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Outdoor workplaces

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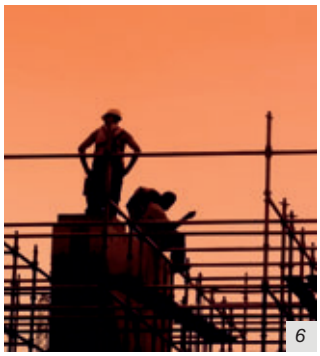
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Correct lighting has long been identified as a crucial factor for health and safety at work. The message that every lighting criterion needs to be duly considered in the design of a plant or facility is communicated in a variety of ways. But attention generally focuses on interiors. It is often forgotten that a considerable amount of work is performed outdoors – at workplaces with no or insufficient natural lighting.

Outdoor workplace lighting needs to meet specific requirements – requirements that differ from those of both classical interior lighting and road lighting. The issue of good lighting for outdoor workplaces merits special attention at present because new stipulations have been developed to take account of technological advances, occupational medicine, hygiene and the results of other occupational research. These requirements are set out in BGR 131, the rule for "Natural and artificial workplace lighting" developed by the institutions responsible for statutory accident insurance and prevention in Germany. Aimed at employers, designers and constructors, it provides pointers on the lighting required for workplaces outside buildings.

BGR 131 focuses on the health and safety of employees at work and sets out requirements for those two areas. It does not look at what is needed to meet visual physiological and production-related requirements. These issues are addressed in the draft European standard DIN EN 12464-2, which defines the standards that need to be observed in practice to meet the visual comfort and visual performance requirements of most outdoor workplaces. There is thus a clear dividing line between the European standard and the BG rule.


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Dipl.-Ing. Gerold Soestmeyer
Chairman of the "Lighting, light and colour" working group of the expert committee looking at "Impacts and work-related health hazards" for the BG Central Office for Safety and Health.

Ensuring that lighting meets all health and safety requirements is an attainable goal for any company.

Compliance with rules and standards aside, energy efficiency is an important investment criterion. Technically sophisticated lamps and luminaires offer a grat deal of scope for optimizing lighting installations from an ergonomic, economic and environmental viewpoint.

Some of that scope is created by lighting management systems, which are now available not only for indoor lighting but also for outdoor installations.

I hope this licht.de booklet will be widely read and received with interest by all those responsible for good lighting.

Introduction


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Outdoor work often entails hazards

Good lighting for outdoor workplaces
Basically speaking, outdoor workplace lighting addresses the same task as interior lighting, ensuring visual task performance and health and safety at work.
However, the design requirements are different. During the day, our eyes provide around 80% of the sensory impressions we register. But at night, the visual acuity of the eye drops to just 3 - 30% of its day-time level – depending on lighting. What is more, the risk of glare is significantly higher than in bright conditions.

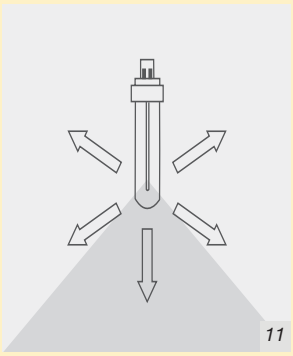
Spatial orientation and field of vision are considerably reduced in darkness and physical performance drops to less than 10% as a result of fatigue due to disruption of natural sleep patterns. This is why most accidents caused by human error occur at night. Human biorhythms are subject to marked fluctuation.

Performance decreases sharply at night; hence the loss of concentration and the increase in the risk of accidents. Accidents at night are both more frequent and more serious than they are during the day.

The four basic lighting quantities

Physical relationships are expressed in lighting by specific variables and units.

The four most widely used terms are explained below: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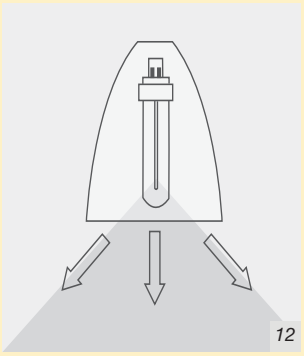
Luminous flux
is the rate at which light is emitted by a lamp. Measured in lumen (lm), it defines the visible light radiating from a light source in all directions.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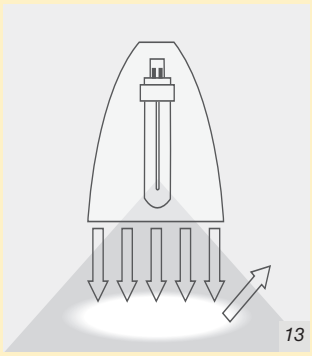
Luminous intensity
is the amount of luminous flux radiating in a particular direction. It is measured in candela (cd). The spatial distribution of luminous intensity – normally depicted by an intensity distribution curve (IDC) – defines the shape of the light beam emitted by a luminaire, reflector lamp or LED.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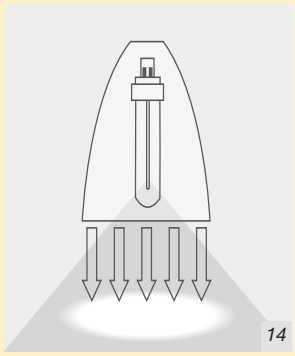
Luminance
is the brightness of a luminous or illuminated surface as perceived by the human eye. Measured in cd/m2 or cd/cm2, it expresses the intensity of the light emitted or reflected by a surface per unit area.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Illuminance,
measured in lux (lx), is the luminous flux from a light source falling on a given surface. Where an area of 1 square metre is uniformly illuminated by 1 lumen of luminous flux, illuminance is 1 lux.

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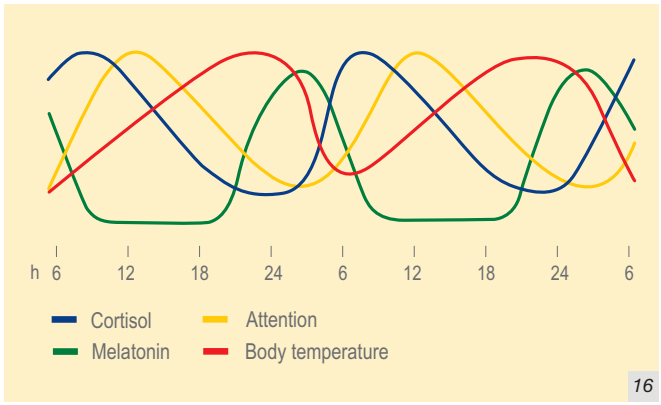
Many areas of an airport are outdoor workplaces

In contrast to indoor work, the visual effort required at outdoor workplaces is significantly increased by the fact that there are generally no walls to reflect light, so only direct lighting is possible. This can often produce deep shadows.
Generally speaking, the visual situation is then further aggravated by a dark background, resulting in higher luminance contrasts. The draft standard DIN EN 12464-2 defines requirements for ensuring good visual performance and good visual comfort.

Due to visual physiological needs and the demands of production processes, these requirements may be higher than those formulated for occupational health and safety.

After a general look at the physiology of vision and the basic variables and quality features of lighting, this booklet examines some of the main lighting requirements that need to be met at outdoor workplaces.

It then profiles a range of major applications, citing specific assessment criteria, and presents a useful table of the requirements set out for the different applications in the draft European standard DIN EN 12464-2.



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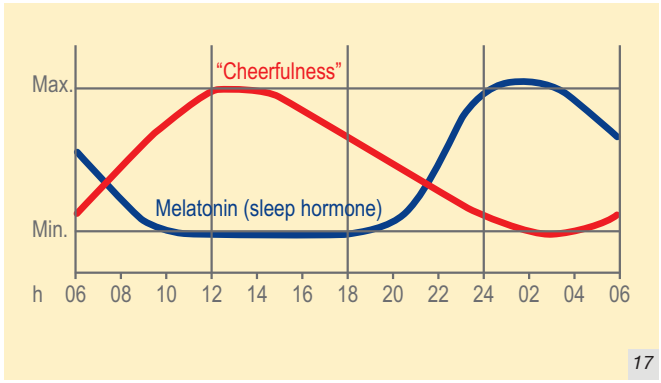
Wave patterns of different circadian rhythms



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Correlation of melatonin levels and "cheerfulness"


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Even signal-coloured objects that are clearly visible during the day are hard to make out in twilight.

Seeing and being seen: good lighting avoids accidents

Daylight illuminance ranges from 5,000 to 100,000 lux (lx). On a moonlit night, however, it reaches only 1 lx at most. The fact that we can "see" over a vast bandwidth like this is due to the eye's ability to adapt. At low illuminance levels, however, visual performance is impaired. Good lighting at outdoor workplaces helps significantly to guard against accidents, enabling us to see well and be seen at all times. In twilight and at night, perception and recognition are no longer sufficiently guaranteed, so artificial lighting is vital for accident prevention. It is absolutely essential, for example, at high-risk workplaces at woodworking machines or on scaffolding or ramps (where safety depends on ability to see) or at hazardous workplaces near trucks, conveyors or tracks (where being seen is a key safety factor).

The need for good lighting at outdoor workplaces is explained by the following physiological facts.


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Where cranes are in operation, care must be taken to ensure good visual conditions for both crane operators and ground personnel.

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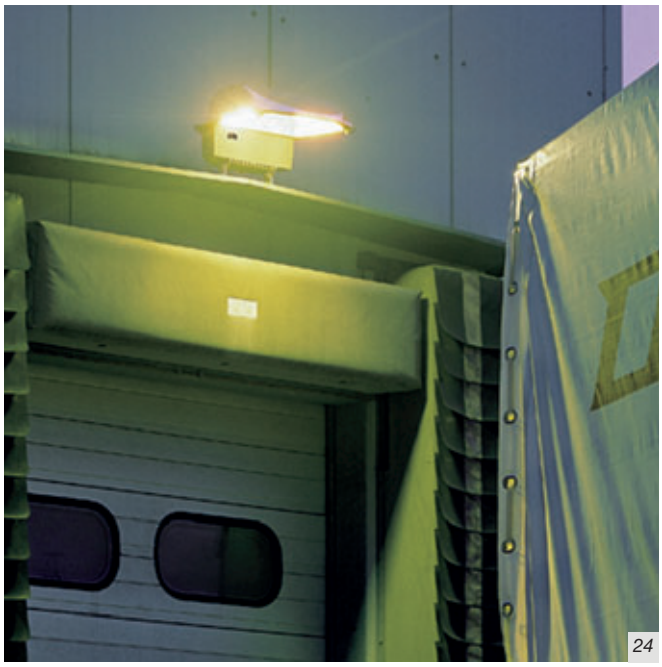
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Good bay entrance lighting avoids adaptation hazards.

Colour vision, light/dark vision
Day vision is provided by cone receptors in the eye which are sensitive to colour. This is when visual performance is at its best: colours can be distinguished and objects can be clearly made out in 3D. At night, colour-insensitive rod receptors take over, providing a degree of light/dark vision that only really enables us to get our bearings.

Where not enough daylight is available – as at outdoor workplaces – adequate visual performance and colour discrimination can only be achieved by using artificial lighting to activate the cone receptors that make better visual performance possible.

Contrast sensitivity
Contrast sensitivity is the term used to describe the ability to perceive differences in luminance in the field of vision. The higher the brightness level (adaptation luminance), the finer the differences in luminance perceived. Contrast sensitivity is reduced by glare.

Visual acuity
The eye's ability to make out the contours and details of shapes as well as shades of colour is determined by visual acuity. Visual acuity improves as adaptation luminance increases, creating better conditions for making out obstructions, etc..

Contrasts
Contrasts are differences in brightness and colour in the field of vision. To be perceived by the human eye, they need to be sufficiently pronounced. The minimum contrast perceived depends on the ambient brightness (adaptation luminance): the brighter the surroundings, the lower the contrast perceived.

In darker surroundings, an object needs either to contrast more sharply or to be larger in order to be perceived. So where fine visual details need to be made out – in an aircraft maintenance zone at an airport, for example – higher illuminance levels are required.

Adaptation time
It takes time for the eye to adapt to different levels of brightness. The adaptation process – and thus the adaptation time – depend on the luminance at the beginning and end of any change in brightness: adapting from dark to light takes only seconds, adapting from light to dark can take several minutes. Visual performance at any one time depends on the state of adaptation: the more light available, the better the visual performance achieved. Visual impairment occurs when our eyes have too little time to adapt to differences in brightness. This explains, for example, the increased risk of accident where fork-lift truck operators leave a brightly lit bay and enter a dark storage area outdoors and collide with persons or objects they fail to see. Correct illuminance levels for factory or warehouse bay entrances need to be geared to the illuminance inside the bay.



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Visual performance and colour identification are dependent on lighting.

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Quality criteria
Activities at outdoor workplaces entail a variety of visual tasks for which specific lighting quality requirements can be identified.

The main criteria for outdoor workplace lighting are: luminance distribution, illuminance, glare, direction of light, light colour and colour rendering, light flicker.

All lighting quality criteria primarily apply to the task area. This is the area of the workplace where the visual task is performed. Where the size and location of the task area are not known, any area where the task could be performed must be assumed to form part of the task area for the purposes of lighting planning. As in interior lighting, precise analyses need to be performed to establish reasonable task area coordinates for each sworkplace.

Adequate level of brightness
To enable people to see well at outdoor workplaces, an adequate level of brightness/lighting is essential. This is determined by the luminance and the way it is distributed. Luminance (in cd/m^2) is the light reflected by a surface into the eyes of the observer. Balanced luminance distribution determines visual acuity, contrast sensitivity and the efficiency of ocular functions such as accommodation, convergence, pupillary change, eye movement, etc.).

Luminance distribution in the field of vision also affects visual comfort. Wherever possible, marked changes in luminance should therefore be avoided within the field of vision. At outdoor workplaces – e.g. construction sites – the scope for doing so is limited because vertical surfaces in the wider surroundings are mostly in darkness. One factor influencing luminance is the reflectance of the illuminated surface, which, in contrast to indoor lighting scenarios, tends to be very low at an outdoor workplace. The basic rule is: the lower the reflectance and the more difficult the visual task, the higher the illuminance needs to be.

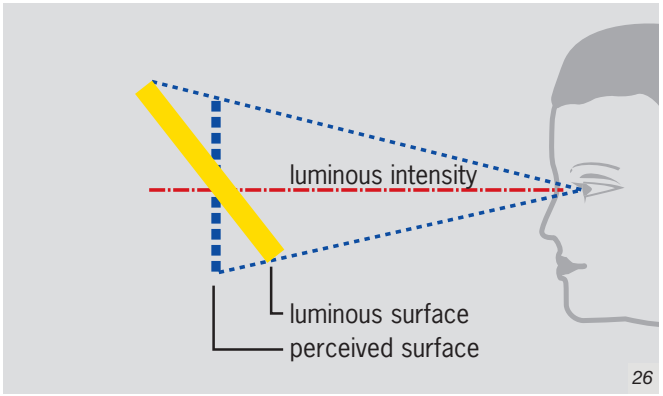
Illuminance
Luminance depends crucially on illuminance (in lx), which is defined as the amount of light falling on a surface.

Illuminance and illuminance distribution are major factors influencing the speed and reliability with which a visual task can be registered and addressed. For outdoor workplaces, the draft standard DIN EN 12464-2 contains tables setting out the illuminance required, depending on the type of area, visual task or activity present. This illuminance needs to be realised in the task area. The reference surface may be horizontal, vertical or inclined. At workplaces that are permanently manned, illuminance must be no lower than 50 lx.

Where visual tasks differ from those assumed as standard, illuminance can be raised or lowered by at least one grade on the illuminance scale, which ranges from 5 lx to 2,000 lx and is divided into grades with a factor of around 1.5. Higher illuminances than those shown in the tables are recommended especially where

- the visual work is particularly demanding,
- the visual task or persons are moving,
- precision or productivity is particularly important,
- the eyesight of the persons working is below average,
- visual details are particularly fine or low-contrast,
- the visual task needs to be performed for an unusually long time.

Illuminance in the surrounding area may be lower than the illuminance in the task area but should make for a balan-



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Luminance describes the physiological impact of light.

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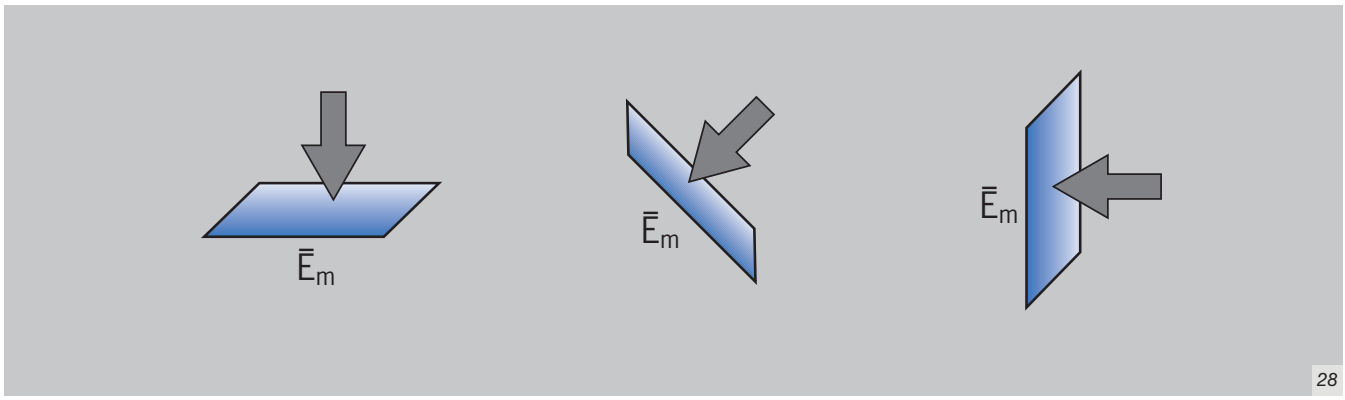

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The planes on which primary visual tasks are performed may be horizontal, vertical or inclined – standard illuminance requirements $\bar{E}_m$ apply analogously.

ced distribution of luminance in the field of vision. The "surrounding area" includes surfaces in the field of vision which immediately surround the work area. The standard cites no dimensions defining this area more closely. It should be noted, however, that the ambient lighting needs to be geared to the task area illuminance so that adequate adaptation luminance is ensured. Given this requirement, the task area defined should not be too small.

Illuminance of the task area	Illuminance of surrounding areas
lx	lx
≥ 500	100
300	75
200	50
150	30
50 to 100	20
< 50	no stipulation

Illuminance levels in surrounding areas, depending on levels in the task area

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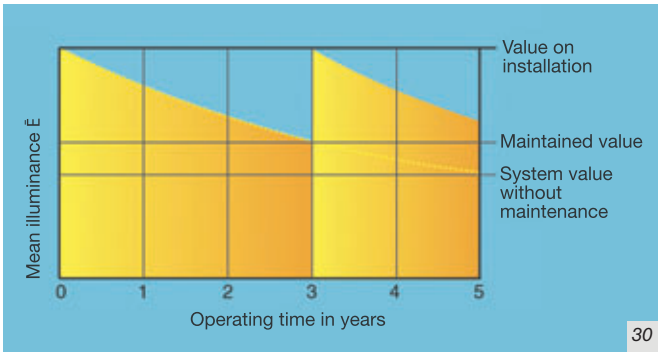
Good lighting takes account of many quality criteria.

Uniformity of illuminance
The task area must be illuminated as uniformly as possible. Uniformity of illuminance $U = E_{min}/E_m$ in the task area is stipulated for different tasks in the draft standard DIN EN 12464-2. Uniformity in the surrounding area must not be lower than U = 0.10.

Value on installation
All the illuminance values stipulated in standards are maintained values, i.e. values below which illuminance must not fall at any time. As the length of time a lighting installation is in operation increases, the values installed at the outset decrease as a result of lamps and luminaires ageing and becoming soiled. So, to enable an outdoor installation's operating life to be extended without additional maintenance work, values on installation should be correspondingly higher. How much higher is determined by maintenance factors. Values on installation are calculated as follows: value on installation = maintained value / maintenance factor. Maintenance factors – as well as all the assumptions made to determine them – must be stated by the lighting designer.



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The maintained value is the local average illuminance at which the system requires maintenance. Example: maintenance interval 3 years.

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Glare

Glare is produced by bright surfaces in the field of vision and can be perceived as either discomforting (psychological) glare or disabling (physiological) glare. The glare caused by light bouncing off reflective surfaces is generally known as veiling reflection or reflected glare.

To avoid errors, fatigue and accidents, it is important to limit glare – especially at viewing angles above the horizontal. The degree of direct glare caused by luminaires in an outdoor lighting installation is described by the glare rating GR.

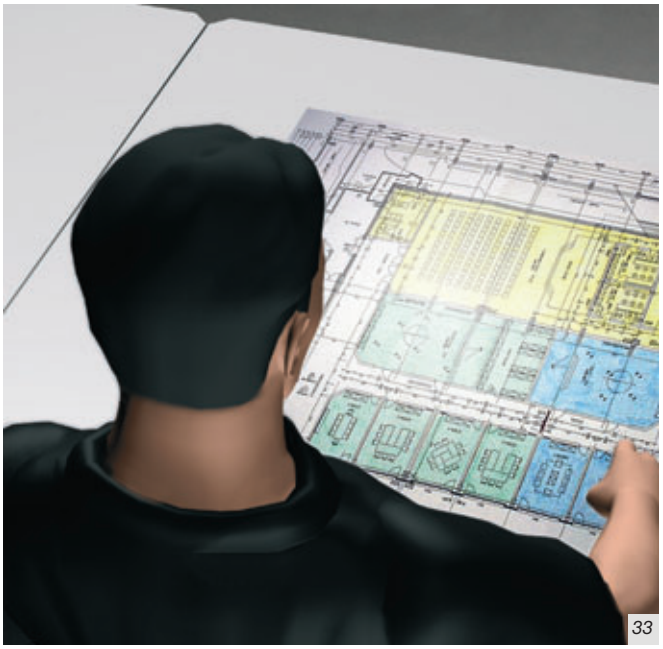
$$GR = 27 + 24 \log_{10} \left[\frac{L_{vl}}{L_{ve}^{0,9}} \right]$$

Where:

- L_{vl} is the total veiling luminance in cd/m² caused by the lighting installation
- L_{ve} is the equivalent veiling luminance of the surroundings in cd/m².

Assessment of glare	GR
unbearable	80 – 90
disturbing	60 – 70
just admissible	40 – 50
noticeable	20 – 30
unnoticeable	10

Connection between glare ratings and assessments of glare



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Reflections can affect the clarity with which a visual task is perceived.

Veiling reflection and reflected glare

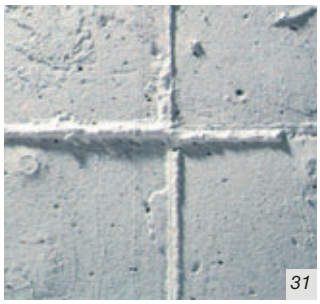
Highly luminous reflections on a visual task can affect how well the task is perceived. Veiling reflections and reflected glare can be prevented or reduced by

- appropriate arrangement of luminaires and workplaces,
- finishes (matt surfaces),
- limitation of luminaire luminance,
- enlargement of the luminous surface of the luminaires.

Light colour and colour rendering

The light colour of lamps is expressed by correlated colour temperatures. Selecting a light colour is a matter of psychology, aesthetics and what is considered natural. Because these broadly subjective criteria differ from one area of Europe to another, planning value tables contain no recommendations for light colours.

That matter aside, light colour also determines lamp luminous efficacy, which in turn impacts on lighting system costs. In Central Europe, warm-white high pressure sodium vapour lamps are the light source most widely used for reasons of economy and metal halide lamps for neutral-white light are the light source of choice where better colour rendering is required.



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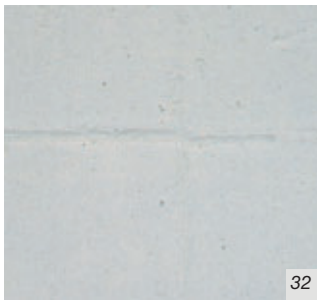

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Only under directional light (left) do three-dimensional structures become visible.

Directional lighting

Directional lighting is a tool used to emphasize objects, surface structures or persons. The term used to express the balance between diffuse and directional light is "modelling", which is thus a lighting quality criterion. Modelling is achieved when light comes predominantly from one direction – although care should be taken to avoid creating harsh shadows.


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Despite identical light colour, the different colour rendering properties of lamps lead to variations in colour perception. Where the spectrum of a lamp contains little red light, for instance, red surface colours are only incompletely rendered.

Light colour	Correlated colour temperature T_{CP}
Warm white	below 3300 K
Neutral white	from 3300 K to 5300 K
Daylight white	over 5300 K

For visual performance, comfort and sense of wellbeing, it is important that the colours of surroundings, objects and human skin are rendered accurately and naturally. This makes people look good and healthy.

To provide an objective yardstick for the colour rendering properties of light sources, the general colour rendering index R_a was introduced. The highest R_a value possible is 100. As colour rendering quality decreases, this declines. Safety colours must always be identifiable as such. To ensure this, the colour rendering index needs to be ≥ 20.


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Flicker and stroboscopic effects

Flickering light can be distracting and give rise to physiological complaints such as headaches. Stroboscopic effects can cause dangerous situations by interfering with perception of machine parts rotating or moving back and forth at high speed. On construction sites, for instance, this can result in a heightened risk of accidents at sawing machines.

Lighting systems should be designed so that light flicker and stroboscopic effects are avoided. This can be achieved, for example, by using discharge lamps operated by electronic ballasts at high frequencies.

Disruptive effects

Lighting systems for outdoor workplaces can contribute to a brighter night sky and surroundings. Apart from this, light emissions can lead to physiological problems such as troubled sleep, and negative impacts on fauna and flora cannot be ruled out. Hence the limits imposed by standards to curb light emissions, especially emissions directed upwards. Limits are set to avoid disturbance for local residents and road users.

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Industrial plants and power facilities


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The kind of workplaces most frequently found outdoors require adequate lighting and agreeable surroundings to enable night-shift workers to perform their duties reliably and without interruption. The draft standard DIN EN 12464-2 provides recommendations and guideline values for specific lighting design variables for a wide variety of concrete applications (see tables on pages 22 ff). On the following pages, we also look at a number of example applications – although the list makes no claim to be exhaustive.

Work at machines and with tools

Activities in an industrial setting are often characterised by people working with tools, at machines or in plants. Outdoor workplaces are typically found in the chemical and petrochemical industry, in other industries with outdoor processing facilities, in the raw materials, waste management and mining sectors, at construction sites, in the engineering, plant construction and shipbuilding industries as well as in the energy sector and agriculture. Alongside production-oriented operations, a major role is played here by storage, logistical and transport activities, which will be dealt with separately in a later section. Values need to be defined for the relevant lighting design variables, depending on the importance of the work, the degree of risk or the difficulty of the visual task. In many cases – provided that jobs are comparable or similar – the lighting guidelines for indoor workplaces (cf. EN 12464-1) can provide pointers on the illuminance levels required outdoors. Values between 30 and 60 lx are typical for general activities outdoors. For places where special activities are performed, appropriate supplementary lighting is required.


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Uniformity
Defining task areas where quality criteria apply is frequently a difficult exercise, especially at industrial workplaces. Small illuminated spaces give rise to marked luminance differences in the field of vision, which means the eye constantly needs to adapt. This leads to an increasing loss of concentration and premature fatigue, resulting, in turn, in work errors and a heightened risk of accidents.

This is avoided where work areas as a whole are brightly lit. It also facilitates communication with the work team and the working environment and thus helps promote a sense of wellbeing, heighten motivation and boost productivity.

So there should be no disturbing dark zones in the task area itself. The admissible ratio between the lowest and average illuminance depends on the visual task performed and ranges from 0.25 for brief, straightforward operations (e.g. handling large construction elements) through to 0.5 (e.g. for inspections or installation work).

In addition, lighting in the surrounding area needs to meet the standard requirements set out for the illuminance stipulated for the relevant task area (see lighting tables). A special consideration here is the need to avoid psychologically negative effects (sense of insecurity, anxiety, etc.), which can result, for example, where the work zone is bordered by a wall of darkness.

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Lighting as a cost factor
As a production overhead, the cost of a lighting installation is also a matter of major significance. So aspects such as energy efficiency, maintenance costs and service life need to be assessed. Even simple lamp replacement operations can entail high costs if, for example, the production process needs to be interrupted or complex apparatus needs to be used. So when selecting luminaires and lamps, it is worth paying attention to quality standards, maintenance requirements and service life ratings. At the planning stage, care should be taken to ensure not only optimal lighting but also convenient positioning (access) in the outdoor space.

High requirements
Depending on application, lighting installations need to stand up to extreme environmental conditions. Workplaces are typically very dirty, dusty, damp and/or wet locations exposed to aggressive or explosive atmospheres, extremely high or low temperatures and – during the day – a high incidence of ultraviolet light due to sunlight. These conditions determine the special requirements that luminaires need to meet in terms of degree of protection, design or materials used in their construction. Industrial plant lighting is comprehensively covered by standards. But beyond the fulfilment of standard requirements, there are recommendations and

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Self-propelled machines are generally fitted with floodlights for manoeuvring and for illuminating the work area.


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Luminaires mounted on industrial facilities outdoors need to meet higher requirements in terms of protection against the ingress of dust and moisture. In some cases, explosion protection is also required.

concepts for harnessing adequate lighting to impact positively and significantly on the sense of wellbeing and productivity of the persons present.

High lighting levels and sufficient cylindrical illuminance in the task area are also key requirements outdoors. Workplace lighting here needs to satisfy two quality criteria. First, for security reasons, the level of lighting needs to be adequately high, especially in areas where encounters may occur, for example, between vehicles and pedestrians. Secondly, to guarantee easy recognition of information, outdoor area lighting needs to be particularly effective at limiting glare. As a result, asymmetrical reflector luminaires for high-pressure lamps are the preferred solution here. These come with high-grade facetted optics and a flat glass enclosure which ensure that the light is mostly directed onto the defined working plane without giving rise to glare. Where lighting is required to illuminate large outdoor areas, such as loading bays, wide-angle flood systems can be profitably used.

For lighting tasks inside buildings, e.g. inside a process plant, linear luminaires with tubular fluorescent lamps and a high degree of protection are frequently used. In comparison to luminaires with high-pressure discharge lamps, fluorescent-lamp models have the advantage of significantly lower luminance along direct lines of sight.

At chemical and petrochemical plants (refineries, etc.) and onshore or offshore oil and gas production facilities as well as in mining and other areas where explosive atmospheres may be present, one important aspect of work-


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The draft standard DIN EN 12464-2 also sets out requirements for general traffic areas at outdoor workplaces.

place lighting is that the luminaires selected – as electrical fixtures – need to meet the requirements of the relevant explosion protection classes.

Outdoor switching stations
At night, the proper operation of outdoor switching stations can only be guaranteed where artificial lighting permits all equipment to be quickly, reliably and safely monitored.

The parts of the high-voltage system mounted on supporting structures – e.g. busbars, line links, insulator sets and switchgear – should present surfaces to the eye with luminances that allow the operating condition of each element to be clearly identified. For inspecting the bushings, oil conservators or protective equipment in the upper transformer sections, angled incident light from below is the recommended solution. Communication route lighting should ensure that controls can be conducted safely. It is essential here to avoid deep and large patches of shadow.

Depending on the prevailing ambient brightness, system arrangement clarity and reflectance factors, horizontal illuminance of 15...30 lx is recommended in order to meet these requirements. Vertical illuminance on the system components mentioned should be in the region of 30...60 lx.

Luminaires should be arranged so that there is no danger of contact with high-voltage elements when maintenance and lamp replacement operations are carried out. Mounting heights should therefore be kept as low as possible so that ladders are not needed.

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Transport, roads and routes

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Vehicle transport and traffic
Vehicle transport is part of daily life worldwide. The highly developed countries are covered by a dense network of roads and motorways.

Public transport routes aside, there are also transport infrastructures in and around large industrial complexes which are used exclusively for plant operations and thus need to be regarded as outdoor workplaces.

For the safety of those using such infrastructures, road and route lighting must conform to specific standards based on the relevant regulations governing lighting for public roads and routes (e.g. EN 13201). In contrast to many public transport routes, however, the speed limit on plant roads may be 20 km/h or walking pace, depending on hazard potential.

Special attention needs to be paid to traffic interchanges (e.g. intersections, roundabouts, bridges...) as well as underpasses and tunnels, where lighting installations need to meet very high requirements in terms of lighting characteristics, reliability and maintenance. Depending on geographical location, luminaires may need to withstand extreme weather and climatic conditions outdoors – a fact which must be borne in mind when products are selected. Vehicle parking facilities are also outdoor workplaces, so are railway lines and shipping routes, which present similar requirements in terms of lighting characteristics to e.g. the apron areas of an airport. While the focus in road lighting is traditionally on criteria such as cost-efficiency, reliability and maintenance-friendly design, a new aspect is becoming increasingly important: light immission. This is the portion of light that radiates upwards from a luminaire and could cause an environmental nuisance. As a source of "light pollution", it should be kept as small as possible.

Main roads
Danger lurks at many points on main roads, especially at twilight and after dark. Good road lighting makes for better visual conditions for all road users and thus heightens road safety.

Statistics show that standard-compliant road lighting substantially lowers the risk of accidents and sharply reduces the severity of the accidents that occur. Luminaires with modern specular reflector technology, e.g. radial facetted optics, in combination with tubular lamps permit wide spacing between columns and thus fewer luminaires per kilometre. At the same time, they avoid patches of darkness and make for greater road safety.


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Traffic interchanges
Roundabouts present a traffic situation that needs a special lighting concept – one that calls for vertical illuminance to make motorists, cyclists and pedestrians clearly visible and, secondly, couples adequately high and uniform illuminance on the horizontal road surfaces with good glare limitation. This is achieved, for example, by a combination of projector-reflector lighting systems positioned at the centre of the roundabout and a row of other luminaires on the periphery.

These luminaires come with efficient specular reflector technology and flat glass enclosures to minimise glare. They also achieve very good colour rendering through the use of metal halide lamps – whose light colour, moreover, contrasts with the lighting on the converging roads and makes for greater alertness.

Fuel stations
Fuel stations are both sales outlets and work premises. Lighting should draw attention to the location, the brand of the product on sale and the nature of the service offered from an adequate distance.

It needs to provide appropriate work lighting for the pump and service areas and should clearly identify access routes and exits. As with any lighting designed to advertise, attention should be drawn here by creating a contrast with the surroundings. Where surroundings are generally dark, however, an excessively high lighting level can easily overstep the mark between conspicuousness and obtrusiveness.

In bright surroundings, there is less risk of conflict between advertising and the needs of nearby traffic. Excessively high luminance of the signs identifying the fuel station can lead to information being obscured and details being missed.

Luminaire luminance should generally be low, especially where luminaires are positioned close to the edge of unlit roads.

Road luminaires for access and exit lighting should be selected from the range of "shielded" luminaires. A tranquil picture overall is achieved with luminaires at low mounting heights, e.g. bollard luminaires. Very low luminance is produced by indirect lighting, for example illuminating the underside of a cantilever canopy.

Emphasizing facades in the fuel station area lends visual appeal, makes for an integrated impact and indicates a facility ready for service.

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Note

Canals, locks and port installations
Port areas need to be illuminated at night to permit round-the-clock operations and minimize the time vessels spend in port. What is required here is outdoor facility lighting designed for extra glare limitation on the water side to ensure no interference with shipping traffic.

Cargo-handling facilities can be divided into two categories:

- Small areas for general cargo, which can be illuminated by a conventional peripheral arrangement of luminaires, i.e. using road luminaires or wide angle projectors or floods at mounting heights up to 12 m;
- Large-scale container terminals, served by high-mast systems with projectors or floods and mounting heights between 25 and 35 m. These permit considerable leeway in positioning, allowing luminaires to be spaced between 100 and 175 m apart. Uniform illumination of large areas coupled with good glare limitation calls for projectors with horizontal diffuser panels and 60° beam angling to the vertical.

Generally speaking, the horizontal luminance required is 20...50 lx and the uniformity $U_o \geq 0.25$. Preferred light sources are sodium vapour lamps – low-pressure models where colour recognition is not required, 400 W or 1.000 W high-pressure sodium vapour lamps as a rule for high-mast systems. In areas where high requirements need to be met for colour recognition, metal halide lamps are used. For operator control lighting, attention needs to be paid to high vertical illuminance. Supplementary lighting is required for charging and discharging facilities as well as for loading points.

So, for all mobile port facilities such as mobile bridges, travelling and slewing cranes in the loading area, dynamic lighting is an appropriate choice. Static lighting tends to direct attention to buildings and highlight them. Because of the low general lighting level, direct glare needs to be limited in the direction of the control and monitoring stations. Projectors and floods should always be directed away from operating personnel.

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Port cargo-handling areas
One lighting option for port cargo-handling areas is to erect a mast at each end of the crane rails so that the light from the floods mounted on them can reach between the rows of wagons. When selecting crane lights, account needs to be taken of the vibrations to which lamps will be exposed. Furthermore, ports shape the face of cities and emphasize their structures. When night descends, a lighting control program can make the importance and role of the port visible and thus forge a visual and emotional link with the city. Port operations establish a presence during the day, illumination takes over the task at night. The lighting requirements for the outdoor area are the same as for outdoor workplaces.

Airports
Lighting for airport aprons, i.e. the areas at gates where aircraft park, needs to meet particularly high requirements, a key one being that pilots must never be dazzled. When they touch down after a night flight, their eyes are adapted to the dark and extremely sensitive to high luminance. At the same time, large areas need to be illuminated as uniformly as possible. Large projector-reflector lighting systems are the solution here. Thanks to their special light-distributing mirrors, these high-performance floods not only spread light over a wide area; they also avoid glare. An alternative solution is to use asymmetrical floods, which should be installed and angled so that there is no possibility of their lamps being directly visible from the cockpit.

The purpose of airport apron lighting is
- to provide guidance for the pilots of taxiing aircraft,
- to help ensure efficient and reliable passenger, baggage and freight handling operations,
- to facilitate service and maintenance work
- to support surveillance and security.

Basically speaking, the task for the lighting planner is to provide sufficient illuminance – i.e. 5...50 lx horizontally and vertically 2 m above the ground – for a large outdoor area.
To guarantee adequate recognition and colour vision at aircraft stands, the average vertical illuminance there should be 20 lx and the minimum vertical illuminance no lower than 5 lx. Other special factors to consider are:

- Air controllers in the control tower must not be dazzled.
- The pilot, who in a modern jumbo aircraft may be as much as 10 m above the ground, must not be dazzled.
- The lighting masts must not interfere with flight operations or traffic on the ground, i.e. positioning is restricted and heights may not exceed 25 m without special approval.

Systems normally feature well-shielded floods fitted either with particularly cost-efficient high-pressure sodium vapour lamps or metal halide lamps.

Railway installations
In yards and along track, operational safety and reliability of lighting installations is a major consideration. The luminaires deployed here need to be glare-suppressed to a particularly high standard. This guarantees a high degree of security for operating personnel.
In railway yards, a great deal of the information for operations is conveyed by light signals. If the lighting is wrong, that information may be missed or misinterpreted.
At level crossings, asymmetrical luminaires with instant hot re-igniters are used. This permits optimal video surveillance from the control centre.
In stations or on station platforms, good lighting helps people get their bearings and brightness makes for greater safety.

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Areas where no actual work is performed require only low levels of lighting – for safe movement of people and vehicles, for security surveillance of the site or for fire detection monitoring. Here, it is particularly important that camouflaging shadows should be avoided by careful planning of light incidence angles. Experience has shown that the use of bright durable coatings or special reflective surfaces to highlight hazard zones is a good idea. Lighting that is intended solely for securing property can be designed as a dedicated monitoring system. Only part of an outdoor work lighting system, for example, can be used for security purposes. Supplementary floods permitting efficient operations through the night can also be provided. Here, high vertical illuminance from the perspective of the security guard is useful. Another solution is periphery lighting, where guards remain in the dark while intruders are exposed to dazzling floodlight. Inside the customary fence, floods with a wide horizontal beam are mounted on low masts at regular intervals. Both the

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periphery and the approach zone are thus fully illuminated to a reasonable depth.

In practice, the vertical illuminance required around 1 m above the ground in the apron area is between 5 and 30 lx, depending on the lighting for the protected site. If risk levels are high, it is advisable to double-lamp luminaires and connect them to two separate supply circuits. Where a peripheral lighting system of this kind is installed, however, care must be taken to ensure that there is no risk of light disturbing or causing problems for occupants of neighbouring properties and that road safety is not compromised. It is advisable to seek the approval of the relevant public agencies and authorities.

Transfer areas
For security reasons, special importance needs to be attached to warehouse entrance and exit lighting. Lighting solutions here must ensure a smooth transition between the levels of brightness inside and outside the building. In many cases, it is also necessary to take account of areas where traffic is static, e.g. nearby car parks, and access routes. Glare suppression and reduction is an issue here, and projector-reflector (secondary reflector) systems can play an important part in achieving it. Light immission should also be kept to a minimum.

Goods-handling operations at night
In yards where goods-handling operations are conducted at night, work areas are normally in the immediate vicinity of the loading and transport facilities. However, it would be wrong to confine lighting to these areas. The correct solution is to provide work zones with an appropriate level of supplementary task lighting in addition to the general lighting for the site. Portal and bridge crane work areas are an example often cited here. As a rule, the crane supports provide useful mounting sites for floodlights, so light incidence is perpendicular to the direction of travel. The illuminance required within the operating range of the crane is achieved using luminaires mounted on the bridge of the crane. Where light incidence is from the side, crane bays with siding track may require further supplementary lighting to dispel shadows cast by rolling stock superstructures.

Supplementary lighting for loading points
For operator control lighting, attention needs to be paid to high vertical illuminance. Supplementary lighting is required for charging and discharging facilities as well as for loading points. So, for all mobile port facilities such as mobile bridges and travelling and slewing cranes in the loading area, dynamic lighting is an appropriate choice. Static lighting tends to direct attention to buildings and highlight them.

Limiting direct glare
Because of the low general lighting level, direct glare needs to be limited in the direction of control and monitoring stations. Projectors and floods should always be directed away from operating personnel.


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Construction sites

Construction sites
Illuminance should be selected according to table 5.3. Key considerations for construction site lighting are the temporary nature of the need for lighting, the need to adapt the lighting to changing activities, and the variety of visual tasks. Flexibility is achieved by facilities such as transportable, extendable lighting masts, which often come mounted on a trailer with a generator. Construction cranes can be another tool of site lighting design. From the vantage of the crane operator, the entire working area (horizontal and vertical) should be illuminated so that loads are clearly visible at the full working height. It is common practice for floods to be mounted on the crane tower, nowadays also on the jib. Correct positioning in relation to the cabin can ensure that glare is avoided for the operator. Attention should also be paid to creating form shadows on objects in order to make for sharper contrasts.

On large construction sites, work often extends beyond the hours of daylight. In civil engineering projects, it is highly undesirable for parts of lighting systems such as supporting structures, masts, overhead/underground cables and distribution cabinets to be scattered around the site. They obstruct site traffic and hinder construction work. The preferred solution here is floodlighting from points outside the site, although supplementary local lighting may also be needed for building pits, dam structures or other areas which cannot be properly illuminated by the floodlights. Warning lights are also essential to identify hazardous areas.


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Arrangement of luminaires:
Wherever possible, no luminaires should be positioned in the actual area where manpower and machines work. As work areas often change, mobile lighting – directed inwards from the perimeter – is useful. Generally speaking, in addition to the measures mentioned above, the mobility required can be achieved either with small mobile luminaires or with adjustable floods on high masts.

Securing site traffic
To make traffic safe and protect site workers, construction sites are secured from an appropriate distance by special identification and orientation lighting. Road users are warned of approaching hazard zones by dynamic light signals, normally coupled with a reduced speed limit.

Luminaires used
For comparatively small construction sites, floods for tungsten halogen lamps or high-pressure discharge lamps are an option. For larger sites, these are supplemented inside buildings by luminaires with tubular fluorescent lamps (luminaires for damp interiors).

The degree of protection of the luminaires should be at least IP 54. When choosing luminaires, always make sure their enclosure is made of an impact-resistant material. It is also recommended that luminaires should be mechanically protected by a wire mesh shield.

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Lighting tables

Table 5.1 – General circulation areas at outdoor workplaces						
Ref. no.	**Type of area, task or activity**	**$\bar{E}_m$ lx**	**U_o**	**GR_L**	**R_a**	**Remarks**
5.1.1	Walkways exclusively for pedestrians	5	0,25	50	20	
5.1.2	Traffic areas for slowly moving vehicles (max. 10 km/h), e.g. bicycles, trucks and excavators	10	0,40	50	20	
5.1.3	Regular vehicle traffic (max. 40 km/h)	20	0,40	45	20	At shipyards and in docks, GR_L may be 50
5.1.4	Pedestrian passages, vehicle turning, loading and unloading points	30	0,40	50	20	For reading labels: $\bar{E}_m = 50$ lx

Note: For routes, as there are no international standards, consult the appropriate road lighting recommendations.

Table 5.2 – Airports						
Ref. no.	**Type of area, task or activity**	**$\bar{E}_m$ lx**	**U_o**	**GR_L**	**R_a**	**Remarks**
						1. Direct light in the direction of the control tower and landing aircraft should be avoided 2. Direct light emitted above the horizontal by floodlights should be kept to a minimum
5.2.1	Hangar apron	20	0,10	55	20	
5.2.2	Terminal apron	30	0,20	50	40	
5.2.3	Loading areas	30	0,20	50	40	For reading labels: $\bar{E}_m = 50$ lx
5.2.4	Fuel depot	50	0,20	50	40	
5.2.5	Aircraft maintenance stands	200	0,50	45	60	

Table 5.3 – Building sites						
Ref. no.	**Type of area, task or activity**	**$\bar{E}_m$ lx**	**U_o**	**GR_L**	**R_a**	**Remarks**
5.3.1	Clearance, excavation and loading	20	0,25	55	20	
5.3.2	Construction areas, drain pipes mounting, transport, auxiliary and storage tasks	50	0,40	50	20	
5.3.3	Framework element mounting, light reinforcement work, wooden mould and framework mounting, electric piping and cabling	100	0,40	45	40	
5.3.4	Element jointing, demanding electrical, machine and pipe mountings	200	0,50	45	40	

Table 5.4 – Canals, locks and harbours						
Ref. no.	**Type of area, task or activity**	**$\bar{E}_m$ lx**	**U_o**	**GR_L**	**R_a**	**Remarks**
5.4.1	Waiting quays at canals and locks	10	0,25	50	20	
5.4.2	Gangways and passages exclusively for pedestrians	10	0,25	50	20	
5.4.3	Lock control and ballasting areas	20	0,25	55	20	
5.4.4	Cargo handling, loading and unloading	30	0,25	55	20	For reading labels: $\bar{E}_m = 50$ lx
5.4.5	Passenger areas in passenger harbours	50	0,40	50	20	
5.4.6	Coupling of hoses, pipes and ropes	50	0,40	50	20	
5.4.7	Dangerous parts of walkways and driveways	50	0,40	45	20	

Table 5.5 — Farms						
Ref. no.	**Type of area, task or activity**	**$\bar{E}_m$ lx**	**U_o**	**GR_L**	**R_a**	**Remarks**
5.5.1	Farm yards	20	0,10	55	20	
5.5.2	Equipment shed (open)	50	0,20	55	20	
5.5.3	Animal sorting pen	50	0,20	50	40	

Table 5.6 – Fuel filling stations						
Ref. no.	**Type of area, task or activity**	**$\bar{E}_m$ lx**	**U_o**	**GR_L**	**R_a**	**Remarks**
5.6.1	Vehicle parking and storage areas	5	0,25	50	20	
5.6.2	Entry and exit driveways: dark environment (i.e. rural areas and suburbs)	20	0,40	45	20	
5.6.3	Entry and exit driveways: light environment (i.e. cities)	50	0,40	45	20	
5.6.4	Air pressure and water checking points and other service areas	150	0,40	45	20	
5.6.5	Meter reading areas	150	0,40	45	20	

Table 5.7 – Industrial sites and storage areas						
Ref. no.	**Type of area, task or activity**	**$\bar{E}_m$ lx**	**U_o**	**GR_L**	**R_a**	**Remarks**
5.7.1	Short-term handling of large units and raw materials, loading and unloading of solid bulk goods	20	0,25	55	20	
5.7.2	Continuous handling of large units and raw materials, loading and unloading of freight, lifting and descending location for cranes, open loading platforms	50	0,40	50	20	
5.7.3	Reading of addresses, covered loading platforms, use of tools, ordinary reinforcement and casting tasks in concrete plants	100	0,50	45	20	
5.7.4	Demanding electrical, machine and piping installations, inspection	200	0,50	45	60	Use local lighting

Table 5.8 – Offshore gas and oil structures						
Ref. no.	**Type of area, task or activity**	**$\bar{E}_m$ lx**	**U_o**	**GR_L**	**R_a**	**Remarks**
5.8.1	Sea surface below the rig	30	0,25	50	20	
5.8.2	Ladders, stairs, walkways	100	0,25	45	20	On treads
5.8.3	Boat landing areas / transport areas	100	0,25	50	20	
5.8.4	Helideck	100	0,40	45	20	1. Direct light in the direction of the control tower and landing aircraft should be avoided 2. Direct light emitted above the horizontal by floodlights should be kept to a minimum
5.8.5	Derrick	100	0,50	45	40	
5.8.6	Treatment areas	100	0,50	45	40	
5.8.7	Pipe rack area / deck	150	0,50	45	40	
5.8.8	Test station, shale shaker, wellhead	200	0,50	45	40	
5.8.9	Pumping areas	200	0,50	45	20	
5.8.10	Life boat areas	200	0,40	50	20	
5.8.11	Drill floor and monkey board	300	0,50	40	40	Special attention to string entry is needed.
5.8.12	Mud room, sampling	300	0,50	40	40	
5.8.13	Crude oil pumps	300	0,50	45	40	
5.8.14	Plant areas	300	0,50	40	40	
5.8.15	Rotary table	500	0,50	40	40	

Table 5.9 – Parking areas						
Ref. no.	**Art des Bereiches, der Aufgabe oder Tätigkeit**	**$\bar{E}_m$ lx**	**U_o**	**GR_L**	**R_a**	**Remarks**
5.9.1	Light traffic, e.g. parking areas of shops, terraced and apartment houses, cycle parks	5	0,25	55	20	
5.9.2	Medium traffic, e.g. parking areas of department stores, office buildings, plants, sports and multipurpose building complexes	10	0,25	50	20	
5.9.3	Heavy traffic, e.g. parking areas of schools, churches, major shopping centres, major sports and multipurpose building complexes	20	0,25	50	20	

Table 5.10 – Petrochemical and other hazardous industries						
Ref. no.	**Type of area, task or activity**	**$\bar{E}_m$ lx**	**U_o**	**GR_L**	**R_a**	**Remarks**
5.10.1	Handling of service tools, utilisation of manually regulated valves, starting and stopping motors, lighting of burners	20	0,25	55	20	
5.10.2	Filling and emptying of container trucks and wagons with risk-free substances, inspection of leakage, piping and packing	50	0,40	50	20	
5.10.3	Filling and emptying of container trucks and wagons with dangerous substances, replacement of pump packing, general service work, reading of instruments	100	0,40	45	40	
5.10.4	Fuel loading and unloading sites	100	0,40	45	20	
5.10.5	Repair of machines and electric devices	200	0,50	45	60	Use local lighting

Table 5.11 – Power, electricity, gas and heat plants						
Ref. no.	**Type of area, task or activity**	**$\bar{E}_m$ lx**	**U_o**	**GR_L**	**R_a**	**Remarks**
5.11.1	Pedestrian movements within electrically safe areas	5	0,25	50	20	
5.11.2	Handling of service tools, coal	20	0,25	55	20	
5.11.3	Overall inspection	50	0,40	50	20	
5.11.4	General servicing work and reading of instruments	100	0,40	45	40	
5.11.5	Wind tunnels; servicing and maintenance	100	0,40	45	40	
5.11.6	Repair of electrical devices	200	0,50	45	60	Use local lighting

Table 5.12 – Railways and tramways						
Ref. no.	**Type of area, task or activity**	**$\bar{E}_m$ lx**	**U_o**	**GR_L**	**R_a**	**Remarks**
	Railway areas including light railways, tramways, monorails, miniature rails, metro, etc.					Avoid glare for vehicle drivers
5.12.1	Tracks in passenger station areas, including stabling	10	0,25	50	20	$U_d \geq 1/8$
5.12.2	Railway yards: flat marshalling, retarder and classification yards	10	0,40	50	20	$U_d \geq 1/5$
5.12.3	Hump areas	10	0,40	45	20	$U_d \geq 1/5$
5.12.4	Freight track, short duration operations	10	0,25	50	20	$U_d \geq 1/8$
5.12.5	Open platforms, rural and local trains, small number of passengers	15	0,25	50	20	1. Special attention to the edge of the platform. 2. $U_d \geq 1/8$
5.12.6	Walkways	20	0,40	50	20	
5.12.7	Level crossings	20	0,40	45	20	
5.12.8	Open platforms, suburban and regional trains with large number of passengers or inter-city services with small number of passengers	20	0,40	45	20	1. Special attention to the edge of the platform. 2. $U_d \geq 1/5$
5.12.9	Freight track, continuous operation	20	0,40	50	20	$U_d \geq 1/5$
5.12.10	Open platforms in freight areas	20	0,40	50	20	$U_d \geq 1/5$
5.12.11	Servicing trains and locomotives	20	0,40	50	40	$U_d \geq 1/5$
5.12.12	Railway yard handling areas	30	0,40	50	20	$U_d \geq 1/5$
5.12.13	Coupling area	30	0,40	45	20	$U_d \geq 1/5$
5.12.14	Stairs, small and medium-size stations	50	0,40	45	40	
5.12.15	Open platforms, inter-city services	50	0,40	45	20	1. Special attention to the edge of the platform 2. $U_d \geq 1/5$
5.12.16	Covered platforms, suburban and regional trains or inter-city services with small number of passengers	50	0,40	45	40	1. Special attention to the edge of the platform. 2. $U_d \geq 1/5$
5.12.17	Covered platforms in freight areas, short duration operations	50	0,40	45	20	$U_d \geq 1/5$
5.12.18	Covered platforms, inter-city services	100	0,50	45	40	1. Special attention to the edge of the platform. 2. $U_d \geq 1/3$
5.12.19	Stairs, large stations	100	0,50	45	40	
5.12.20	Covered platforms in freight areas, continuous operation	100	0,50	45	40	$U_d \geq 1/5$
5.12.21	Inspection pit	100	0,50	40	40	Use low-glare local lighting

Table 5.13 – Saw mils						
Ref. no.	Type of area, task or activity	$\bar{E}_m$ lx	U_o	GR_L	R_a	Remarks
5.13.1	Timber handling on land and in water, sawdust and chip conveyors	20	0,25	55	20	
5.13.2	Sorting of timber on land or in water, timber unloading points and sawn timber loading points, mechanical lifting to timber conveyor, stacking	50	0,40	50	20	
5.13.3	Reading of addresses and markings of sawn timber	100	0,40	45	40	
5.13.4	Grading and packaging	200	0,50	45	40	
5.13.5	Feeding and stripping and chopping machines	300	0,50	45	40	

Table 5.14 – Shipyards and docks						
Ref. no.	Type of area, task or activity	$\bar{E}_m$ lx	U_o	GR_L	R_a	Remarks
5.14.1	General lighting of shipyard area, storage areas for prefabricated goods	20	0,25	55	40	
5.14.2	Short term handling of large units	20	0,25	55	20	
5.14.3	Cleaning of ship hull	50	0,25	50	20	
5.14.4	Painting and welding of ship hull	100	0,40	45	60	
5.14.5	Mounting of electrical and mechanical components	200	0,50	45	60	

Table 5.15 – Water and sewage plants						
Ref. no.	Type of area, task or activity	$\bar{E}_m$ lx	U_o	GR_L	R_a	Remarks
5.15.1	Handling of service tools, utilisation of manually operated valves, starting and stopping of motors, piping packing and raking plants	50	0,40	45	20	
5.15.2	Handling of chemicals, inspection of leakage, changing of pumps, general servicing work, reading of instruments	100	0,40	45	40	
5.15.3	Repair of motors and electric devices	200	0,50	45	60	

Lamps

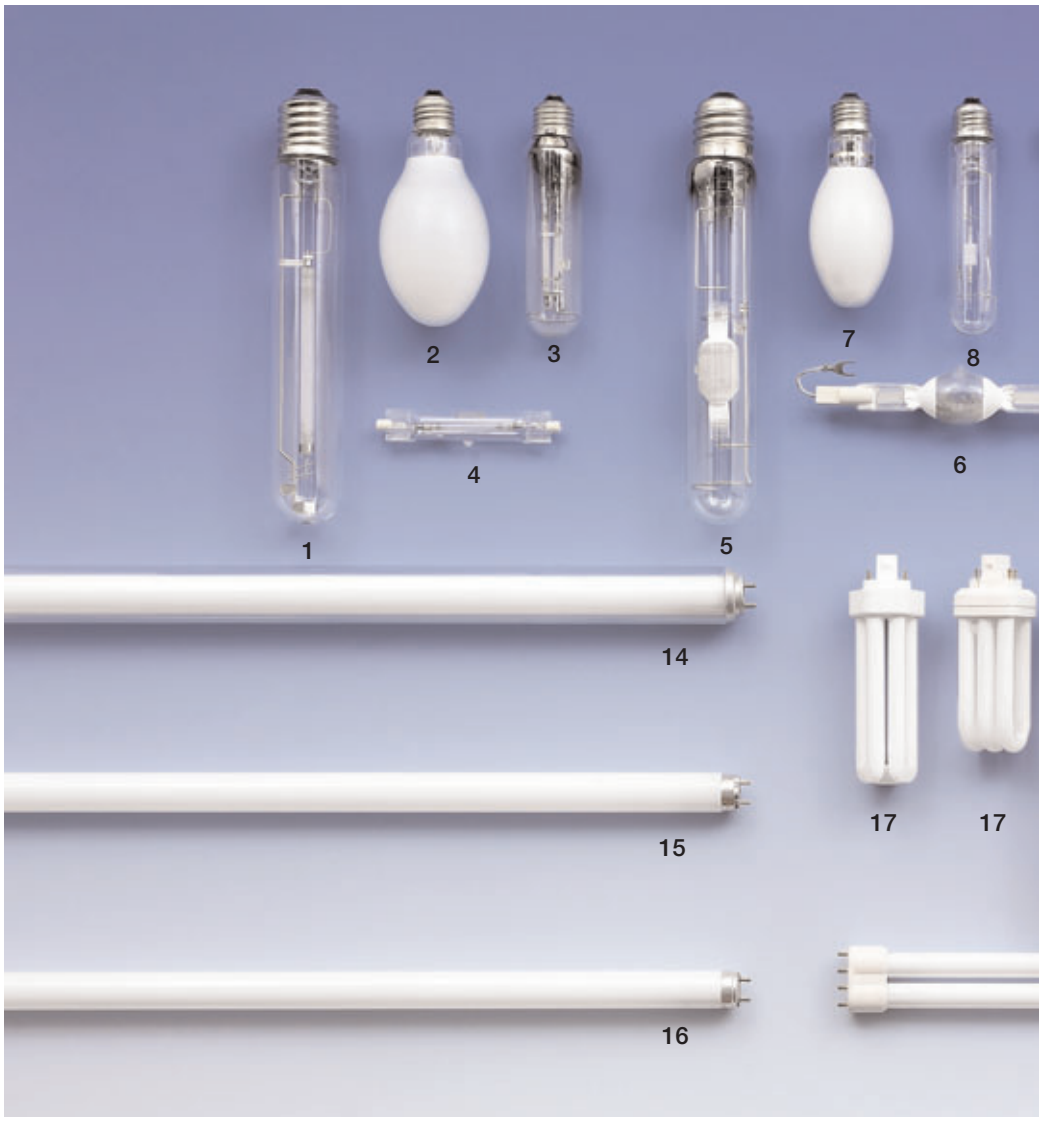
The principal selection criteria for road lighting lamps are energy balance (luminous efficacy) and service life. Closely connected with these is the decision on wattage (W). Light colour and colour rendering properties are less important here than for interiors (see page 8).

Luminous efficacy

Luminous efficacy is the measure of a lamp's efficiency, expressed in lumens (lm) per watt: the higher the ratio of lumens to watts, the more light a lamp produces from the energy it consumes. An ordinary tungsten filament lamp generates only 12 lm/W, whereas the luminous efficacy of discharge lamps is several times higher (see table). Discharge lamps operated by electronic ballasts achieve even greater efficiency.

Service life

Service life is the length of time a lamp is operated before it becomes unserviceable. Average service life is defined as the average electrical service life (survival rate) of a number of lamps operated under standard conditions. Manufacturers publish service life ratings, indicating the switching rhythm and the failure rate on which they are based.



		tubular (T)	ellipsoid (E)	T or E with double burner	with base at both ends	T (quartz)	with base at both ends	E (quartz)
Lamp type		**1**	**2**	**3**	**4**	**5**	**6**	**7**
Features	**Type of lamp**	**High-pressure sodium**				**Metal halide**		
Power rating classes	**from**	50	35	50	70	250	1 000	35
(Watt)	**to**	1 000	1 000	400	400	2 000	2 000	1 000
Luminous flux	**from**	4 400	2 200	4 000	6 800	20 000	90 000	2 850
(Lumen)	**to**	130 000	130 000	55 000	48 000	240 000	230 000	100 000
Luminous efficacy	**from**	70	63	66	80	80	86	74
(Lumen/Watt)	**to**	150	139	138	120	120	115	100
Light colour		ww	ww	ww	ww	nw, dw	nw, dw	ww, nw, dw
Colour rendering index		< 40	< 40	< 40	< 40	60 – 95	60 – 90	69, 80 – 95
R_a (range)								
Base		E27 E40	E27 E40	E27 E40	Fc2 RX7s	E40	K12s	E27

Light colour: ww = warm white (colour temperature below 3,300 K), nw = neutral white (colour temperature 3,300 to 5,300 K), d

[1] Where lamps are EB-operated, luminous efficacy increases to 81–100 lm/W. Power input decreases from 18 W to 16 W, from 36 W

When individual lamps fail, road safety is compromised. So spent lamps should be replaced immediately. Group replacement intervals are determined by the failure rate tolerated. This is normally 5%.

The longer a lamp operates before it needs to be replaced, the lower the cost of relamping and maintenance. Detailed comparative data on the service life of discharge lamps is available from the electric lamp division (Fachverband Elektrische Lampen) of the German electrical and electronic manufacturers' association ZVEI.

	T or E (ceramic)	T (ceramic)	T (ceramic)	with base at both ends (quartz or ceramic)	ellipsoid	tubular	longlife Ø 38 mm, for low temperatures	longlife Ø 26 mm	fluorescent lamp Ø 26 mm	1, 2- and – illustrated – 3-tube lamp	3- or 4-tube lamp	elongated [2]	bulb-shaped	ring-shaped
	8	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**
					Mercury vapour	**LP sodium**	**Tubular three-band fluorescent**			**Compact fluorescent**			**Induction**	
	70	35	60	70	50	18	18	18	18	5	60	18	55[4]	70
	250	250	140	400	1 000	180	58	58	58	70	120	80[3]	165[4]	150
	5 600	3 100	6 850	5 100	1 600	1 800	1 350	1 350	1 350	250	4 000	1 200	3 650	6 500
	22 500	25 000	16 500	37 000	58 000	32 000	5 150	5 150	5 200	5 200	9 000	6 000	12 000	12 000
	80	85	114	73	32	100	75	75	75/81[1]	50	67	67	64[4]	75[4]
	90	100	118	100	60	178	89	89	93/100[1]	82	75	87	73[4]	79[4]
	ww	ww, nw	ww	ww, nw	ww, nw	–	ww, nw, dw	ww, nw, dw	ww, nw, dw	ww, nw	ww, nw	ww, nw	ww, nw	ww, nw
	80–85	80–95	60–70	75–96	36, 45–60	–	–	80–85	80–85	80–85	80–85	80–85	80–85	80–85
	E27 E40	G12, G22 E40	PGZ12	Fc2	E27 RX7s	BY22d E40	G13	G13	G13	G23	2G8-1 G24, 2G7 GX24	2G11	special	special

dw = daylight white (colour temperature over 5,300 K)
V to 32 W and from 58 W to 50 W. [2] 18–55 W also as special design for outdoor lighting [3] 40 W and 55 W only with EB [4] System (lamp + EB)

Luminaires

Luminaire selection is determined by the lighting requirements of the lighting task as well as by mechanical and electrical requirements and the design intent.

It makes good economic sense to choose quality luminaires. Key features of their design and manufacture are:

- cost-efficient operation (high utilisation factors)
- lighting quality and functionality (VDE, ENEC),
- mechanical and electrical reliability,
- long life (materials, finish, compact design),
- in-process quality control,
- simple assembly and maintenance-friendly design

Professional advice and planning aids are also significant features.


Figs. 69 + 70

Pendant luminaires for suspension on catenary (overhead) wires for A1, A2, A3 or B1 roads


Figs. 71 + 72

Post-top luminaires for A1, A2, A3 or B1 roads


Figs. 73 + 74

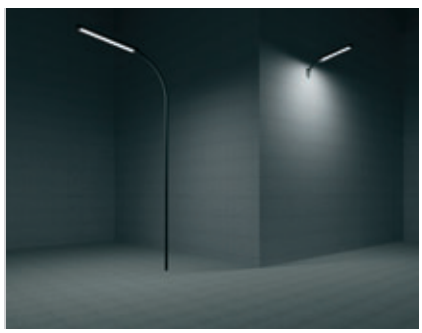
Large-area luminaire, used e.g. for outdoor car park lighting


Figs. 75 + 76

Side-entry luminaires, a preferred option for A1, A2, A3 or B1 roads


Figs. 77 + 78

Luminaire with light distribution curve specially designed for pedestrian crossings

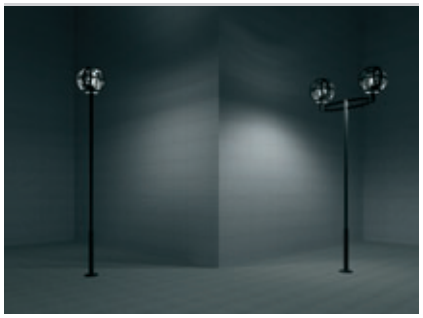



Figs. 79 + 80

Post-top luminaire (left) with fluorescent lamps for A1, A2, A3 or B1 roads and as wall luminaire (right) e.g. for paths

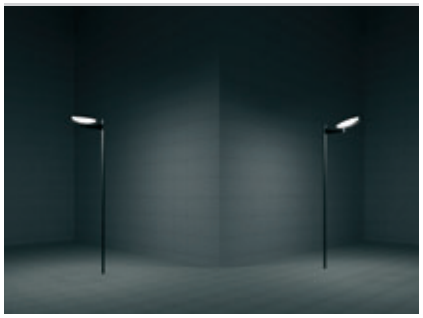

Figs. 81 + 82

Tunnel luminaires with special light distribution curve and higher degree of protection.



Figs. 83 + 84

Decorative column luminaires, a preferred option for D and E lighting situation roads as well as for parks and gardens

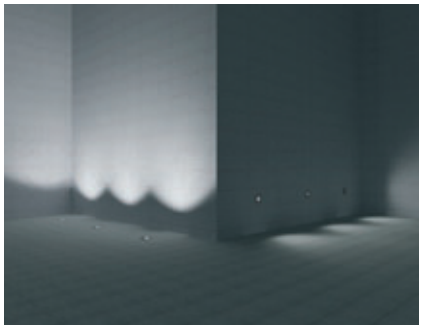


Figs. 85 + 86

Path luminaires, a preferred option for D and E lighting situation roads as well as for parks and gardens

Figs. 87 + 88

Secondary luminaires (also: indirect luminaires), a preferred option for D and E lighting situation roads as well as for parks and gardens

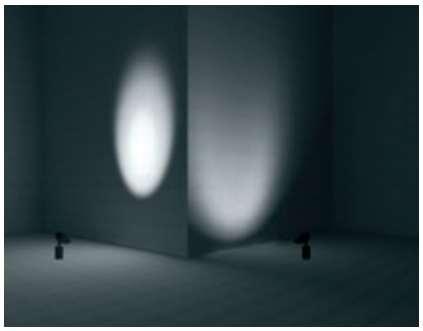


Figs. 89 + 90

Recessed ground luminaires (left) for object illumination and accentuating lighting as well as orientation luminaires (right) as recessed wall lights

Figs. 91 + 92

Small floods and spots for object illumination; the spot on the right integrates well in facades



Figs. 93 + 94

Projector luminaires for spot- (left) and floodlighting (right).

Standards and literature

DIN EN 12464-2 Light and lighting – Lighting of work places – Part 2: Outdoor work places

DIN 13201 Road lighting - Part 1: Selection of lighting classes

DIN EN 13201 Road lighting
Part 2: Performance requirements
Part 3: Calculation of performance
Part 4: Methods of measuring lighting performance

DIN 5340 Terms for physiological optics

DIN 67523 Lighting of pedestrian crossings (sign 293 StVO)with additional lighting
Part 1: General characteristics and guide values
Part 2: Calculation and measurement

R-FGÜ 2001 – Richtlinien für die Anlage und Ausstattung von Fußgängerüberwegen, published in Verkehrsblatt (VkBl) 2001, page 474 (www.verkehrsblatt.de)

Guide for lighting of road tunnels and underpasses, CIE publication 88 (2nd edition), Vienna 204 (www.cie.co.at/cie)

Conflict zones: (in German). Allgemeines Rundschreiben für den Straßenbau 23/98 of the Federal Transport Ministry (BMV)

Life behaviour of discharge lamps for general lighting, Fachverband Elektrische Lampen im ZVEI – Zentralverband Elektrotechnik- und Elektronikindustrie (ZVEI) e.V., Frankfurt am Main 2005 (www.zvei.org)

Straßenbeleuchtung und Sicherheit, publication no. 17:1998, Deutsche Lichttechnische Gesellschaft (LiTG) e.V., Berlin 1998 (www.litg.de)

Messung und Beurteilung von Lichtimmissionen künstlicher Lichtquellen, publication no. 12.2:1996, Deutsche Lichttechnische Gesellchaft (LiTG) e.V., Berlin 1996 (www.litg.de)

Hinweise zur Messung und Beurteilung von Lichtimmissionen, Beschluss des Länderausschusses für Immissionsschutz (LAI) resolution of 10 May 2000 (www.lai-immissionsschutz.de)

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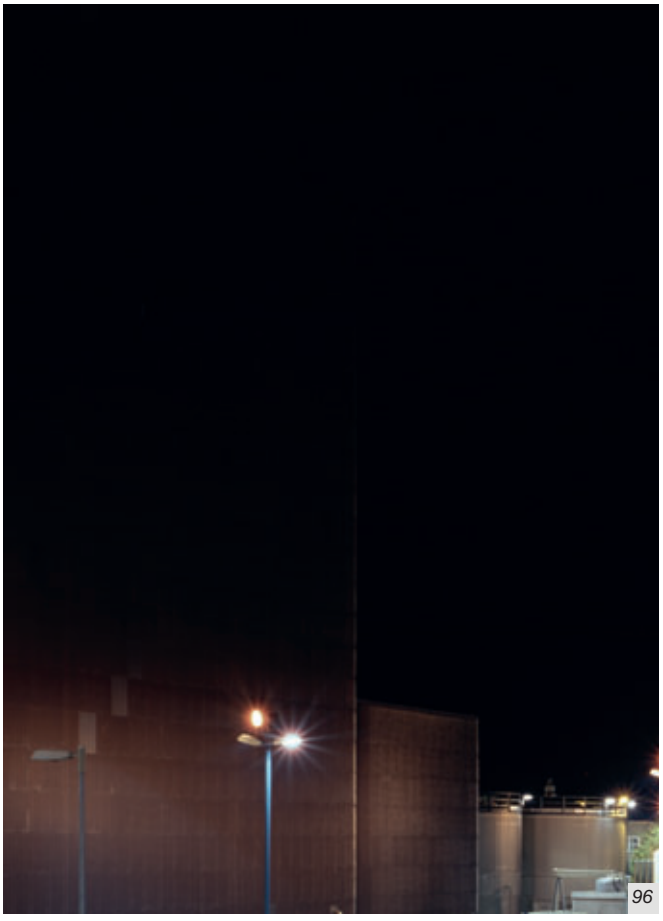

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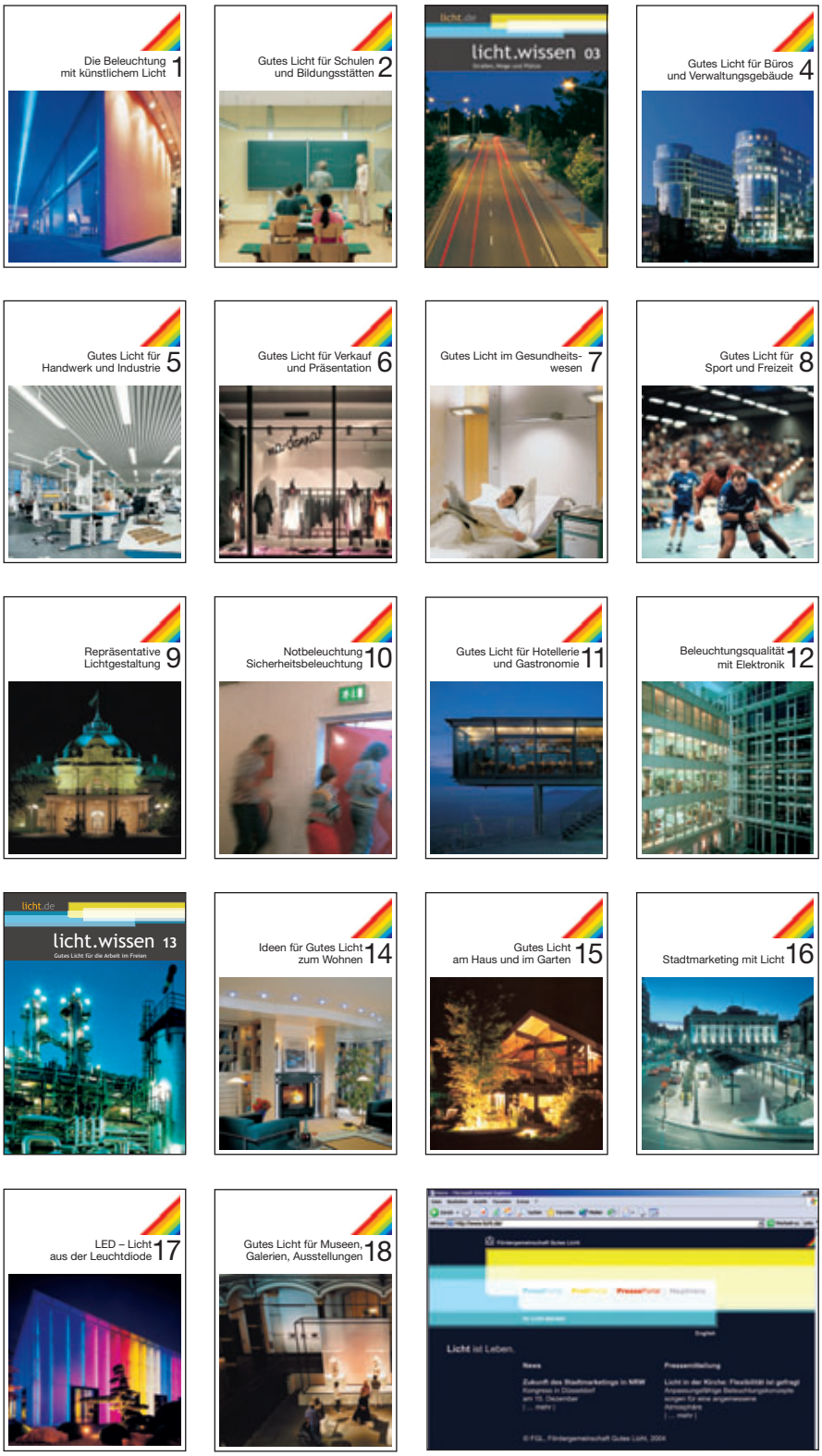

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