminous environment
- harmonious luminance distribution
- adequate illuminance for the activities listed in the "Schedule of lighting requirements"
- good uniformity
- limitation of direct and reflected glare and veiling reflections
- correct directional lighting and agreeable modelling
- suitable colour appearance and colour rendering
- avoidance of lamp flicker and stroboscopic effects
- account of daylight

## 4 Maintained illuminance $\bar{E}_m$

Illuminance levels impact significantly on the speed, ease and reliability with which visual tasks can be performed. The illuminance values specified in the standard for the task area and the immediate surrounding area are maintained illuminance values, i.e. values which the average illuminance on a reference surface must not fall below. In other words, they are the average illuminance values reached when maintenance needs to be carried out.

## 5 Task area and immediate surrounding area

The **task area** is defined as the partial area in the work place in which the visual task is carried out. The visual performance required for the visual task is determined by the visually relevant elements (size of objects, background contrast, luminance of objects and presentation time) of the activity performed.

For places where the size and/or location of the task area is unknown, the area where the task may occur should be taken as the task area.

The **immediate surrounding area** is defined as the area surrounding the task area within the field of vision. According to DIN EN 12464-1, this surrounding area should be at least 0.5 m wide and can thus be seen as a band around the task area.

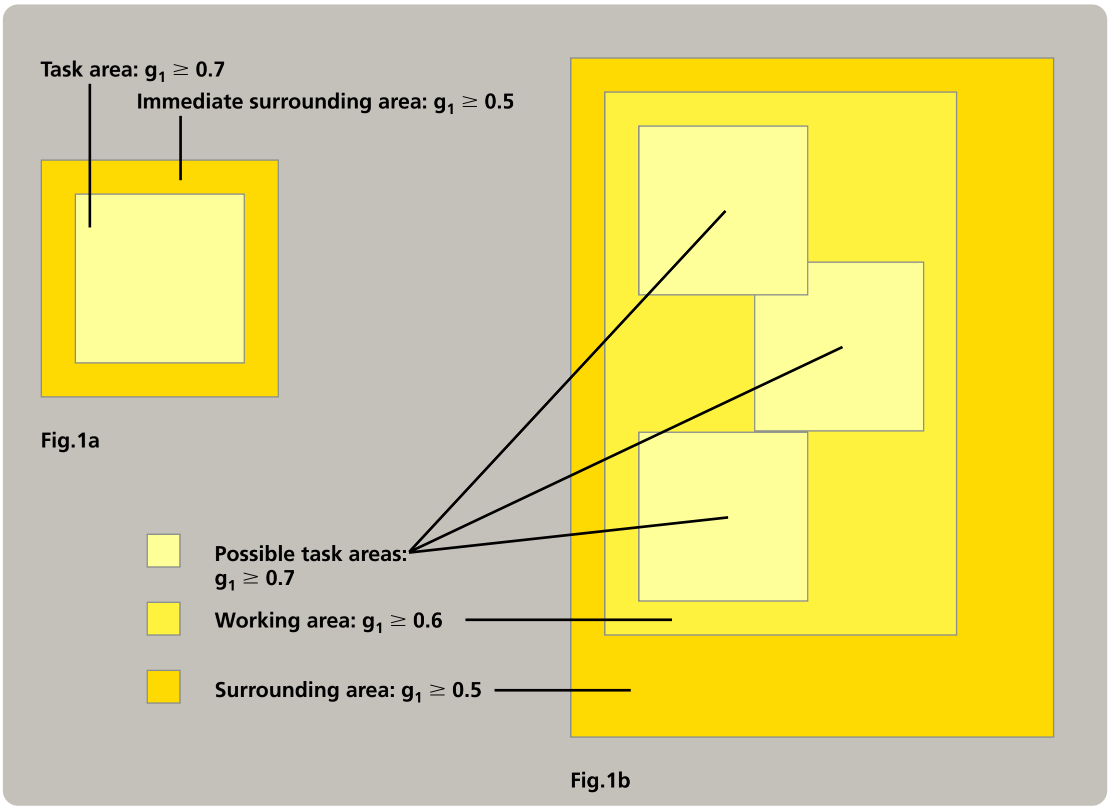
When a lighting system is designed, the precise location of the visual task often cannot be defined because

- the precise location of the task area is unknown or
- the activity performed involves a number of different visual tasks.

In such cases, it is recommended that several task areas should be combined to form a larger area *(referred to below as the working area*). Where the location of work places is unknown, this working area can also be the entire room. If illuminance distribution in these larger areas has a uniformity of $g_1 \geq 0.6$, it can be assumed that the required $g_1 \geq 0,7$ is always fulfilled in the individual task areas (see Fig.1b for example).

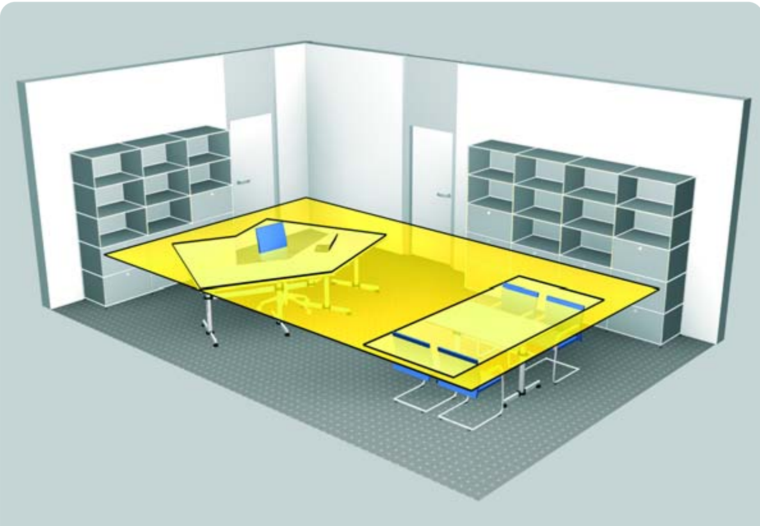
*Fig. 1a: Task area and immediate surrounding area according to DIN EN 12464-1*

*Fig 1b: Working area where task areas may be located, and surrounding area.*



**The DSE working area (yellow) encompasses work surface (grey desktop) and user space (red)**

*Fig. 2a: Task area*



**Horizontal working areas in an office: „DSE work" (light yellow, left) and "conference" (light yellow, right) with "surrounding area" (dark yellow).**

**Reference height for illuminance: 0.75 m above floor level**

*Fig. 2b: Working areas and surrounding area in an office (see also FGL booklet 4 "Good Lighting for Offices and Office Buildings")*

Defining task areas:

a. Areas where different visual tasks may be performed are normally on the work surface, in movement space and on surfaces used for tasks directly related to the activity.

b. When defining task areas, attention also needs to be paid to vertical surfaces such as boards and other inclined surfaces as well as to horizontal surfaces in the room and in the working area.

c. Where the immediate surrounding area is the marginal strip, it should not be rated separately because, as a general rule, the requirements the surrounding area needs to meet are fulfilled automatically. Care must be taken here to ensure there are no task areas in the marginal strip.

Examples of how task areas can be defined for lighting design:

a. Office with single workplace

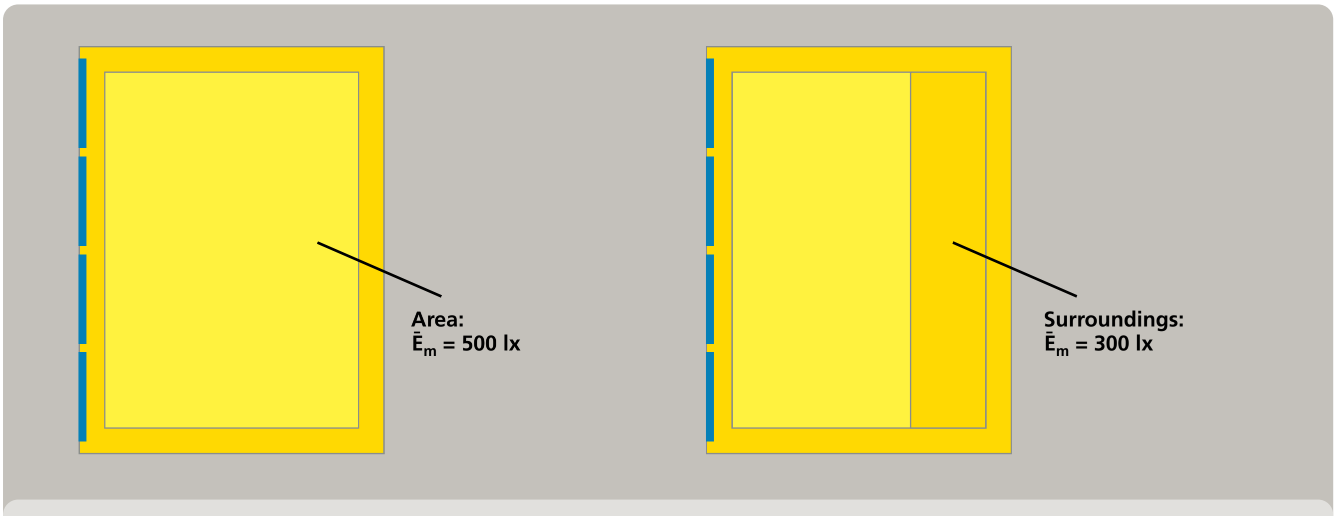
The location of the workplace is known. Working areas encompass the desktop and user space. The height of the working area is assumed to be 0.75 m. The surrounding area is taken to be the rest of the room less a 0.5 m wide marginal strip.

b. Office with unknown arrangement of workplaces

If the arrangement of workplaces is completely unknown, the working area should be taken as the whole room less a marginal strip.

Where planning documents show workplaces close to windows, a correspondingly wide strip can be taken as the working area. Planned uniformity can be $g_1 \geq 0.6$. Experience shows this is enough to ensure that a minimum of 0.7 uniformity is observed at the individual workplaces.

The surrounding area is the rest of the room.




**Office: Area of the room in which the arrangement of workplaces and therefore the location of task areas is unknown at the design stage. Height: 0.75 m; 0.5 m wide marginal strip is ignored.**

**Office: Strip in which the approximate arrangement of workplaces and therefore the location of task areas is known at the design stage. Height: 0.75 m; 0.5 m wide marginal strip is ignored.**

*Fig. 3: Working areas where the precise location of workplaces is unknown.*

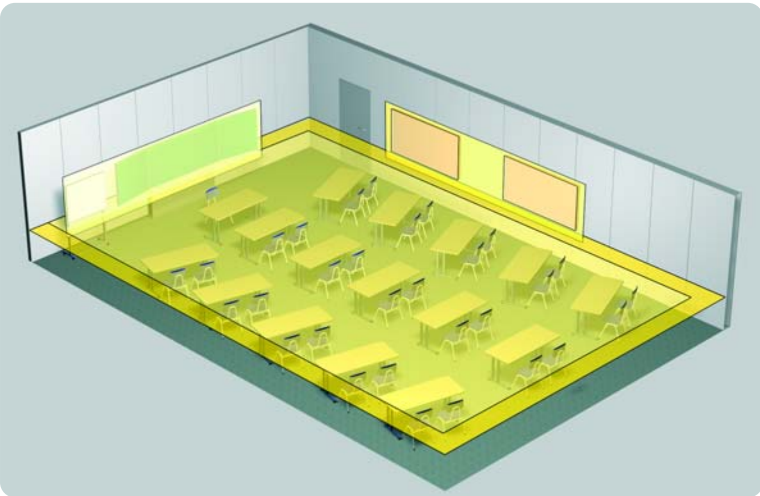
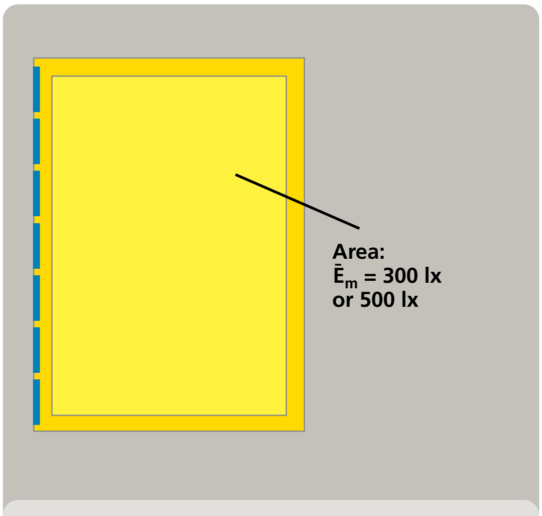


*Fig. 4: Horizontal and vertical areas in which task areas may be located (see also FGL booklet 2 "Good Lighting for Schools and Educational Establishments")*



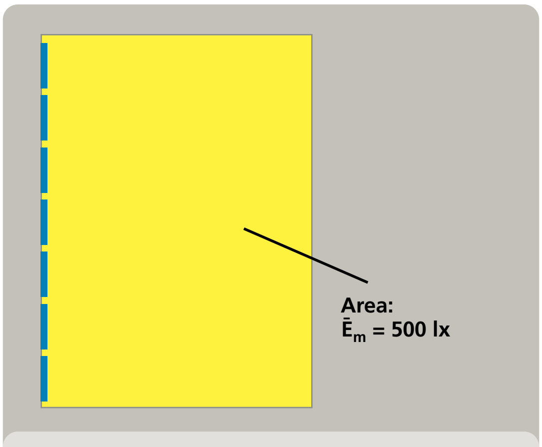

**School: Lighting area in a room where the arrangement of desks and hence the location of task areas is unknown at the design stage: 0.5 m wide marginal strip is ignored.**

*Fig. 5: In ordinary classrooms, the whole room is taken as the working area. Maintained illuminance: 300 lux for primary and secondary schools, 500 lux for evening classes and adult education.*

### c. Classroom with flexible arrangement of desks

Students' desks are often rearranged in classrooms, so the working area should be taken as the whole room less a 0.5 m wide marginal strip. Planned uniformity can be $g_1 \geq 0.6$. Experience shows this is enough to ensure that a minimum of 0.7 uniformity is observed at the individual desks.

*Fig. 6: Office-like room with working areas extending to walls.*




**Office-like room: Where it is known that the arrangement of working areas may extend to the boundaries of the room, the lighting area encompasses the whole room.**

d. Office-like room with possible arrangement of workplaces extending to the boundaries of the room.

Where it is known that working areas may extend to the boundaries of the room but the precise location of the working areas is unknown, the whole room is taken as the working area without deducting any marginal zones. Planned uniformity can be g1 ≥ 0.6. Experience shows this is enough to ensure that a minimum of 0.7 uniformity is observed at the individual workplaces.

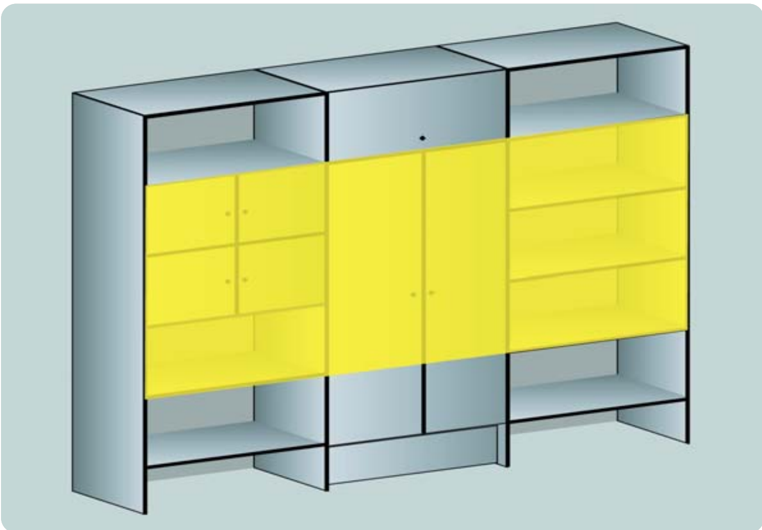


*Fig. 7 (above): Position of the vertical task area*

e. Shelving systems and other vertical surfaces

Shelving systems and cabinets can be vertical task areas (e.g. ticket counter, accounts section). The vertical area starts 0.5 m above floor level and ends at the height of the task area; in the case of an office shelving system, this is 2 m above floor level.

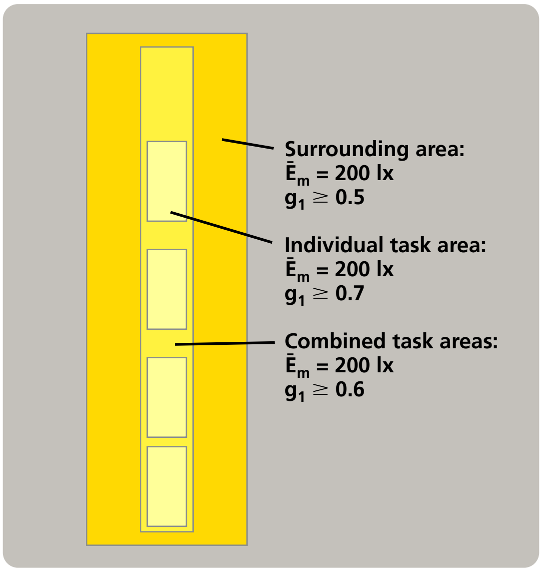



*Fig. 8: Corridor: The individual task areas are small. For lighting design purposes, they can be combined to form a single large area. Attention must be paid to the different uniformities. 200 lux illuminance is required (during the day) for corridors in health care establishments.*

f. Corridor

For corridors up to 2.5 m wide, it is recommended – in line with DIN EN 1838 (1999) – that the individual task areas should be taken as central 1 m wide strips on the floor and combined to form a single large task area. The rest of the space should be regarded as the surrounding area. In wider corridors, the central strip task area should be adjusted accordingly. Where applicable, a lateral strip (up to 0.5 m wide) should be deducted along each wall, provided it is not part of the traffic zone. Vertical task areas such as doors, door handles and signs must also be borne in mind, although no particular illuminance values are specified.


*Fig. 9: Examples of task areas meeting different workplace requirements: space for turning and measuring moderately fine parts presenting vertical and horizontal visual tasks (1), place for studying drawings on vertical surfaces (2), place for checking workpiece measurements and depositing tools (3)*

### g. Single industrial workplace

A variety of visual tasks are performed at many industrial workplaces. These need to be defined individually in terms of location and size.

If the individual visual tasks are comparable, a working area in which they are all performed can be defined.

The immediate surrounding area forms a 0.5 m wide band around the working area. It is advisable, however, to install general lighting for the whole of the hall to ensure enough light is available for all the workplaces in it.

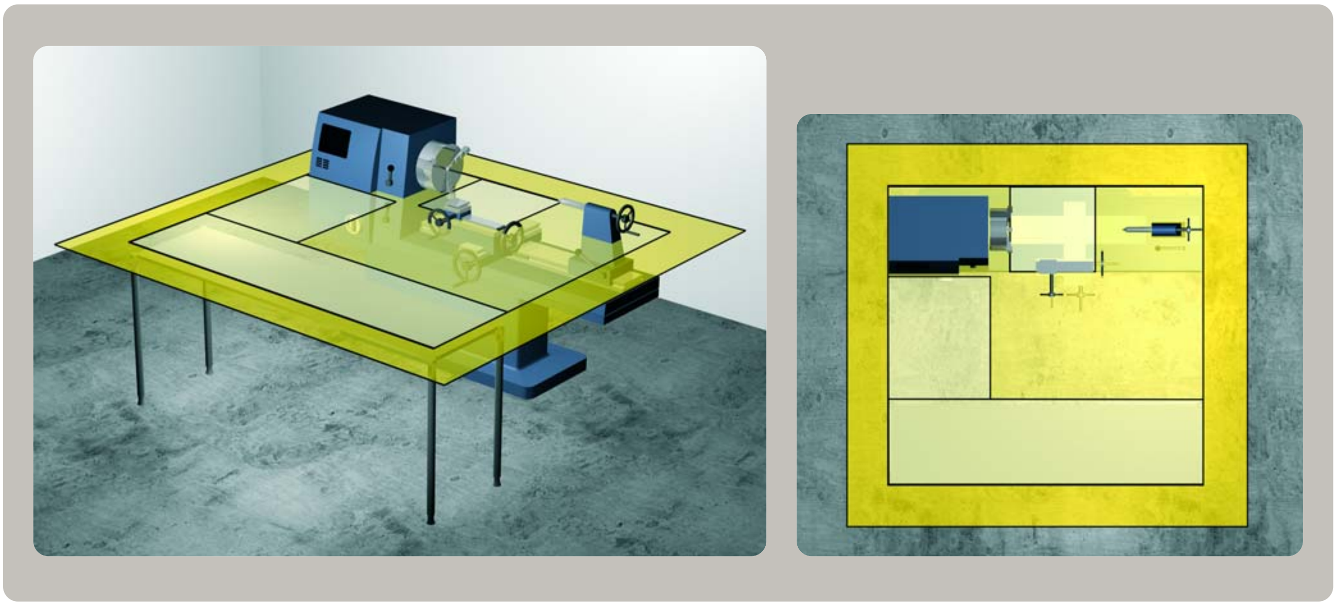


*Fig. 10: Several task areas at a lathe considered as a single working area. The immediate surrounding area is a 0.5 m wide band around it.*

### h. Industrial hall with zones for different activities

Industrial halls generally incorporate a number of task areas with diverse illuminance requirements. Where this is the case, it is recommended that, as a first step, a general hall lighting concept should be developed treating the whole hall – less a 0.5 m wide marginal strip along the walls – as a task area with the lowest requirements. The immediate surrounding area (marginal strip) does not require separate assessment because, as a general rule, the requirements which the surrounding area needs to meet are fulfilled automatically.

For other task areas with different requirements, appropriate, preferably rectangular task areas with their own surrounding areas should be defined and provided with the illuminances and uniformities required.

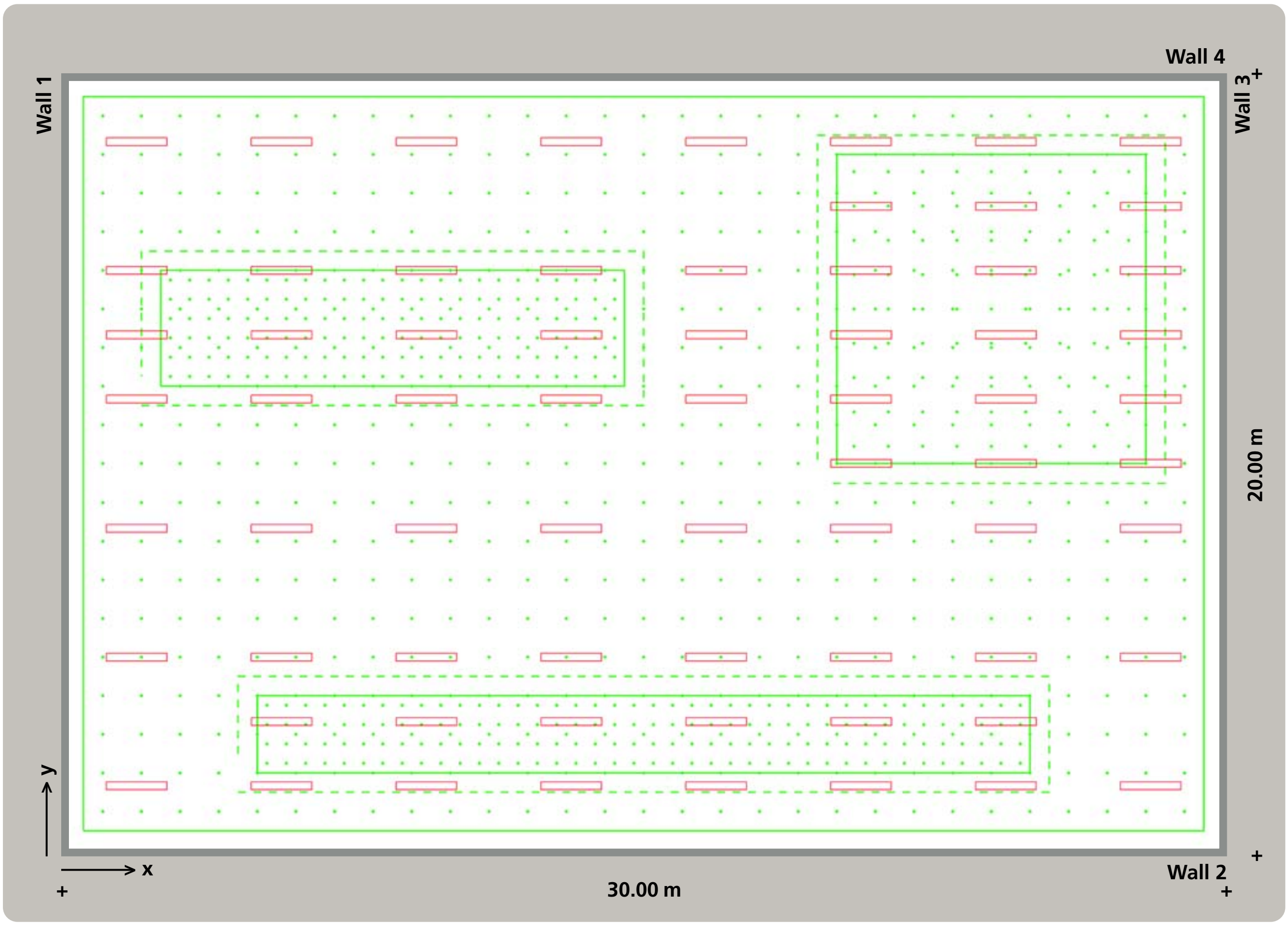



*Fig. 11: Industrial hall with zones for different activities*

## 6 Calculation grid (for lighting system design and computation)

In addition to the content of DIN EN 12464-1, the requirements set out for calculation grids in DIN EN 12193 "Sports Lighting" are also adopted and recommended.

In principle, the grid required to determine average illuminances and uniformities depends on the size and shape of the reference surface (task area, working area or surrounding area), the geometry of the lighting system, the luminous intensity distribution of the luminaires used, the required accuracy and the photometric quantities to be evaluated.

The grid size recommended for rooms and room zones is:

| | **Longest dimension of zone or room** | **Grid size** |
|---|---|---|
| Task area | approx. 1 m | 0.2 m |
| Small rooms/room zones | approx. 5 m | 0.6 m |
| Medium-size rooms | approx. 10 m | 1 m |
| Large rooms | approx. 50 m | 3 m |

For the precise definition of a calculation grid, see Section 9.2.

# 7 Glare limitation

Glare is the sensation produced by excessively bright areas or excessively marked differences in luminance within an observer's field of view. Glare which causes direct impairment of vision is known as disability glare. Glare which is found disturbing, which impairs our sense of wellbeing, is known as discomfort glare.

## 7.1 Rating discomfort glare by the UGR method

The degree of discomfort glare caused by a lighting system can be determined by the UGR method (see Section 9.3). Depending on the difficulty of the visual task, the $UGR_L$ limit should not be exceeded. The following are examples of maximum limits:

Examples of maximum $UGR_L$ limits

| | |
|---|---|
| Technical drawing | ≤ 16 |
| Reading, writing, classrooms, computer work, inspections | ≤ 19 |
| Work in industry and craft workshops, reception | ≤ 22 |
| Rough work, staircases | ≤ 25 |
| Corridors | ≤ 28 |

A lighting system should be appropriate for the relevant UGL category (e.g. "≤ 19"). UGR values can be ascertained by the tabular method. UGR tables are available from manufacturers and incorporated in commercial lighting calculation software.

For initial luminaire selection, it is advisable to use the tabular value of the reference room (4H / 8H) based on a spacing-to-height ratio of 0.25 (see Section 9.3).

Individual UGR values in a lighting system can be calculated using CAD software. This may be useful for designing systems where glare is a critical factor but it does not indicate the standard of glare limitation of the installation as a whole.

## 7.2 Shielding

As excessively bright light sources in the field of view can cause glare, lamps must also be suitably shielded. For luminaires which are open from below or fitted with a clear enclosure, the shielding angle is defined as the angle between the horizontal and the line of sight below which the luminous parts of the lamp in the luminaire are visible.

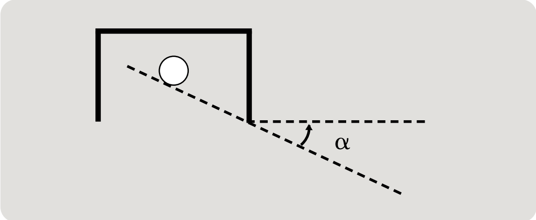



*Fig. 12: Shielding angle α*

The following table shows minimum shielding angles at specific lamp luminances.

Minimum shielding angles specified by DIN EN 12464-1

| **Lamp luminance in cd/m²** | **Minimum shielding angle** |
|---|---|
| 20,000 to < 50,000<br>e.g. fluorescent lamps (high output) and compact fluorescent lamps | 15° |
| 50,000 to < 500,000<br>e.g. high-pressure discharge lamps and incandescent lamps with matt and inside-coated bulbs | 20° |
| ≥ 500,000<br>e.g. high-pressure discharge lamps and incandescent lamps with clear bulbs | 30° |

The minimum shielding angles for the lamp luminances shown need to be observed for all emission planes. They do not apply to luminaires with only a top-side light exit opening or to luminaires mounted below eye level.

7.3 Luminance limits for avoiding reflected glare

As well as rating direct glare due to excessively luminant surfaces, special attention needs to be paid to avoiding reflected glare, which is the glare caused by light reflecting from shiny surfaces. Reflections of excessively bright luminous parts of a luminaire can seriously interfere with work at a screen or even at a keyboard. So care needs to be taken to arrange suitable luminaires so that no disturbing reflections are created.

In DIN EN 12464-1, luminance limits are specified for luminaires which could reflect along normal lines of sight from a screen inclined at up to 15°. As a general rule, 1,000 cd/m$^2$ needs to be observed for positive display LCD or CRT monitors with a good anti-reflective or anti-glare finish and 200 cd/m$^2$ for negative display CRT monitors such as those used at CAD workstations.

The luminances specified must not be exceeded at elevation angles ≥ 65° from the downward vertical in **any** radiation plane.

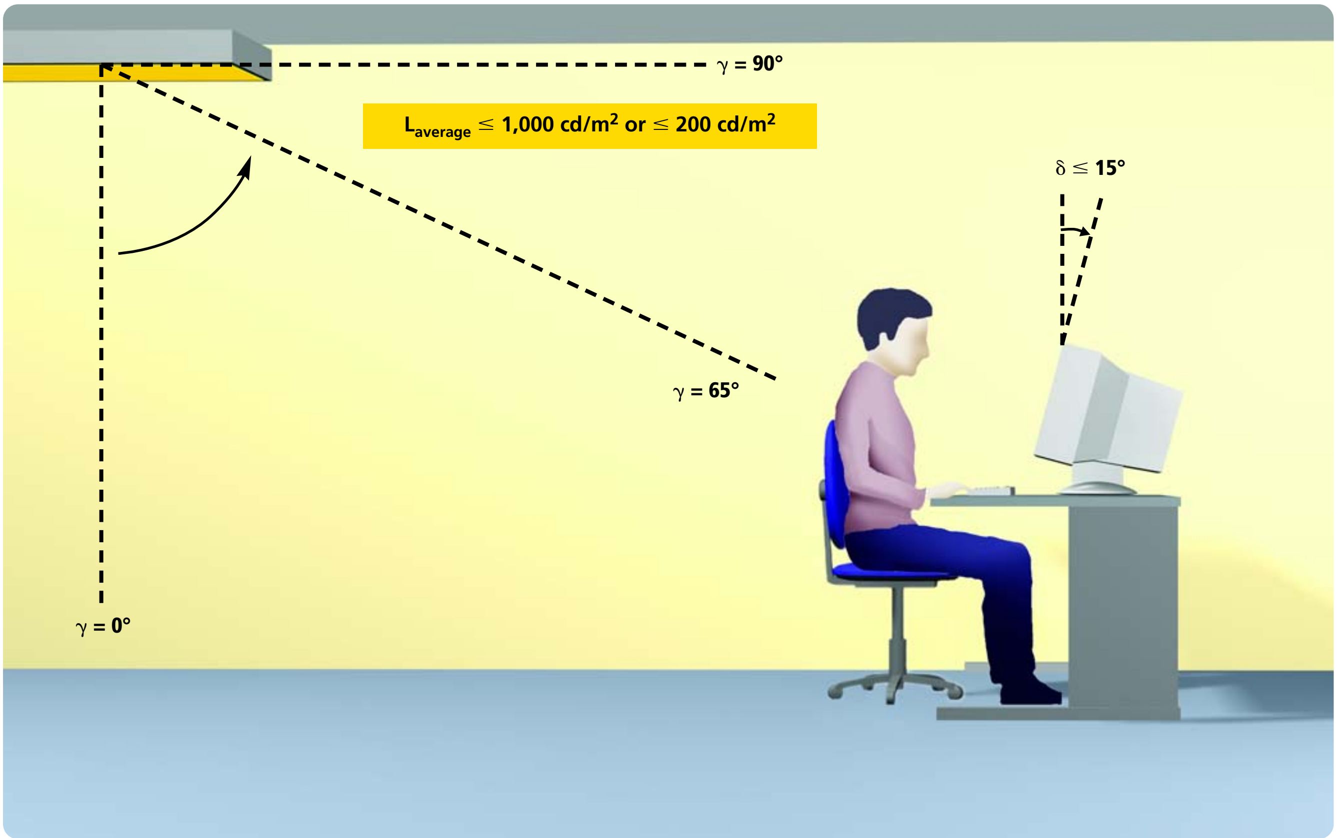



*Fig. 13: Critical zone of radiation (γ ≥ 65°) for luminaire luminance which could give rise to reflected glare on a screen.*

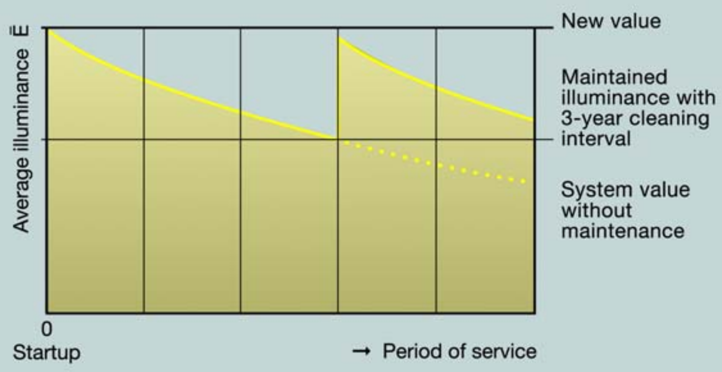



*Fig. 14: Illuminance during the period of service of a lighting system*

*Fig. 15: Example of maintenance factor documentation*

| | | |
|---|---|---|
| Project: | | |
| Room: | | |
| Processed by: | | |
| Date: | 02.03.2005 / 11:47:00 | |
| | | |
| **Luminaire** | | |
| Description: | luminaire xyz | |
| Article number: | 42157193 | |
| Luminaire type: | enclosed IP2X | |
| Cleaning interval in years: | 1.0 | |
| Luminaire maintenance factor LMF: | | 0.88 |
| | | |
| **Lamp** | | |
| Description: | T16 High Ouput | |
| Watt rating: | 54 W | |
| Lamp replacement: | group | |
| Operating gear: | EB | |
| Lamp maintenance in years: | 2.0 | |
| Operating hours per lamp/year: | 6,000 | |
| Lamp lumen maintenance factor LLMF: | | 0.91 |
| Lamp survival factor LSF: | | 0.95 |
| | | |
| **Room** | | |
| Length: | 8 m | |
| Depth: | 6 m | |
| Height: | 3 m | |
| Environment | clean | |
| Room cleaning interval in years: | 2.0 | |
| Type of lighting: | direct | |
| Room maintenance factor RMF: | | 0.96 |
| | | |
| Maintenance factor | | 0.73 |

## 8 Lighting system maintenance

With increasing length of service, the luminous flux delivered by a lighting system decreases as lamps and luminaires age and accumulate dirt. The anticipated decline of luminous flux depends on the choice of lamps, luminaires and operating gear as well as on the operating and environmental conditions to which they are exposed.

To ensure that a specific lighting level – expressed by maintained illuminance – is reached for a reasonable period of time, an appropriate maintenance factor needs to be applied by the lighting designer to take account of this decrease in system luminous flux.

The maintenance factor is the ratio of maintained illuminance to the level of illuminance when the lighting system is new.

### 8.1 Maintenance factor documentation

The designer needs to prepare a maintenance schedule for the lighting system. In particular, this should specify the frequency of lamp replacement, luminaire and room cleaning intervals and, where appropriate, the cleaning techniques used.

The maintenance factor shown in the example (Fig. 15) is 0.73 under the following conditions:

- lamps are replaced in groups every 12,000 operating hours
- luminaires are cleaned every year
- room surfaces are cleaned every two years.

## 8.2 Determination of maintenance factor

The maintenance factor (MF) is a multiple of factors and is determined as follows:

MF = LLMF x LSF x LMF x RMF

where:

LLMF takes account of the decline in lumen output

LSF takes account of the effects of lamp ageing,

LMF takes account of the reduction of light output due to dirt accumulating on luminaires

RMF takes account of the reduction in reflectance due to dirt deposition on room surfaces (see Section 9.4). In many cases, it can be assumed that "lamp failure maintenance factor = 1" because the failure of individual lamps leads to unacceptable falls in lighting level, which is why individual lamp replacement is required.

Individual maintenance factor values can be obtained from manufacturers or found in standard average value curves and lighting publications such as CIE 97*.

Examples of maintenance factors and their inverse counterparts, new-value factors, are cited below on the basis of data available at present. Lamps are replaced individually as soon as they fail and are group replaced when illuminance falls to the maintained illuminance level.

* The reference curves shown for lamps and luminaires in CIE Publication 97 have been discussed in depth in the relevant circles of the German lighting society Deutsche Lichttechnische Gesellschaft e.V. (LiTG). More recent measurements conducted on lamps and luminaires from existing systems have confirmed only a few of the CIE luminaire maintenance values; most showed higher lamp and luminaire maintenance factors, i.e. better performance figures than those based on the CIE values. The CIE is currently updating its publication.

### Examples of maintenance factors for interior lighting systems with fluorescent lamps (improved luminous flux performance)

| Maintenance factor | New-value factor | Example |
|---|---|---|
| 0.80 | 1.25 | very clean environment, maintenance cycle 1 year (luminaire cleaning), 2,000 burning hrs/year with lamp replacement every 8,000 hrs, individual replacement, direct and direct/indirect luminaires with little tendency to collect dust, LLMF = 0.93; LSF = 1.00; LWF = 0.90; RMF = 0.96 |
| **0.67** | 1.50 | normal environmental pollution load, maintenance cycle 3 years, 2,000 burning hrs/year with lamp replacement every 12,000 hrs, individual replacement, direct and direct/indirect luminaires with little tendency to collect dust, LLMF = 0.91; LSF = 1.00; LWF = 0.80; RMF = 0.90 |
| 0.57 | 1.75 | normal environmental pollution load, maintenance cycle 3 years, 2,000 burning hrs/year with lamp replacement every 12,000 hrs, individual replacement, luminaires with normal tendency to collect dust, LLMF = 0.91; LSF = 1.00; LWF = 0.74; RMF = 0.83 |
| 0.50 | 2.00 | dirty environment, maintenance cycle 3 years, 8,000 burning hrs/year with lamp replacement every 8,000 hrs, LLB, group replacement, luminaires with normal tendency to collect dust, LLMF = 0.93; LSF = 0.93; LWF = 0.65; RMF = 0.94 |

Examples of maintenance factors for interior lighting systems with compact fluorescent lamps

| Maintenance factor | New-value factor | Example |
|---|---|---|
| 0.80 | 1.25 | very clean environment, maintenance cycle 1 year, 2,000 burning hrs/year with lamp replacement every 4,000 hrs, individual replacement, direct and direct/indirect luminaires with little tendency to collect dust, EB, LLMF = 0.92; LSF = 1.00; LWF = 0.90; RMF = 0.96 |
| **0.67** | 1.50 | normal environmental pollution load, maintenance cycle 3 years, 2,000 burning hrs/year with lamp replacement every 6,000 hrs, individual replacement, direct and direct/indirect luminaires with little tendency to collect dust, EB, LLMF = 0.91; LSF = 1.00; LWF = 0.80; RMF = 0.90 |
| 0,.57 | 1.75 | normal environmental pollution load, maintenance cycle 3 years, 2,000 burning hrs/year with lamp replacement every 6,000 hrs, individual replacement, luminaires with normal tendency to collect dust, EB, LLMF = 0.91; LSF = 1.00; LWF = 0.74; RMF = 0.83 |
| 0.50 | 2.00 | dirty environment, maintenance cycle 3 years, 6,000 burning hrs/year with lamp replacement every 6,000 hrs, LLB, group replacement, luminaires with normal tendency to collect dust, LLMF = 0.88; LSF = 0.95; LWF = 0.65; RMF = 0.94 |

Examples of maintenance factors for interior lighting systems with metal halide lamps

| Maintenance factor | New-value factor | Example |
|---|---|---|
| 0.80 | 1.25 | very clean environment, maintenance cycle 1 year, 2,000 burning hrs/year with lamp replacement every 2,000 hrs, individual replacement, direct and direct/indirect luminaires with little tendency to collect dust, LLMF = 0.87; LSF = 1.00; LWF = 0.94; RMF = 0.97 |
| **0.67** | 1.50 | clean environment, maintenance cycle 2 years, 2,000 burning hrs/year with lamp replacement every 4,000 hrs, individual replacement, direct and direct/indirect luminaires with little tendency to collect dust, LLMF = 0.81; LSF = 1.00; LWF = 0.90; RMF = 0.96 |
| 0.57 | 1.75 | normal environment pollution load, maintenance cycle 2 years, 2,000 burning hrs/year with lamp replacement every 4,000 hrs, individual replacement, direct/indirect luminaires with little tendency to collect dust, LLMF = 0.81; LSF = 1.00; LWF = 0.82; RMF = 0.83 |
| 0.50 | 2.00 | normal environmental pollution load, maintenance cycle 2 years, 2,000 burning hrs/year with lamp replacement every 4,000 hrs, individual replacement, luminaires with normal tendency to collect dust, LLMF = 0.81; LSF = 1.00; LWF = 0.74; RMF = 0.83 |

## 8.3 Reference maintenance factors

The multiplication described above to determine the maintenance factor from the individual components offers the lighting designer many opportunities to optimise lighting system maintenance intervals – and therefore lighting system investment and operating costs – through the use of suitable lamps, luminaires and operating gear.

**For rough project planning or where detailed information is not available, it seems reasonable initially to assume a reference maintenance factor of 0.67.**

Later, when the lamps and luminaires to be used have been identified and the environmental and operating conditions are known, the reference value can be modified.

Where one or more of the following – potentially inter-impacting – conditions applies, maintenance factors can generally be increased.

0.8

- Use of lamps subject to little light depreciation (depending on burning life), e.g. fluorescent lamps
- Use of luminaires with little tendency to collect dust
- Use of operating gear which lengthens lamp life (e.g. EB)
- Short periods of service per year
- Low number of operations per year
- Short cleaning and/or maintenance intervals, individual and group lamp replacement
- Low exposure to dust in the atmosphere
- Low tendency to collect dust and/or for reflecting surfaces to become discoloured

**Reference value: 0.67**

- Use of lamps subject to marked light depreciation (depending on burning life), e.g. metal halide lamps
- Use of luminaires with tendency to collect dust
- Long periods of service per year
- Large number of operations per year
- Long cleaning and/or maintenance intervals (e.g. because of difficult access), only group lamp replacement
- High exposure to dust or exposure to tobacco smoke
- Tendency to collect dust and/or for reflecting surfaces to become discoloured

0.5

Where one or more of the above – potentially inter-impacting – conditions applies, maintenance factors generally need to be reduced.

## 9 Appendices

**9.1 Areas where DIN EN 12464-1 requirements are less exacting than DIN 5035 (Appendix 1)**

Generally speaking, designers who meet the requirements of DIN EN 12464-1 and observe the reference surfaces recommended in this guide automatically comply with DIN 5035 Parts 1 and 2. However, there are exceptions, where detailed attention needs to be paid to requirements.

The table below lists interiors and activities for which the nominal illuminance required by DIN 5035 Part 2 is higher than the maintained illuminance stipulated in DIN EN 12464-1. It should be noted here that, in contrast to the horizontal illuminances of DIN 5035 (e.g. paint shop), the reference surface in DIN EN 12464-1 can be horizontal, vertical or inclined. The table also contains recommendations on design procedure.

| | Interior/activity | Nominal illuminance [lx] (DIN 5035-2) | Maintained illuminance [lx] (DIN EN 12464-1) | Design procedure |
|---|---|---|---|---|
| | **Offices** | | | |
| 1a | Open-plan office, light-coloured walls and ceiling | 750 | 500 | Cylindrical illuminance according to BGI 856 |
| 1b | Open-plan office, dark walls and ceiling | 1,000 | 500 | |
| | **Metalworking** | | | |
| 2 | Casting bays, dressing rooms in foundries | 300 | 200 | 300 lx maintained illuminance |
| 3 | Paint shop spraying chamber in vehicle construction | 1,000 | 750 | |
| | **Electrical engineering industry** | | | |
| 4 | Assembly of fine radio and television sets | 1,000 | 750 | |
| 5 | Assembly of precision parts | 1,500 | 1,000 | |
| | **Paper manufacture, printing industry** | | | |
| 6 | Hand printing, paper sorting | 750 | 500 | |
| | **Leather industry** | | | |
| 7 | Leather dyeing (by machine) | 750 | 500 | |
| 8 | Quality control, very exacting requirements | 1,500 | 1,000 | |
| | **Textile processing** | | | |
| 9 | Millinery | 750 | 500 | |
| | **Food, drinks and tobacco industry** | | | |
| 10 | Laboratories | 1,000 | 500 | |
| | **Plastics industry** | | | |
| 11 | Injection moulding | 500 | 300 | |
| | **Services** | | | |
| 12 | Self-service restaurants | 300 | 200 | 300 lx maintained illuminance |
| 13 | Inspection and stain removal in laundries | 1,000 | 750 | |

The fact that maintained illuminance is sometimes lower than nominal illuminance but requirements for individual workplaces are no less exacting is explained as follows:

DIN 5035 Part 1 permits illuminance to fall as much as 60 percent below the nominal illuminance at individual workplaces provided the mean value of illuminances does not fall below 80 percent of the nominal illuminance.

According to DIN EN 12464-1, on the other hand, the lighting system requires maintenance as soon as workplace illuminance falls below 100 percent of the maintained illuminance value.

So workplace lighting level requirements are met where maintained illuminance is 60 percent of nominal illuminance. This is the case in all the applications shown above, with the exception of nos. 1b (open-plan office, dark walls and ceiling) and 10 (laboratories).

## 9.2 Calculation grid (Appendix 2)

Experience has shown that the following grid size p should not be exceeded:

$$p = 0.2 \times 5^{\log_{10} d}$$

where:
p is the grid size and d the relevant dimension of the reference surface. The number of points is then given by the next whole number of the ratio d to p.

Rectangular reference surfaces are subdivided into smaller, roughly square rectangles with the calculation points at their centre. The arithmetic mean of all the calculation points is the average illuminance. Where the reference surface has a length-to-width ratio between 0.5 and 2, the grid size p and therefore the number of points can be determined on the basis of the longer dimension d of the reference area. In all other cases, the shorter dimension needs to be taken as the basis for establishing the spacing between grid points.

For non-rectangular reference surfaces, i.e. surfaces restricted by irregular polygons, grid size can be determined analogously using an appropriately dimensioned circumscribing rectangle. Arithmetic means and uniformities are then established taking only the calculation points within the restricting polygons of the reference surface.

For ribbon-like reference surfaces, which normally result from the surrounding areas evaluated, the dimension of the ribbon at its widest point should be taken as the basis for determining grid size. However, the grid size thus established must be no greater than half the dimension of the ribbon at its narrowest point if that is 0.5 m or more. Arithmetic means and uniformities are again determined taking only the calculation points within the ribbon.

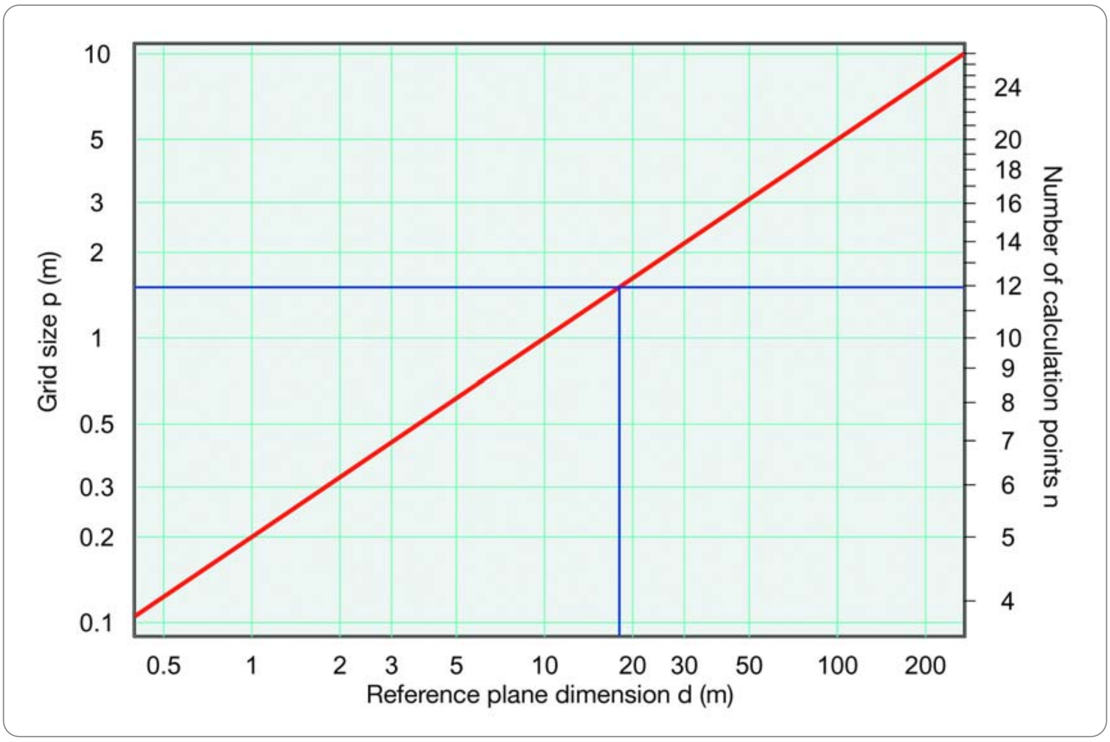



*Fig. 16: Grid size as a function of reference plane dimensions*

### 9.3 Indoor lighting system glare rating (Appendix 3)

Direct glare caused by luminaires in an indoor lighting system can be rated using the CIE Unified Glare Rating (UGR) method. This method is based on the formula:

$$UGR = 8 \log_{10} \left( \frac{0.25}{L_b} \sum \frac{L^2 \omega}{p^2} \right)$$

where:

$L_b$ = the background luminance in cd/m², calculated as $E_{ind} / \pi$, in which $E_{ind}$ is the vertical indirect illuminance at the observer's eye,

$L$ = the average luminance in cd/m² of the luminous parts of the luminaire in the direction of the observer,

$\omega$ = the solid angle in sr of the luminous parts of the luminaire visible from the vantage of the observer,

$p$ = the Guth position index for each individual luminaire.

Use of the UGR method is restricted to direct luminaires and direct/indirect luminaires with an indirect component up to 65 percent. In the case of luminaires with an indirect component > 65 percent, the UGR method produces unduly favourable ratings. Generally speaking, however, glare can be largely ruled out in the case of these luminaires because of the very low glare potential of the direct component.

According to CIE Publication 117, the UGR method can no longer be used for large light sources (solid angle > 1 sr) or small light sources (solid angle < 0.0003 sr).

Large light sources can be individual luminaires with luminous surfaces > 1.5 m², luminous ceilings with at least 15 percent luminous panelling or uniformly illuminated ceilings.

As the dazzling effect of large light sources depends to only a small extent on their position index, solid angle or background luminance, the glare caused by large light sources can be fairly approximated on the basis of luminance and limited by defining a maximum permissible value. In DIN 5035 Part 1, the maximum permissible luminance was set at 500 cd/m². In LiTG Publication 20 on the UGR method, the limit recommended for limiting glare to a UGR of 19 is 350 cd/m² for large rooms and 750 cd/m² for small rooms.

Small light sources visible below a solid angle < 0.0003 sr are generally found in the following situations:

a. in low interiors (room height h < 3 m e.g. office lighting systems). Downlights, for example, can occupy small solid angles here if they are a fairly long way from the observer.
b. in high halls (e.g. sports and industrial hall lighting systems). High-bay reflector luminaires, for example, are visible to the observer at small solid angles here because of their high mounting height.

In both cases, glare due to light sources < 0.0003 sr cannot be ruled out. Drawing on field study findings, LiTG Publication 20 therefore recommends that the lower solid angle limit should be abolished to avoid situations where glare fails to be anticipated because disturbing luminaires are below the solid angle limit and are therefore disregarded.

### Rating by the tabular method

According to the standard, the degree of direct glare caused by a lighting system can be determined using the UGR tabular method.

Here, the system concerned is compared with a standard table listing UGR values for 19 standard rooms and various reflectance combinations for the selected luminaire. The computations for the 19 standard rooms are based on the assumption that the observers – positioned at the midpoint of each wall – observe the luminaires along and across their lines of sight along the room axes. The luminaires are mounted in a regular grid on the luminaire plane, the midpoints of the luminaires set at a distance **0.25 times** the distance H between the luminaire plane and the height of the observer's eye and the midpoints of the luminaires closest to the walls set half as far from the wall as the luminaire midpoints from each other.

When selecting suitable luminaires, care must be taken to ensure that only tables with the same spacing-to-height ratio and the same lamp luminous flux are compared.

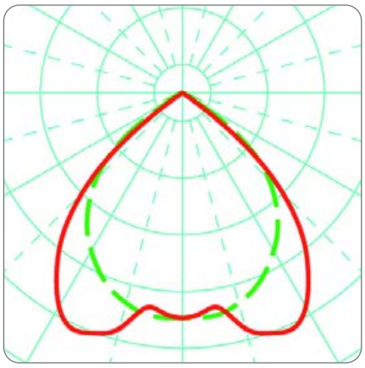
A "table of corrected standardised glare ratings" is shown overleaf.

### Rating in the reference room

If not all UGR tables are available or if dimensions or reflectances are unknown at the design stage, glare can be rated using the UGR value for the **reference room.**

The reference room is a medium-sized room measuring 4H / 8H with ceiling, wall and floor reflectances of 0.7, 0.5 and 0.2 respectively. The ranking resulting from comparison of different lighting systems is generally maintained provided the UGR values compared were computed for the same luminaire midpoint spacing and the same lamp luminous flux. At all events, glare rating must be based on the installation values of the lighting systems and the rated values of the lamps used.

Whichever method is used, the UGR values thus established must not exceed the UGR limits for interiors, tasks and activities stated in the "Schedule of lighting requirements" tables contained in the standard.



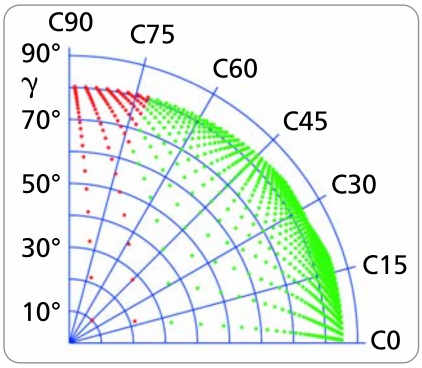



**Table of corrected standardised glare ratings (UGR)**

| | | Luminaire spacing/mounting height above observer's eye a/h = 0.25 Reflectances | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Ceiling** | | 0.70 | 0.70 | 0.50 | 0.50 | 0.30 | 0.70 | 0.70 | 0.50 | 0.50 | 0.30 |
| **Walls** | | 0.50 | 0.30 | 0.50 | 0.30 | 0.30 | 0.50 | 0.30 | 0.50 | 0.30 | 0.30 |
| **Floor** | | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 | 0.20 |
| **Dimensions** | | **Corrected glare ratings – luminous flux 5,200 lm** | | | | | | | | | |
| **X** | **Y** | **Across line of sight** | | | | | **Along line of sight** | | | | |
| 2H | 2H | 16.4 | 18.0 | 16.8 | 18.3 | 18.6 | 17.4 | 19.0 | 17.7 | 19.2 | 19.5 |
| | 3H | 16.3 | 17.7 | 16.6 | 18.0 | 18.3 | 17.2 | 18.6 | 17.6 | 19.0 | 19.3 |
| | 4H | 16.2 | 17.5 | 16.6 | 17.9 | 18.2 | 17.2 | 18.5 | 17.5 | 18.8 | 19.2 |
| | 6H | 16.2 | 17.4 | 16.6 | 17.7 | 18.1 | 17.1 | 18.3 | 17.5 | 18.7 | 19.0 |
| | 8H | 16.2 | 17.3 | 16.6 | 17.6 | 18.0 | 17.1 | 18.2 | 17.5 | 18.6 | 18.9 |
| | 12H | 16.1 | 17.2 | 16.5 | 17.5 | 17.9 | 17.1 | 18.1 | 17.5 | 18.5 | 18.9 |
| 4H | 2H | 16.4 | 17.7 | 16.8 | 18.1 | 18.4 | 17.3 | 18.6 | 17.6 | 18.9 | 19.2 |
| | 3H | 16.3 | 17.4 | 16.7 | 17.7 | 18.1 | 17.1 | 18.2 | 17.5 | 18.6 | 19.0 |
| | 4H | 16.2 | 17.2 | 16.7 | 17.6 | 18.0 | 17.1 | 18.0 | 17.5 | 18.4 | 18.8 |
| | 6H | 16.1 | 17.0 | 16.6 | 17.4 | 17.8 | 17.0 | 17.8 | 17.4 | 18.2 | 18.6 |
| | 8H | 16.1 | 16.8 | 16.5 | 17.3 | 17.7 | 16.9 | 17.7 | 17.4 | 18.1 | 18.6 |
| | 12H | 16.1 | 16.7 | 16.5 | 17.2 | 17.6 | 16.9 | 17.5 | 17.4 | 18.0 | 18.5 |
| 8H | 4H | 16.1 | 16.8 | 16.5 | 17.3 | 17.7 | 16.9 | 17.7 | 17.4 | 18.1 | 18.6 |
| | 6H | 16.0 | 16.6 | 16.5 | 17.1 | 17.6 | 16.9 | 17.4 | 17.3 | 17.9 | 18.4 |
| | 8H | 16.0 | 16.5 | 16.5 | 17.0 | 17.5 | 16.8 | 17.3 | 17.3 | 17.8 | 18.3 |
| | 12H | 15.9 | 16.3 | 16.4 | 16.8 | 17.4 | 16.7 | 17.2 | 17.2 | 17.7 | 18.2 |
| 12H | 4H | 16.1 | 16.7 | 16.5 | 17.2 | 17.6 | 16.9 | 17.5 | 17.4 | 18.0 | 18.5 |
| | 6H | 16.0 | 16.5 | 16.5 | 17.0 | 17.5 | 16.8 | 17.3 | 17.3 | 17.8 | 18.3 |
| | 8H | 15.9 | 16.3 | 16.4 | 16.8 | 17.4 | 16.7 | 17.2 | 17.2 | 17.7 | 18.2 |

## 9.4 Notes on maintenance factors (Appendix 4)

Maintenance factor is often abbreviated to MF. The abbreviations below are taken from CIE Publication 97.

### Lamp lumen maintenance factor LLMF

As length of service increases, the lumen output of practically any lamp decreases as a result of ageing. How gradual and how pronounced that decrease is depends on the type and watt rating of the lamp in question and, where applicable, on the operating gear used. The ratio of luminous flux after a specific number of burning hours to the luminous flux when the lamp was new is indicated by the lamp lumen maintenance factor (LLMF).

LLMF values can be obtained from manufacturers or found in standard average value curves and lighting publications such as CIE Publication 97.

### Lamp survival factor LSF

Each lamp in a lighting system has an individual life which is longer or shorter than the average service life. Average service life is the number of hours for which an observed group of lamps operate before half of the lamps fail. The probability that a relative set will still be operative after a specified number of burning hours is expressed by the lamp survival factor (LSF).

As with the lamp lumen maintenance factor, the magnitude and time-frame of the lamp survival factor depend on the type and watt rating of the lamp in question. In the case of discharge lamps, the LSF also depends on the operating gear used and the frequency of operation of the system.

In the case of fluorescent lamps, average service life is normally calculated on the basis of a switching rhythm of 2 $^{3}/_{4}$ h on / $^{1}/_{4}$ h off. With discharge lamps, the rhythm is 11 h on / 1 h off. LSF values are obtained from the same sources as LLMF values.

### Luminaire maintenance factor LMF

Generally speaking, dirt deposited on lamps and luminaires causes a greater reduction of luminous flux than any other factor. The degree of light loss depends on the nature and particle size of the airborne pollutants, on the design of the luminaires and on the lamps used in them.

CIE Publication 97 proposes a six-stage schematic type-coding common luminaires. Here, depending on luminaire type and accumulation of dust/dirt, luminaire maintenance factors (LMF) can be determined as a function of the time luminaires have spent in the lighting system since the last cleaning operation.

### Room maintenance factor RMF

Dust deposits on ceiling, walls, floor and furnishings generally cause a reduction of indirect illuminance due to inter-reflection. The room maintenance factor takes account of the impact of these environmental conditions.

The room maintenance factor (RMF) can be defined as the ratio of utilance at a particular time to the utilance when the room surfaces were last cleaned.

Like utilance, the room maintenance factor basically depends on the size of the room, the reflectance of the room surfaces and the luminous flux distribution of the lighting system. In addition, the room maintenance factor depends on the type and amount of dirt in the air, which has a direct impact on the reduction of room surface reflectance. For simplified assumptions, standard RMF values can be found in CIE Publication 97.

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