SMARTLIGHTINDUSTRY

SMARTLIGHT/INDUSTRY

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smart lighting engineering

“When Thomas Edison worked late into the night on the electric light, he had to do it by gas lamp or candle. I’m sure it made the work seem that much more urgent.”

George Carlin

Luckily the times when the craftsmen were slouching over their makes in the twinkling flame of a candle or a paraffin lamp belong to the past. The invention of the artificial light in 1789 meant a breakthrough in the area of technology and made the “light” an accessible product independently of the season of the year and the hour of the day. Together with other inventions from the second half of the 18th century the light played one of the supporting roles of industrialisation.

When the artificial light ceased to be luxurious goods it found its way also to the factories thanks to the massive electrification where thanks to the multi-shift operation a boom of the industrial manufacturing literally arose. The need for permanent searching for more economical solutions motivated the scientists and inventors to develop better and better and more sophisticated methods how to produce and spread the artificial light. After some time the halogen lamps and later fluorescent lamps began to compete with the bulbs and finally in 1962 also the predecessors of the LED diodes which currently represent the most effective and most economical type of the light source.

Together with the development of the light technologies the interest of the scientists in the influence of the light on the human organism was also increasing. The long-year investigations led to a quantity of interesting findings which more and more frequently find an effective application in practice. The fact that people spend up to 80 % of their productive life at work increases the importance of the appropriate and biologically efficient lighting at the workplace. In the manufacturing sphere and all lines of business a correctly designed lighting system can positively affect the performance efficiency and concentration of the employees in all working shifts, minimise the occurrence of failures and the risks of injuries.

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CONTENT

LIGHT AND HUMAN

NEW ORDER IN LIGHTING WORLD

When designing the lighting system of the industrial space the lighting designer has to take into account, besides the legal standards, also other parameters which are no less important and affect the quality of the lighting solution of the whole industrial building. Until recently, the summary of these criteria has represented a chaotic system that has not offered any sufficient overview to the customer. The six-point assessment system of the lighting quality – Lighting Quality Standard developed by the company SLE, brings a new order to the chaotic lighting world.

Living by rules is important.
Respecting laws is relevant as well. The ancient conflict of our world is driven by patterns and order; otherwise we become adrift by chaos that is present in our civilisation to these days. Whether the former or the latter concept is the right one, is an eternal question. One thing is certain: we in SLE love the order much more than chaos. That is why we have created a brand new lighting quality standard to help the customers, buyers and competitors better understand and evaluate lighting devices and solutions.

Until now there was no unifying system used in the world of lighting for evaluation of eiher light fixtures or lighting solutions, and every producer has got its own way for that. Consumers get lost in the vast array of criteria used, and comparing neither products nor solution was an option. SLE brings order to this chaos. We are prepared to help the LQS become a unified standard used by the whole lighting sector. No overstatement, the LQS is an important step to the new level. Not just for our company, but for the branch and the giant world of lighting.

We have chosen more than twenty objectively quantifiable criteria and we are using them to evaluate both individual light fixtures and complete lighting solutions for different types of spaces. Each criterion has got its value and the result is the LQS Index. The higher the index is, the better the lighting device or solution is for use in a given space. Simple and intuitive approach to the agenda is exemplified by the LQS Composer, a unique tool to evaluate each and every lighting product.

There is a six-part program behind the acronym LQS.
The chapters are named ERGONOMICS, EMOTION, ECOLOGY, EFFICIENCY, ESPRIT AND EXCEPTIONALITY, **or just 6 E's.**
If you imagine a house, the first four chapters are strong pillars representing criteria that are well-known in the world of lighting. The remaining two are the roof, a powerful superstructure on the top of these pillars. Together, they create an inseparable complex, because the parts of the whole cannot be perceived independently, but only in their context. That is the basic philosophy of the LQS. Immerse in the 6 E's and conceive the idea of living in a place where rules are crystal clear.

ERGONOMICS

The delicate and complex interaction of light with the human body

A sufficient amount of uniform lighting ensures safe navigation of the darkness, making it the master criteria in ergonomic lighting design.

EFFICIENCY

The scientific advancement of lighting and control technologies

With so many lighting and control possibilities to choose from, an optimum solution can be prepared for every space.

EMOTION

The profound impact light has on emotional response

Science repeatedly brings to our attention the ability of light to affect mood, perception and performance through the use of physiologically effective light and appropriate illumination techniques.

ESPRIT

The soul of a lighting solution lays in its design and aesthetic value

Do not underestimate the power of beauty to transform a lighting solution from merely functional to something inspirational.

ECOLOGY

The minimisation of environmental impacts related to the illumination of our world

The ratio of energy converted to light by a light source, in combination with product lifetimes and maintenance costs, are key to making the right lighting choices.

EXCEPTIONALITY

A chain of value that unites and strengthens suppliers, architects, lighting designers, project companies and brands

A unique vision that combines innovation, global trends, sales and promotion support and the power of mutually beneficial collaboration to create solutions of superior quality and value, and nurture business success.

ERGONOMICS

By adequate lighting we are able to reduce the undesirable glare, to improve performance efficiency and ability to concentrate, to prevent sight damage as well as stressful and dangerous situations. Nowadays nowhere else respecting the ergonomic standards appears as important as at the workplace.

Ergonomics examines the impact of light on the human eye.

Knowing the principles of ergonomics the lighting designer – by planning the lighting solution - can make a choise of the right lighting fixture and light source and their distribution in related space.

The basic quantities which are taken into account by the ergonomics when creating optimal lighting conditions are – the colour rendering index (CRI), glare prevention, illumination level of the task area and surrounding of task area, lighting uniformity and harmonious distribution of brightness.

From the practical point of view the colour rendering index is one of the most important aspects when selecting the light source.

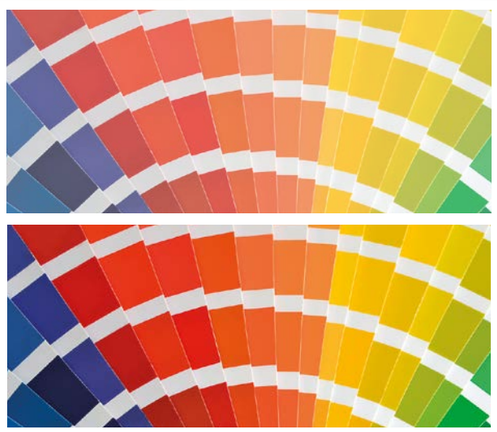
COLOUR RENDERING INDEX

Correct perception of colours plays in many industry segments a decisive part. To provide an adeguate colour rendering is therefore one of the key tasks for a lighting designer when planning the lighting system.

The influence of the artificial light source on the appearance of the colour objects is expressed by the colour rendering index (CRI) which indicates how truthfully the individual light sources are able to copy the object's colouring compared with daylight. The CRI value of the light source is expressed by the average of the first eight factors R1 – R8 out of fifteen colour samples illuminated at first under a reference light source with an ideal value (CRI = 100) and under the light source being tested. The larger the difference of the truthfulness of colour reproduction is, the lower the CRI value of the tested light source is and thus, also its ability to display the object's colouring truthfully.

From the practical point of view the colour rendering index is one of the most important aspects when selecting the light source. The European standard EN 12464-1 requires light sources with the colour rendering index of minimally 80 for a common workplaces, for a workplaces where the right assessment of colours is essential (e.g. colour inspection in chemical, plastics, automotive, food industry or in multicoloured printing, jewellery manufacturing, painting and touch-up of vehicles, some wood working activities) the standard requires to use light sources with at least CRI 90.

From the point of view of LQS the highest ranking is assigned to the light sources with CRI 90 and more.



Comparison of colour rendering indices – CRI. Up CRI 70. Down CRI 93

For the multicolour printing process and the inspection operations it is necessary to use the light sources with the colour rendering index CRI ≥ 90 for correct distinguishing of colours.

LQS VALUE

Colour rendering index (CRI)

CRI	LQS Value
>90	5
80-90	4
70-80	3
60-70	2
40-60	1
20-40	0

GLARE PREVENTION

Glare is a negative visual perception caused by light surfaces in the field of vision. Preventing it or minimising its occurrence is particularly important not only from the point of view of the visual comfort but also the work-place safety and performance of employees.

The excessive direct and reflected glare at the workplace in industry and production areas can cause fatigue, visual impairment, it can lead to reduced concentration, increases risk of injuries, it makes the text visibility on the PC monitor as well as reading a printed text on the glossy paper more difficult. Therefore a properly lit facility should be void of glare and reflection.
Preventing the disruptive glare belongs therefore to the basic designer's tasks when planning a lighting system. By choosing the luminaires, light sources and by solving theire distribution in the space the designer should consider the fact, that the sensitivity to glare increases with age. The older the employee, the more accurate and safe their task lighting must be.

In production halls the glare is especially undesirable in the spaces where visual display units (VDU) are placed. The excessive light can decrease the contrast of informations displayed on the VDU by veiling reflections caused by dazzling of the screen surface, the luminance of the luminaires and bright surfaces which are reflected on the screen. The requirements on the visual quality of the screens concerning the undesirable reflections are stated by the European standard ISO 9241-307.

Reducing the risk of exposing the employees to the glare begins with the correct organisation of the workplace. Placing the workstations rectangular to the glass window areas for the daylight not to reflect directly to the eye and to fit them out with the blinds are the basic measures of the glare prevention.

Another way how to prevent glare is a correct selection of the lighting fixture and its appropriate placement in the space. It is recommended to choose luminaires with low luminance and matte surface and to place them in such a way that the light will not reflect from the objects directly to the eye, e.g. when sitting at the desk while carrying out everyday activities.

Screen high state luminance	High luminance screen L > 200 cd/m²	Medium luminance screen L ≤ 200 cd/m²
Case A *Values for spaces with common demands on the correct colour rendering and details of the depicted information.*	≤ 3,000 cd/m²	≤ 1,500 cd/m²
Case B *Values for spaces with increased demands on the colour rendering, precise work and details of the depicted information.*	≤ 1,500 cd/m²	≤ 1,000 cd/m²

The limit values of the lighting fixtures luminance in the angle of 65° and more from the vertical axis.

Reducing the risk of exposing the employees to the glare begins with the correct organisation of the workplace.

Unified glare rating

The method of Unified Glare Rating (UGR) is used for uniform qualification of the rate of the psychological glare. This method was defined by the Commission Internationale de l'Eclairage.
The lower the UGR value is, the lower the probability of the psychological glare in the assessed space is.
The European standard EN 12464-1 states the UGR maximally 16 for workplaces with high demands on precision and a high rate of visual load (grinding of optical glass, hand engraving, manufacture of synthetic precious stone), UGR 19 for laboratories and measuring rooms, UGR 25 for common workplaces with constantly manned workstations in processing installations and UGR 28 for workstations with limited manual intervention.

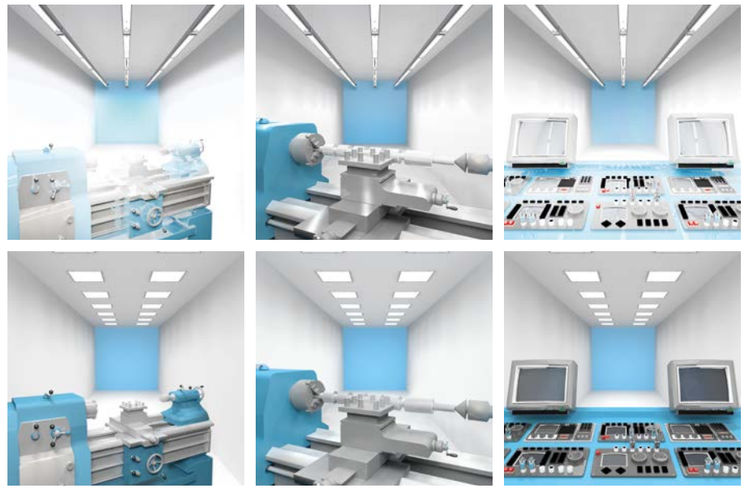
LQS assigns the highest rating of 5 points to solutions achieving UGR maximally 16 and less.

$$UGR = 8\log\left[\frac{0.25}{L_b}\sum\frac{L^2\Omega}{p^2}\right]$$

Where:
- *L stands for luminance of lighting parts of every luminaire in the direction of the eye (in candelas per square meter).*
- *Ω is a cut-off angle of a luminaire relative to the eye of an observer (in steradians).*
- *p is a Guth factor of spatial position of every single luminaire relative to the field of view.*
- *L_b expresses background illuminance (in candelas per square meter).*

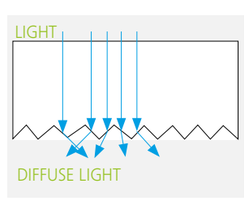
Microprism

RELAX XTP luminaire with direct distribution of diffuse light through microprism is an ideal solution for the selected industrial spaces. The microprism represents the most effective method for the diffuse light distribution as the light breaks at the end of the material, on the so called optical prisms which results in its uniform distribution. The soft diffuse light is more pleasant for the human eye, it strains less and in this way the rate of psychological load UGR is reduced.



Direct glare
causes excessive luminance, e.g. from incorrectly placed luminaires or from unshielded general-diffuse lamps. It arouses a feeling of psychological as well as visual discomfort and therefore it is inevitable to reduce it to minimum.

Reflected glare
represents the same psychological and physiological load as the direct glare and moreover it reduces the capability to perceive contrasts. It is aroused by a disruptive reflection of light falling from unshielded windows from the glossy surfaces e.g. glossy paper or monitor).



LQS VALUE

Glare prevention

Glare prevention	LQS Value
URG<16	5
URG<19	4
URG<22	3
URG<25	2
URG<28	1
URG>28	0

ILLUMINATION LEVEL

The minimum values of illumination level for production areas are defined by the standard. Scientific researches and our practical experience are prooving, that adequate illumination level influences in positive way the performance of the employees, their ability to concentrate, decreases the mistake rate and the risk of injuries.

To define minimum values of illumination level the standard EN 12464-1 distincts between the task area, where visual tasks are carried out, the sourrounding area – which immediately surrounds it, and the background, at least 3 m wide band adjacent to the immediate surrounding area. The decision what kind of lighting system should be installed depends on the visual task performed at the workplace.

If the exact organisation of the facility is unknown at the time, when the lighting system is designed, the illumination level in whole area should respond to the normative requirements for the task area. At workstations where employees are performing activities requiring accuracy, where sharp objects are used (e.g. drilling, grinding), or where activities include writing or drawing, the optimal solution is considered when the luminaire is placed towards the working surface slightly from the left of the employee's view. When the situation is solved like this the employees do not cast a shadow upon the desk when they are working and also good visibility of the working tool's spike or pen's nib is ensured. Such a direction of the luminous flux is determined for the right-handers; the left-handers are often disadvantaged in this case. However, currently there are lighting solutions which enable adjusting the luminous flux to create the same conditions also for the left-handers.

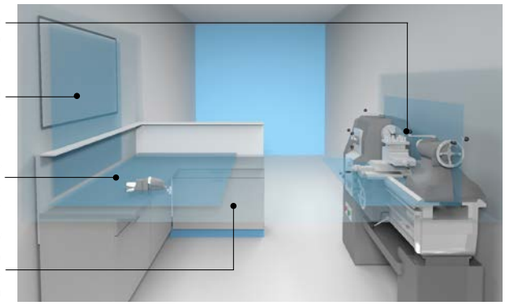
The insufficient or erroneous lighting of the production area can have a negative impact not only on the quality of employees' activities or quality of their performance, but also on their state of health and mind. The modern lighting solutions are based on the research results showing that natural light is the decisive factor for the well-being of every individual. This is the reason why the designers attempt to get as close as possible to its properties.

Task Area

From the point of view of demands on the illumination of the industrial and production area, it is the desk or the task area that plays the most important role. The European standard EN 12464-1 states the value of minimally 50 lux for the common working activities and automatic processing (drying, remote-operated processing installations, fuel supply plant) and tightens the requirements on the illumination level to the value of 1,500 lux for those task areas where time-demanding tasks, tasks requiring precision, productivity, concentration are carried out or where the visual capability of the employee is reduced (quality control, colour inspection, painting, manufacturing precious stones). To provide adequate values of illumination level of task area and to achieve constant lighting conditions supplementary luminaires like workplace luminaires and machine luminaires can be installed.

From the point of view of safety it is also necessary to prevent the rise of the stroboscopic effect when the artificial lighting is on at the workplace. The stroboscopic effect represents an extreme danger, specially when working with the rotational tools because when the frequency and the rotational speed are the same an impression can arise, that the tool is off and it can cause hard injury to the user. The stroboscopic effect can be avoided by installing the LED luminaires or high-frequency control gears emitting the light with a frequency that the human eye cannot notice and therefore it perceives it as constantly continuous.

Single industrial workplace



Various industrial workplaces require different lighting solutions for individual visual tasks. These must be defined individually in terms of location and intensity of illumination. The individual tasks may be combined and performed in the same working area.

LQS VALUE

Illumination level (task area)

Illumination level (task area)	LQS Value
Yes	5
No	0

The modern lighting solutions are based on the research results showing that natural light is the decisive factor for the well-being of every individual. This is the reason why the designers attempt to get as close as possible to its properties including illumination level.

Surrounding area

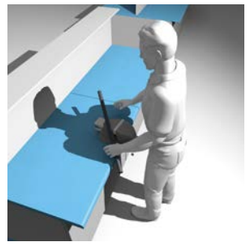
The correct illumination of surrounding area (band with a width of at least 0.5 m around the task area within the visual field) and the background (at least 3 m wide adjacent to the immediate surrounding area within the limits of the space) is an important factor in the industry areas. Their correct illumination can prevent problems with perceiving the objects, it can minimise the damage of the sense of sight, developing stress and strain.

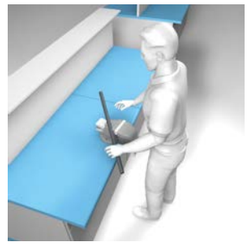
The illuminance of the surrounding area and the background is connected with the illuminance of the task area and is to ensure a harmonious distribution of brightness in the field of vision. The standard EN 12464-1 states that the illuminance of the immediate surrounding area may be lower than the illuminance on the task area but shall be not less then the values given in table below.

LQS assigns the spaces meeting requirements of the standard 5 points; those failing to fulfil the illumination value level 0 points.

Illuminance on the task area E_{task} lux	Illuminance on immediate surrounding areas lux
≥ 750	500
500	300
300	200
200	150
150	E_{task}
100	E_{task}
≤ 50	E_{task}

Relationship of illuminances on immediate surrounding to the illuminance on the task area.





The optimal solution is considered when the luminaire is placed towards the working surface slightly from the left of the employee's view. When the situation is solved like this the employees do not cast a shadow upon the desk when they are working and also good visibility of the working tool's spike or pen's nib is ensured.

LQS VALUE

Illumination level (surrounding area)

Illumination level (surrounding area)	LQS Value
Yes	5
No	0

Big differences in the illumination rate create the impression of a broken space and increase demands on the adaptation capability of the human eye.

LIGHTING UNIFORMITY

The uniform illumination affects our ability to perceive the surrounding area and to orient ourselves inside of it. We perceive a uniformly illuminated space as a consistent one.

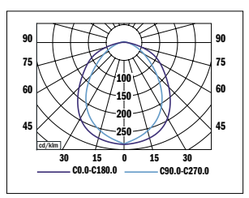
From this point of view the ergonomic quantity - lighting uniformity – is a matter of considerable importance in industrial and production areas. Big differences in the illumination rate create the impression of a broken space and increase demands on the adaptation capability of the human eye.

The lighting uniformity is expressed as a ratio of the minimal and average illuminance of the space assessed. The closer their values are, the more uniform the illuminance of the space is.

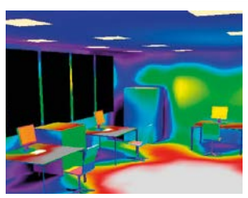
An optimal state can be achieved by selecting an appropriate type and number of luminaires and their correct distribution. From the point of view of type of luminaires the direct and indirect lighting fixtures with a wide luminous intensity curve seem to be the most suitable.

The lighting uniformity index is adapted by the European standard EN 12464-1 which, as in the case of the illumination level, places heavier demands on workplaces requiring precision (e.g. drawing, grinding, decorating). For these ones it states the index with a minimal value of 0.7.

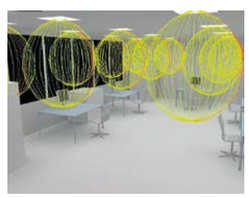
From the point of view of LQS, the optimal lighting solution meeting the standard is assessed by 5 points, those failing to fulfil requirements by 0 points.



Luminous intensity curve of INDIRECT XTP C L2 FSD 2x36W



A specialised software dialux enables a simulation of the lighting uniformity of the space already during the design phase of the lighting system.



The luminous intensity curve gives the designer a hint about the resulting effect.

The customer acquires the visualisation of the room space including the definitions of the material surfaces and parts of the interior as well.

LQS VALUE

Lighting uniformity

Lighting uniformity	LQS Value
Yes	5
No	0

In industrial spaces the requirements of harmonious distribution of brightness are particularly relative to areas where visual quality control is performed, in laboratories, on workplaces with VDU or in the offices.

HARMONIOUS DISTRIBUTION OF BRIGHTNESS

People acquire up to 80 % of information through their sense of vision therefore lighting is the key factor for a correct visual perception in all industrial and production areas.

Luminance is the only quantity to which the human eye responds and therefore its harmonious distribution is the key task for a lighting designer when planning the illumination in every type of industrial space. Harmonious distribution of brightness affects sharpness of vision and enables the human eye to perceive the contrast. Unequal distribution of brightness places increased demands on the adaptation ability of the human eye, the low contrast reduces the visual stimulation, causes eye fatigue and in this way it affects the performance efficiency of the employees at the workplace. Excessive brightness in the space causes an undesirable glare.

In industrial spaces the requirements of harmonious distribution of brightness are particularly relative to areas where visual quality control is performed, in laboratories, on workplaces with VDU or in the offices. To achieve an optimal distribution of brightness in the space means to begin with a correct organisation of the interior and its design. The types of the material and colour used are decisive. In general, it is recommended to use brighter colours because dark walls, ceilings as well as furniture have, in comparison to the brighter materials, a lower reflectance and therefore they can cause depressive feelings. An appropriate selection of the luminaire (ceiling or suspension lighting fixtures with direct distribution of the luminous flux) and their correct deployment are a key factor for the harmonious distribution of brightness.

The values of adequate harmonious distribution of brightness are defined by the european standard EN 12464-1. The standard recommends for the major interior diffusely reflecting surfaces following values: ceiling 0.7 to 0.9, walls 0.5 to 0.8, floor 0.2 to 0.4. According to the same standard, the reflectance of major objects (e.g. machinery) should be in the range of 0.2 to 0.7.
The european standard EN 12464-1 sets further values of the maintained illuminences on the major surfaces in small industrial spaces, such as laboratories, small rooms or offices, For the maintained illuminance of walls are stipuleted values of 50 lux with uniformity ≥ 0.10, for ceiling 30 lux with uniformity ≥ 0.10. In common spaces (e.g. corridors and staircase) the stipulated value for maintained illuminance for walls is 75 lux with uniformity ≥ 0.10, for ceiling 50 lux with uniformity of ≥ 0.10.

LQS awards 0 to 5 points based on illuminance level and its uniformity on room surfaces.

LQS VALUE

Harmonious distribution of brightness

Harmonious distribution of brightnees (contrast)	LQS Value
Em(wall)>150 lux with U_o>0.3 Em(ceiling>75 lux with U_o>0.3	5
Em(wall)>75 lux with U_o>0.3 Em(ceiling>50 lux with U_o>0.3	4
Em(wall)>75 lux with U_o>0.1 Em(ceiling>50 lux with U_o>0.1	3
Em(wall)>50 lux with U_o>0.1 Em(ceiling>30 lux with U_o>0.1	2
Em(wall)>30 lux with U_o>0.1 Em(ceiling>10 lux with U_o>0.1	1
Em(wall)<30 lux with U_o>0.1 Em(ceiling<10 lux with U_o>0.1	0

The harmonious distribution of brightness in a space can be influenced by a selection of luminaires. By using luminaires with direct distribution of the luminous flux (Figure 1-3) we don't achieve sufficient illuminance of vertical surfaces, which causes a cave effect. It can be avoided by using luminaires with a very wide luminosity curve. (Fig. 4).

LIGHTING REQUIREMENTS FOR INDUSTRY AREAS, TASKS AND ACTIVITIES EN 12464-1 AND EN 12464-2

Type of indoor, task or activity	Em[lux]	UGR_L	U_0	CRI
Heavy industry				
Production plants without manual operation	50	–	0.40	20
(Safety colours shall be recognisable)				
Production plants with occasional manual operation	150	28	0.40	40
Production plants with continuous manual operation	200	25	0.60	80
Slab Store	50	–	0.40	20
(Safety colours shall be recognisable)				
Furnaces	200	25	0.40	20
(Safety colours shall be recognisable)				
Mill train; coiler; shear line	300	25	0.60	40
Control platforms; control panels	300	22	0.60	80
Test, measurement and inspection	500	22	0.60	80
Underfloor man-sized tunnels; belt sections, cellars, etc.	50	–	0.40	20
(Safety colours shall be recognisable)				
Metal working and processing				
Mechanical and plant engineering				
Open die forging	200	25	0.60	80
Drop forging	300	25	0.60	80
Welding	300	25	0.60	80
Rough and average machining: tolerances ≥ 0.1 mm	300	22	0.60	80
Precision machining; grinding: tolerances < 0.1 mm	500	19	0.70	80
Scribing; inspection	750	19	0.70	80
Wire and pipe drawing shops; cold forming	300	25	0.60	80
Plate machining: thickness ≥ 5 mm	200	25	0.60	80
Sheet metalwork: thickness < 5 mm	300	22	0.60	80
Tool making; cutting equipment manufacture	750	19	0.70	80
Assembly:				
- rough	200	25	0.60	80
- medium	300	25	0.60	80
- fine	500	22	0.60	80
- precision	750	19	0.70	80
Galvanising	300	25	0.60	80
Surface preparation and painting	750	25	0.70	80
Tool, template and jig making, precision mechanics, micro-mechanics	1,000	19	0.70	80
Automotive engineering				
Automobile workshops				
Body work and assembly	500	22	0.60	80
Painting, spraying chamber, polishing chamber	750	22	0.70	80
Painting: touch-up, inspection	1,000	19	0.70	90
(4,000 K ≤ T_{CP} ≤ 6,500 K)				
Upholstery manufacture (manned)	1,000	19	0.70	80
Final inspection	1,000	19	0.70	80
General vehicle services, repair and testing	300	22	0.60	80
(Consider local lighting)				
Warehouse				
Store and stockrooms	100	25	0.40	60
(200 lux if continuously occupied)				
Dispatch packing handling areas	300	25	0.60	60

Type of indoor, task or activity	Em[lux]	UGR_L	U_0	CRI
Gangways: unmanned	20	–	0.40	40
(Illuminance at floor level)				
Gangways: manned	150	22	0.40	60
(Illuminance at floor level)				
Control stations	150	22	0.60	80
Storage rack face	Ev [lux]= 200	–	0.40	60
(Vertical illuminance, portable lighting may be used)				
Plastics industry				
Chemical industry				
Remote-operated processing installations	50	–	0.40	20
(Safety colours shall be recognisable)				
Processing installations with limited manual intervention	150	28	0.40	40
Constantly manned work stations in processing installations	300	25	0.60	80
Precision measuring rooms, laboratories	500	19	0.60	80
Pharmaceutical production	500	22	0.60	80
Tyre production	500	22	0.60	80
Colour inspection	1,000	16	0.70	90
(4,000 K ≤ T_{CP} ≤ 6,500 K)				
Cutting, finishing, inspection	750	19	0.70	80
Woodworking and processing				
Automatic processing e.g. drying, plywood manufacturing	50	28	0.40	40
Steam pits	150	28	0.40	40
Saw frame	300	25	0.60	60
(Prevent stroboscopic effects)				
Work at joiner's bench, gluing, assembly	300	25	0.60	80
Polishing, painting, fancy joinery	750	22	0.70	80
Work on wood working machines, e.g. turning, fluting, dressing, rebating, grooving, cutting, sawing, sinking	500	19	0.60	80
(Prevent stroboscopic effects)				
Selection of veneer woods	750	22	0.70	90
(4,000 K ≤ T_{CP} ≤ 6,500 K)				
Intarsia, inlay work	750	22	0.70	90
(4,000 K ≤ T_{CP} ≤ 6,500 K)				
Quality control, inspection	1,000	19	0.70	90
(4,000 K ≤ T_{CP} ≤ 6,500 K)				
Electrical and electronic industry				
Cable and wire manufacture	300	25	0.60	80
Winding:				
- large coils	300	25	0.60	80
- medium-sized coils	500	22	0.60	80
- small coils	750	19	0.70	80
Coil impregnating	300	25	0.60	80
Galvanising	300	25	0.60	80
Assembly work:				
- rough, e.g. large transformers	300	25	0.60	80
- medium, e.g. switchboards	500	22	0.60	80
- fine, e.g. telephones, radios, IT equipment (computers)	750	19	0.70	80
- precision, e.g. measuring equipment, printed circuit boards	1,000	16	0.70	80
Electronic workshops, testing, adjusting	1,500	16	0.70	80

Type of indoor, task or activity	Em[lux]	UGR_L	U_0	CRI
Printing				
Cutting, gilding, embossing, block engraving, work on stones and platens, printing machines, matrix making	500	19	0.60	80
Paper sorting and hand printing	500	19	0.60	80
Type setting, retouching, lithography	1,000	19	0.70	80
Colour inspection in multicoloured printing	1,500	16	0.70	90
(5,000 K ≤ T_{CP} ≤ 6,500 K)				
Steel and copper engraving	2,000	16	0.70	80
Foodstuffs industry				
Butchery				
Work stations and zones in: - breweries, malting floor, - for washing, barrel filling, cleaning, sieving, peeling, - cooking in preserve and chocolate factories, - work stations and zones in sugar factories, - for drying and fermenting raw tobacco, fermentation cellar	200	25	0.40	80
Sorting and washing of products, milling, mixing, packing	300	25	0.60	80
Work stations and critical zones in slaughter houses, butchers, dairies mills, on filtering floor in sugar refineries	500	25	0.60	80
Cutting and sorting of fruit and vegetables	300	25	0.60	80
Manufacture of delicatessen foods, kitchen work, manufacture of cigars and cigarettes	500	22	0.60	80
Inspection of glasses and bottles, product control, trimming, sorting, decoration	500	22	0.60	80
Laboratories	500	19	0.60	80
Colour inspection	1,000	16	0.70	90
(4,000 K ≤ T_{CP} ≤ 6,500 K)				
Bakery				
Preparation and baking	300	22	0.60	80
Finishing, glazing, decorating	500	22	0.70	80

Type of outdoor, task or activity	Em[lux]	GR_L	U_0	CRI
Petrochemical and power industry				
Pedestrian movements within electically safe areas	5	50	0.25	20
Handling of servicing tools, coal	20	55	0.25	20
Overall inspection	50	50	0.40	20
General servicing work and reading of instruments	100	45	0.40	40
Wind tunnels: servicing and maintanance	100	45	0.40	40
Repair of electric devices	200	45	0.50	60
(Use local lighting)				
Handling of servicing tools, utilisation of manually regulated valves, starting and stopping motors, lighting of burners	20	55	0.25	20
Filling and emptying of container trucks and wagons with risk free substances, inspection of leakage, piping and packing	50	50	0.40	20

Type of outdoor, task or activity	Em[lux]	GR_L	U_0	CRI
Filling and emptying of container trucks and wagons with dangerous substances, replacements of pump packing, general service work, reading of instruments	100	45	0.40	40
Fuel loading and unloading sites	100	45	0.40	20
Repair of machines and electric devices	200	45	0.50	60
(Use local lighting)				
Storage and logistics				
Short term handling of large units and raw materials, loading and unloading of solid bulk goods	20	55	0.25	20
Continuos handling of large units and raw materials, loading and unloading of freight, lifting and descending location for cranes, open loading platforms	50	50	0.40	20
Reading of addresses, covered loading platforms, use of tools, ordinary reinforcements and casting tasks in concrete plants	100	45	0.50	20
Demanding electrical, machine and piping installations, inspection	200	45	0.50	60
(Use local lighting)				
Construction sites				
Clearance, excavation and loading	20	55	0.25	20
Construction areas, drain pipes mounting, transport, auxiliary and storage tasks	50	50	0.40	20
Framework element mounting, light reinforcement work, wooden mould and framework mounting, electric piping and cabling	100	45	0.40	40
Element jointing, demanding electrical, machine and pipe mountings	200	45	0.50	40
Canal, lock, port, shipyard and dock				
Waiting quays at canals and locks	10	50	0.25	20
Gangways and passages exclusively for pedestrians	10	50	0.25	20
Lock control and ballasting areas	20	55	0.25	20
Cargo handling, loading and unloading	30	55	0.25	20
(For reading labels: Em = 50 lux)				
Passenger areas in passenger harbours	50	50	0.40	20
Coupling of hoses, pipes and ropes	50	50	0.40	20
Dangerous part of walkways and driveways	50	45	0.40	20
General lighting of shipyard area, storage areas for prefabricated goods.	20	55	0.25	40
Short term handling of large units	20	55	0.25	20
Cleaning of ship hull	50	50	0.25	20
Painting and welding of ship hull	100	45	0.40	60
Mounting of electrical and mechanical components	200	45	0.50	60

Em = average illuminance in lux (maintained value)

Ev = average vertical illuminance in lux (maintained value)

UGR_L = UGR unified glare rating limit (upper limit of glare)

GR_L = glare rating limit (upper limit of glare)

T_{CP} = correlated colour temperature

U_0 = uniformity

CRI = colour rendering index of lamps

EMOTION

The light is able to substantially affect the ability of people to perceive, to change their mood, to arouse a feeling of visual and psychological well-being and to regulate the human circadian rhythm. This knowledge has enlarged the perception of the task of artificial illumination by a new dimension. Its role today is not only to illuminate the space but also to be biologically effective.

The scientific research during recent decades has substantially changed the view at the task of illumination and its influence on people. Light is able to fundamentally affect not only people's ability to perceive things around but also to change the mood, to arouse a feeling of comfort or vice versa discomfort and to regulate the human circadian rhythm. All this knowledge has enlarged the perception of the task of the artificial illumination by a new dimension – to be biologically active. When designing a lighting solution of an industrial space it is from understandable reasons inevitable to take into account both requirements equally. With proper illumination of the space we can achieve the visual and psychological well-being of the employees without any negative influence on their regeneration capabilities. Extensive scientific research and demonstrated, that higher illuminance level can influence the productivity of employees in the positive way and at the same time it can decrease the risk of accidents. The results of the mentioned research shows, that by illumination level of at least 500 lux grows the productivity of employees by 40 %, and the risk of accidents decreases by 66 %. A very important discovery, that should be taken into account when designing a lighting solution for a production areas is, that the demands on illumination level proportionally increases with increasing age of the employees. The eyes lose permeability and the average pupil width decreases. This creates the need for more light in any environment. A 60-year old employee requires double more light as his 20-year old colleague to see clearly. Even employees over the age of 35 have a greater need for light than 20-year old.

LQS has a holistic approach to the illumination of spaces. It perceives its solution as a whole, with the goal to copy the properties of the natural light as truthfully as possible.

LQS VALUE

Biological factor of illumination

Biological factor of illumination	LQS Value
availability of daylight	0/1 (No/Yes)
blue light content	0/1 (No/Yes)
daylight simulation	0/1 (No/Yes)
dynamic lighting	0/1 (No/Yes)
tunable white	0/1 (No/Yes)

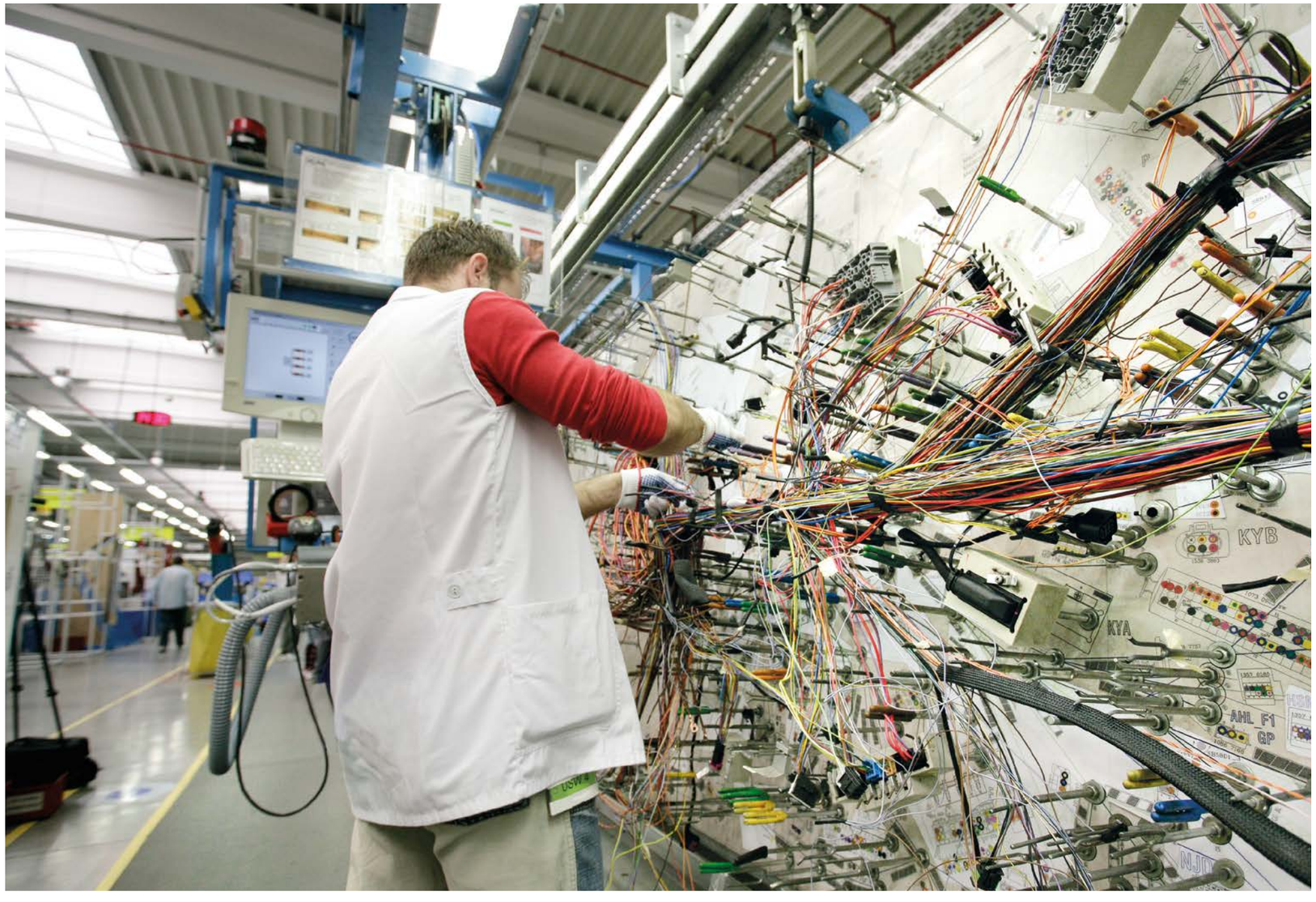
A very important discovery is, that the demands on illumination level proportionally increases with increasing age of employees.

BIOLOGICAL FACTOR OF ILLUMINATION

AVAILABILITY OF DAYLIGHT

Working people spend a great part of their life in closed spaces. That is the reason why the quality of the artificial light is attributed extraordinary importance. As we have already mentioned on several pages, the scientific research has unambiguously confirmed the positive impact of the natural light on the feeling of people's visual and psychological well-being, their performance efficiency, the ability to concentrate and last but not least also the ability to regenerate. Many industrial spaces have to deal with limited availability of daylight, therefore a proper artificial lighting has the highest importance.

The most important moment when planning the illumination for any space is a correct solution, the luminaire type itself is of second-rate importance, if it is able to ensure the required result. In general, it is valid that the human eye responds best to large continuous illuminated surfaces and the white diffused light reflected from the ceiling and walls. This type of illumination simulates the properties of the natural light in the best way.



BLUELIGHT CONTENT

Revealing the function of the third type of receptors in the human eye belongs among the biggest discoveries of the modern science. They are able to affect the production of melatonin, a hormone controlling the circadian rhythm of people. These receptors are sensitive to that part of the light spectrum which has the wavelength of 464 nanometres, i.e. the blue light. This knowledge became the basis for the luminaire producers – the lighting fixtures with a proper proportion of the blue part of the artificial lighting spectrum are able to affect the human activity effectively. The correct ratio of the blue light in the light spectrum from an artificial light source can stimulate the performance of the employees.

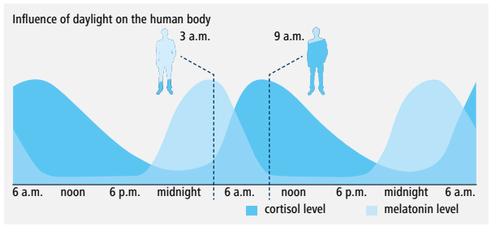
The workplaces with a three-shift operation represent a challenge where a sufficient amount of the blue light is able to adjust the biorhythm of those employees who are working during the night.

From this point of view especially the workplaces with a three-shift operation represent a challenge where a sufficient amount of the blue light is able to adjust the biorhythm of those employees who are working during the night shifts. A shortage of blue light component in the illumination will stimulate production of melatonin which signals to the human organism that there is time for rest and induces an increased need of sleep. This leads to lost of concentration, reduced performance and can cause injuries.

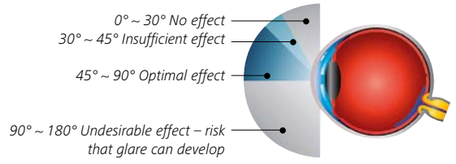
On the contrary, in appropriate lighting conditions the human body begins to secrete serotonin, which mediates to the employees a sense of excitement and in this way enhances their performance. A suitable lighting solution can be achieved by using luminaires with light sources producing a light with a correlated colour temperature of 6,500 K.

3,000 K

6,500 K



During morning hours the human organism produces the hormone cortisol which stimulates metabolism. Its concentration in blood reaches its maximum at about 9 a.m., then during the rest of the day its content continually decreases. Melatonin, also called the hormone of sleep, is produced by the human organism also during the night and its concentration in the human organism culminates at 3 a.m.



The third type of the photoreceptors in the human eye is sensitive to that part of the light spectrum which has the wavelength of 464 nanometres, i.e. the blue light. These receptors have influence on creating melatonin, a hormone controlling the circadian rhythm of people.

Melatonin
Melatonin makes us feel drowsy, slows down bodily functions and lowers activity levels to facilitate a good night's sleep. It also ensures that a large number of metabolic processes are wound down. Body temperature falls; the organism, as it were, is put on the back burner. In this phase, the body secretes growth hormones that repair cells at night.

Cortisol
Cortisol is a stress hormone, produced from around 3 a.m. onwards in the adrenal cortex. It stimulates metabolism again and programmes the body for day-time operation. The first light of the day then stimulates the third receptor in the eye and suppresses the production of melatonin in the pineal gland. At the same time, the pituitary gland makes sure the body secretes more serotonin.

Serotonin
Serotonin acts as a mood-enhancing, motivating messenger. While the level of cortisol in the blood falls during the day in a counter-cycle to melatonin, serotonin helps us achieve a number of performance peaks. When daylight fades, the internal clock switches to night.

However, if our body does not get enough light during the day, it produces only a low level of melatonin. As a result, we sleep badly, we wake feeling unrested, we are tired during the day and lack energy and motivation. Insufficient exposure to stimulating light during autumn and winter can turn the process into a downward spiral. At that time of year, some people develop seasonal affective disorder (SAD). Their internal clock misses its cues because the hormonal balance in the brain is upset.

The natural daylight is not monotonous. It changes its properties not only in dependence on the season of the year but it is also dependent on the cloudiness during the day.

DAYLIGHT SIMULATION

As we have mentioned several times, the scientific research confirmed that the daylight is the most natural type of light for people. The effort to adapt the artificial lighting to its properties results from this knowledge. That is the reason why, when designing the light system in the industrial spaces, we utilise the function of daylight simulation. The natural daylight is not monotonous. It changes its properties not only in dependence on the season of the year but it is also dependent on the cloudiness during the day. Its intensity and colour change during the day. All these factors affect our perception of the space and objects inside of it.

The daylight simulation can be achieved by various methods with the same goal: to achieve such an intensity and light colour that copies the properties of the daylight as truthfully as possible. At the beginning of the working hours higher illuminance with a high proportion of the cold light that will energise to a higher performance is desirable. On the contrary, during the lunch time it is suitable to increase the colour temperature and to strengthen the feeling of employees' relaxation. The afternoon decline can be avoided by increasing the proportion of the cold light which is replaced by warmer tones preparing the human organism for rest at the end of the working hours.

The goal of the daylight simulation is to achieve such a light intensity and colour that copies the properties of the daylight as truthfully as possible.

The daylight simulation is often implemented with the daylight sensor that assesses the lighting intensity in the room during the day and according to this it increases or reduces the luminaire output in the light system. In this way constant illuminance of the space in compliance with the standard is ensured during the whole day.

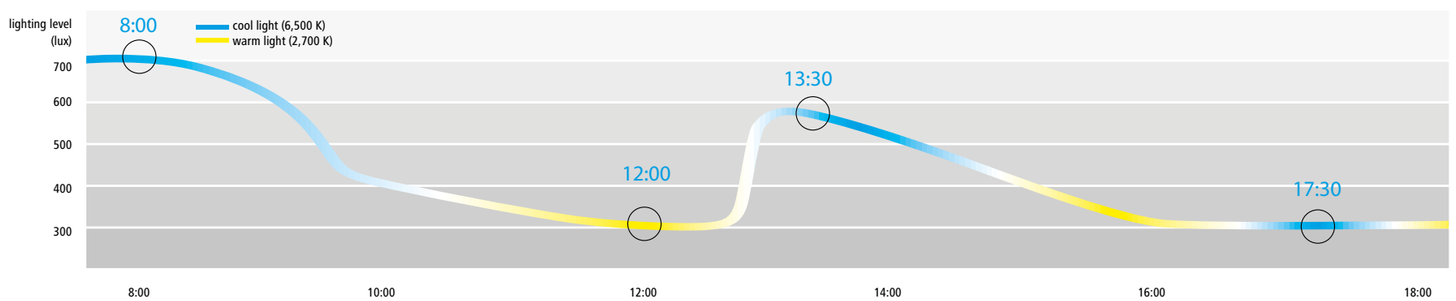
An assumption for simulating the daylight in the industrial spaces is the utilisation of the luminaires with the function dynamic light which can change the lighting intensity and tunable white technology which allows altering the correlated colour temperature in the room. The dynamic lighting in the luminaire is ensured by the DALI driver which is able to switch on or dim the light source from the value from 10 to 100 %. The function of the tunable white is ensured by two light sources radiating the light with different correlated colour temperature (cool white 6,500 K and warm white 2,700 K). Through changing the output of individual light sources we can achieve various levels of the white colour temperature. E.g. at a 50 % performance of both light sources the luminaire radiates neutral light with correlated colour temperature 4,000 K. This solution enables creating illumination of the workplace that corresponds to its task and emotional state we want to evoke in the persons who are present.

Good morning
Cool, fresh light raises the energy level of people coming into the workplace and provides a good start to the day.

Lunch time
A short rest helps us to recharge out batteries. The light level decreases and the warm light facilitates relaxation.

Post-lunch dip
After lunch,we usually feel sleepy. The light level rises again and changes to cool white to counter the „post lunch dip".

Happy hour
Just before the end of the working day a change to cooler white light provides an alertness boost ahead of the journey home. For people working late, warm white light creates a pleasent „homely" atmosphere.

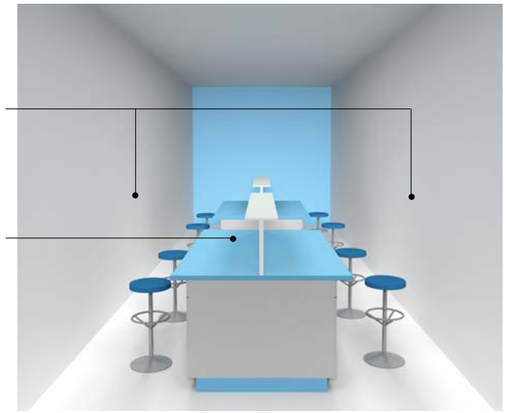


ILLUMINATION OF ROOM SURFACES

The recommended lighting of surfaces in the industrial space is bound to the general lighting of the workplace. In industrial areas, the importance of adequate vertical illuminance increases in terms of safety and smooth implementation of the work. Proper lighting of vertical surfaces is especially important where oversized machinery is used and by supervisory and control work.

Vertical Illumination

The vertical illumination which is based on the ability of the human eye to respond to the light falling from above plays an important role for the lighting of an industrial space. Using luminaires emphasising the vertical surfaces, we achieve optical brightening and appropriate visibility in production halls with oversized production machines or at the workplaces, where constant surveillance is required. It will enable the employees to recognise shapes and faces better, it will make their orientation in the space and reading numerical values at the machines easier. The vertical illuminance should achieve 50 % of the working place's horizontal illuminance value. LQS assesses the spaces with satisfactory illuminance with 5 points. A LED luminaire with a strongly asymmetric radiation characteristic can be a suitable type of lighting fixture that meets the demands on vertical lighting of the walls in the production halls. If placed correctly, the photometric luminaire characteristic will ensure a very uniformly illuminated wall almost from the top to the bottom.



By a correct ratio of the illuminance of all surfaces in the room we can prevent both the psychological and eye fatigue and damaging the human sight as well.

LQS VALUE

Vertical illumination

Vertical illumination	LQS Value
$Ev_{avg} > 0.5\ Eh_{avg}$ (Wall LG7) $Ev_{avg} > 150$ lux	5
$Ev_{avg} > 0.5\ Eh_{avg}$ (Wall LG7)	4
$Ev_{avg} > 0.4\ Eh_{avg}$	3
$Ev_{avg} > 0.3\ Eh_{avg}$	2
$Ev_{avg} > 0.1\ Eh_{avg}$	1
$Ev_{avg} < 0.1\ Eh_{avg}$	0

ECOLOGY

ECO
FRIENDLY

The ecology and ecological solutions respecting the fragile equilibrium of the environment are important topics which have become key values across the whole industrial spectrum during the last decades. The manufacturers of the luminaires and light sources are no exception in this area.

Together with awareness of the limited character of the energy sources that causes the permanent increase of their prices, taking into account the ratio of the luminaire or light source effectiveness and the energy consumed the trend is coming to the foreground.

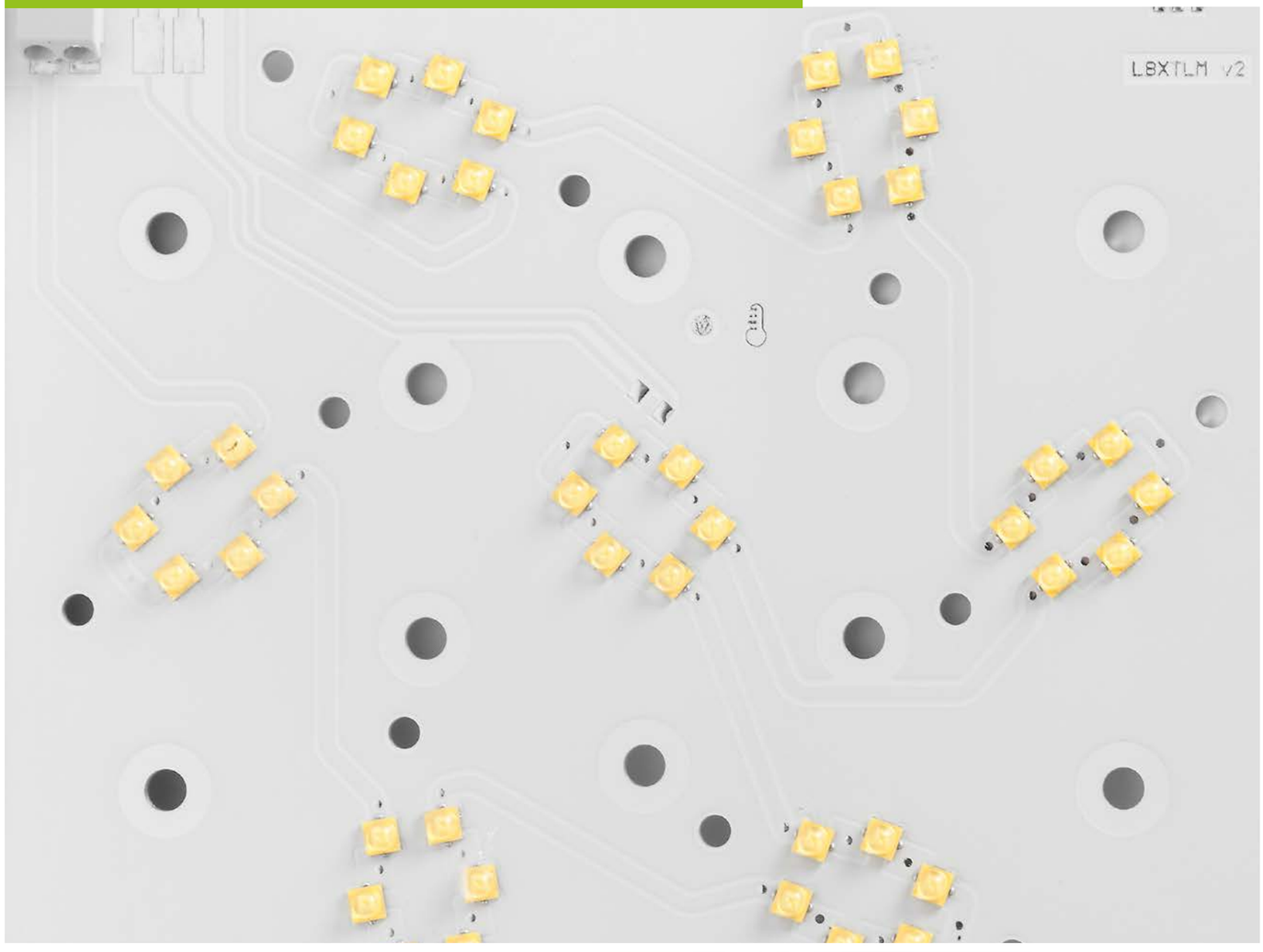
Also in this line of business the demands on efficient utilisation of energy, the recyclability and long life of the products constantly rise. In the area of manufacturing the luminaires and the light sources, the effectiveness of the light sources, the effectiveness of the luminaires and their impact on the environment are more and more emphasised. These are categories which, besides the ecological approach, contain a substantial potential for energy savings and in this way also reducing the operating costs. For the developers and architects of the industry buildings and production halls just this factor is the source of the strongest motivation when designing the light systems. Categories which are relevant from the point of view of ecology are: latest lamp technology, system efficacy of luminaire, dangerous material content, thermal output of a lamp, and finaly – product lifetime and maintenance costs.

The trend heads to manufacturing more effective and economical types of the existing light sources.

LATEST LAMP TECHNOLOGY

The times when the whole world applauded Thomas Alva Edison for the discovery of the light bulb are irrecoverably over. Although he made his mark on history forever as the inventor of artificial light, other scientists and inventors came after him and they shifted and are still shifting the development by leaps and bounds ahead.

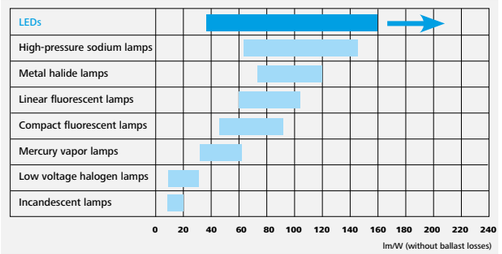
With the knowledge about the limitedness of the energy sources which causes permanent increase of their prices, the trend taking into account the ratio of effectiveness of the luminaire or the light source and the consumed energy is coming to the foreground. As late as three years ago, the metal-halide lamps especially met these requirements but even they are retreating in favour of the light emitting diodes – LED. Compared to the conventional sources the LEDs achieve better parameters in any respect: they are more effective, they emit a negligible amount of heat, they place lower demands on the consumption of electrical energy, they do not contain mercury and so they are more ecological. In the area of manufacturing the light sources just LEDs represent a category which currently progresses most quickly. Up to 90 % of all innovations today take place in the category of the light sources LED. Of course, the development and production of the conventional light sources has not been stopped but they progress more slowly. However, also here it is valid that the trend heads especially to manufacturing more effective and economical types of the existing light sources. The original types are replaced by the eco and long-life fluorescent lamps or metal-halide lamps with ceramic burner of the second generation.



The main indicator for selecting an optimal light source which the designer of the lighting system in an industrial or production hall has to follow is the efficacy of the light source. Its value shows with what effectiveness the electric power is changed into light, i.e. how much of the luminous flux (lm) is produced from the input power (W) delivered to the light source. The unit is lumen per watt (lm/W). The LED light sources achieve the best parameters also in this category. Currently the LED chips with efficacy of 160 lm/W at cool white CCT, are commercially available, however, in the lab conditions the value of 254 lm/W has already been achieved.

The higher price of the LED luminaires is the reason why they have not replaced the lighting fixtures with conventional light sources in spite of the fact they are clearly of higher quality. But also this factor is to be viewed in a wider context. Although the initial costs for purchasing the LED luminaires will always be higher, the return on investment in the form of energy savings during the whole luminaire life time and practically no maintenance costs make the LED luminaires extraordinary commercially interesting. From this point of view the retrofits where we only change the conventional light source for a more modern type prove to be only temporary and from a long-term point of view it is also a loss-making solution.

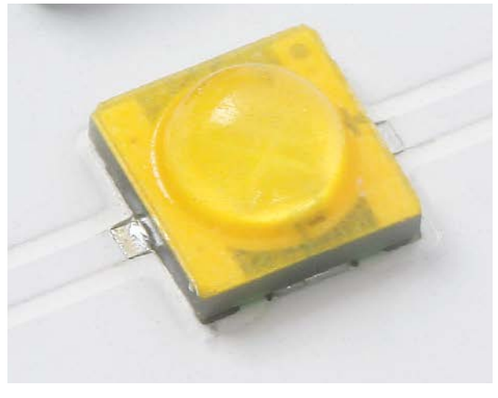
EFFICACY OF LIGHT SOURCES

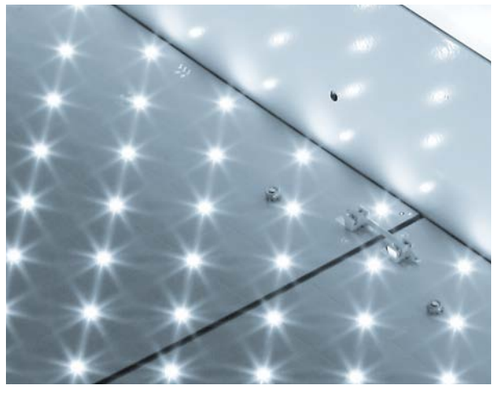


LQS VALUE

Latest lamp technology

Latest lamp technology	LQS Value
η > 100 lm/W	5
η > 90 lm/W	4
η > 80 lm/W	3
η > 70 lm/W	2
η > 60 lm/W	1
η > 50 lm/W	0





The materials used for luminaire production have the biggest influence on its efficiency.

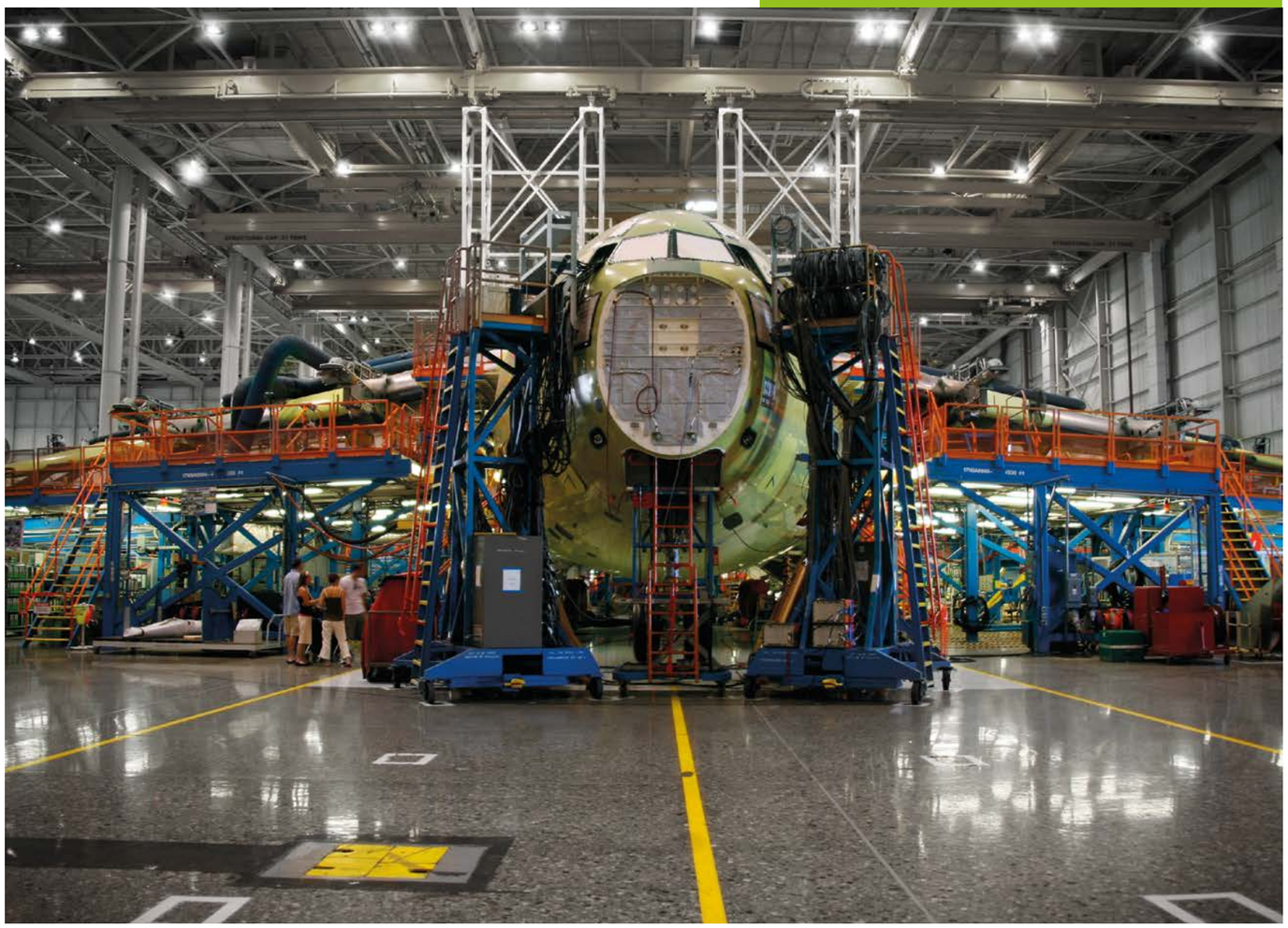
SYSTEM EFFICACY OF LUMINAIRE

The luminaire efficacy factor determines how effectively the lighting fixture itself is able to direct the light from the light sources with the smallest possible losses on the surfaces of the optical system. It is expressed as ratio of the lumen output of luminaire and installed power of luminaire. The light output ratio (LOR) expresses the ratio of the luminous flux flowing from the luminaire and the sum of the luminous fluxes of all light sources in the system.

$$LOR = \frac{\text{Lumen output of luminaire}}{\text{Lumen output of lamps}} \times 100\ \%$$

This value can be divided into the upward and downward ratio that expresses how many percent of the luminous flux from the luminaires heads to the upward and downward space (i.e. over and under the luminaire). This is of special importance for those spaces which place high demands on the illumination of the ceiling.

$$\text{System efficacy of luminaire} = \frac{\text{Lumen output of luminaire}}{\text{Installed power of luminaire}} \left[\frac{\text{lm}}{\text{W}}\right]$$



The materials used for luminaire production have the biggest influence on its efficiency. The luminous materials enable changing the distribution of the sources´ luminous flux, diffusing the light or changing the spectral composition. They are divided into reflective and permeable ones. Aluminium, using various surface finishes, creates the predominant part of the reflective materials for manufacturing reflectors.

The most commonly used permeable materials are glass and plastics. Aluminium, glass, plastics, steel have different reflectance and capability to absorb light. However, in general it is valid that the more effective the materials used in the optical system are, the lower the losses on these surfaces will be as well as the luminaire efficiency being higher.

Besides the used material themselves the luminaire efficiency is also affected by the design or the shape of the optical system. A correctly designed luminaire reflects the largest amount of light to the surroundings at minimal losses. The optimal mathematical and physical geometrical shapes of the lighting fixture can be calculated by modern computer systems.

LQS VALUE

System efficacy of luminaire

System efficacy of luminaire	LQS Value
η > 80 lm/W	5
η > 70 lm/W	4
η > 65 lm/W	3
η > 55 lm/W	2
η > 40 lm/W	1
η > 30 lm/W	0

The materials used for luminaire production have the biggest influence on its efficiency. The luminous materials enable changing the distribution of the sources´ luminous flux, diffusing the light or changing the spectral composition.

THERMAL OUTPUT OF LAMP

The light spectrum visible for the human eyes is between the ultraviolet (UV) and infrared (IR) spectrum. In spite of the fact that the human eye is not able to catch the infrared radiation, it perceives it as radiant heat. Every object that is exposed to such radiation is constantly strained. However, the majority of the light sources used radiate this part of the spectrum in various extents. The lower the value of the radiated IR is, the more effective the light source is. From this point of view, on the bottom of the scale as the least efficient, there are the usual light bulbs which change up to 95 % of energy into heat and only remaining 5 % into visible light.

In the industrial and production areas with air-conditioning the light sources with a high IR radiation percentage are a sufficiently big load for the electric power consumption. The heat from the non-effective sources continually heats the air in the closed space cooled by the air-conditioning – this fact is connected with the need for a higher performance of the air conditioning. It is approximately valid that for 2.5 W of the luminaire energy 1 W of the air-conditioning energy is used, i.e. if the energy consumption of the lighting system increases, the energy consumption for the air-conditioning operation grows in direct proportion also. The user of the industrial spaces illuminated by outdated light sources is burdened by increased costs not only for the energy needed for the operation of the light system but also for the air-conditioning.

From this point of view the installation of luminaires with light sources creating the minimal percentage of the IR radiation is considered the most economical. These requirements are currently reliably fulfilled by the latest LED light sources that radiate only a negligible amount of the IR radiation.

LQS assesses with the highest number of points those light systems which on average do not exceed 15 % proportion of the IR radiation in the overall radiated spectrum. This assessment is fulfilled especially by the LED light sources.

LQS VALUE

Thermal output of lamp

Thermal output of lamp	LQS Value
< 15 % proportion of IR radiation	5
< 26 % proportion of IR radiation	4
< 28 % proportion of IR radiation	3
< 31 % proportion of IR radiation	2
< 60 % proportion of IR radiation	1
> 60 % proportion of IR radiation	0

ECO FRIENDLY

DANGEROUS MATERIAL CONTENT

The vision of danger in connection with luminaires and light sources for common people is connected with the risk of cutting by a broken bulb. As a matter of fact, the risks connected with using some types of the light sources are much more serious and can have an impact on the people's health as well as on the quality of the environment.

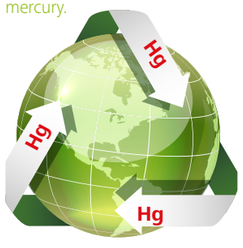
The reason is the mercury content, a heavy metal with high toxicity, which is an inevitable part of the fluorescent lamps and metal-halide lamps. In spite of extensive scientific research, until now we have not revealed a material which would replace the task of mercury in the light sources. The solutions which would not represent any risk from the point of view of safety are extremely costly and therefore unsuitable for the mass market.

The task of mercury in some types of the light sources remains thus irreplaceable. When the luminaire is switched on, a discharge arises during which ionisation of the mercury atoms develops and they subsequently emit ultraviolet radiation. This radiation excites the phosphorus molecules spread on the internal side of the fluorescent lamp and during their return to the original state they emit photons of visible light. The risk connected with the light sources containing mercury does not consist in their common usage. It arises when they are broken during handling or they are not disposed in compliance with legislation which defines the method how the used and damaged light sources containing toxic substances are to be removed.

In the first case there is a threat that the mercury vapours can leak to the air which in dependence of the number of disrupted sources, the size of the room and method of airing can cause the employees at the workplace short-term health problems (nausea, anxiety). In the second case, when disposing the toxic waste inadequately, it represents a long-term risk of soil contamination, as the heavy metals do not decompose and become a permanent part of the environment.

The designers of the lighting system for industrial areas should also take into account the ecological potential of the light sources when they select them. The new types of the fluorescent lamps marked "eco" contain a smaller proportion of mercury than the older types. However, from the point of view of safety the LED light sources are undoubtedly considered the least dangerous option.

LQS assesses the light sources according to the mercury content and the highest score – 5 points are assigned to the light sources with no content of mercury.



PRODUCT LIFETIME AND MAINTANANCE COSTS

When designing a lighting system of an industrial and production area one of the key factors the architect and developer should take into account is the lifetime of the light source and the costs for its maintenance.

When the general awareness of the unsuitable parameters of the common light bulb arose, the most spread reason for replacing this light source by fluorescent lamps was just its longer lifespan. The high quality fluorescent lamps can really achieve a lifespan of up to 24,000 hours but many disadvantages, not visible at first sight, are connected with their usage.

These light sources wear off rapidly when they are frequently switched on and off. Therefore their placement e.g. in a corridor with an installed movement detector (most frequently due to saving of electric power) is not the best solution, just because of the shortened lifespan. The user of the space is then burdened by the costs not only for the purchase of the replacement light sources but also for activities connected with maintenance and service of the lighting system. Further indirect costs aroused by the need to make the space of the industrial area accessible during maintenance operations and not to restrict the everyday operation of the individual workplaces are connected with a more frequent replacement of the light sources.

Compared to the light bulbs the LED light sources represent at the first sight a more costly solution. Their price compared with the conventional light sources is really higher; however, their utilisation in the lighting system is profitable for several reasons. Their first and the biggest advantage is the extremely long lifetime reaching more than 50,000 hours and it represents at 11 hours operation time 250 days during the year approximately 18 years. In the case of LED the end of the lifetime is given by the decrease of the light source output to 70 % (in some cases 50 %). At the same time they are light sources which show an extremely low failure rate, only two LED sources pre million pieces produced. The regular costs for their replacement and maintenance are thus removed. By adding the functionality lighting management system into the lighting system we can reduce the need of the manual control which is also considered a certain type of maintenance. The long lifetime and minimal demandingness in the area of maintenance in combination with energy economy make the LED light sources an ideal solution when designing the lighting system in the industrial areas and production halls.

When taking into account all relevant criteria, LQS assigns the highest score for the parameter "product lifetime" and the "costs for maintenance" just to those light sources with the lifetime of or higher than 50,000 hours.

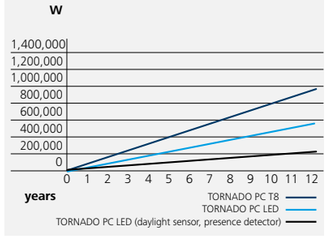
LQS VALUE

Dangerous material content

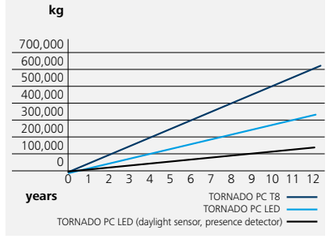
Dangerous material content	LQS Value
mercury content 0 mg	5
mercury content < 0.5 mg	4
mercury content < 1.5 mg	3
mercury content < 2.4 mg	2
mercury content < 5 mg	1
mercury content > 5 mg	0

	TORNADO PC T8	TORNADO PC LED	TORNADO PC LED (daylight sensor, presence detector)	
type of light source	FD (T8)	LED	LED	
power consumption	36	51	51	W
number of light sources in luminaire	2	1	1	pcs
control gear	CCG	ECG	ECG	
type of lighting control	none	none	daylight sensor + presence detector	
lifetime of light source	15,000	50,000	50,000	hours
power consumption of luminaire	90	51	30	W
luminous flux	6,700	5,100	5,100	lm
LOR	74	100	100	%
luminaire light output	4,958	5,100	5,100	lm
number of luminaires	200	200	200	pcs
average time when luminaire switch on between 6.00 – 18.00	12	12	12	hours
average time when luminaire switch on between 18.00 – 6.00	5	5	5	hours
number of days in week when luminaire switch on	5	5	5	days
price for electrical energy	0.18	0.18	0.18	€/kW/hour
purchase price of luminaire	34.3	180	190	€
purchase price of light source	2	0	0	€
purchase price of service hour	20	20	20	€
time needed for the exchange of one source	0.25	0.25	0.25	hours
COOLING ENERGY				
cooling system usage factor	0	0	0	%
cooling efficiency	2.5	2.5	2.5	Wh/Wc
purchace for initial instalation	7,660.00	36,000.00	38,000.00	€
Number of maintenance required per 12 years	3	1	1	
Maintenance fee	1,800.00	0.00	0.00	€
power consumption of luminaire	90.00	51.00	30.00	W
power consumption of cooling system	0.00	0.00	0.00	W
completly power consumption of room	18,000.00	10,200.00	6,000.00	W
consumption of el. energy for day	306.00	173.40	70.08	kWh
month	6,648.21	3,767.32	1,522.57	kWh
year	79,778.57	45,207.86	18,270.86	kWh
production of emission CO_2 per year	51,058.29	28,933.03	11,693.35	kg
price for el. energy per day	55.08	31.21	12.61	€
month	1,196.68	678.12	274.06	€
year	14,360.14	8,137.41	3,288.75	€
difference between input costs		28,340.00	30,340.00	€
saving difference per year - power consumption		-6,222.73	-11,071.39	€
saving CO_2 per year		-22,125.26	-39,364.94	kg
payback excluding maintenance		**4.6**	**2.7**	**Years**
payback including maintenance		**4.3**	**2.8**	**Years**

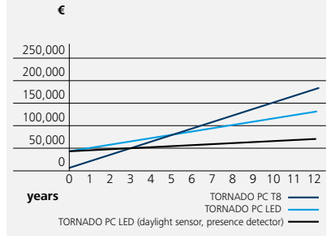
POWER CONSUMPTION OF LIGHTING INSTALLATION



PRODUCTION OF CO_2



OPERATING COSTS AND PAYBACK TIME



LQS VALUE

Product lifetime & maintenance costs

TProduct lifetime & maintenance costs	LQS Value
≥ 50,000	5
> 24,000	4
> 19,000	3
> 12,000	2
> 10,000	1
≥ 2,000	0

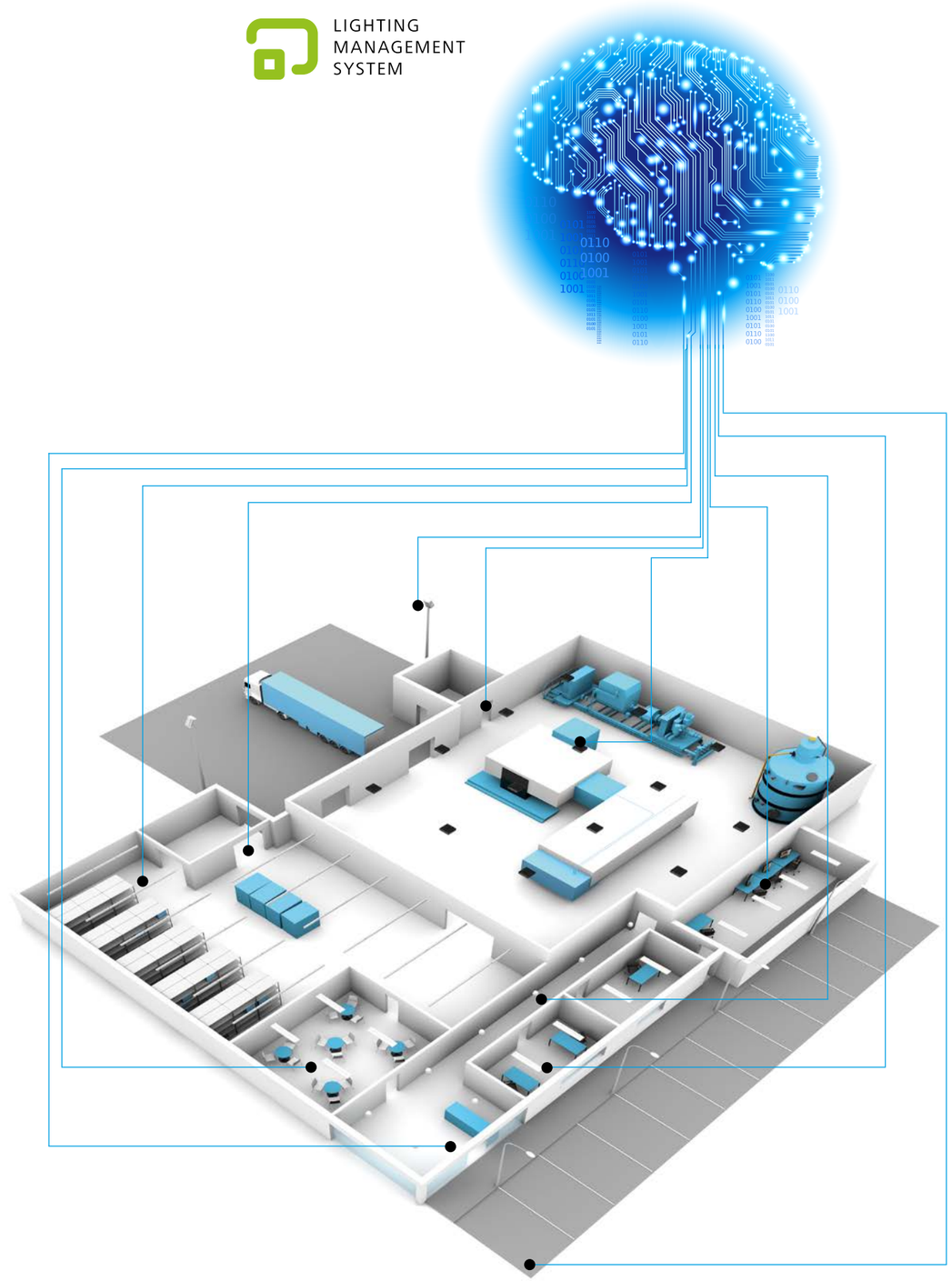
EFFICIENCY

The industrial buildings represent spaces with a complex infrastructure. They are energy-intensive objects in the framework of which the lighting has to work economically and at the same time it has to be designed in such a way that it will flexibly respond to the change of the manufacturing processes. The lighting system in these premises should functionally integrate the artificial and daylight; it should be biologically effective and should positively affect the employees´ performance efficiency. Its optimal functionality can be achieved by implementing suitable management tools. A comprehensive overview of available methods and lighting management systems, including an overview of the technical specifications is contained in specialized brochure SLE Lighting Management System.

In the time period when we face continual growth of the energy prices, the decision of the owners and operators of the industrial objects to integrate the management tools into the lighting systems is most frequently motivated by the vision of the financial savings for the consumed power. The potential of the financial savings is, however, only one parameter which improves the efficiency of the lighting systems. Through implementing suitable tools of the lighting management system the owners contribute to reducing the CO_2 emissions to the air and at the same time they can make profit from other not negligible advantages – especially the management comfort, autonomous character and flexibility of the lighting system.

The comfort of the lighting system is defined by two basic parameters. The first parameter is the tailor-made system functionality itself for the given space, the other one are the control elements which carry out the management itself. The task of these control elements is to simplify the management process. The more sophisticated the control elements included to the management are, the greater comfort to the lighting system owner is brought. In an ideal case it can be controlled by a remote control, tablet or through internet from a remote computer. The autonomous character of the lighting system is ensured by the automatic control. A fully autonomous system works without any forced interventions of the user.

The priority task of the management system's automation is to exclude the failure of the human factor. An autonomously working lighting system is a benefit especially for the spaces with a large potential of saving the electrical power where it is not possible for the space users to know or to be able to operate the system of luminaires. It finds a wide implementation in the manufacturing and warehousing premises. The requirement on the flexibility of the lighting system in the industrial sphere belongs to one of the most fundamental criteria. Due to the variedness of the working activities the requirements on the illumination often change in this type of spaces. Through implementing suitable management tools using the light scenes or firmly adjusted time schedules the existing lighting system can flexibly adapt to the actual needs without any necessity to change the luminaires or wiring.



The task of the artificial lighting is to balance the differences and to complete or to replace in full extent the natural light when its availability is limited.

AUTOMATIC CONTROL

The automatic control includes comfort with maximal savings of electricity and CO_2. It represents the most effective type of management in the industrial objects as they are spaces where it is not suitable for the change of the lighting to be always brought about by the user. An appropriately designed, installed and adjusted lighting system guarantees that we always have so much light as it is really necessary for the currently carried out activity. The automatic control is divided into the control based on the lighting intensity, movement or time and just the combination of the first two regulation methods is the most advantageous solution.

DAYLIGHT SENSOR

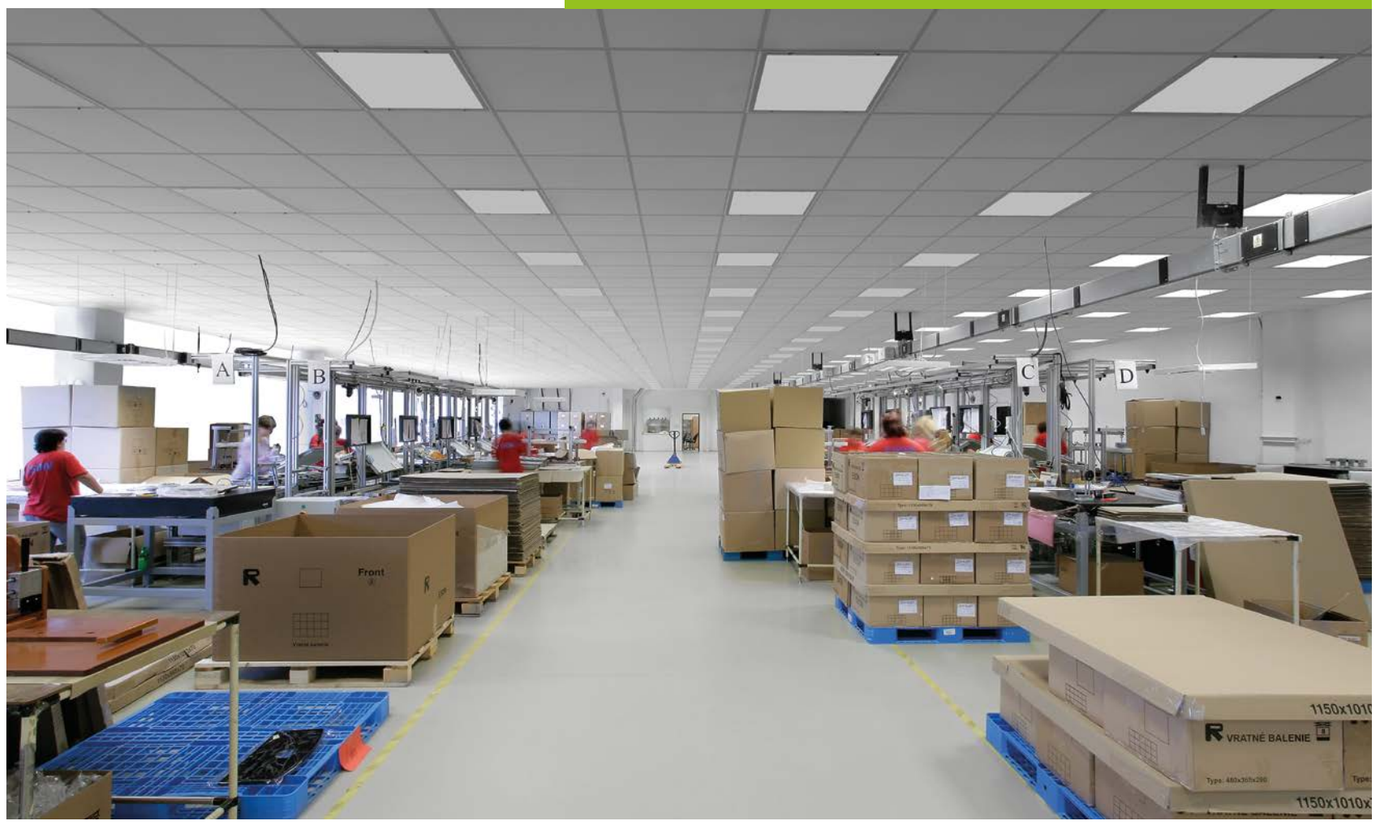
It is especially suitable to use the automatic control based on the luminance intensity in the industrial premises with availability of the daylight. In principle it is valid that the greater the share of the daylight in the concrete space is, the higher the effectiveness of this management is and it can achieve up to 60 % energy saving.

The daylight sensor is the core of the system. It scans the light reflected from the scanning plane from the surface under the sensor. The daylight sensor functionality is stressed by the fact that in the area with the daylight availability the natural light and artificial lighting complete each other. If the share of the daylight decreases, the luminance sensor records it and increases the intensity of the artificial lighting. And vice versa, if there is enough daylight in the space, it is able to reduce the intensity of the artificial lighting or to dim the luminaires up to a value of 0 %. When the scanned zone is covered correctly, the sensors can ensure that there is always so much light as necessary and the luminaires will not emit light of an unnecessarily high intensity.

Controlling the luminaires based on the luminance intensity is carried out fully automatically and besides saving the energy it also increases the user comfort.

From the design point of view the sensors for scanning the luminance are produced in various designs – for installing in the ceiling, for ceiling surfacing, for placing directly into the luminaire or for anchoring on the fluorescent light source. From the point of view of functionality and the way of utilisation the daylight sensors can be divided into the local and global ones. In the manufacturing and warehouse premises both types are used in dependence on the overall character of the space.

In the manufacturing halls with a standard height of ceilings without any skylight we recommend to implement a local sensor for every workplace. In this way we achieve accurate lighting regulation to the required luminance intensity in the space. The disadvantage of the local sensors is that they are not able to scan the light conditions from the workplaces where the properties of the reflection surface are often changed or materials with high reflectance are used. The local sensor also responds to the short-term changes of the luminance intensity and this fact is negative for regulating the artificial lighting. In this case we recommend using the global luminance sensor in the space. The global luminance sensor finds its place in the manufacturing and warehouse spaces with high ceilings and skylights where it is impossible to implement the local daylight sensors. The global sensor subsequently scans the lighting intensity in the whole space. For the sensor to scan the light conditions correctly, it is necessary to locate it appropriately. In the skylight space we recommend to install the sensor closely under the skylight. In difference to the local sensors the global sensor represents a guarantee of a more stable regulation. However, at the same time it is not able to record the failures of individual luminaires or any reduction of their luminous flux due to ageing and this fact can cause inaccurate regulation of the lighting system.



The light conditions change during the day in dependence of the time of the day, weather and the season of the year. The task of the artificial lighting is to balance the differences and to complete or to replace in full extent the natural light when its availability is limited.

50 % of power consumption

75 % of power consumption

100 % of power consumption

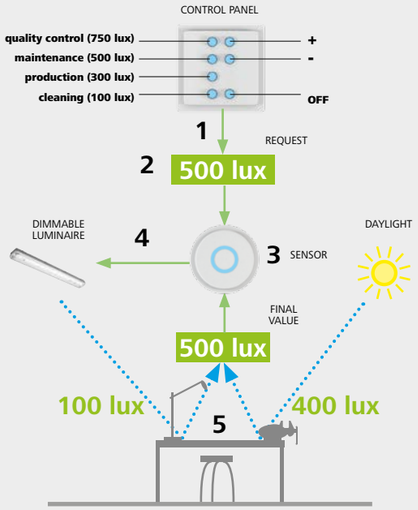
LQS VALUE

Daylight sensor

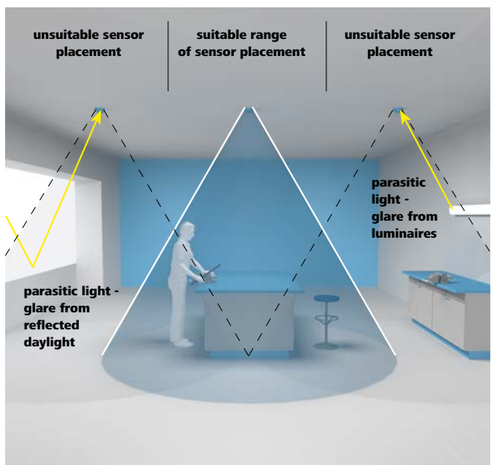
Daylight sensor	LQS Value
Yes	2
No	0

Comparison: global vs. local system	Global sensor system	Local sensor system
Accuracy of measurement	++	–
Constancy of illumination	++	–
Suggestibility by lighting effects	++	–
Undisturbed room design	++	+
Restrictions in relation to installation	++	+
Installation costs	++	+

When implementing the control functionality based on the luminance intensity to the industrial spaces it is necessary to take into account the fact that in the spaces with daylight availability (with windows, skylight) the luminance intensity in individual parts of the premises achieves different values. This irregularity is aroused by the sunshine which is stronger in the window area than in the remaining part of the space. This problem can be removed by the systems enabling to control the luminaire system with the offset function thanks to which it is possible to ensure the uniform distribution of the lighting intensity in the whole room. Two groups of luminaires, one by the windows and the other in the space more remote from the windows are the basis of such a system. When the daylight falls to the space during the day, the daylight sensor scans it and completes the control of the lighting intensity by the offset in such a way that the group of luminaires close to the windows lights e.g. on 40 % of the luminous flux and the other group of luminaires where less daylight occur, on 70 % of the luminous flux. In this way we achieve the required uniformity of lighting in the whole space. And vice versa, if the daylight availability from the external environment is small or even of 0 value, all luminaires in both groups light with the same intensity. When using the daylight sensors it is necessary to be aware that the availability of the daylight in the space does not change only in dependence on the time of the day but is also depends on the orientation of the windows towards the cardinal points or changing cloudiness.



1. *Through the control panel user set level at which shall be maintained illuminance.*
2. *Setpoint is delegated to control system (sensor).*
3. *The daylight sensor scans luminance and compares the current value with the required.*
4. *When detecting difference, system makes a change (luminaires are dimmed up or dimmed down).*
5. *The resulting illuminance on the working plane is composed of sunlight and adjusted artificial lighting.*

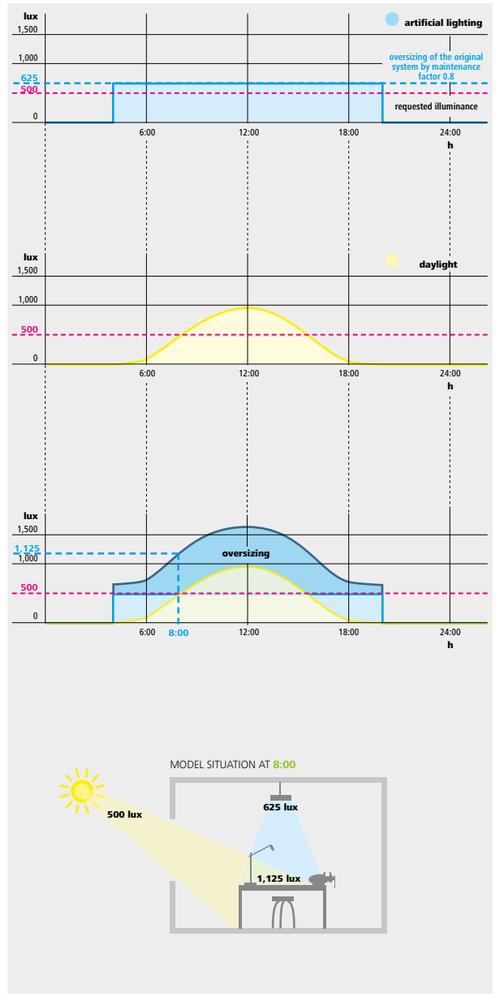


Proper placement of daylight sensor - the exclusion of adverse effects.

When placing the sensors it is necessary to ensure that the luminous fluxes of the luminaires of one group do not touch the scanned surface of the sensor from the other group of the luminaires. It is also valid that the scanned surface of the sensors must not overlap. It avoids their mutual influence and subsequent destabilisation of the system regulated. At the same time the daylight sensor has to be placed in a sufficient distance from the windows and light sources which could illuminate the sensor itself and in this way affect its function.

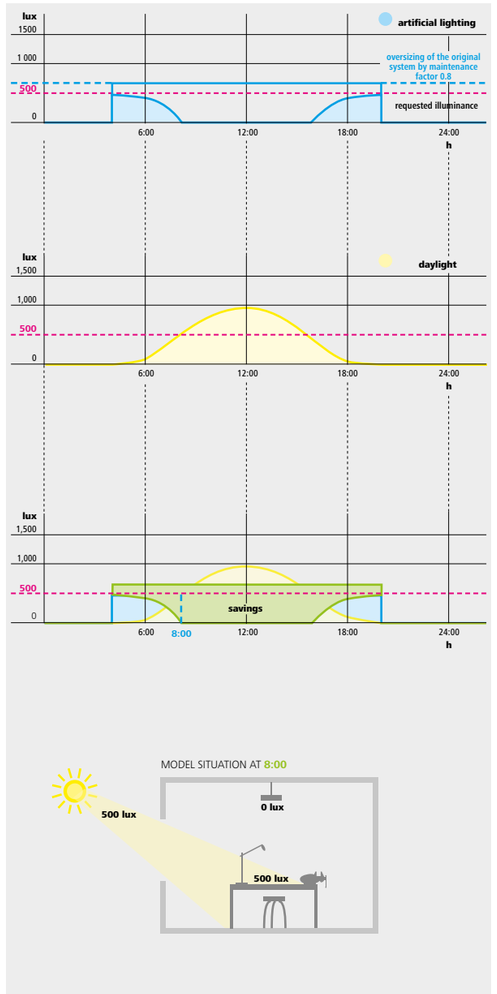
The amount of the luminance scanned by the sensor depends very much on the reflective surface and colour of the scanned area. If these conditions are changed, e.g. during operation with a material with reflectance, also the scanning conditions are changed. In this case the sensor detects increased luminance intensity and causes dimming of the luminaires. This shortage is partially removed by adjusting suitable time for delaying the change of the luminaire luminous flux and in this way we achieve a more fluent transition and the change of the lighting intensity will not be that visible. A sudden change of the light conditions can be prevented by placing the scanned surface of the sensor to a place where the properties of the environment do not change so often. The primary adjustment of the illumination level to which the lighting system is to be adjusted is to be carried out without any daylight or at the lowest possible share of the ambient light.

UNMANAGED SYSTEM



Incorrect solution *– oversized illuminance level*

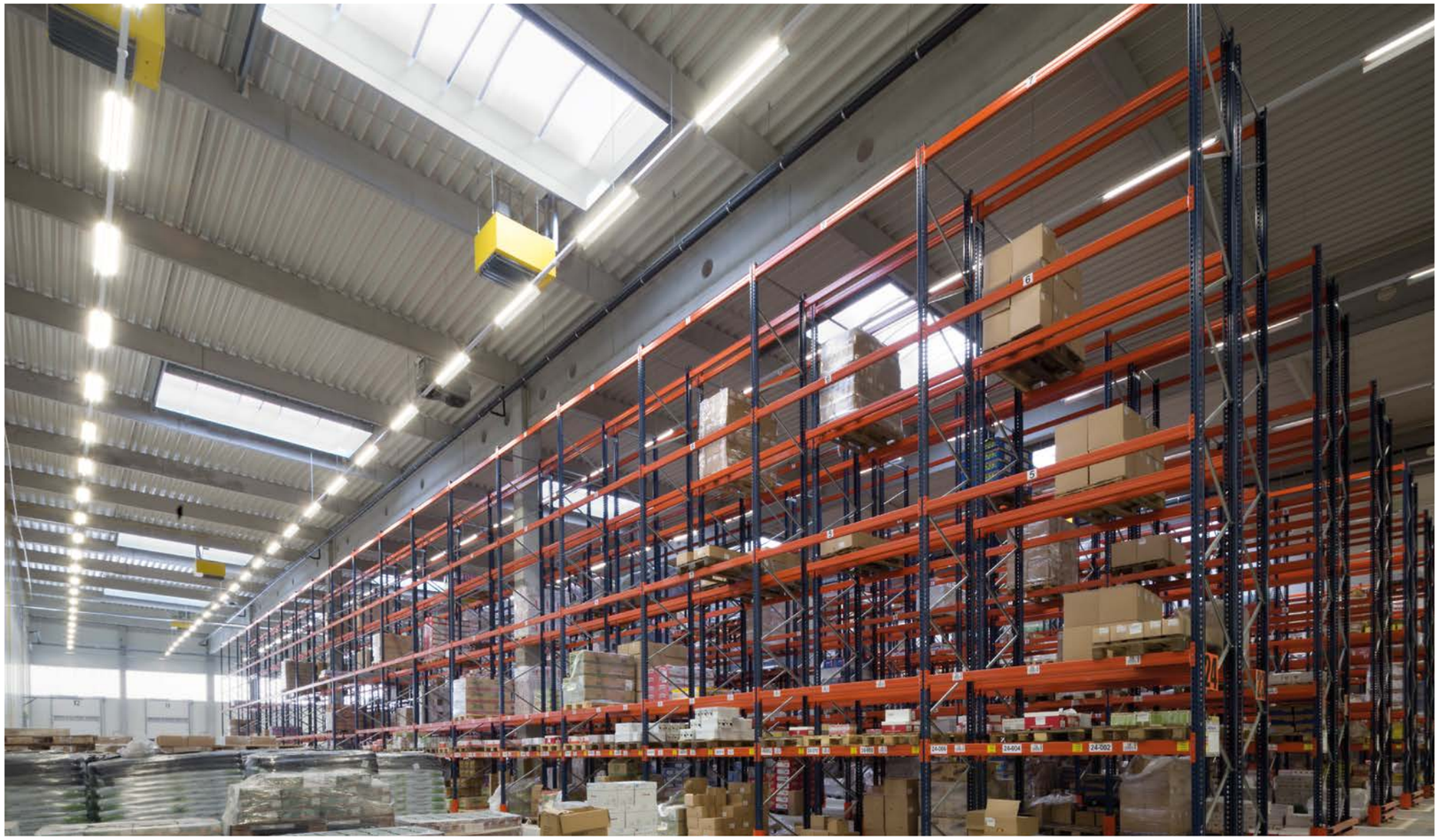
MANAGED SYSTEM BASED ON ILLUMINANCE LEVEL

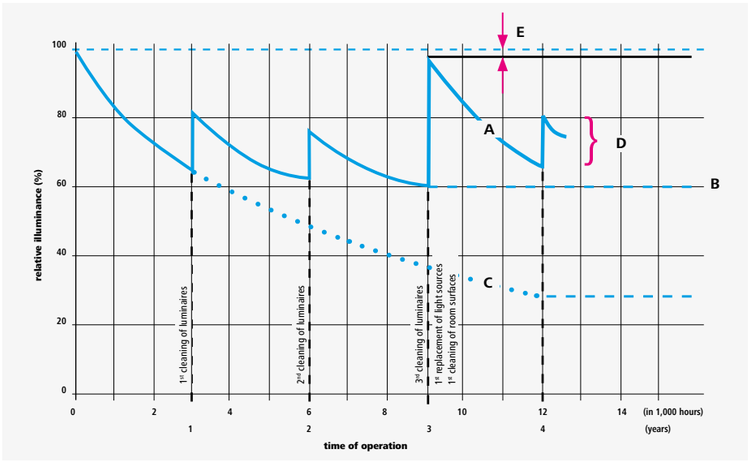


Correct solution *– required illuminance level*

CONSTANT ILLUMINANCE SENSOR

During the operation of the lighting system the light properties of the installed luminaires gradually deteriorate. This fact is caused by ageing, wear and polluting the optical parts and the light sources of the luminaire. When designing the lighting system it is therefore necessary to count on decrease of the luminous flux due to ageing the light sources from the very beginning. The greater these declines are the more over-dimensioned the lighting system has to be. It means during its operation it will produce more unrequired light. This over-dimensioning can be removed by the constant illuminance sensor and using such luminaires that can be dimmed according to the need. The sensor is adjusted to the required illuminance and adapts the luminaire output in such a way that the required illuminance will not be exceeded – the so called maintained illuminance. In this way we can achieve considerable energy savings. The constant illuminance sensor behaves as a luminance sensor and it artificially reduces the luminous flux of the luminaires. This solution can be only implemented when the lighting system will be over-dimensioned from the very beginning. The economy of this solution can look contradictorily at the first sight. However, the reality is that the savings occur because during the first years of operation of the over-dimensioned lighting system the light sources do not work at peak output. The system is adjusted to the 100 % output after it begins to show signs of wear. Thanks to this solution we achieve constant illuminance of the whole scanned space. From the point of view of the increased economy of this solution it is suitable to combine the constant illuminance sensor with the daylight sensor. In this combination both sensors are able to utilise the natural daylight potential falling from the windows or skylights in full extent and to adapt the artificial light intensity to it.





Illumination changes during the life of the lighting system
A – maintained lighting system curve
B – maintained value – maintenance factor
C – unmaintained lighting system curve
D – benefits of cleaning luminaires at regular intervals
E – irreversible loss caused by ageing of luminaire materials

LQS VALUE

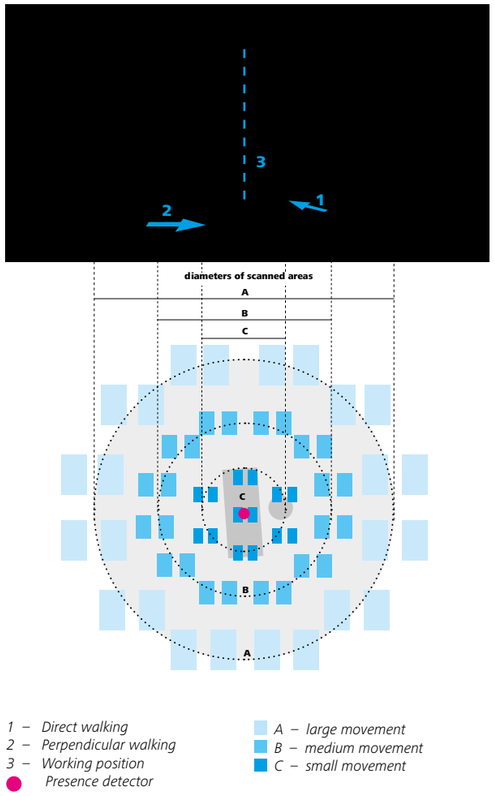
Constant illuminance sensor

Constance illuminance sensor	LQS Value
Yes	1
No	0

PRESENCE DETECTOR

The control based on the movement belongs to automatic management methods which makes the luminaires lights only when persons or objects move in the space, i.e. when lighting is really necessary. This type of management involves both the user comfort and saving potential which can achieve up to 50 % in the individual premises. It finds its place in the industrial and manufacturing halls especially in the warehouses, communication zones and for the external lighting.

The functionality of this lighting management system ensures the presence detector, which responds to the persons´ or objects´ movement in the detection area. Routinely are used in industry the passive infrared presence detectors or high-frequency presence detectors. Their usage is given by the type and structure of the space.



1 – Direct walking
2 – Perpendicular walking
3 – Working position
Presence detector

A – large movement
B – medium movement
C – small movement

Presence detector areas of sensitivity.

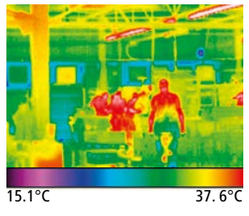
Passive Infrared (PIR) Presence Detector

The passive infrared technology with a built-in scanner in the sensor ensures the scanning operation of this type of sensor. These sensors respond to the thermal radiation of the human body, they transfer it to an electric signal; the sensor evaluates it and switches on the lighting. The scanner itself emits no radiation and therefore we can speak about the PIR sensors. The passive infrared sensors can be used both in the internal and external spaces. They can be installed in various assembly heights (routinely up to the height of 12 metres) and can possess various sensitivities. The extent of the maximal scanned area depends on the assembly height and the sensitivity of the sensor used.

The maximal sensitivity of the movement detection is achieved if the person or moving object passes the detection areas at a perpendicular direction. If the movement is direct to the sensor, i.e. longitudinal with the detection area the sensor sensitivity is reduced and the area scanned is also smaller. A disadvantage of the PIR detectors is the fact that their sensitivity is dependent on the ambient temperature, the temperature of the moving object or person, the scanning direction and the size of the movement the sensor is to scan. The lower the ambient temperature is, the higher sensitivity the sensor has and is able to scan a larger area. However, at a higher ambient temperature the scanning sensitivity of the PIR presence detector declines as the level of the temperatures in the space and the temperature radiated by people is negligible. A similar situation develops if the moving person wears several layers of clothes. The functionality of the PIR sensors is also substantially limited in indented spaces or in premises with large obstacles.

For the PIR scanning sensitivity not to be negatively affected, it is important not to install them close to the light sources, air-conditioning and heating units or other sources of a strong infrared radiation.

Real picture of the scanned environment.



Infrared photograph of scanned heat from moving people and objects.

LQS VALUE

Presence detector

Presence detector	LQS Value
Yes	1
No	0

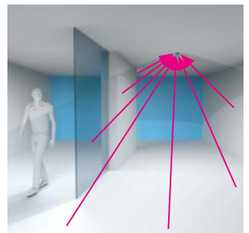
The presence detector can be used in the indoor and outdoor applications with different sensitivity and mounting height.

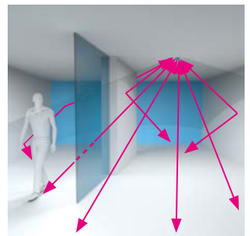
High Frequency (HF) Presence Detector

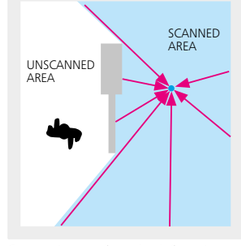
The functionality of this type of the presence detector consists in emitting and receiving the signals. It is suitable for spaces as warehouses where the scanned area is limited partially or temporarily due to the occurrence of large-sized objects. These sensors are able to scan the movement also through bulky obstacles, e.g. various types of materials in the industrial spaces, glass or thin walls. They are also able to respond to a minimal movement and their sensitivity is not affected by the ambient temperature. For an ideal space coverage it is suitable for the scanning areas of the individual movement sensors to overlap each other.

When installed appropriately, the sensor responds to the presence of a person in the detected zone by immediate switching on the lighting.

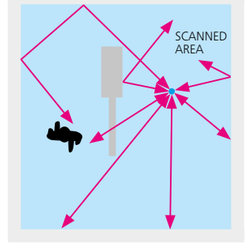
When using the control based on the presence detector we can make use of the function of delay for dimming and it means the luminous flux of luminaire luminous flux does not change immediately after the movement detection decays but after passing the adjusted time without any detected movement of a person or object. This time is determined according to the type of the space and the frequency of the assumed movement. Dimming can be stated either for a certain level (e.g. 10 %) of the luminaire luminous flux or dimming up to the 0 % level. The luminous flux level of 10 % is used especially for safety reasons for the space without any detected movement not to be fully dark or due to the security cameras or prolonging the lifespan of the light sources. This functionality is called the “corridor function” where it is possible with the second time delay to switch off the luminaires in the whole extent. When there is a movement again, the sensor detects it and the luminaires switch on. The luminaires can switch on and off either continuously when the luminous flux changes gradually during some time or by leaps when they switch on and off immediately. The advantage of the continuous start-up is that the human eye is not stressed by the immediate change of the light conditions as in the case of a leap change. The duration of two seconds is considered the optimal time of switching on of the luminaires to the 100 % level of the luminous flux.



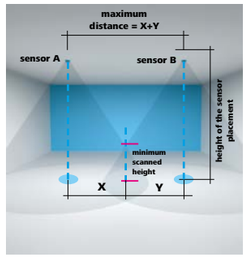




Scanned area of passive infrared sensor (PIR)



Scanned area of high frequency sensor (HF)



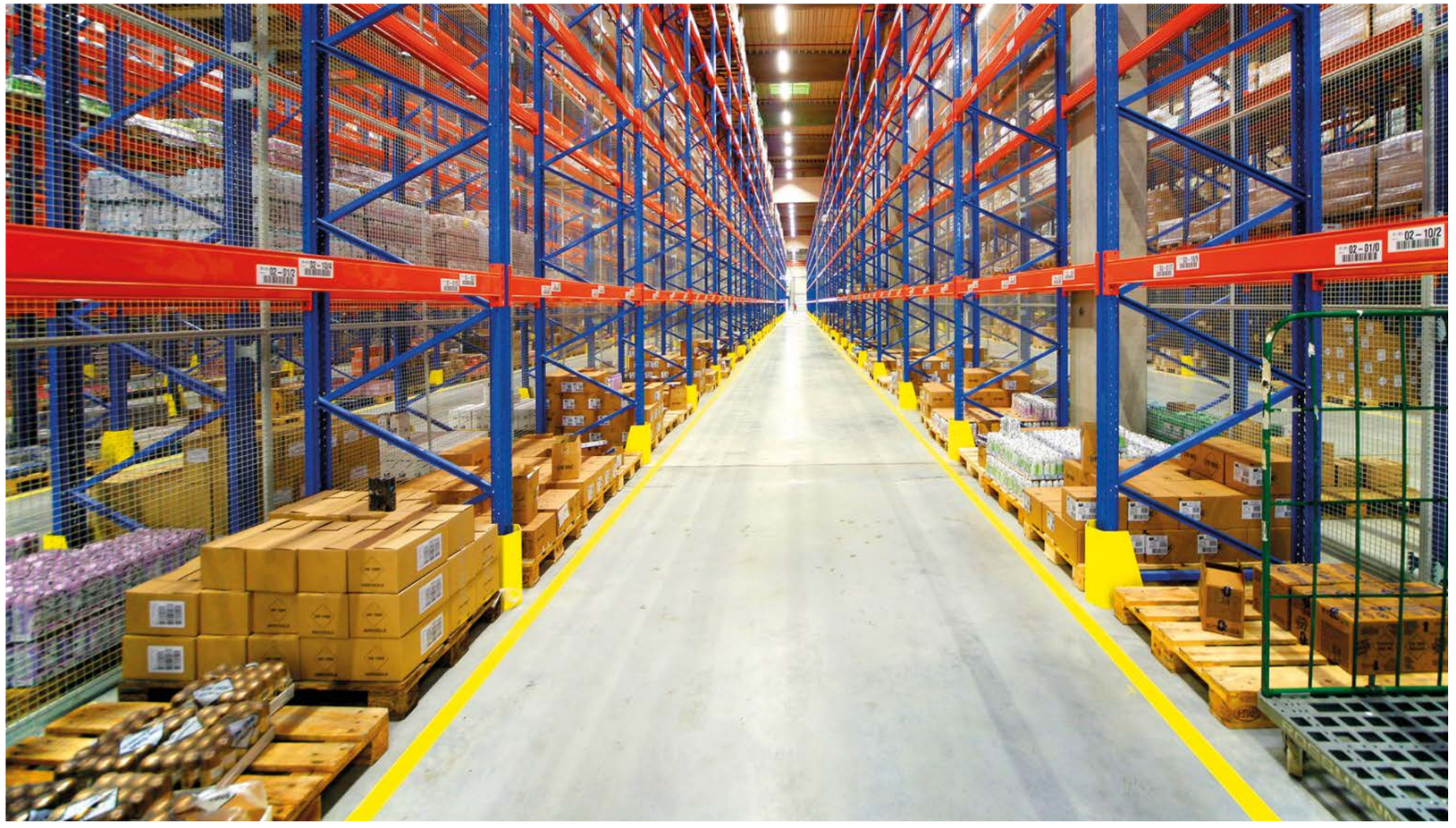
Suitable placement of presence detectors with partial overlap of scanned areas

Comparison PIR vs. HF	Passive infrared sensor – PIR	High frequency sensor – HF
Detection through the thin walls and obstacles	– (advantage/disadvantage, depending on needs)	+ (possibility to reduce the sensitivity to limit this feature)
Detection by reflection from room surfaces	–	+
Influence on detection of heat sources - air conditioning, heating elements, luminaires	–	+
Influence on detection: difference between ambient and human body temperature	–	+
Suitability to storage rack aisles (blocked sensing areas in side aisles)	++	–
Undisturbed room design	+	++
Installation costs	++	+

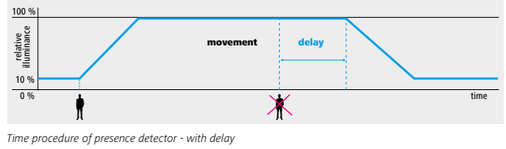
Corridor function

In the industrial objects the warehouses and especially the warehouse aisles are the spaces without any permanent occurrence of persons. From this point of view they are spaces where we can achieve considerable energy savings through installing the presence detectors. When planning the movement sensor layout, it is necessary to take into account that part of the space where it will be placed and according to this fact to choose the shape and extent of the storage areas. The scanning area of the presence detector in the handling part of the warehouse and in the area of the entrance and exit requires a circular shape. When detecting the movement in this part of the space the presence detector switches on several luminaires on a larger area to ensure sufficient illuminance level for the handling activities. And vice versa, the narrow and high warehouse aisles require implementing the presence detector with an oval scanning area that controls only the luminaires in the given aisle. To ensure an accurate delimitation of the scanned surfaces the sensor scanning surface is limited by the so called blank plugs. This prevents the sensors located in a concrete aisle from scanning the movement in the neighbouring one and in this way not to switch on the luminaires which are in neighbouring aisle. In dependence on the length of the warehouse aisle it is possible to adjust the presence detector functionality in such a way that after scanning a movement all luminaires in the given aisle will switch on at the same time or they will switch on step by step according to the movement of the scanned person / object.

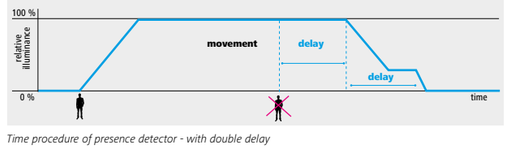
The presence detector switches on the luminaires in selected spaces when somebody is present and thus the lighting is really needed.



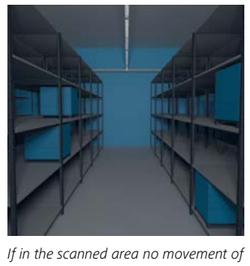
Time procedure of presence detector - without delay



Time procedure of presence detector - with delay



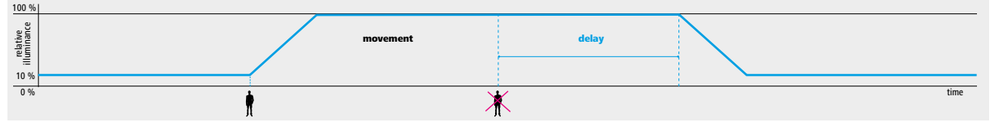
Time procedure of presence detector - with double delay



If in the scanned area no movement of an employee has been detected, the luminaires remains on low illumination level (safety reasons).

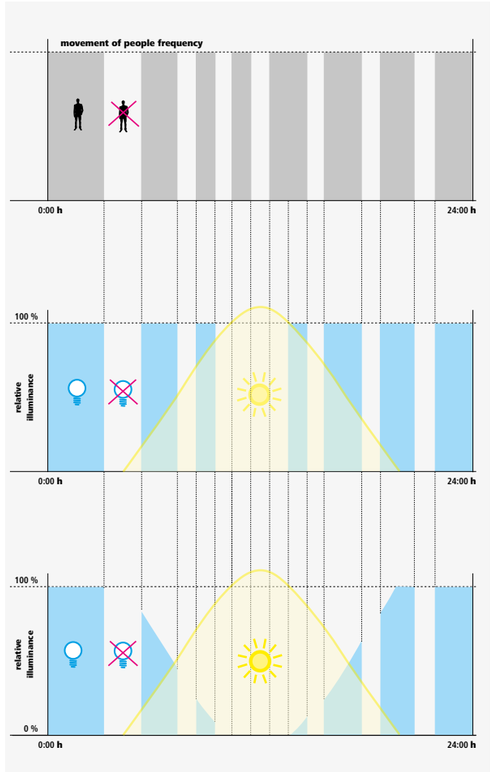
When an employee enters the scanned area, the presence detector responds to the infrared radiation which the human body or working machine emits and switches the lighting on.

The presence detector can be adjusted in such a way that the lighting will not switch off /dim in a vacant storage lane immediately after the employee leaves it,but gradually with a predefined delay time.



COMBINED LIGHTING MANAGEMENT SYSTEM

Combining the control based on the movement (presence detector) and intensity (daylight detector), i.e. using the combined sensors we can achieve the highest energy savings. According to the regulation method the lighting management can be carried out continuously or in leaps in dependence on the daylight availability of the space. When we regulate using the combined control the luminaires switch on (after detecting a movement) only if the scanned level of lighting in the space is lower than the firmly adjusted value. If the luminance intensity scanned is higher the luminaires do not switch on also when the movement continues. On the contrary, if there is a lower luminance level in the space and the sensors detect a movement, the luminaires switch on and the illumination is gradually regulated to the required level. If the movement continues, the luminaires dim according to the need and switch on according to the daylight availability.



When using combined lighting management system responds presence detector on persons in scanned area turning luminaires on only if intensity of daylight, which incident to the space through windows or skylights is below a preset value. Luminaires in the room remain off even if there are not persons.

Regulation in leaps: *When presence is detected, the luminaires turn on in leap only when illumination level is lower than the preset value. If the illuminance is higher, luminaires in the room remains off even if movement continues. For this type of combined lighting management system luminaires do not need to be equipped with dimmable control gear power components.*

Continuous regulation: *When presence is detected, the luminaires turn on, followed by a continuous adjustment of desired level based on scanning of illuminance in area. If the movement persist, the luminaires are dimmed up and down according to requirements on illuminance level. For this type of combined lighting management system must be luminaires equipped with dimmable control gear power components.*

CALLING OF LIGHTING SCENES

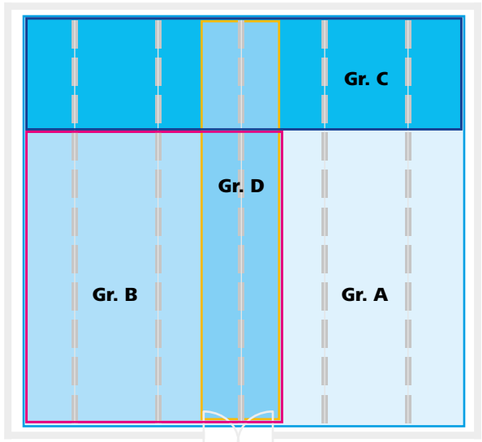
The lighting system management based on the changes of the adjusted lighting scenes finds a broad implementation in the industrial spaces. It can be utilised where it is not necessary to achieve dimming based on the lighting intensity or movement. The adjusted lighting scenes can be switched on manually or automatically according to the adjusted time schedules.

Manual lighting scene

Under the manual lighting scene we can understand an adjusted value of the lighting level which can be brought about at any moment or changed by a button. The used control buttons can be pre-defined for the value of the luminous flux (e.g. 100 %, 75 %, 50 %, 25 %, 0 %) the luminaires are to work on or to dim after we press them.

In the industrial halls the management method can be used e.g. for lighting the manufacturing lines which are currently in operation. In that part of the space which is not used it is possible to reduce the illuminance level to the required level by calling the adequate lighting scene. In a similar way, it is possible to pre-define the lighting scenes for breaks or cleaning.

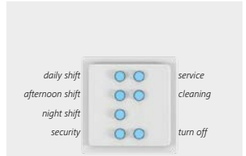
Dividing luminaires to control groups. Some luminaires may be assigned to more than one group.



Gr. A | Gr. B | Gr. C | Gr. D

This type of management can be controlled by a built-in panel or remote controls. Especially for structured spaces we recommend using controls working on the wave basis. The electromagnetic waves they emit are able to penetrate materials which create an obstacle between the sender and receiver. This enables building-in a receiver also in spaces that are remote from the given room and to control the lighting system also through walls and on several floors. The current modern technologies enable to control the lighting through a tablet or smartphone. Through creating a specific application it is possible to control the lighting system in the whole manufacturing space by a simple touch. Through the wireless communication the selected actuator sends a signal to the controller, it assesses it and sends information through the control unit directly to the luminaire or a group of luminaires whose radiation intensity can be remotely switched on and off, increased or decreased.

The management based on the adjusted lighting scenes belongs to those types of the manual control which from the point of view of savings are not as effective as the automatic solutions. Due to the fact that an intervention of the staff is necessary for calling a lighting scene, it is not possible to exclude any failure of the human factor.



Description near the buttons on the control panel for calling of lighting scenes

Automatic lighting scenes

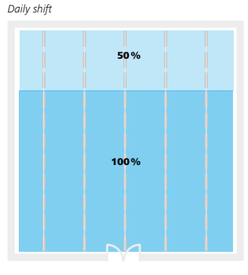
The automatic lighting scenes represent adjusted lighting scenes based on a firmly stated time schedule. The adjustment of the one-time or regularly repeating actions is realised through specialised software applications. In this way it is possible to change the illumination and adapt it to the currently realised activity in the manufacturing spaces automatically without any interventions of the user. The management system at the pre-defined times automatically changes the lighting system intensity for the individual working shifts, breaks or cleaning. The advantage of this lighting system management is its fully autonomous character which excludes the human factor.

1st lighting scene:

2nd lighting scene:

3rd lighting scene:

4th lighting scene:



luminaires

100 % 100 % of power consumption

50 % 50 % of power consumption

0 % 0 % of power consumption

Lighting control based on occupancy of workplaces. In differentd scenes, different luminaires are turned on or luminaires lit with different intensity.

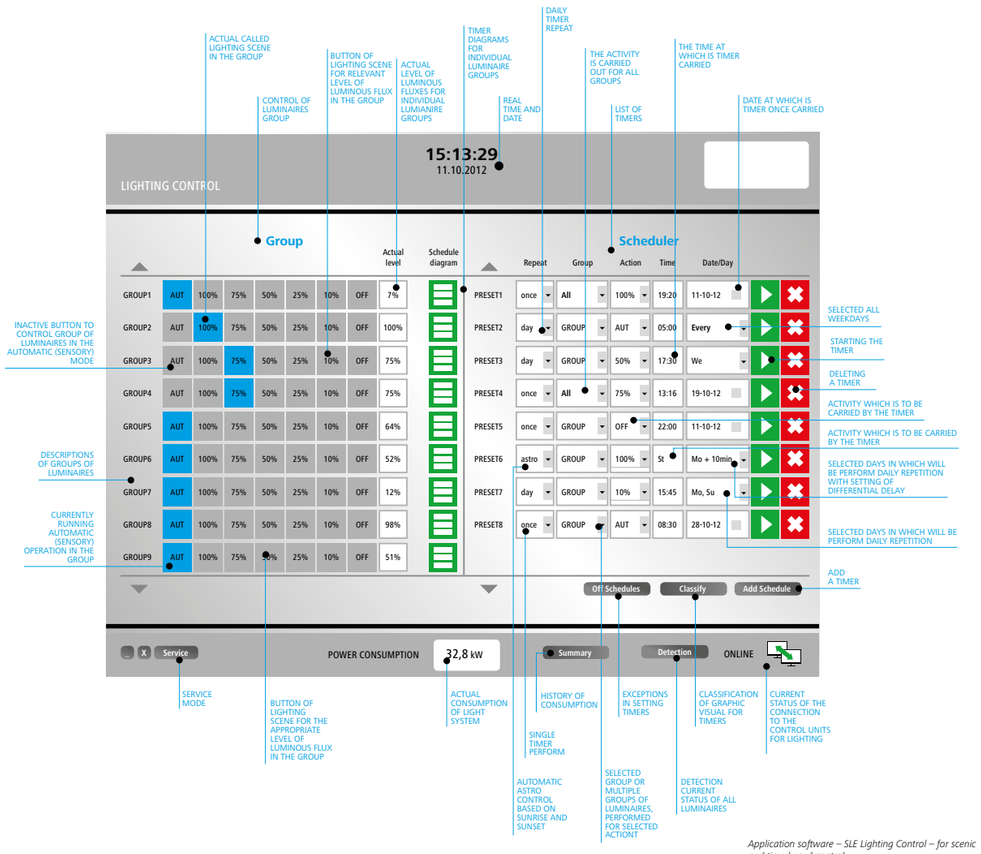
LQS VALUE

Calling of lighting scenes

Calling of lighting scenes	LQS Value
Yes	1
No	0

LIGHTING CONTROL

The automatic management systems provide the users with maximal comfort and enable them to use the saving potential of the lighting system in full extent. Moreover, the existing technologies enable to realise the control of the lighting system from a remote point. The company SLE gives its customers an opportunity to utilise the system SLE Lighting Control. It is a sophisticated system enabling to control the lighting system through internet. This application allows reading the actual energy consumption, it informs about failures of the luminaires and localises exactly the place of the breakdown and also provides information of what will be necessary for its removal.



Application software – SLE Lighting Control – for scenic and time based control.

DALI

Already the name Digital Addressable Lighting Interface says that it is a digital control of the lighting systems which enables to dim the luminaires in full extent from 0 – 100 %.

The limits of one DALI bus enable controlling 64 address devices which can be divided to 16 groups. For a bigger number of luminaires it is possible to combine several DALI buses and in this way to create larger and more complex systems. Except for the luminaires with the DALI control gears we can also control other peripheral devices (e.g. the blinds, heating, air-conditioning, etc.) and signalisations through address DALI components.

Thanks to the DALI management we can control each luminaire in the lighting system independently. The advantage of this system is the feedback thanks to which we can read the current state of the lighting fixture (e.g. the current dimming level, failure of the light source or electronic control gear). The DALI system allows using a large number of the action components and control elements, e.g. the standard wall buttons, touch panels, remote control and utilising several parallel control places.

ESPRIT

People love flawlessness. Therefore the lighting producers do not take only their light and technical properties into consideration but also their overall design. Where an attractive look is combined with modern technology also inanimate objects acquire a new dimension. Let us call it esprit.

To breathe spirit into the inanimate objects is the basic ambition of the current industrial design. In the area of luminaire manufacturing it means the effort of the luminaire designers for an innovative connection of shapes and functionality. Today the modern materials and technologies enable countless numbers of variations which can be modified according to the client's vision.

Although the usage of designer luminaires in industrial and production halls still isn´t very common, there are always few exceptions to the rule to find also in this kind of spaces. By planning the lighting solution the lighting designers actually do not only emphasise the functionality when selecting the luminaires but also the ability to add interest to individual parts of the interior, to contribute to their specific atmosphere or to represent.

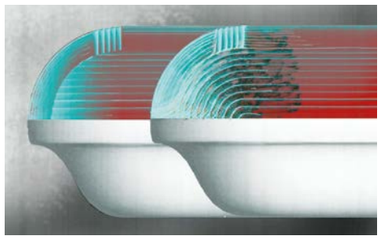
Although there are no quantifiable criteria for assessing the quality, it is important to respect a few rules in the creative process. They are as follows: overall impression of the luminaire, luminaire appearance in the room, detailed solution, surface finish, material of construct parts, functional elements.

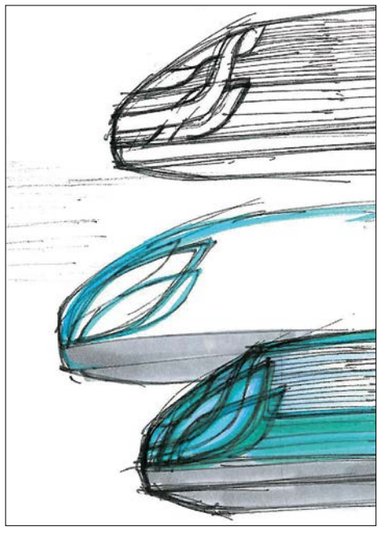
The company SLE has responded to the design demands for the space illumination by creating an in-house department of research and development in the framework of which the "court" designers in collaboration with technical departments and the students of the Academy of Fine Arts and Design in Bratislava, specialisation industrial design, are working on the development of new design luminaires using the latest technologies. The result of this collaboration is a series of the design and highly functional luminaires falling into the category of futuristic visions.

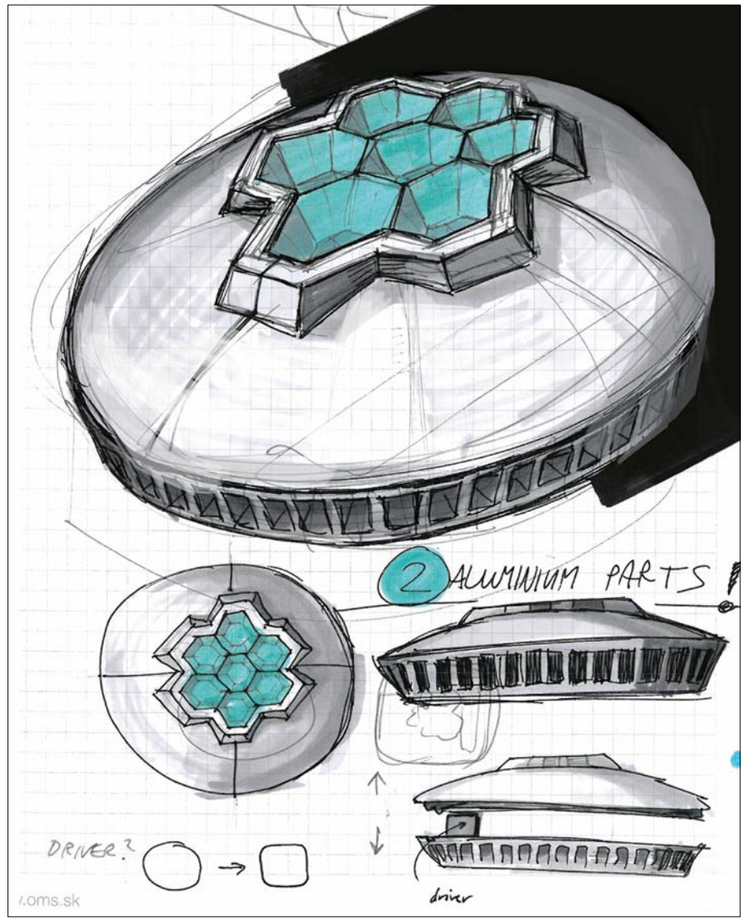
TORNADO II

by Ján Štofko

This is one of the most important luminaires in SLE portfolio. Working on project like this, takes a lot of responsibility. Designing new generation of succesfull product like TORNADO needs full involvement of all stakeholders and needs reasonable design decisions. While focusing on performance, price and efficiency, there is at the same time work for design team. Injection moulded parts like polycarbonate prismatic diffuser end segments and luminaire body gives enough space to import steady and reliable character to this industrial place.



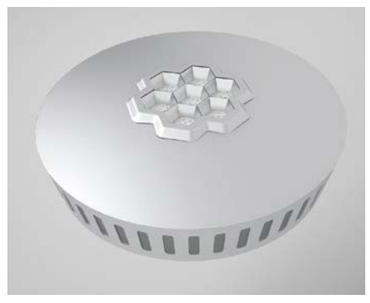




GRAFIAS ROUND

by Ján Štofko

Some people think that industrial luminaires don´t have right for design and aesthetic. Grafias Round ancestor - Grafias - was living proof that design can be incorporated even in strictly performance and efficiency focused products. It is the matter of company philosophy. In this round version we keep the optic which is a great example of cooperation between optic designer and product designer. The body gets modern oval shape and updated thermal design which makes the luminaire lighter. Lumen output rethinking is also part of this Grafias Round future.



EXCEPTIONALITY

It is our ambition to create smart lighting solutions that bring added value and wellbeing to our lives in addition to showing respect for the environment. To this end, we act as a lighting solutions project platform focused on connecting everyone involved in lighting in mutually beneficial collaboration under the umbrella of SLE's knowledge, tools and services. In this way, each participant can contribute their unique skill set towards a cooperative final solution of higher value and quality than could be achieved alone.

We tailor our services and support to current and future market needs, thereby increasing the effectiveness of every link in the value chain, from supply to end use

METHODOLOGY

We have created a framework of clear and accessible knowledge, practical and theory-based support, and insights into the development of lighting through research. To achieve this, we eagerly follow the trends that are driving technological and ecological development in the global market and apply them to lighting and its influence on both humans and the environment. This knowledge is implemented both through our own lighting services and in the development of a number of specialised proprietary supportive tools for all involved in sales, project planning and implementation.

Lighting Quality Standard & LQS Composer PRO

The Lighting Quality Standard (LQS) and supplementary LQS Composer PRO software tool enable the objective and quantifiable evaluation and comparison of lighting solutions. Using a framework categorised into six key areas, they support the assessment of the quality of lighting solutions.

Smart Light

The Smart Light methodology is presented as a series of guides for various types of application that show how to put the entire depth of our knowledge into practical use.

Lighting trends

The global trends of health, wellbeing, sustainability and technology affect our everyday activity and behaviour. Interpreted by the lighting world, these global trends become light and psychology, human centric lighting, light and safety, and energy saving.

EXCLUSIVE PRODUCTS

Our distinctive product portfolio offers cutting-edge luminaire and lighting control technologies that are guaranteed to perfectly integrate with each other and in every solution we provide.

Each product it designed for a specific application, so partners can rely on finding the best fit for every project. The possibility of product customisation further assures both partners and customers that every solution is specialised and therefore unique and worry-free.

www.sleprojects.com

SERVICES

We provide partners with access to almost 80 R&D, lighting, sales and marketing services, allowing them to focus on their markets and customers while we take care of the rest.

Research & development

All our luminaires and control technologies are developed in our own R&D department by a team of experienced and inventive specialists who consistently implement the latest scientific findings and global, technological and lighting trends. The result is a portfolio of truly innovative, stylish and technologically advanced products that will bring added value to every solution they are used in.

Lighting planning & realisation

Exceptional lighting solutions can only be conceptualised and realised by the best minds and trustworthy specialists with the help of an in-depth understanding of light, lighting and its application.

Sales

Our partners' realisation is at the heart of our interests, which is why almost everything in SLE is useful for those on the front line. From technical support tools through product information to marketing materials and project promotion, we provide everything needed to achieve sales success. And once a sale has been made, we will also help with financing, giving customers a name they can trust. With such a complete business package, our partners will never be short of help in attracting and building a firm and long-term relationship with customers and brands.

Marketing

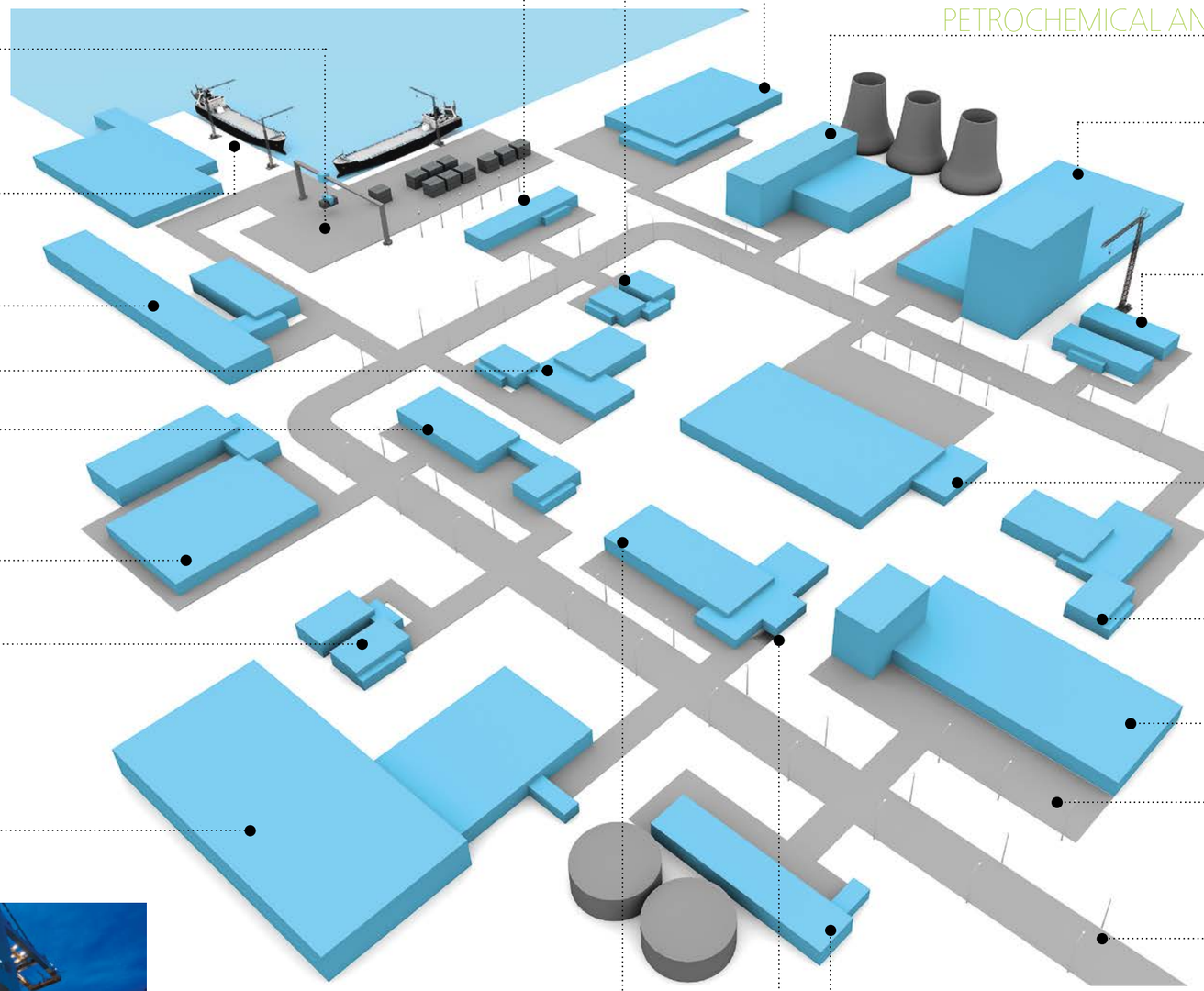
It is no fun doing the work and never getting any credit, which is often the case for the individuals and small companies involved in the provision of lighting solutions. We believe that everyone involved in a project should be given due recognition. All partners involved in our projects are included in related promotion. This strengthens both the presence of truly skilled professionals on the global lighting scene and the network of support and collaboration that will drive the success of all.

BEST-FIT SOLUTIONS

Lighting can be complicated, especially considering the constant influx of new technologies, terminology and possibilities. With this in mind, we offer a range of complete 'ready-made' solutions to keep things simple for everyone, but never at the expense of quality or suitability.

Each solution includes everything needed for its implementation. Moreover, as each solution is provided as a whole, full compatibility of all components is guaranteed, and the entire system falls under one straightforward warranty. In this way, lighting suddenly becomes very simple.

LIGHTING IN THE INDUSTRY



BUTCHERY

WOODWORKING AND PROCESSING

AUTOMOBILE WORKSHOP

PETROCHEMICAL AND POWER INDUSTRY

STORAGE AND LOGISTICS

ELECTRICAL AND ELECTRONIC INDUSTRY

CANAL, LOCK, PORT,
SHIPYARD AND DOCK

CONSTRUCTION SITES

METAL WORKING
AND PROCESSING

BAKERY

PRINTING

WAREHOUSE

MECHANICAL AND
PLANT ENGINEERING

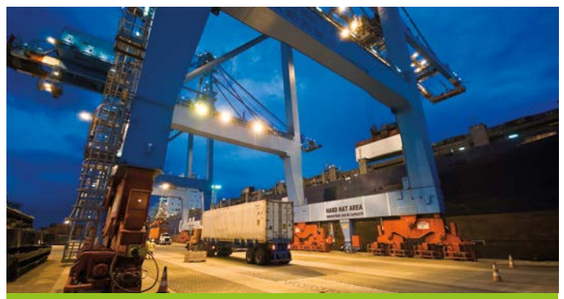
PLASTIC INDUSTRY

FOODSTUFFS INDUSTRY

HEAVY INDUSTRY

AUTOMOTIVE ENGINEERING

EXTERIOR ILLUMINATION
AND PARKING AREA



CLEANROOM

CHEMICAL INDUSTRY

UNDERGROUND PARKING

INDOOR WORKPLACES

The fact that people spend up to 80 % of their productive life at work increases the importance of the appropriate and biologically efficient lighting at the workplace. In the manufacturing sphere and all lines of business a correctly designed lighting system can positively affect the performance efficiency and concentration of the employees in all working shifts, minimise the occurrence of failures and the risks of injuries.

HEAVY INDUSTRY

From the point of view of the industry classification, the heavy industry includes the areas of metallurgy, energy, machinery and chemical industry. The production premises in all these lines of business place specific demands on lighting solutions and selection of the light sources.

The normative requirements on the average maintained illuminance in the production halls in the individual branches of the heavy industry differ according to the fact if they are workplaces without manual operation, processing installations with limited manual intervention or workplaces with a permanent occurrence of employees. The European standard EN 12464-1 states a minimal illuminance level 50 lux for the workplaces without manual operation, 150 lux for processing installations with limited manual intervention, and the minimal illuminance level 200 lux for workplaces with a permanent occurrence of employees. To achieve the optimal visual comfort of the employees especially at the workplaces with a permanent occurrence of people we recommend ensuring higher illuminance levels.

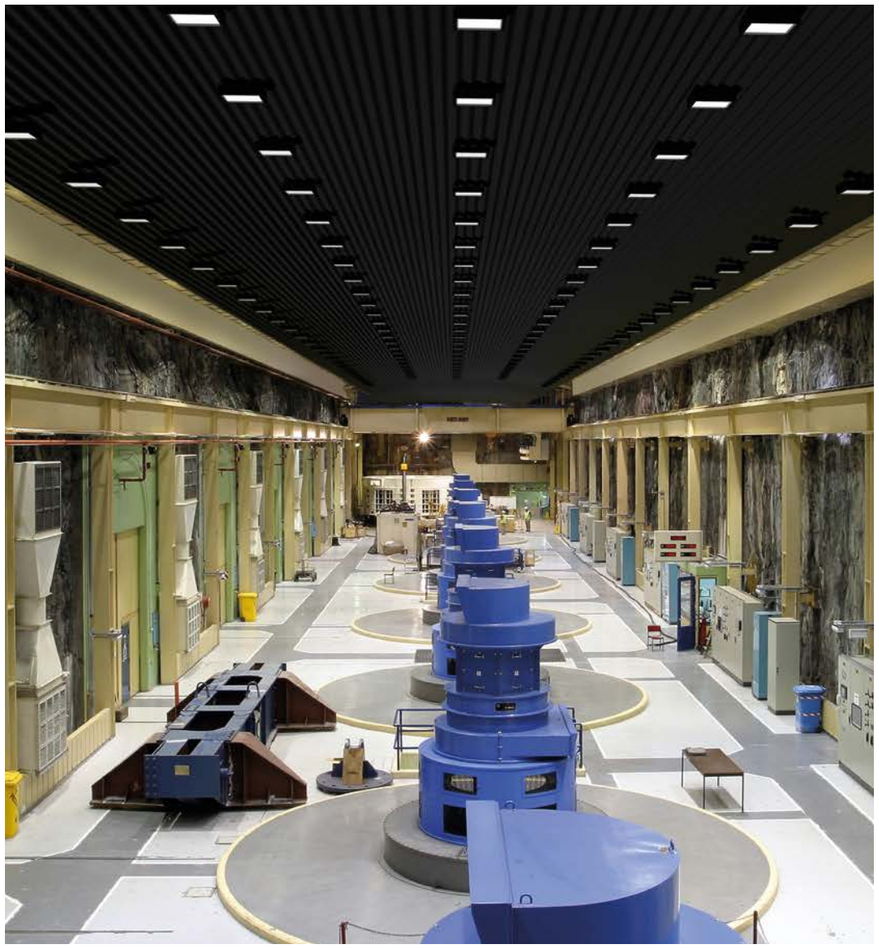
When designing a lighting system it is important to create uniform lighting conditions in the production premises and in this way to avoid an undesirable formation of sharp shadows. The uniform lighting enables the employees' correct handling with tools and reduces not only the failure rate but also the risk of injury. In the high manufacturing halls in the heavy industry it is also important to achieve sufficient illuminance of the vertical surfaces along the whole height of the walls. Good vertical illuminance improves the orientation ability of the employees, better identification of the large-size machines and improves safety when moving on the stairs or hall girders.

To achieve the standardised stated values of illuminance in the high production halls in the heavy industry, it is suitable to use the luminaires with a wide luminous intensity curve and/or suspended luminaires with the asymmetric radiation curve which at the same time will ensure sufficient vertical illuminance of the surfaces. The continuous row systems with specular reflectors are an appropriate choice for the task area lighting for the workplaces. For an optimal adaptation to the local circumstances, the luminaires should permit variable light distribution.

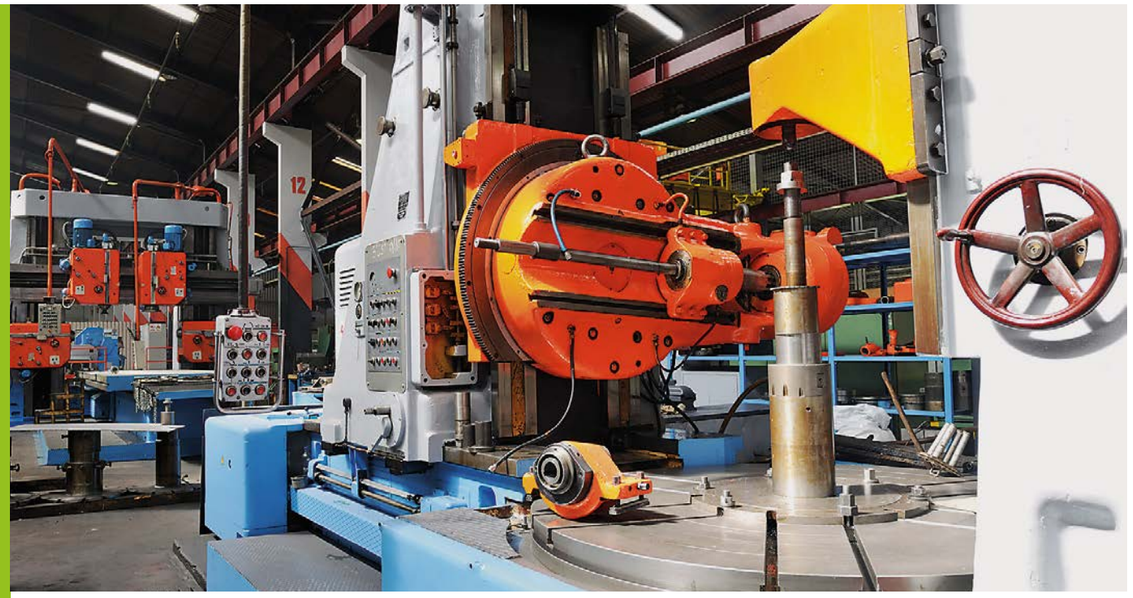
The selection of the light source depends on the activity which is carried out at the given workplace. In the production spaces without permanent attendants and in the premises with reduced visibility it is possible to use the light sources with CRI>40. At the workplaces with permanent presence of operators the standard determines the minimal value of CRI>80.

From the economic and luminous point of view the high-intensity discharge lamps are considered a suitable solution. This type of light source achieves adequate intensity and uniformity lighting values and at the same time it is not maintenance-intensive.

In the individual branches of the heavy industry the production premises place increased demands on the resistance of the luminaires against explosion (Ex) and corrosion with appropriate values IP 20 or IP 50.



Good vertical illuminance improves the orientation ability of the employees, better identification of the large-sized machines and improves safety when moving on the stairs or hall girders.



METAL WORKING AND PROCESSING

This line of business aimed at metal working and processing includes a lot of various activities from assembly through forging and welding up to operations requiring maximal precision for soldering, inspection or measuring. Each of these activities places specific demands on the lighting solution.

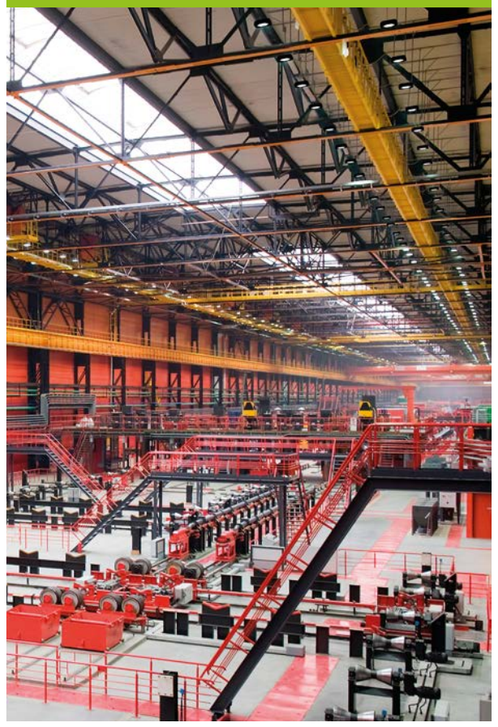
The variety of the realised activities during metal working and processing does not create any conditions for a universal solution of the lighting system. The task of the lighting designer when planning the illumination is therefore to propose such lighting that would comply with the normative requirements and at the same time respect the ergonomic criteria for appropriate lighting of the task area in dependence on the activity realised.

The European standard EN 12464-1 determines different minimal values of the average illuminance for individual wokplaces in dependence on the activity the employee is carrying out at the workplace.

For workplaces where the employees do not carry out any demanding visual tasks, e.g. assembly, forging or welding, the standard states the minimal value of the average maintained illuminance at the place of the visual task 300 lux. The experience from practice shows that e.g. during welding it is suitable to achieve higher values of illuminance at the place of the visual task. The higher lighting intensity can compensate the employee the reduced visibility caused e.g. by using the welding goggles. The required illuminance levels in the high halls (6 metres and more) can be achieved by using the luminaires with a wide luminous intensity curve and the high-intensity discharge lamps which at the same time represent an economical solution. However, this type of luminaires is less suitable in the case when bright metals are processed at the workplace. The linear luminaires with cut-off louvers or with matt housing are a more suitable solution for this type of space.

For the workplaces where the employees carry out demanding visual tasks and where emphasis is laid on precision (light engineering shops, monitoring and measuring stations) the standard states in the minimal values of the maintained illuminance 750 lux to 1,000 lux dependence on the activity realised. For these types of workplaces it is suitable to complete the general lighting by additional luminaires. The luminaires with asymmetric radiation curve placed over the task area are a suitable type of luminaires for these types of spaces. In this way we achieve sufficient vertical illuminance which will enable the employee to recognise the shapes of the machined pieces and flawless reading of the measured values from the devices.

The task of the lighting designer is to propose such lighting that would comply with the normative requirements and at the same time respect the ergonomic criteria for appropriate lighting of the task area in dependence on the activity realised.



Specific requirements on selecting and placing the luminaires are placed by a metal-processing workplace where the employees use the lathe or at workplaces where soldering is carried out. During turning it is important to ensure good visibility of the machined work piece and to prevent the creating of undesirable shadows. The linear suspended or ceiling surfaced luminaires placed rectangular to the working area are a suitable solution. At the same time it is recommended to additionally illuminate the place of the visual task by additional luminaires and to place them in such a way that the luminous flux will head to the task area moderately from above and from the right side in the direction of the employee's view. This lighting solution discriminates the left-handers, however, there already exist sophisticated solutions which are able to create the same light conditions for them, as well. By using the LED light sources or luminaires fitted with electronic control gears we can prevent the undesirable stroboscopic effect which increases the risk of injury especially when we use machines working on the rotational principle.

At the workplaces where soldering is carried out it is important to check the operation immediately. The undesirable reflection reducing visibility can be prevented by using luminaires with matt housing.
At the workplaces equipped with CNC machines with displays/screens the most important task of the light designer is to restrict the rise of undesirable reflections which could make it more difficult or even impossible to read the displayed information.
A reduced luminance level of 1,000 cd/m² to 1,500 cd/m² is required in order to ensure the reflection-free operation on the CNC screens.

If an excessive amount of dust develops during metal-processing at the workplace it is necessary to use the dust-proof luminaires with IP 54 or IP 65.

The more precision demanding the activity the employee carries out is, the higher the requirements on the lighting quality are laid.

MECHANICAL AND PLANT ENGINEERING

Similarly as in the area of metal processing, the mechanical and plant engineering is typical by its variedness of activities performed. When planning the lighting system it is inevitable to take into consideration the specific demands they place on the lighting solution.

The area of the mechanical and plant engineering represents a whole spectrum of activities typical in various levels of precisions: from the basic assembly through handling with small components up to the demanding visual quality control. In general it can be said that the more precision demanding the activity the employee carries out is, the higher the requirements on the lighting quality are laid.

The European standard EN 12464-1 states for the production premises in this line of business the minimal levels of the maintained illuminance from 200 lux to 750 lux in dependence on the activity realised. The scientific research and our experience from practice confirms that a higher illuminance level positively affects the visual and psychological well-being of the employees and stimulates their performance efficiency and therefore we also recommend to maintain higher illuminance levels in those spaces where the standard does not require it.
To achieve the standard stated values of the minimal maintained illuminance, it is suitable to use the linear luminaires with the direct characteristic of the luminous flux distribution which help us gain sufficient quality of lighting uniformity. In the case it is the assembly line production, it is recommended to place the luminaires parallely with the assembly line.

The construction and technological parameters of our luminaire Prestige, which is able to achieve appropriate illuminance level with mounting hight up to 12 metres, enable the lighting designer to use this lighting fixture also in high halls.

By choosing the optimal light source for this industrial space, LED light sources could be the most economical and effective solution. They achieve high lifespan values, they are typical by high efficacy and effectiveness and due to their low failure rate and long lifespan they do not represent any increased burden from the point of view of the maintenance costs.

In the spaces that are not defined as sterile but at the same time they place large demands on the workplace cleanliness, it is necessary to use luminaires which can be cleaned easily and which do not contain components where impurities or dust is trapped.

In production halls with standard hight of the walls it is suitable to use linear luminaires with the direct characteristic of the luminous flux. To obtain the standard stated levels of the maintained illuminance it production halls with non standard hight of the walls (6 m and more) it is important to choose luminaires that can be used in different mounting hight

Special requirements on the lighting solution are laid by the workplaces equipped with the visual display units (VDU). To prevent the rise of undesirable reflections on the screens which would disturb the employees or make it impossible to distinguish the displayed information, it is suitable to use the non-glaring luminaires, e.g. the special computer workstation luminaires or luminaires fitted with microprism which is the most effective method of spreading the soft diffuse light.

For activities with demanding visual tasks (e.g. inspection or handling with small components), it is recommended to support the main illumination with additional table luminaires in the place of the visual task. For the inspection activities the luminaires with a narrow luminous intensity curve represent a suitable solution.


salvagnini
salvagnini

AUTOMOTIVE ENGINEERING

Work in the automotive industry is typical for high demands on the quality of operations performed. Independently of the fact if it is the assembly of large parts or small components the precision is highly emphasised. To meet this requirement and to adapt the lighting system to it is the task for the lighting designer.

The European standard EN 12464-1 states the minimal level of maintained illuminance 500 lux for the manufacturing halls in the automotive industry. It can be achieved by suspended or ceiling surfaced luminaires with the direct characteristic of the luminous flux which can also provide us with sufficient quality of the lighting uniformity. The assembly line production creates the predominant part of production in the automotive industry. For achieving the optimal light conditions we recommend to place the luminaires parallely with the assembly line.

For lighting the production halls with the height of 6 metres we recommend our luminaire Prestige, Thanks to its construction and technological parameters it is able to achieve appropriate illuminance level with mounting hight up to 12 metres.

By choosing the optimal light source also for this industrial space, LED light sources could be the most economical and effective solution. They achieve high lifespan values, they are typical by high efficacy and effectiveness and due to their low failure rate and long lifespan they do not represent any increased burden from the point of view of the maintenance costs.

By an appropriate selection of the light sources or luminaires with matt housings we can avoid the rise of undesirable reflection at workplaces where bright components are used. The VDU workplaces require a special lighting solution. By an appropriate selection of luminaires and their correct layout in the space it is possible to avoid the rise of undesirable reflections on the screens which complicate or even disable the employee to perceive the displayed information. The luminaires with microprism which is the source of soft diffuse and non-glaring light are a suitable solution.

The places of the visual task at which the employees carry out an activity which is extremely demanding on precision should be fitted with additional local luminaires. The inclined working surfaces and inspection workplaces require additional lighting.

The places of the visual task at which the employees carry out an activity which is extremely demanding on precision should be fitted with additional local luminaires.

Paintshop

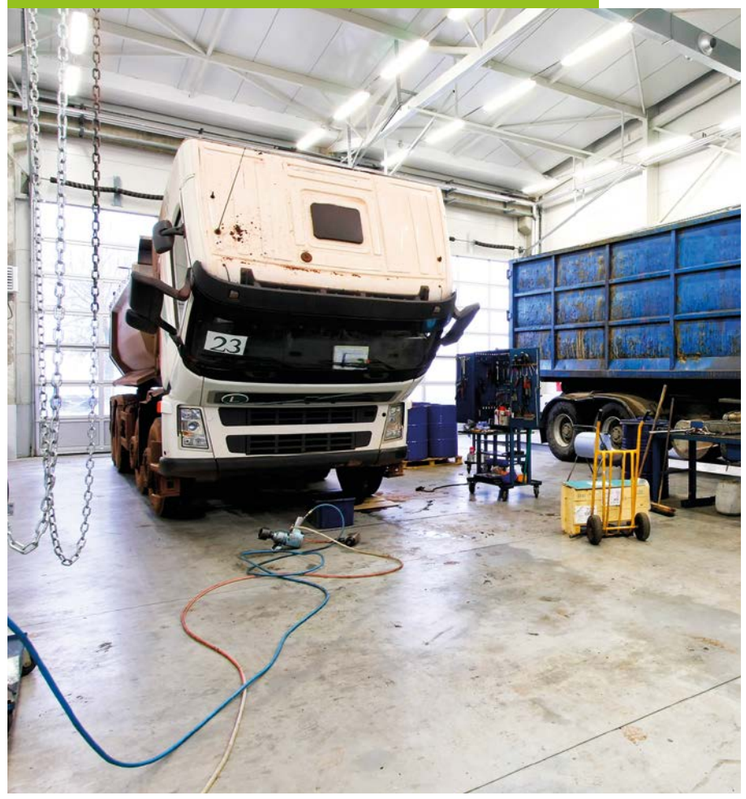
In the production halls of the automotive industry the Paintshop is a space which places specific demands on the lighting solution. The standard EN 12464-1 states the minimal illuminance level 750 lux for the paintshops (1,000 lux for the touch-up jobs). The linear luminaires with the direct distribution of the luminous flux and additional luminaires with a distinctively asymmetric luminous intensity curve by which we can achieve sufficient lighting of the vertical surfaces (walls) are a suitable solution. In dependence on the type of the spraying booth in some cases it is necessary to use the explosion-proof luminaires. Some operations in the paintshop places extraordinary high demands on correctly recognising the colours. It is inspection and touch-up of painting where is inevitable to use luminaires with the light sources achieving excellent CRI values ≥ 90.

AUTOMOBILE WORKSHOP

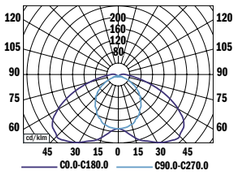
The performance in an automobile workshop includes a lot of various activities. The task of a lighting designer is to design a lighting system which would cover all demands that the operations place on the illumination.

The common feature of the majority of the automobile workshops is the limited accessibility of the daylight. From this point of view a correct solution of the artificial light plays a key role for the visual well-being of the employees and the quality of the work done. The European standard EN 12464-1 states the value of the minimal illuminance 300 lux for the general service of the vehicles, repair and testing in the automobile workshops.
When planning a lighting system it is necessary to take into account the type of performance carried out in the given space. The spaces assigned for maintenance and waxing the vehicles require sufficient vertical illuminance therefore it is suitable to complete the main lighting with luminaires having the asymmetric radiation curve for additional lighting of the task area. In the spaces of the car washroom which are typical for high humidity and where it is impossible to exclude any contact of the luminaires with water, it is necessary to use the water-proof luminaires with minimal IP 54, if it is not clear in advance, what type of strain

In the spaces of the car washroom which are typical for high humidity and where it is impossible to exclude any contact of the luminaires with water, it is necessary to use the water-proof luminaires with minimal IP 54.



the luminaire will be exposed to, the luminaires with an IP 65 have to be installed. In the floor pits where the luminaires are installed on vertical surfaces of the walls, it is possible to use a glare free linear lighting fixture. By its suitable placement we can achieve sufficient illuminance in the upper as well as bottom part of the floor pit space.



The luminous intensity curve Tornado PC LED

Special demands are also placed on the illumination of the paint shop area. The standard EN 12464-1 states a minimal level of illuminance of 750 lux for the paint shop. For activities connected with repairing the paint and inspection activities the illuminance of 1,000 lux is determined, the value of the psychological factor of the glare UGR 19 and the correlated colour temperature CCT 4,000 K ≤ T_{CP} ≤ 6,500 K. Due to good recognition of colours it is necessary to use luminaires with a good colour rendering index CRI ≥ 90. Because in the paint shop we work with flammable and explosive materials it is necessary to install luminaires resistant against explosion.

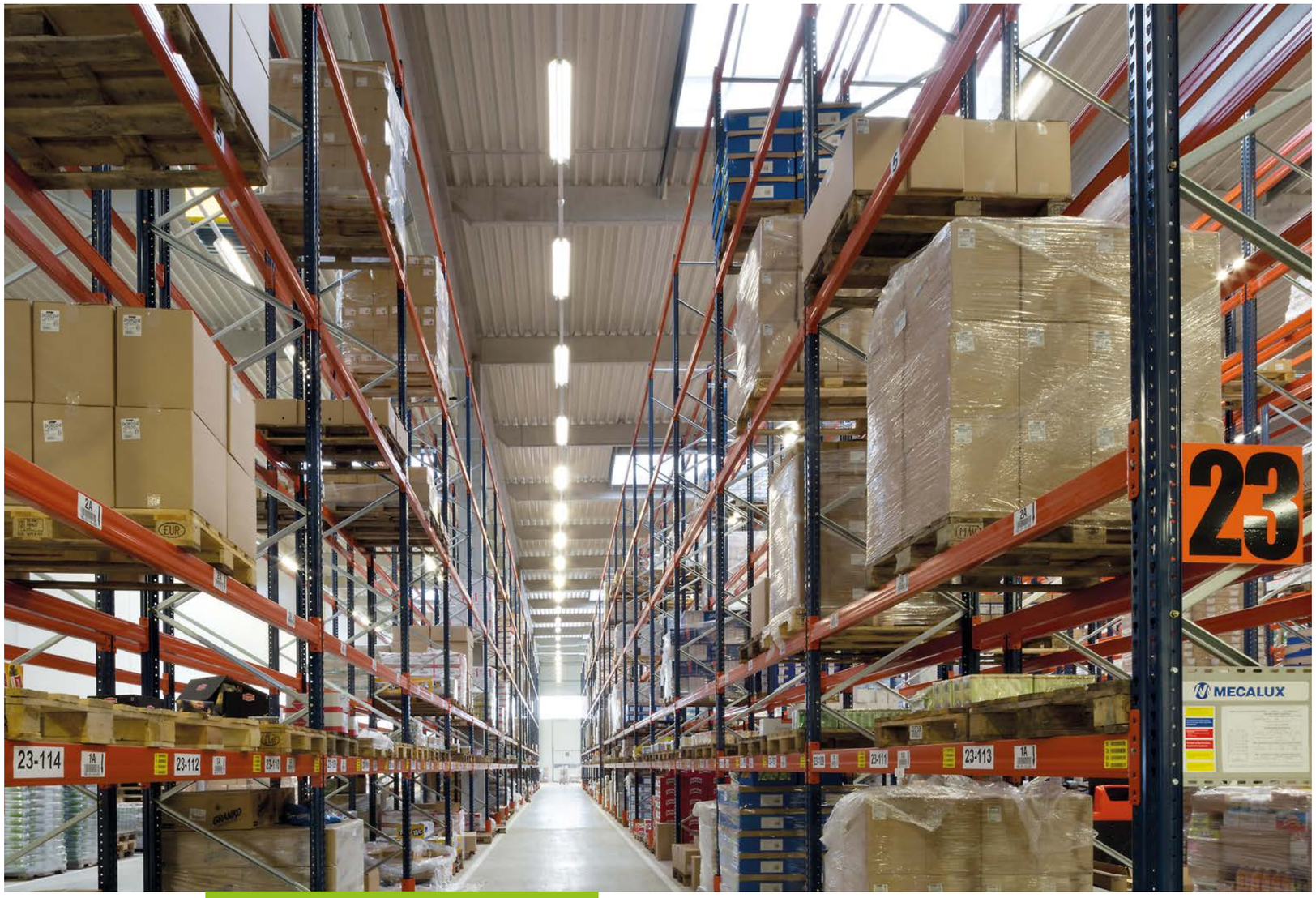
WAREHOUSE

The common property of the warehouse spaces in all lines of business is the low accessibility of the daylight. In combination with the high racks here, bad light conditions develop which can only be solved by an appropriately designed lighting system.

In the warehouse spaces furnished with the racks the importance of sufficient illuminance comes to the foreground.

The European standard EN 12464-1 states the minimal value of the maintained illuminance 100 lux for the warehouse premises without permanent occurrence of persons, for warehouses with permanent presence of employees 200 lux. The experience from practice unambiguously shows that these values are insufficient. They do not give the employees the sufficient visual comfort and especially in the warehouses with high racks they do not create sufficient light conditions for the warehouse employees to be able to read the information from the delivery notes, the packaging of the stored goods or racks. To achieve the adequate visual conditions we recommend the minimal value of the maintained illuminance 300 lux.

The required illuminance level and sufficient vertical illuminance can be achieved by using the linear suspended luminaires with the direct radiation component placed along the aisles between the racks. For the good illuminance of the high-positioned racks in the halls with the wall height 6 metres and more, it is suitable to use the high-bay reflector luminaires with asymmetrical reflectors fitted with housing which will prevent direct glare of the employees when they look directly upwards. Besides the required level of the maintained illuminance it is simultaneously possible to achieve the uniform distribution of the luminance in the warehouse premises with both lighting solutions.



It is important to pay attention to the zones of vehicle entrance and exit from the warehouse. The light scene is distinctively changed in this part of the warehouse space. Especially the transfer from lighter to darker spaces places greater demands on the human eye's adaptation phase which from the point of view of safety is to be reduced to minimum.

It is important to pay attention to the zones of vehicle entrance and exit from the warehouse. The light scene is distinctively changed in this part of the warehouse space. Especially the transfer from lighter to darker spaces places greater demands on the human eye's adaptation phase which from the point of view of safety is to be reduced to minimum. The optimal solution consists of the increased density of the luminaires installed (similarly as in the tunnels) and this will increase the illuminance level in the critical zones and in this way a softer transfer from different light environments will be achieved. When solving the lighting of the warehouse spaces by installing the intelligent tools of the lighting management system we can reach substantial savings of energy. The presence detectors installed are able to switch on the lighting only in those parts of the warehouse where it is necessary.


15.

If an excessive amount of dust develops during this type of production, it is recommended to use the luminaires with the higher-degree protection.

PLASTICS INDUSTRY

The industrial branch of plastics industry includes three different manufacturing processes: injection moulding, extrusion and reaction foam moulding, which place specific demands on the lighting solution.

In general the European standard EN 12464-1 determines the minimal level of maintained illuminance 300 lux for the production spaces with permanent occurrence of employees. For activities which include the demanding visual tasks or work with a PC (or computers controlled machines) it requires the minimal illuminance level 500 lux. In the production halls where plastic processing is under way is besides the general lighting recomended additional illumination of the task area where the higher illumination is needed.

The linear systems of luminaires with the direct characteristic of the luminous flux are a suitable light solution here. In the manufacturing premises with the height of more than 6 metres it is possible to use the suspended luminaires with a wide luminous intensity curve and the metal-halide lamp. Through this solution we achieve the required level of illuminance as well as the uniform illuminance of the whole space.

Plastics industry is often computer-controlled and is managed from a display. When choosing the luminaires and laying them out in the space it is important to avoid the rise of any undesirable reflections which would make it difficult or even impossible for the employees to read the displayed information. In the manufacturing premises with the height of walls 6 metres and more, it is suitable to use luminaires with a wider luminous intensity curve and the high-intensity discharge lamps. If an excessive amount of dust develops during this type of production, it is recommended to use the luminaires with the higher-degree protection IP 54 or IP 65.

Besides the main lighting, some manufacturing activity requires higher illumination level, so its possible to use there additional lighting of the task area. For injection moulding, it is necessary to ensure increased illuminance of the clamping units during the tool replacement. Also the extrusion process requires additional lighting of the task area when the final products (profiles, foils or plates) are subsequently adjusted to the required form or length.

The process of the reaction foam moulding during plastic processing where explosive substances are used places additional demands on the illumination. Therefore it is inevitable to use the explosion-proof luminaires in this part of the premises.

WOODWORKING AND PROCESSING

When solving the illumination of halls in the woodworking and processing industry especially the question of security and safety comes to the foreground. The appropriately designed lighting system creates optimal conditions for the visual well-being of the employees and at the same time it reduces the risk of the rise of injuries.

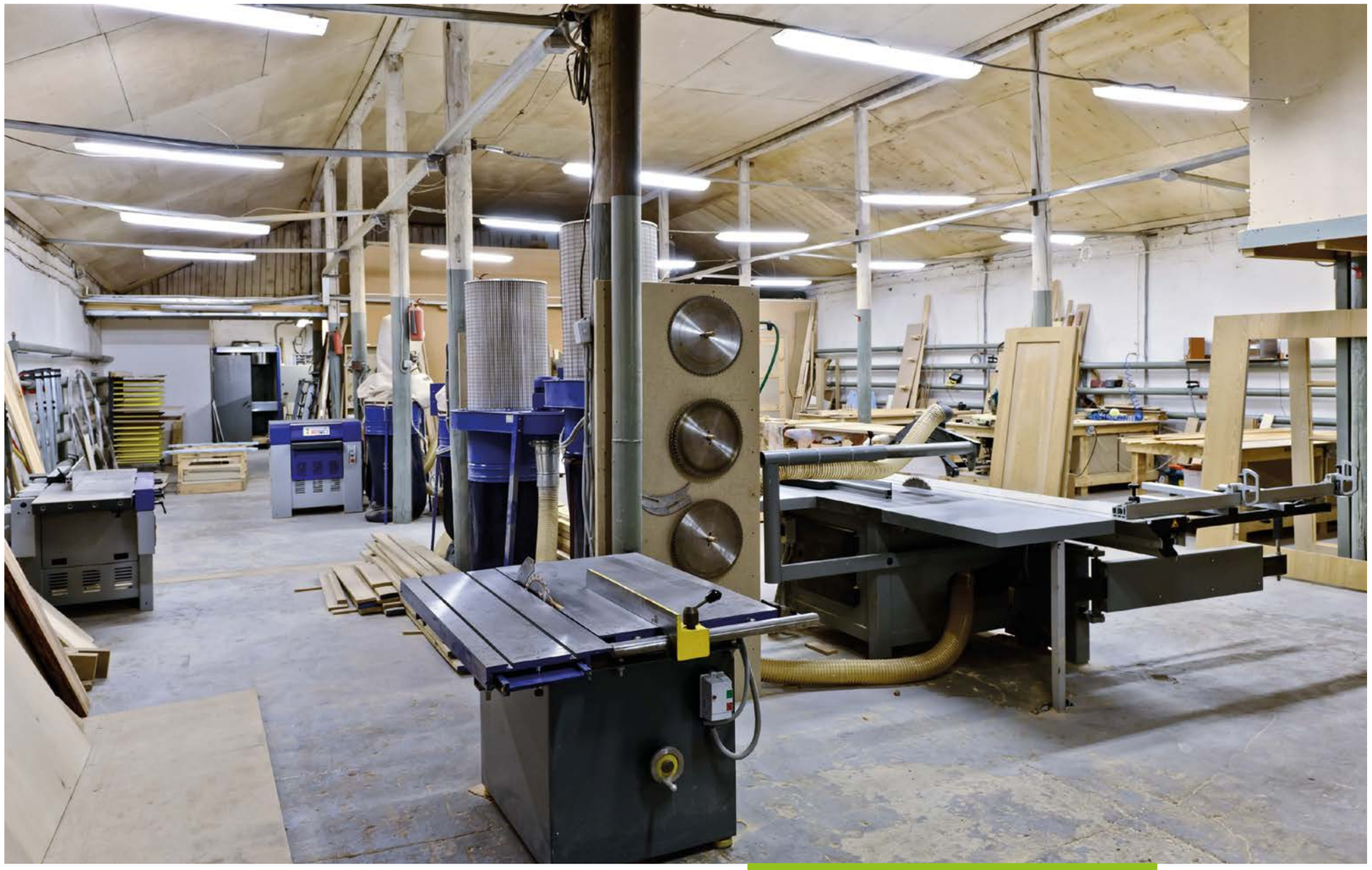
The line of business aimed at woodworking and processing includes a lot of various activities which are frequently concentrated in one hall. The task of the lighting designer is to create such light conditions which will be suitable for all types of activities carried out. In general it means that the main lighting system designed for this type of space is to be strengthened by additional luminaires or lighting fixtures with adequate protection level.

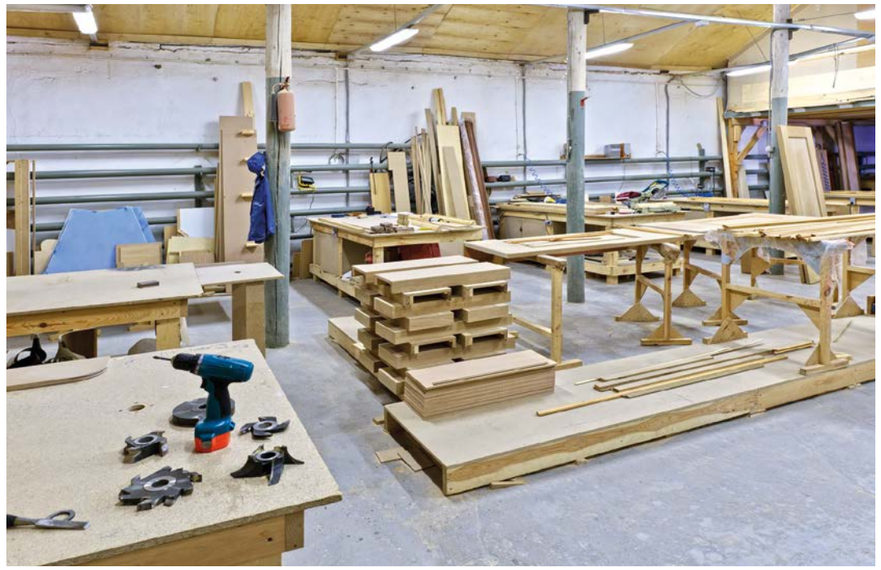
The European standard EN 12464-1 states the value of minimal illuminance 500 lux for the production spaces in the woodworking and processing industry. For the activities as varnishing, grinding and wood inlay work it needs the minimal illuminance level 750 lux and for the inspection 1,000 lux. The variety of the realised activities and frequent transfers in the premises place increase demands on the uniform luminance distribution.

The required illuminance levels and its corresponding uniformity can be achieved by using the ceiling or linear luminaires with the direct component of radiation and a wide luminous intensity curve. In the halls with height 6 metres and more it is suitable to use the suspended luminaires with a wide luminous intensity curve with a metal-halide discharge lamp. At the workplaces where, due to the realised operations an increased concentration of dust occurs, it is necessary to install the luminaires with IP 54 or IP 65.

If the production is concentrated to a hall with access of daylight it is suitable to place the working desks rectangular to the area with windows for ensuring good visual conditions. For activities that require additional lighting – e.g. sawing, milling, drilling – it is good to place the luminaire in such a way that the luminous flux directs moderately from above, from the left hand side in the direction of the employee's view. This lighting minimises the risk of arising sharp shadows and at the same time it ensures good visibility of the sharp part of the machine.

When solving the lighting system in the woodworking and processing industry it is necessary to avoid the stroboscopic effect when the artificial lighting is on. The stroboscopic effect represents a serious danger especially when we work with rotational tools because when the frequency and rotational speed are the same there can develop an impression that the tool is off and cause serious injuries to the user. The stroboscopic effect can be avoided by installing the electronic control gears.





When solving the lighting system in the woodworking and processing industry it is necessary to avoid the stroboscopic effect when the artificial lighting is on. The stroboscopic effect represents a serious danger especially when the employee works with rotational tools.

At the workplaces where the visual inspection is carried out or we work with computers, it is suitable to use the luminaires with diffuser.

ELECTRICAL AND ELECTRONIC INDUSTRY

The production in the electrical and electronic industry consists of a number of processes including simple service activities which do not place heavy demands on the eyes but on the other hand precision work with small components where it is inevitable to ensure the optimal visibility. The appropriate light conditions play a key role here.

When designing the lighting system for the electrical and electronic industry the lighting designer has to take into consideration the variedness of the performed activities and to adjust the lighting solution to them. The individual activities connected with the production of the electrical components or repair of the electrical appliances place different demands on the intensity and lighting solution.

The European standard EN 12464-1 states the minimal illuminance level of 300 lux up to 500 lux for the electrical workshops. For the workplaces where the employees carry out activities demanding on precision or work with small components, it states the value of the minimal illuminance of 1,000 lux, and 1,500 lux for the inspection workplaces and calibration. If the workplace is equipped with high machines it is necessary to ensure sufficient vertical illuminance which will enable the employees to reliably identify machine outlines and to read the displayed digital values. The main lighting consisting of a system of linear suspended luminaires with the direct characteristic of the luminous flux distribution can be in this case completed by luminaires with the asymmetric luminous intensity curve in the task area where the activity carried out requires sufficient vertical illuminance.

The radio and television workshops place similar demands on the lighting solutions as the electrical shop floors. The demandingness of the realised visual tasks requires maintaining the minimal illuminance level of 500 lux at the workplaces where the employees assemble small components, by production of fine wire-wound coils or soldering – here the standard requires the minimal illuminance level of 750 lux. To ensure the optimal light conditions at the workplace it is important to achieve sufficient lighting of the walls and ceiling. In this case the linear suspended luminaires are a suitable solution. In the halls with the height of 6 metres and more, the suspended luminaires with a wide luminous intensity curve and the metal-halide lamps represent an economical alternative.

At the workplaces where the visual inspection is carried out or we work with computers, it is suitable to use the luminaires with diffuser. They are a source of non-glaring soft diffuse light which will form uniform lighting conditions without any risk of creating sharp shadows and undesirable reflections. The activities which include especially demanding visual tasks require increasing the level of the minimal illuminance to 1,500 lux. It can be achieved by installing an additional luminaire directly towards the task area. The higher level of illuminance will enable the employee to perceive the contrast better and will improve his/her 3D perception.

Those spaces place specific demand on lighting where production and assembly of miniature components, chips and microprocessors are carried out. These spaces require dust-free and sterile environment and high levels of the maintained illuminance – 1,500 lux. Those luminaires are suitable which can be cleaned easily, are fitted with a housing made of material which does not change its luminous and chemical properties even when disinfection is carried out frequently.

In the premises typical for high dustiness, it is necessary to install luminaires resistant against dust with IP 54 or IP 65. In the production premises with a high level of humidity (e.g. galvanisation) it is necessary to use luminaires resistant against corrosion. When solving the lighting system it is necessary to avoid the stroboscopic effect when the artificial lighting is on. The stroboscopic effect poses an extraordinary danger especially for operations with rotational tools (e.g. coil winders) as at the same value of frequency and rotational speed an impression can arise that the tool is switched off and in this way the user can be heavily injured. The stroboscopic effect can be avoided by installing the electronic control gears.

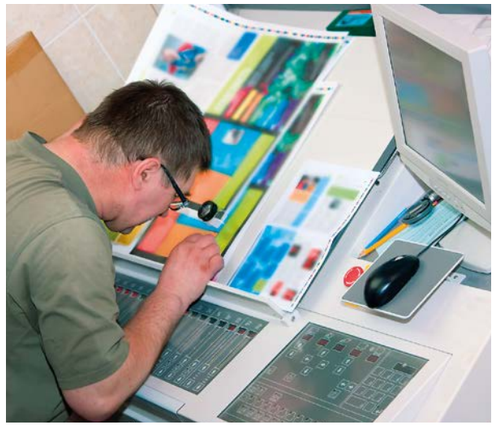
PRINTING

The appropriate illumination of the space in the printing industry plays a key role. Good light conditions are the basic assumption not only for high-quality work but also for safety during handling with fast running printing machines.

As a rule, the space in the printing production is divided into two parts. In the first part the printing operations are carried out, in the second one it is the prepress and finalising the printed material e.g. binding and lithographical processes. The standard EN 12464-1 states the minimal illuminance level 500 lux for both spaces and for typesetting, retouching and litography it increases the required value of the minimal maintained illuminance to 1,000 lux, for the inspection activities to 1,500 lux and for copper engraving up to 2,000 lux.
The required illuminance levels can be achieved by using linear luminaires with the direct characteristic of the luminous flux distribution. In the printing works with the height of walls 6 metres and more the suspended luminaires with the wide luminous intensity curve and metal-halide lamps are an alternative. By the appropriate layout of the luminaires and the corresponding proportion of the indirect component of the luminous flux we can avoid the rise of undesirable reflections when working with glossy paper or foils. If the printing is realised on large machines, it is at the same necessary to achieve sufficient vertical illuminance. We can use the additional luminaires placed directly over the machine or the task area.
For the multicolour printing process and the inspection operations it is necessary to use the light sources with the colour rendering index CRI >90 for correct distinguishing of colours. It is important to choose such light sources that produce neutral white or daylight white colour of light with the correlated colour temperature $5{,}000\,K \leq T_{CP} \leq 6{,}500\,K$ which is closest to the properties of the natural daylight.

The prepress workplaces are today almost always equipped with computers therefore when designing the lighting system we have to pay attention to fulfilling the requirements of the standard EN 12464-1 valid for the VDU workplaces as to the usage and layout of the luminaires. The standard states the minimal illuminance level 500 lux for this workplace and the boundary values of the average luminance which can be reflected from the flat screens must not exceed the values of 1,500 cd/m² (displays with high luminance) or the value of ≤ 1,000 cd/m² (displays with medium luminance).

For the multicolour printing process and the inspection operations it is necessary to use the light sources with the colour rendering index CRI ≥ 90 for correct distinguishing of colours.



CLEANROOM

Originally these types of rooms were utilised in medicine. Today when the requirements on quality and flawlessness of the final product are getting stricter and stricter, we can meet this type of manufacturing premises also in various lines of business.

Nowadays we can find the cleanroom in the chemical, microelectronic as well as electronic industry. They are part of industrial halls aimed at manufacturing semiconductors or biotechnologies; they have their place in industrial processing of metals and even in the food industry. The main task of the cleanroom is to prevent pollution or product contamination. The requirements on equipping and furnishing the space adjust to this purpose and it also concerns the lighting solution in full extent.

In general the optimal solutions here are considered the ceiling recessed luminaires with the direct characteristic of the luminous flux distribution. As in the case of the cleanroom there are rooms with directed air flow, the luminaires without an extended diffuser represent an optimal solution as they have almost no impact on the air flow. When selecting the luminaires the overall shape and material they are made of play a very important role. As to the shape it is important to avoid luminaires with undercuts, slits, joints and the so called wake space harbour where the remnants of the manufacturing material could be trapped. As a matter of fact, here is a risk that the primary air will not take these particles out. Subsequently it is difficult to remove them from such problem zones by cleaning. The microorganisms which come repeatedly into contact with a low concentration of detergents can build resistance against them and in this way become a source for generating highly resistant bacterial germs.

When selecting luminaires for the cleanroom it is similarly important to take into account the material they are made of. In general, it is valid that they should be produced from a material with low porosity which even after repeated contacts with chemicals and detergents does not change its properties. The rough surfaces increase the risk of catching the particles of the manufacturing waste and subsequent contamination of the products. In dependence on the type of production it is necessary for the luminaires to be fitted out with housings with a corresponding IP factor.

The selection of a luminaire with an adequate IP depends on the procedure how the cleanroom is air-conditioned or how the air flow is directed in the room. In principle two methods are used: the laminar airflow and mixed airflow. In the case of the laminar airflow the air flows from top to bottom. This type of directing the air is often utilised in manufacturing semiconductors and microcomponents. The luminaires with the IP 40 are suitable for this type of cleanrooms.

When using the type "mixed airflow" the air is distributed in the room in turbulent patterns. This method of directing the airflow in the cleanroom belongs to the most frequently used ones because it is the most economical. In dependence on the type of production it is necessary for the used luminaires to achieve IP 54 or IP 65.

Luminaires for the cleanroom should be produced from a material with low porosity which even after contacts with chemicals does not change its properties.

The luminaires used for the main lighting should have housings made of unbreakable materials.

FOODSTUFFS INDUSTRY

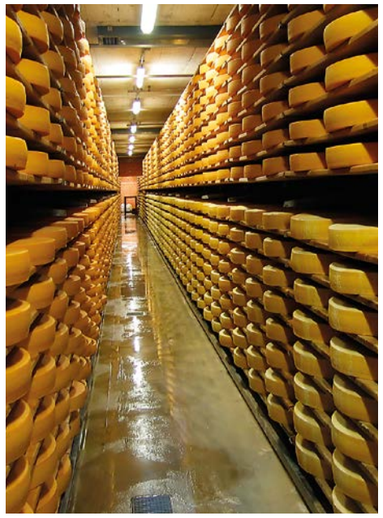
The foodstuffs industry places higher demands especially on the cleanliness and hygiene of the manufacturing premises. The correct illumination is another task, which is no less important, when processing foodstuffs and making drinks. A sufficiently illuminated space enables the employees problem-free realising the work activities and at the same time it creates a trustworthy atmosphere which highlights the positive picture of the company.

The spectrum of the working activities which are connected with processing or manufacturing the foodstuffs and drinks extends from simple and mostly mechanised activities when the employees fulfil only an inspection task up to specific and visually demanding tasks. The task of the lighting designer is to design the lighting system in such a way that it will comply with the light requirements laid on each of the activities carried out. The standard EN 12464-1 states the minimal level of illuminance 200 lux for the spaces where washing, boiling, drying, fermenting and filling operations are realised. For the manufacturing premises where the employees carry out cutting, grinding, mixing, sorting and packaging the standard states the minimal illuminance level of 300 lux, for the spaces where the employees fulfil visually demanding tasks or at a high risk of injury it states the minimal illuminance level 500 lux (abattoirs, butcheries, dairies, mills, delicatessen food production).

At the inspection workplaces and where recognising the colours is important it requires the minimal illuminance level 1,000 lux, luminaires with the colour rendering index CRI 90 and correlated colour temperature 4,000 K ≤ T_{CP} ≤ 6,500 K.

The required illuminance level can be achieved by using suspended linear luminaires with the direct characteristic of distribution and to complete them with additional lighting fixtures with the asymmetric radiation curve where it is important to achieve sufficient values of the vertical illuminance for a concrete task area. E.g. they are workplaces with fully automated manufacturing. The additional luminaires are required also at workplaces where the employees carry out especially demanding visual tasks (e.g. decorating, checking bottles). The luminaires with matted housing or microprism which are a source of soft diffuse light and minimise the risk of the rise of undesirable reflections from the bright surfaces (cans, bottles) are suitable. The luminaires used for the main lighting should have housings made of unbreakable materials which prevent fragments falling down to the foodstuffs or drinks being processed when the luminaire is damaged. From the point of view of safety it is suitable to use luminaires with LED sources which contain in comparison with the conventional sources incomparable lower amounts of hazardous materials (mercury). Moreover, in comparison to other light sources they contain mercury in solid state, i.e. in the case of damaging the light source there is no risk of the air contamination in the manufacturing premises.

At the same time the importance of recognising the colours correctly in all manufacturing processes in the foodstuffs industry comes to the fore. It is valid for workplaces where we work with food colouring as well as for all other workplaces where the employees carry out the visual inspection of the food freshness. Therefore we recommend using the light sources with high values of the colour rendering index with CRI minimally 80. From the point of view of safety it is suitable to use luminaires resistant against humidity, dust and at some places also against explosion with IP 50, for wet places IP 65 in the manufacturing halls



determined for processing and production of foodstuffs.

The cold stores require a special lighting solution in the foodstuffs industry. From the point of view of the standard they are warehouse spaces for which the minimal illuminance level 100 lux is stated. However, the experience from practice shows that this value is insufficient and it is recommended to maintain also in these spaces the minimal illuminance level 300 lux. In the light conditions like this the employees are able to read the information from the delivery notes and to see the designation of the foodstuffs in the racks better. The luminaires have to be resistant against coolness and humidity therefore we recommend to use the types with IP 54 or higher. One of the key tasks of the lighting designer when designing the illumination of the cold stores is to take into account the fact that at the temperature 0°C there is a significant reduction of the luminous flux which can achieve up to 40 % at lower temperatures. Therefore it is necessary to implement the correction factor to the lighting system already during the planning phase. Another way how to avoid this problem is to use the luminaires with the LED sources which even at substantially low temperatures do not show any reduction of the luminous flux and vice versa, their luminous flux picks up intensity with the declining temperature.

BUTCHERY

Processing meat includes a lot of various activities which utilise, almost without any exception, sharp working tools. Correct lighting of the manufacturing spaces is therefore important not only from the point of view of creating optimal lighting conditions for the employees´ visual comfort but also due to safety at the workplace.

The European standard EN 12464-1 states the minimal illuminance level of 500 lux for the manufacturing halls of the meat processing industry. This value is valid also for seemingly simple operations, e.g. washing. As just in meat processing the hygienic flawlessness is emphasised, washing is considered a demanding visual task.

The required illuminance level can be achieved by installing a system of linear luminaires with direct characteristic of the luminous flux distribution which achieves adequate values of the illumination of the vertical surfaces. At workplaces which require sufficient illuminance of the vertical surfaces, it is suitable to complete the main lighting by the luminaires with the asymmetric luminous flux curve. We recommend them to be placed parallely with the working area and windows.

The luminous flux should head to the task area from above and moderately from the left from the employee's view. This minimises the risk of creating sharp shadows and at the same time perfect visibility of the sharp ends of the working tools is ensured – it reduces the risk of injuries. At the workplaces where the employees carry out especially demanding visual tasks it is suitable to complete the main lighting by additional luminaires. For the employees to be able to carry out the visual inspection of the meat's freshness it is necessary to use the light sources with the colour rendering index CRI 80 minimally. Due to the safety at work it is suitable to use the luminaires with housing made of unbreakable material or protected by a grid which prevents fragments falling down to the meat being processed in the case the luminaire is damaged. Because of the working conditions the luminaires used have to be resistant against humidity and corrosion, with IP 54 or higher.

If there is a store in the meat-processing plant where the producers sell their products it is suitable to use luminaires with a high proportion of red light for illuminating the showcases with meat. The goods illuminated with this type of light gives an impression of a redder and thus a fresher product.

If there is a store in the meat-processing plant where the producers sell their products it is suitable to use luminaires with a high proportion of red light for illuminating the showcases with meat. The goods illuminated with this type of light gives an impression of a redder and thus a fresher product.

The LED light sources represent an optimal solution which compared to the conventional sources contain incomparably lower amount of hazardous materials.

BAKERY

When planning the lighting system for a bakery the lighting designer has to take into account not only the variedness of the realised activities but also the shift operation.

The standard EN 12464-1 states the minimal illuminance level of 300 lux for preparation and baking. For finishing, glazing and decorating it increases the requirement to 500 lux. A higher illuminance simultaneously positively affects the activity and performance efficiency of the employees and influences the potential customers or the visits by a pleasant welcoming impression.

When designing the lighting system it is good to take into account the fact that a substantial part of manufacturing runs during the night hours or early in the morning. Optimal performance efficiency and the feeling of the visual and psychological well-being of the employees during the night shifts can be achieved by increasing the lighting intensity to 1,000 lux. At the same time it is suitable to use the light sources which are able to produce daylight white colour of light with the correlated colour temperature CCT of more than 6,500 K. In such light conditions that copy the properties of the daylight, melatonin which would signal to the employees that it is time for sleep stops being created in the human organism. And on the contrary, it increases the production of serotonin that stimulates the activity and performance efficiency.

When taking these facts into consideration, it is possible to meet all demands on the required lighting level of 1,000 lux and through integrating the lighting management tools to reduce its performance to a value which is stated for the individual activities by the standard.

A suitable solution for lighting in the bakery premises is the system of linear suspended luminaires with the direct characteristic of the luminous flux distribution and to complete them with luminaires with the asymmetric radiation curve in the task area which require a sufficient illuminance of the vertical surfaces. In the bakeries with higher ceilings it is possible to use the suspended luminaires with a wide luminous intensity curve and metal-halide lamps. In both cases it is necessary for the luminaires to be protected by an unbreakable housing which prevents fragments falling down to the working surface when the light source is damaged. It is necessary to use protection level of luminaires with a housing of IP 50 value. From the security point of view the luminaires with the LED light sources represent an optimal solution which compared to the conventional sources contain incomparably lower amount of hazardous materials (mercury). Moreover compared to other light sources they contain mercury in solid state, i.e. also if the light source is damaged there is no risk of contaminating the air in the manufacturing spaces. At the same time the light sources used have to enable the recognition of the colours correctly (e.g. when choosing the ingredients or during decorating) therefore we recommend using the light sources achieving the value of the colour rendering index CRI 80 and more.

To avoid the rise of undesirable reflections from the materials and tools with bright surface or on the screens, it is suitable to use non-glaring luminaires with factor of the psychological glare UGR max.19

CHEMICAL INDUSTRY

When planning the lighting system for the chemical industry the lighting designer has, besides the required illuminance levels, to take into account also the resistance of the luminaires against dust and explosions.

The European standard EN 12464-1 states for the production premises in the chemical industry the minimal illuminance level 300 lux for the zones with a permanent occurrence of employees, 150 lux for activities with a limited occurrence of people and 50 lux for the remotely controlled activities. The required illuminance levels can be achieved with ceiling surfaced or suspended linear luminaires with the direct characteristic of the luminous flux distribution. At the inspection workplaces and at the workplaces with permanent supervision of the manufacturing process it is at the same time necessary to achieve adequate values of the vertical illuminance. The additional luminaires with the asymmetric radiation curve (wall washers) are a suitable solution. In the production halls with the height of 6 metres and more it is possible to achieve the optimal light conditions by installing the luminaires with a wide luminous intensity curve and the metal-halide lamps.

At the workplaces with an increased occurrence of dust and dirt (e.g. mixing, grinding, pulverising) it is necessary to use the luminaires with the protection housing IP 65.

The laboratories in the chemical industry require a special lighting solution. The normative requirements state the minimal illuminance value 500 lux, for the inspection workplaces 1,000 lux and the neutral white or the daylight white colour of the light corresponding to the range of Correlated Colour Temperature $4{,}000\,K \leq T_{cp} \leq 6{,}500\,K$. For the employees to be able to identify the colour reliably during usage of the chemicals, the light sources used have to achieve excellent values of the colour rendering index CRI 90 and more. To avoid the rise of undesirable reflections from the materials and tools with bright surface or on the screens, it is suitable to use non-glaring luminaires with a matt housing or microprism and the factor of the psychological glare UGR max.19. As the explosive and flammable substances are used for work in the labs, it is necessary to use the luminaires with IP 65.

UNDERGROUND PARKING

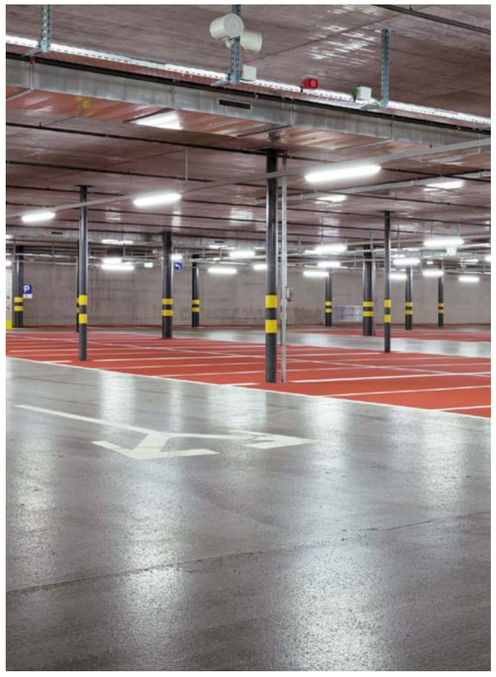
The underground parking lot places special demands on the intensity and type of illumination, beginning with the luminaire marking the entrance and way out, through the guidance lighting up to general lighting of the functional area.

One of the most important tasks of the lighting system designers when they solve the illumination of an underground parking lot is the entrance and exit zone from the parking area in the framework of which the light scenery is distinctively changed. Such an environment places extraordinary demands on the adaptation phase of the human eye during transition from various light environments. It is inevitable to reduce this phase to minimum. The optimal solution includes a higher quantity of the luminaires installed in these zones (similarly as in the tunnels) which means a softer change of illuminance and safer transition.

The task of the general lighting in the underground parking lot is not only to ensure the basic visibility but to provide the person in the parking area a feeling of comfort and security. For the road users in the parking lot environment to be able to assess and solve the situation sufficiently quickly, it is inevitable to choose the luminaires with the lighting intensity of minimally 75 lux. In general it is recommended to use the luminaires in anti-vandal version and a long lifetime placed on both sides of the traffic lanes. A sufficient illumination especially in the areas with irregular occurrence of people is inevitable also from the security point of view. It enables the persons to recognise faces and to respond in time to the first signs of aggression.

The task of the general lighting in the underground parking lot is not only to ensure the basic visibility but to provide the person in the parking area a feeling of comfort and security.

When designing the light solution it is to also take into account the lifetime of the light sources. From the point of view of the lifetime and demandingness on the maintenance the LED luminaires are especially suitable. As they are areas without any access of daylight and at the same time without permanent occurrence of persons, it is suitable from the point of view of energy saving to consider the installation of the constant illuminance sensor and presence detector that scans the movement of the vehicles in the garage, manages the illumination in the zones where it is necessary and creates the guidance lines in the area of the underground parking lot.

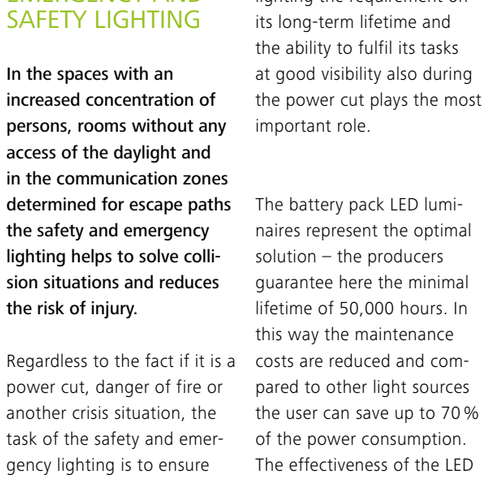


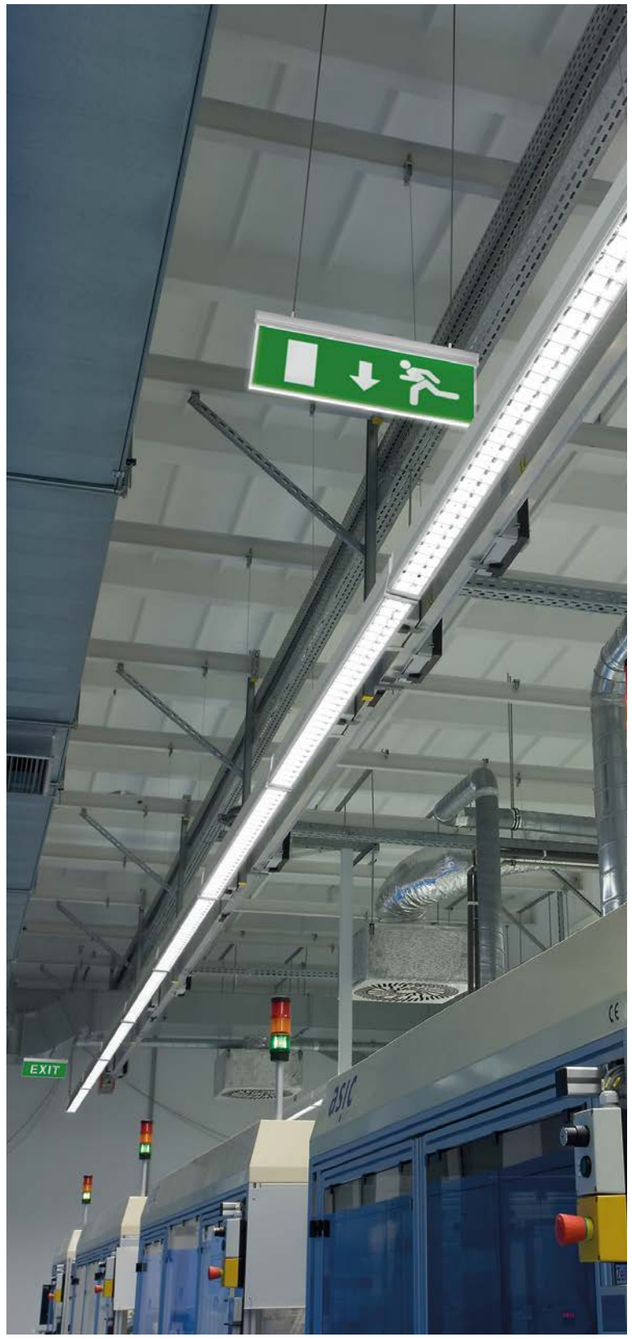
EMERGENCY AND SAFETY LIGHTING

In the spaces with an increased concentration of persons, rooms without any access of the daylight and in the communication zones determined for escape paths the safety and emergency lighting helps to solve collision situations and reduces the risk of injury.

Regardless to the fact if it is a power cut, danger of fire or another crisis situation, the task of the safety and emergency lighting is to ensure the persons basic visibility and orientation during leaving the space or to make their access to the fire extinguishers easier. Correctly planned and carefully maintained emergency lighting can prevent an outbreak of panic, injuries and even save lives. When selecting the type of the emergency lighting the requirement on its long-term lifetime and the ability to fulfil its tasks at good visibility also during the power cut plays the most important role.

The battery pack LED luminaires represent the optimal solution – the producers guarantee here the minimal lifetime of 50,000 hours. In this way the maintenance costs are reduced and compared to other light sources the user can save up to 70 % of the power consumption. The effectiveness of the LED emergency lighting can be increased by installing the additional optics and reflectors which will reduce the number of the LED luminaires when the legal standard is fulfilled. The requirement on the safety and emergency lighting is adapted by the European standard EN 1838.





Correctly planned and carefully maintained emergency lighting can prevent an outbreak of panic, injuries and even save lives.

Definition of emergency lighting
The relevant standards define emergency lighting as lighting that is activated as a result of a malfunction in the general artificial lighting.

Objectives of emergency lighting
- Safe escape from the problem zone on failure of the general power supply (visibility required for evacuation)
- Adequate visibility and orientation along escape routes and in danger zones (illuminated or backlit safety signs along escape routes, direction signs to assist progression towards the emergency exit)
- Easy identification of fire-fighting and safety equipment

1. Safety lighting for escape routes
The safety lighting for escape routes is that part of safety lighting that enables escape facilities to be effectively identified and safely used.

Escape routes up to 2 m in width:	
Illuminance	at least 1 lux along the central axis, 0.5 lux over at least half the width
Uniformity	$E_{max} : E_{min} \leq 40 : 1$ lux
Colour rendering	CRI ≥ 40
Rated service time for escape routes	1 hour
Switch-on delay	50 % of the required illuminance level within 5 seconds, 100 % within 60 seconds

(wider than 2 m can be considered as a group of 2 m wide strip or can provide by lighting as in open area – anti-panic lighting)

2. Anti-panic lighting
Anti-panic lighting is that part of safety lighting that serves to avoid panic and provide illumination to allow people to reach a place where an escape route can be reliably identified.

Illuminance	E *(horizontal at floor level)* ≥ 0.5 lux
(Marginal areas with a width of 0.5 m are not taken into consideration)	
Uniformity	$E_{max} : E_{min} \leq 40 : 1$ lux
Colour rendering	CRI ≥ 40
Rated service time for escape routes	1 hour
Switch-on delay	50 % of the required illuminance level within 5 seconds, 100 % within 60 seconds

3. Hazardous workplaces
There are special requirements that relate to potentially hazardous work processes and situations. Proper shut-down procedures are needed for the safety of operators and all other occupants of the premises, for example in places where machines are running, in laboratories handling hazardous and in control rooms.

Illuminance	E_{min} = 10 % of the level needed for the task or at least > 15 lux
Uniformity	$E_{max} : E_{min} \leq 10 : 1$ lux
Colour rendering	CRI ≥ 40
Rated service time for escape routes	for as long as the hazard persists
Switch-on delay	0.5 seconds


SWL UNDER SPREADER
SWL UNDER CARGO BEAM
HARD HAT AREA
OBRIGATÓRIO USO DE CAPACETE

OUTDOOR WORKPLACES

When planning the lighting system for industrial spaces it is important to take into account the fact that lots of activities are carried out in the external environment. The task of the artificial lighting comes to the foreground, here especially after dark, when it is necessary to ensure optimal conditions for carrying out various demanding, visual tasks and at the same time to minimise the risk of injury at the workplace.

While in the internal working spaces the artificial light plays only an additional task during the day, the outdoor workplaces use it only from the evening to early morning hours when we cannot count on the support of the natural light.

This fact fundamentally affects not only the employees´ sharpness of vision but also their physiology. The sharpness of the human vision achieves only 3 % to 30 % after dark compared with the vision during the day. Moreover, the activity of the retinal cones in the human eye which enable to recognise colours and shapes is suppressed. After getting dark the so called mesopic vision starts when the retinal rods which recognise only grey shades are activated in the retina of the human eye. When the evening is coming, the level of the relaxation hormone melatonin increases in the human organism which causes decline of the performance efficiency of the human organism to less than 10 %. Due to the increased fatigue the employee's concentration capability decreases and therefore the risk of injury occurrence is greater. The adequate lighting intensity and suitably selected correlated colour temperature can create such light conditions at the outdoor workplace which activate the activity of the colour-sensitive cones, improve the employees´ performance efficiency and their ability to concentrate and in this way it also increases their safety at work.

When planning the lighting system, besides the biological influence of the light on people it is necessary to solve a few other problems connected with the ergonomics of the outdoor workplace. Due to the fact that when planning the illumination we cannot count on the reflective surfaces here, it is only possible to use the luminaires with a direct characteristic of the luminous flux distribution for the illumination of these spaces. This type of lighting presents an incomparable higher risk of developing undesirable sharp shadows and direct glare caused by the light source. They can be prevented only by a correct layout of the luminaires, by using the lighting fixtures with shields against glare and through rectifying the luminous flux.

As there are frequent movements of employees and equipment at the outdoor workplaces, defining the task area itself poses another frequent problem for a lighting solution. When it is impossible to determine exactly the place of the visual task, it is necessary to dimension the lighting system for the whole outdoor workplace on the highest illuminance level required by the standard for carrying out the most demanding visual task.

We are to take into account such a fact that the outdoor workplace is often surrounded by a dark area which can pose a risk of a non-uniform luminance distribution. If there is a too big difference between the luminance levels in the individual parts of the space, it takes the human eye a few minutes until it adapts. There is an increased eye strain, the premature visual fatigue develops and subsequently the employees lose their concentration. This increases the risk of injuries at the workplace. To prevent this, it is necessary to create a homogeneous light environment without any distinctive differences in the luminance intensity at the workplace. A uniformly illuminated workplace contributes to the psychological well-being of the employees and creates a positive communication atmosphere. From the point of view of safety it is also necessary to prevent the rise of the stroboscopic effect when the artificial lighting is on at the workplace. The stroboscopic effect represents an extreme danger, specially when working with the rotational tools because when the frequency and the rotational speed are the same an impression can arise, that the tool is off and it can cause hard injury to the user. The stroboscopic effect can be avoided by installing the LED luminaires or high-frequency control gears emitting the light with a frequency that the human eye cannot notice and therefore it perceives it as constantly continuous.

The European standard EN 12464-2 adjusts the requirements on the illumination of the outdoor workplaces.

The key factor when solving the illumination of these spaces is to achieve a sufficient illuminance level of the task area and the surrounding of the task area with the luminance distribution as uniform as possible.

PETROCHEMICAL AND POWER INDUSTRY

The maintenance and operating activities in a lot of industrial lines of business require creating outdoor workplaces. Handling with machines and tools demands a thorough lighting solution not only for ensuring sufficient sharpness of vision but also from the point of view of safety.

Creating external workplaces is necessary in various industrial lines of business. They are needed e.g. for the chemical, petrochemical and power industry or mining and processing minerals. The key factor when solving the illumination of these spaces is to achieve a sufficient illuminance level of the task area and the surrounding of the task area with the luminance distribution as uniform as possible in the whole manufacturing space and a minimal risk of undesirable glare.

The European standard EN 12464-2 requires the minimal illuminance level from 20 lux to 100 lux, with the uniformity from U_o= 0.25 to U_o= 0.4 for general activities carried out in the external workplaces in the petrochemical and power industry. For the activities involving the machine repairs as well as repairs of the electrical equipment it increases the requirement for the minimal illuminance to 200 lux with the uniformity of U_o= 0.5 and determines the additional local lighting in the place of the visual task.

When designing the lighting system the lighting designer's task can be made more difficult by the fact that it is hard to determine the task area. Then it is necessary to achieve the standard determined illuminance levels in the whole manufacturing space.

An increased emphasis, when solving the illumination of the external workplaces in the petrochemical and power industry, is laid on the uniform luminance distribution in the whole manufacturing area. If there is too big difference between the luminance levels in the individual parts of the space, it takes for the human eye a few minutes to adapt and due to this fact the eyes are exposed to an increased strain and it can cause the premature visual fatigue and subsequently the loss of concentration. This increases the risk of injury at the workplace. The dark and insufficiently illuminated zones can, moreover, arouse feelings of depression of the employees. On the contrary, the homogeneously illuminated space where the employees can see each other induces a communication atmosphere and improves the feeling of the psychological comfort. The communication atmosphere can be also improved by sufficient cylindrical illumination in the task area which enables to recognise the face of the colleagues with any occurrence of disruptive dark shadows. The task of the lighting system designer is to design the lighting system in such a way that homogeneous light environment without any great differences in the luminance intensity will be created in the whole panoramic field of the vision of the employees.

The required illuminance levels with the corresponding uniformity of the luminance distribution can be achieved by using the asymmetrical reflector luminaires for high pressure lamps. At the same time, their high-grade facetted optics and a flat glass enclosure minimise the risk of developing glare of the employees. This type of luminaires achieves the sufficient illuminance of the whole working plane. For lighting large surfaces we can use the wide-angle flood systems. Due to the fact that the outdoor workplaces in the petrochemical and power industry are typical by a high concentration of dirt, dust and humidity, it is necessary to select luminaires produced from a sufficiently resistant material and adequate IP coverage level.

At the workplaces where we handle with explosives or where explosive fumes are released to the environment (refineries, natural gas wells) it is necessary to use luminaires resistant against explosion.

When solving the illumination the outdoor switching stations require increased attention due to the safety reasons. During the night operation it is important to create such light conditions when it is possible to carry out reliably the visual inspection of wiring at any time. In this connection the requirement on the sufficient illuminance comes to the foreground – here the standard EN 12464-2 determines the minimal value 50 lux. The luminaires in the lighting system have to be installed in a sufficient distance from the high voltage power line for the employees not to be exposed to the danger of hitting by the electric current while maintenance and lamp replacement are carried out. It is recommended to install the luminaires to the height where it is not necessary to use a ladder for handling with them.

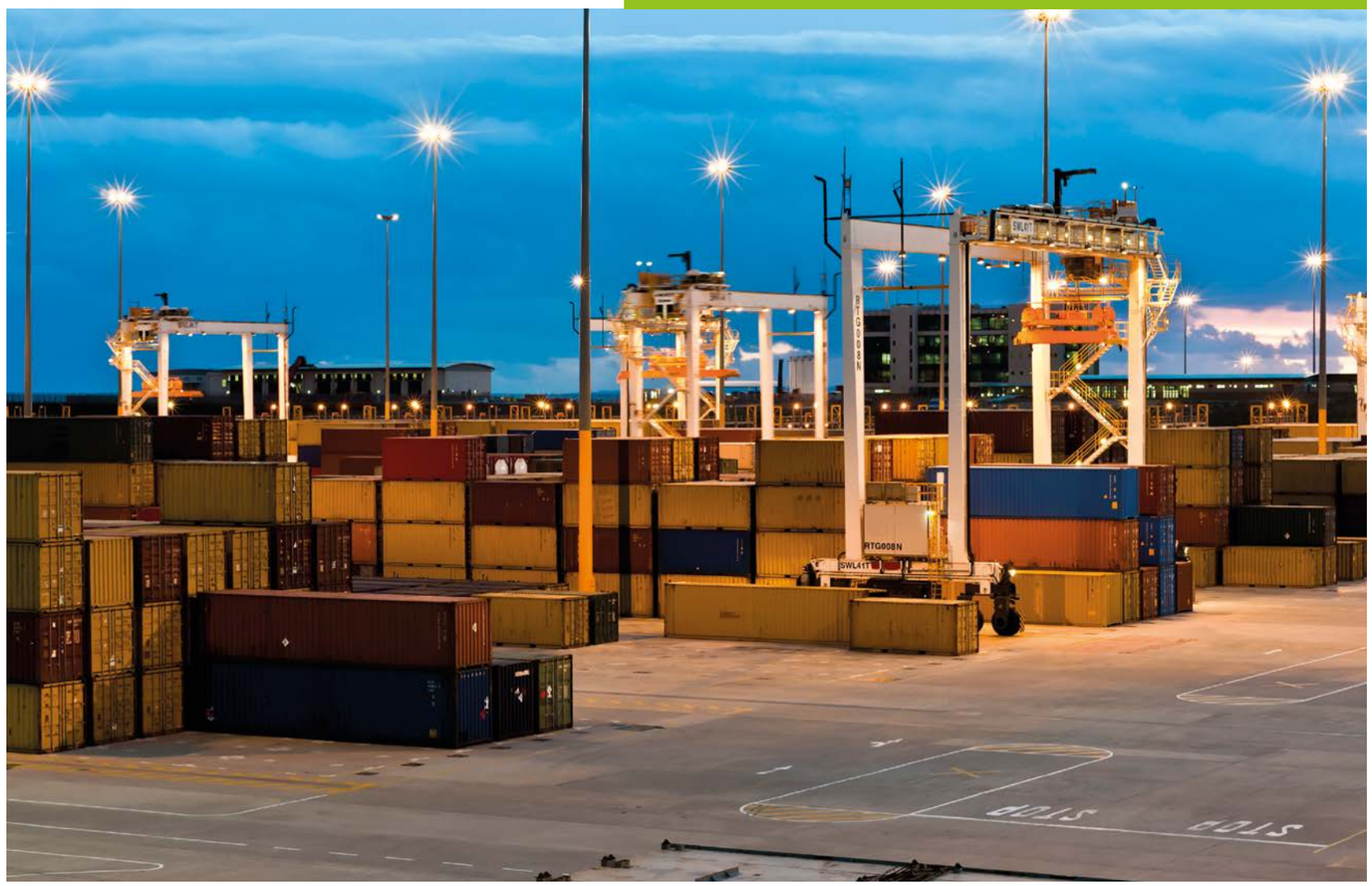
STORAGE AND LOGISTICS

The solution of the illumination in the storage spaces requires a flexible approach. While in the outdoor warehouses without night operation especially the question of the property protection comes to the foreground, in the warehouses with a non-stop operation the key factor is to ensure the safety at work for the employees.

The required illuminance levels stated by the standard EN 12464-2 change in dependence on the type of the space and the activity performed. In the storage spaces without the night operation where it is necessary to protect the property or in the warehouses with the non-stop operation where only short-time handling with large parts and raw materials or loading and unloading of solid bulky goods is carried out, the standard requires the minimal illuminance level 20 lux. With the increasing demandingness of the visual task the employees have to carry out and the rising risk of the injury occurrence at the workplace, the standard increases the requirements on the minimal illuminance level 50 lux (non-stop handling with raw materials, the movements of the crane, loading and unloading of goods) and 100 lux (reading addresses, working with tools). For the activities connected with installing the electrical, machine and pipeline devices and the inspection operations it states the minimal illuminance level 200 lux with the uniformity of U_o=0.5 and also requires installing the local lighting in the task area.

In the outdoor warehouses where no handling with goods occurs during the night hours it is important to ensure the minimal security lighting level especially for protecting the property. Therefore it is important to prevent the rise of the camouflaging shadows. The risk zones and dangerous places in the warehouse premises should be emphasised by the reflexive paint. For the general lighting of the space it is suitable to use the pole luminaires with a wide luminous intensity curve. The sufficient periphery illuminance will provide the security staff an overview about the movement of unauthorised persons in the storage space. The checkpoints of the security staff should remain unlit from outside. The unauthorised persons who would enter the warehouse cannot identify where the security is while they themselves will be easily seen in the light of the reflectors. If the warehouse is enclosed by a fence, it is suitable to install lower pole luminaires with a wide luminous intensity curve on the circumference of the fence. This lighting solution will ensure sufficient periphery illuminance and the illumination of the access zone. If there is an increased risk of damage or theft it is suitable to fit every pole with two luminaires and to connect them to a special circuit.

The risk zones and dangerous places in the warehouse premises should be emphasized by the reflexive paint.



However, this type of light solution should not exceed the permissible illuminance levels to avoid obtrusive light on the adjacent estates.

The outdoor warehouses with the night operation are usually situated close to the loading and transport facilities. Besides the general lighting, this type of workplaces should be illuminated adequately in the framework of the whole working plane and this will be achieved by the additional illumination of the task area. If moving devices are used for transporting the goods from place to place, the dynamic lighting solution is suitable. When portal and bridge cranes are utilised, it is suitable to place the luminaires with a wide luminous intensity curve directly to the undercarriage of the device for the luminous flux to head perpendicular to the route the crane moves on.

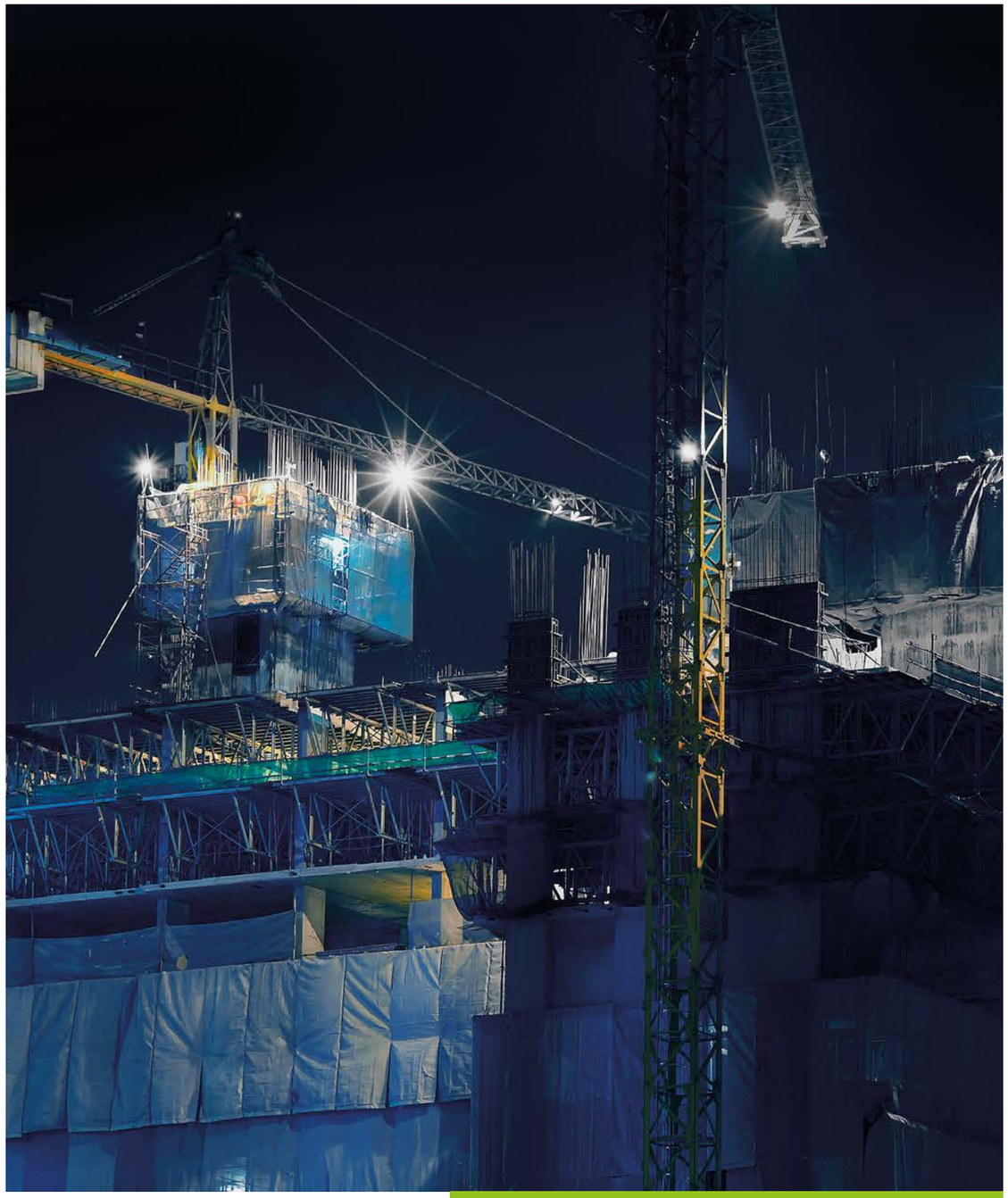
To prevent the undesirable glare of the employees and to reduce the risk of injury, it is suitable to solve the illumination in such a way the luminous flux from the installed luminaires will fall in the direction of the employee's view.

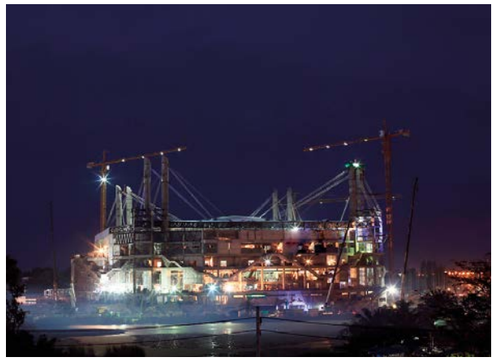
CONSTRUCTION SITES

The construction sites are time-limited outdoor workplaces where changes are often happen in this field. Therefore when we solve the lighting system here, the requirement of a flexible lighting solution comes to the foreground.

The European standard EN 12464-2 states for the construction sites in dependence on the activity carried out the illuminance level from 20 lux (clearance of buildings, excavation work) to 200 lux (element joining, demanding electrical, machine and pipe mountings). Due to the fact that the construction site's appearance is changed during the construction operations it is necessary for the lighting system to be solved flexibly. The portable stands with luminaires fitted with adjustable reflectors powered from an autonomous source of energy are an optimal solution. The required illuminance levels can be achieved by using the floods for metal-halide lamps or high pressure sodium lamps.
To ensure throughput of communications at the construction site, it is suitable to place the luminaires providing the main illuminance along the building site's circumference, outside the communication zones. However, this lighting solution requires at the same time the additional illumination in the task area during the excavation work or partially roofed spaces. The luminaires with tubular fluorescent lamps represent here a suitable solution. In the dangerous zones it is also necessary to install the warning lights.
As the construction site is a space with an increased concentration of dust and high humidity it is necessary to use luminaires with the coverage level of minimally IP 54 for the lighting system. It is recommended to use luminaires made of unbreakable materials. To increase the safety level it is recommended to use a protection grid, in case a luminaire is damaged will avoid injury the employees by not permeating the fragments from the luminaire to fall down.

The cranes require a special lighting solution at the construction site. It is a key role when designing the illumination to ensure the crane operator good visibility of the whole workplace and at the same time of the load transported.
From the crane operator's view it is extraordinary important to achieve sufficient horizontal as well as vertical illuminance of the whole working plane. These lighting conditions create an assumption for good modelling of the objects necessary for transferring the material and at the same time they increase the orientation capability of the employee. To achieve the optimal lighting conditions it is suitable to install the luminaires with a wide lighting distribution curve directly to the tower and jib of the crane. When placing the luminaires it is necessary to take into account the position of the crane cabin and to install them in such a way they cannot glare the crane operator.





The appropriate illumination can improve the employees´ sense of orientation and simultaneously reduce the risk of collisions when motor vehicles and machines move around the construction site. From the point of view of navigation it is suitable to place the identification and orientation lighting to the communication zones. The drivers´ attention can be drawn to the risk zones and the necessity to slow down by using the dynamic light signals.

It is recommended to use a protection grid, in case a luminaire is damaged, it will avoid injury the employees by not permeating the fragments from the luminaire to fall down.

At the checkpoints it is necessary besides the sufficient illuminance level to prevent the risk of undesirable glare.

CANAL, LOCK, PORT, SHIPYARD AND DOCK

The water cargo transportation and subsequently the reloading of the goods in the ports require a consistent solution of the lighting system. The correct illumination of these spaces shortens the time for anchoring the ships to a minimum, it accelerates the transfer of goods and at the same time it reduces the risk of collisions in the port.

For the canal, lock, port, shipyard and dock the European standard EN 12464-2 determines the minimal illuminance levels in dependence on the demandingness of the activity carried out and the risk character of the space in the range from 10 lux (quays, gangways) up to 50 lux (connecting hoses, pipes and ropes; reading notices). The lighting uniformity requires U_0 from 0.25 to 0.4. When designing the illumination it is necessary to pay attention to the fact that the selected light solution must not pose any risk of glare for the ships moving in the discharging berth or in its vicinity. The lighting solution itself and the type of the luminaires used depend on the size of the surface that needs to be illuminated.

For illuminating smaller surfaces in the spaces of the cargo port it is possible to use the standard luminaires suitable for the public lighting but also reflectors with a wide luminous intensity curve or the flood lights with the assembly height of 12 metres.

The large-scale terminals with containers can be illuminated by reflectors or flood lights placed on the masts in the height between 25 to 35 metres. For lighting large areas and due to preventing undesirable glare it is necessary to use the luminaires with a wide radiation angle in the vertical direction and a diffuse optical system in the horizontal direction. The places of loading and unloading the goods are to be fitted with the additional illumination of the task area. At the checkpoints it is necessary besides the sufficient illuminance level to prevent the risk of undesirable glare through suitable directing the luminous flux of the luminaires used.

When selecting the light sources the factor of efficacy and lifespan of the light source come to the foreground. A longer lifespan of the light source prolongs the interval necessary for maintenance and in this way it reduces the costs for the operation of the whole lighting system. From this point of view the LED sources represent the most effective solution. Moreover, they are highly resistant against temperature fluctuations and in comparison to the conventional light sources they do not have any decrease of the luminous flux at low temperatures. As the main lighting we often use the high-pressure sodium lamps, for spaces and activities where recognising the colour is of great importance, e.g. the illumination of the docks where it is suitable to use the luminaires with the metal-halide lamps which achieve the values of CRI between 80 and 95.

In spite of their industrial orientation the cargo ports are often one of the most prominent dominants of the towns. Therefore when designing the lighting system, besides functionality it is necessary to take into account also the aesthetical potential. Through suitable programming of the lighting system it is possible just during the evening hours to increase the attractiveness of this industrial area.

The transhipment point determined for loading and unloading the goods equipped with cranes requires a special solution. One lighting option for the 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 the light source of the crane it is necessary to take into consideration the fact that there occur vibrations when it moves. Therefore the luminaires are to be put on places insulated from this influence as much as possible. If the port is equipped with a rail crane or another mobile port facilities, it is suitable to implement the functionality of the dynamic illumination to the lighting system.

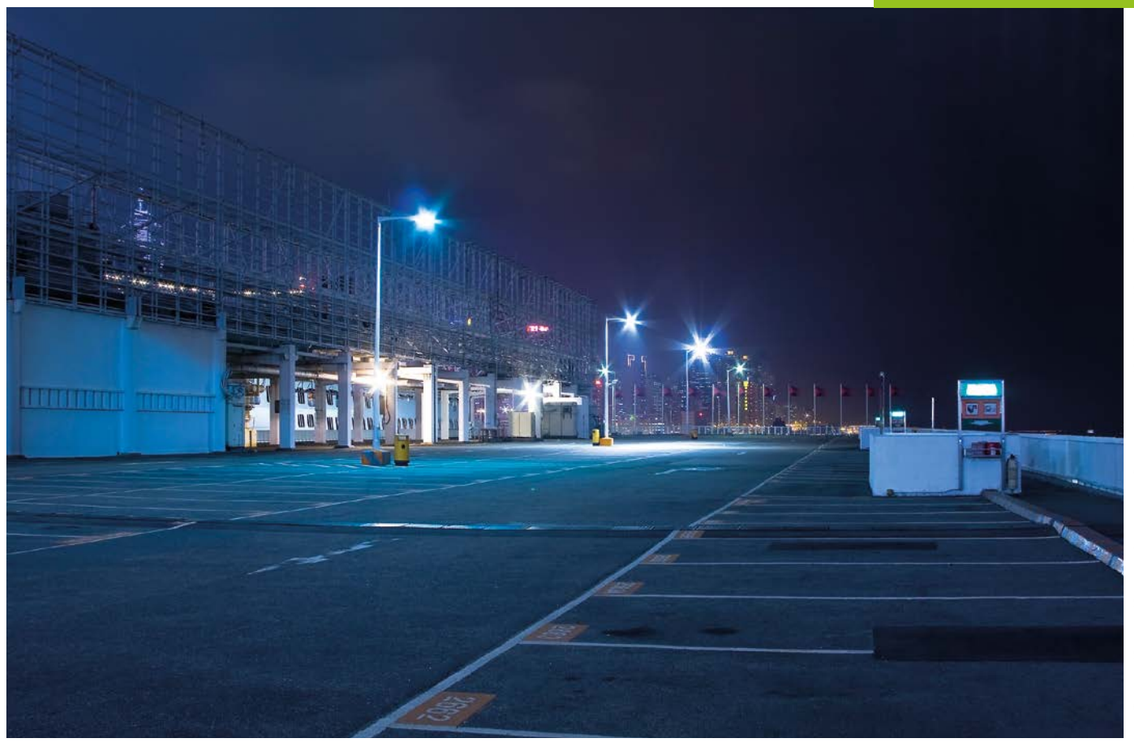
The increased demand on the illumination of the external spaces is especially in parking areas where the pedestrians, and drivers meet.

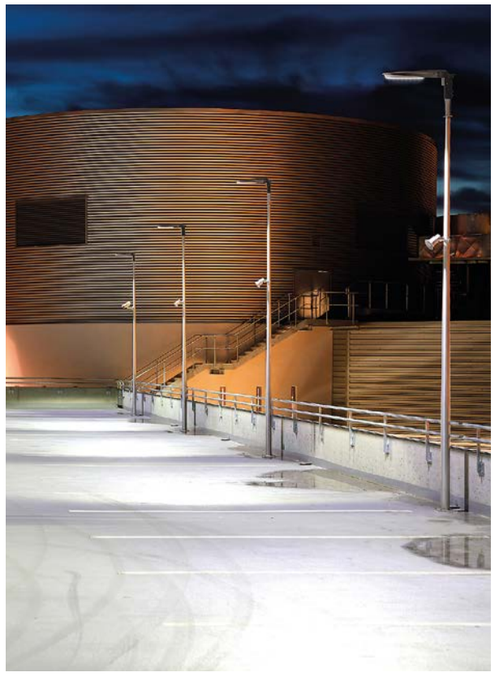
EXTERIOR ILLUMINATION AND PARKING AREA

Besides the aesthetic task the exterior lighting in an industrial area especially fulfils the security function. It makes the orientation in the external spaces easier, it refers to the entrances and the entry ways to the building, it increases the feeling of safety and comfort. The increased demand on the illumination of the external spaces is especially in parking areas where the pedestrians and drivers meet.

The correctly illuminated vertical as well as horizontal areas minimise the risk of collision and provide enough information about the orientation in the space. The access roads and external parking lots are made visible by the pole luminaires; decent in the ground recessed lighting fixtures separate the parking areas from the traffic lanes and the pedestrian zones. For all types of luminaires for external usage there are strict criteria as to the resistance against humidity, the temperature fluctuations and pollution.

From the ecological point of view, new types of luminaires that do not emit the light towards the upper half-space and thus do not produce the light smog are a suitable solution. These requirements are met especially by the LED light sources. They are typical by high efficacy and effectiveness. Due to their low failure rate and long lifespan they do not represent any increased burden from the point of view of the maintenance costs. In difference to the traditional light sources, e.g. fluorescent lamps or discharge lamps, the LEDs reach the full luminance immediately, moreover, after a short power cut the full luminance is reached without any delay. For the illumination of the external areas and the parking area of an industrial building it is possible to achieve full luminance immediately and this fact significantly improves the safety of employees movement in the industrial areas. In the external environment, the fact that in difference to the conventional sources there is no decline of efficiency at low temperatures and vice versa its effectiveness is even increased in such conditions, says in favour of the LED. From the point of view of safety it is a very resistant light source that can be hardly damaged, moreover also in the case of damage they do not constitute any threat for the health of employees. Compared to the conventional sources they contain a negligible amount of heavy metals which are, moreover, only in the solid state in the LED and this reduces the danger of air contamination.





SPECIAL REQUESTS FOR LUMINAIRES IN INDUSTRY

The luminaires applied in the industrial and manufacturing spaces are exposed to the influence of the surrounding environment. For the security and safety to be guaranteed at the workplaces in any respect, they have to be resistant against increased strain which is represented in this type of spaces by dust, humidity, water and flammable or explosive materials.

The value IP (International Protection Rating) defined by the international standard IEC and the European standard EN 60529 as well as the value Ex by which the European directive ATEX (Atmosphéres Explosibles) defines the necessary protection level of the luminaire at workplaces with the occurrence of flammable and explosives materials gives the information if the luminaires used fulfil the usage criteria in the concrete manufacturing spaces.

International protection IP

The code IP expresses the protection level of the interior or exterior luminaire against penetrating a foreign body or liquid. The code consists of two numbers IP XY – the first one assesses the protection level against a dangerous contact and penetrating of the foreign bodies (X) and the second one against penetrating water (Y). The luminaires with the minimal value IP44 are recommended for the exterior usage, in the case of a direct contact with water IP65. The dust-proof and water-proof luminaires which can be also used under water have the highest possible protection level expressed by the code IP 68.

Explosion-protected luminaires

The usage of flammable and explosive materials in the industrial manufacturing premises requires luminaires resistant against fire or explosions. Especially those spaces that are typical by a high level of dustiness (up to 80 % of dust arising due to the production is classified as flammable) or spaces in the framework of which operations with oxygen are carried out represent a risk. Based on the unified classification the individual spaces are divided into zones according to the risk of an explosion occurrence. Each zone is assigned a value of the protection level which the luminaires used for the illumination have to achieve.

	Degrees of protection	
	1st code numeral (Protection against foreign bodies and contact)	**2nd code numeral (Protection against water)**
0	Non-protected	Non-protected
1	Protected against solid foreign bodies > 50 mm	Protected against dripping water
2	Protected against solid foreign bodies > 12 mm	Protected against dripping water when 15° titled
3	Protected against solid foreign bodies > 2.5 mm	Protected against spraywater
4	Protected against solid foreign bodies > 1 mm	Protected against splashwater
5	Protected against dust	Protected against jets of water
6	Dustproof	Protected against powerful jets of water
7	–	Protected against temporary immersion
8	–	Protected against prolonged submersion ...m

HAZARDOUS LOCATION BASICS

Hazardous locations are separated into three "Classes" or types based on the explosive characteristics of the materials. The Classes or type of material is further separated into "Divisions" or "Zones" based on the risk of fire or explosion that the material poses. The Zone system has three levels of hazard versus the Division System's two levels.

Class I locations are those in which flammable „gases or vapors" are, or may be, present in the air in quantities sufficient to produce explosive or ignitible mixtures. The terms, „gases or vapors" differentiates between materials that are in a gaseous state under normal atmospheric conditions, such as hydrogen or methane, and a vapor that is flashed off from a liquid, under normal atmospheric conditions, such as gasoline.
The subdivision of Class I, locations into "Divisions" or "Zones" is based on the probability that an explosive gas atmosphere may be present in a location. If the risk is extremely low, the location is considered non-hazardous. A good example of a low risk area is a single family home with natural gas or propane furnace for heating. The gas could, and does on extremely rare occasions, leak into the home, encounter an ignition source and an explosion occurs, usually with devastating results. However, since the risk is so low, because of the safety systems built into the gas supply and heating equipment, these areas are not "hazardous classified locations".

Hazardous Materials	Class/Division System	Zone System
Gasses or Vapors	Class I, Division 1 Class I, Division 2	Zone 0 Zone 1 Zone 2
Combustible Dusts	Class II, Division 1 Class II, Division 2	Zone 20 Zone 21 Zone 22
Fibers or Flyings	Class III, Division 1 Class III, Division 2	No Equivalent

Frequency ol Occurrence	Division System	Zone System
Continuous	Class I, Division 1	Zone 0
Intermittent Periodreally		Zone 1
Abnormal Condition	Class I, Division 2	Zone 2

The following chart illustrates the differences between the various Zones.

Grade ol Release	Zone	Flammable Mixture Present
Continuous	0	1,000 hours per year or more (10 %)
Primary	1	Between 10 and 1,000 hours per year or more (0.1 % to 10 %)
Secondary	2	Less than 10 hours per year (0.01 % to 0.1 %)
Unclassified	–	Less than I hour per year (Less than 0.01 %)

Class I locations are further divided into Groups based on the explosive properties of the materials present. North America has traditionally used four groups while the IEC and CENELEC use three. The chart below compares the two systems.

Typical Gas	Class/Division Gas Groups	Zone Gas Groups
Acetylene	A	II C
Hydrogen	B	
Ethylene	C	II B
Propane	D	II A

Class II locations are those which are hazardous due to the presence of combustible or electrically conductive dusts. The dust must be present in sufficient quantities for a fire or explosion hazard to exist. The fact that there is some combustible dust present does not mean a Class II hazardous location exists.

Groups	Type of Material	Examples
E	Electrical ly Conductive Dusts	Powder ed Metals such as Alum num or Magnesium
F	Carbonaceous Dusts	Carbon Black, Coal Dust or Coke Dust
G	Agricultural Dusts	Grain, Flour, Sugars, Spices and certain Polymers

Zone 20 - an area in which a combustible dust, as a cloud, is present continuously or frequently during normal operations in sufficient quantities to produce an explosive mixture.
Zone 21 - an area in which a combustible dust, as a cloud, is likely to occur during normal operations in sufficient quantities to produce an explosive mixture.
Zone 22 - an area in which combustible dust clouds may occur infrequently and persist for only short periods of time or in which accumulations or layers may be present under abnormal conditions.

Class III locations are those which are hazardous due to the presence of easily ignitable fibers or flyings. However, the material is not suspended in the air in quantities sufficient to produce ignitable mixtures. Easily ignitable fibers and flyings present a serious fire risk, not normally an explosion hazard. The greater danger with Class III materials is that if a layer forms throughout a facility, an ignition will cause a flash fire which moves at near explosive speeds.

TEMPERATURE CLASSES

Ignition temperature or auto-ignition temperature (ATI) is the minimum temperature of a surface at which an explosive atmosphere ignites. Flammable vapors and gases can be classified into temperature classes according to their ignition temperature. The maximum temperature of a piece of equipment must always be lower than the ignition temperature of the gas - air mixture or vapor - air mixture in which it is placed. Equipment shall be marked to show the operating temperature or temperature class referenced to a +40°C (+104°F) ambient. **The temperature class (T code) is indicated on the manufacturers nameplate** and is based on the table below.

North American Temperature Code	IEC/CENELEC/NEC 505 Temperature Classes	Maximum Temperature	
		°C	°F
T1	T1	450	842
T2	T2	300	572
T2A	–	280	536
T2B	–	260	500
T2C	–	230	446
T2D	–	215	419
T3	T3	200	392
T3A	–	180	356
T3B	–	160	329
T3C	–	150	320
T4	T4	130	275
T4A	–	120	248
T5	T5	100	212
T6	T6	85	185

SPECIAL REQUESTS FOR LUMINAIRES IN INDUSTRY

TYPICAL NORTH AMERICAN MARKING TO NEC 505

Ignition temperature or auto-ignition temperature (ATI) is the minimum temperature of a surface at which an explosive atmosphere ignites. Flammable vapors and gases can be classified into temperature classes according to their ignition temperature. The maximum temperature of a piece of equipment must always be lower than the ignition temperature of the gas - air mixture or vapor - air mixture in which it is placed. Equipment shall be marked to show the operating temperature or temperature class referenced to a +40°C (+104°F) ambient. The temperature class (T code) is indicated on the manufacturers nameplate and is based on the table below.

TYPICAL EUROPEAN ATEX/CENELEC MARKING

Ignition temperature or auto-ignition temperature (ATI) is the minimum temperature of a surface at which an explosive atmosphere ignites. Flammable vapors and gases can be classified into temperature classes according to their ignition temperature. The maximum temperature of a piece of equipment must always be lower than the ignition temperature of the gas - air mixture or vapor - air mixture in which it is placed. Equipment shall be marked to show the operating temperature or temperature class referenced to a +40°C (+104°F) ambient. The temperature class (T code) is indicated on the manufacturers nameplate and is based on the table below.

Equipment Group I Overview

Equipment intended for use in underground parts of mines, and to those parts of surface installations of such mines, liable to be endangered by firedamp and/or combustible dust.

Equipment Category	Protection	Comparison To Current IEC Classification
M1	2 levels of protection; or 2 independent faults	Group I
M2	1 level of protection based on normal operation	Group I

Equipment Group II Overview

Equipment intended for use in other than Equipment Group I places that are liable to be endangered by explosive atmospheres.

Equipment Category	Protection	Comparison To Current IEC Classification
1G 1D	2 levels of protection; or 2 independent faults	Group II, Zone 0 (gas) Zone 20 (dust)
2G 2D	1 level of protection based on frequent disturbances; or equipment faults	Group II, Zone 1 (gas) Zone 21 (dust)
3G 3D	1 level of protection based on normal operation	Group II, Zone 2 (gas) Zone 22 (dust)

CLASS I ZONE 1AEX DE IIC T6

- Class I (Gases and Vapors)
  - Zone 0 — Areas where explosive gas atmosphere is continously present or present for long periods of time
  - Zone 1 — Areas where explosive gas atmosphere is likely to occur in normal operation or can be expected to be present frequently
  - Zone 2 — Area where explosive gas atmosphere is not likely to occur and if it does, it will only exist for a short period of time
- AEx designates built to a US ANSI standard
- Methods of protection, d, e, p, i, o, q, m, n
- Apparatus Group
  - I Mining - Underground (methane)
  - II Surface Industires
    - A (propane) B (ethylene) C (hydrogen)
- Temperature class
  - T1 450°C T3 200°C T5 100°C
  - T2 300°C T4 135°C T6 85°C

Ex II 2G EEX DE IIC T6

- Approved mark for apparatus certified by EU test authority
- Equipment group I (mining)
  - Category M1 and M2
- Equipment group II (on surface)
  - Category 1G, Zone 0 — Areas where explosive gas atmosphere is continuously present or present for long periods of time
  - Category 2G, Zone 1 — Areas where explosive gas atmosphere is likely to occur in normal operation or can be expected to be present frequently
  - Category 3G, Zone 2 — Area where explosive gas atmosphere is not likely to occur and if it does, it will only exist for a short period of time
  - Category 1D, zone 20 — Area where combustible dust is continuously or frequently present
  - Category 2D, Zone 21 — Area where combustible dust clouds are likely to occur during normal operation
  - Category 3D, Zone 22 — Area where combustible dust clouds may occur infrequently during normal operation
- Explosion protected according to CENELEC standards EN 50...
- Methods of protection, d, e, p, i, o, q, m, n
- Apparatus Group
  - I Mining - Underground (methane)
  - II Surface Industires
    - A (propane) B (ethylene) C (hydrogen)
- Temperature class
  - T1 450°C T3 200°C T5 100°C
  - T2 300°C T4 135°C T6 85°C

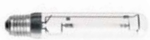
Methods of protection:
Flameproof Type of Protection "d"- or Explosionproof Equipment
Encapsulation - Type of Protection "m"
Increased Safety - Type of Protection "e"
Intrinsically Safe Equipment - Types of Protection "i", "ia" and "ib"
Oil Immersion - Type of Protection "o"
Purged And Pressurized - Type of Protection "p"
Powder Filling - Type of Protection "q"

SELECTING THE RIGHT LIGHT SOURCE

The individual areas in industrial and production spaces have different demand on the illumination. When designing a lighting system the task of the lighting designer is to choose the light sources with the most suitable parameters where besides the procurement price the categories of effectiveness, lifespan and safety are also included.








Lamp type	power rating from - to (W)	luminous flux from - to (lm)	efficacy (lm/W)	light colour	colour rendering index (CRI) from-to	lifespan from - to	socket
Tube-shaped fluorescent FD (T8) Ø 26 mm	18 - 70	860 - 6,200	61 - 93	ww/nw/dw	80 - 96	16,000 - 80,000	G13
Tube-shaped fluorescent FDH (T5) Ø 16 mm	14 - 80	1,100 - 6,150	67 - 104	ww/nw/dw	80 - 93	24,000 - 45,000	G5
Compact fluorescent lamp	5 - 80	250 - 6,400	46 - 95	ww/nw/dw	80 - 90	5,000 - 32,000	2G11, 2G7, 2G8–1
High pressure metalhalide lamp MT/ME (HIT/HIE)	35 - 2,000	3,200 - 240,000	67 - 120	ww/nw/dw	65 - 96	6,000 - 15,000	E 27, E 40, PG12-2
High pressure sodium lamp ST/STH (HST)	35 - 1,000	3,500 - 150,000	74 - 150	ww	20 - 25	12,000 - 32,000	E 27, E 40, PG12-1
Double ended metalhalide lamp MD/MN (HID)	70 - 2,000	5,500 - 230,000	73 - 117	ww/nw/dw	65 - 95	4,500 - 15,000	RX7s, K12s
Double ended high pressure sodium lamp SD (HSD)	70 - 150	6,800 - 15,000	97 - 100	ww	20 - 25	12,000 - 32,000	RX7s
LED module	1 - 140	100 - 17,200	90 - 200	ww/nw/dw	70 - 98	50,000	-

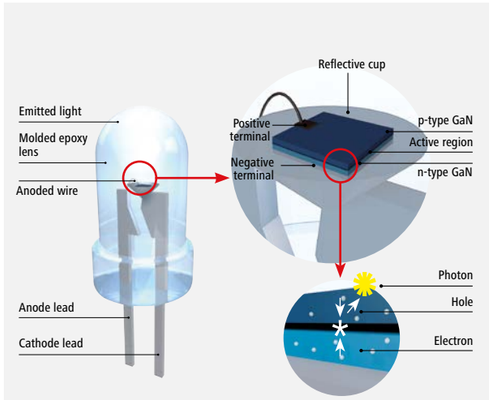
ww = warm white correlated colour temperature (CCT) below 3,300 K
nw = neutral white correlated colour temperature (CCT) 3,300 K to 5,300 K
dw = daylight white correlated colour temperature (CCT) over 5,300 K

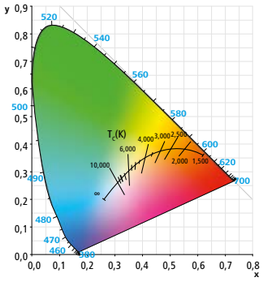
LED FOR INDUSTRY

When in 1962 the American professor Nick Holonyak created the prototype of the first "light emitting diode" – LED, his invention remained almost unnoticed. The only one who anticipated its revolutionary future on the pages of the magazine Reader's Digest was the inventor himself. It lasted almost forty years until the industry revealed all the exceptional properties of the LED and learned how to utilise them. In the lighting industry the LED sources currently represent an area that is developing in the most dynamic way.

In what respect are the LED light sources so exceptional and exceed the properties and parameters of the conventional sources? Why do the architects, developers and users of industrial buildings concentrate more and more frequently on the LED sources when designing the lighting systems? It would be possible to answer in a very simple way: The LED sources are highly effective, they have a long lifespan and an excellent colour rendering, they are cost-effective and environment-friendly. But let us have a look at the individual categories more thoroughly and we will explain why the LED sources represent also for your industrial spaces the best solution.

The LEDs are light sources based on the semi-conductor basis. A very small amount of energy is necessary for emitting the light. The diodes emitting light consist of two types of semi-conductors – the N-type with surplus of electrons and the P-type which has lack of electrons (the so called holes). After connecting the power the excessive electrodes and holes begin to migrate to the PN junction. When they meet the recombination develops and the diode starts emitting photons. By its size that is not larger than a dot made by a pencil the LED ranks among the smallest light sources. The package which is at the same time a lens serves as protection. It enables distributing the luminous flux directly under the angle 15° to 180°. While a common light bulb is able to change into visible light only 5 % and the fluorescent lamp 30 % of the electric power, the LED with its ability to change up to 40 % of the total energy reaches incomparably better parameters in this category. The efficiency of the light source or its efficacy says with what efficiency the electric energy is changed into the light, i.e. how much of luminous flux it produces from. the electric input power (W) delivered to the light source. The unit is lumen per watt (lm/W). While the first LEDs in 1996 had an efficacy of 0.1 lm/W, today there are commercially available LED chips with an efficacy of 160 lm/W for cool white CCT LED and in the labs there has been achieved an efficacy of up to 254 lm/W.

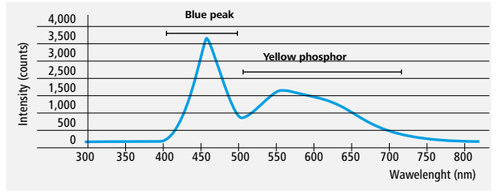




If the LED sources after binning are on the Planck curve, they emit "pure white", i.e. pure white light.

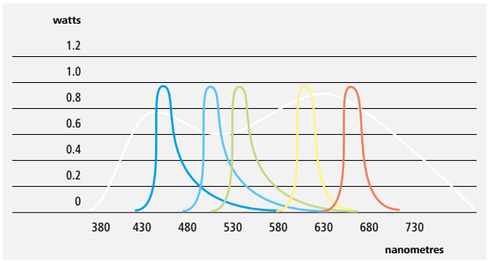
The LED luminaires used in the industrial and production spaces have to fulfil high ergonomic and economic requirements. In the industrial areas they are required to deliver high-quality, glareless lighting for the optimal visual comfort also for the Visual Display Units (VDU) and at the same time they have to fulfil the requirements of the European standards. The LED diodes are primarily the source of the white colour radiation. The white LED light can be acquired by various methods; however, the principle of luminescence is most frequently used for its production. In this method a thin phosphorus layer is applied to the blue LED which, after the switching on of the source, changes part of the blue light which passes it into the white one. This technology of the LED production enables achieving the emission of the white light with various correlated colour temperature from 2,700K to 10,000 K.

Another method making it possible to acquire the white LED light consists of mixing the coloured light of various wavelengths. Through additive mixing the red, green and blue colours (RGB) the white light can arise. The advantage of this method is that besides the white light by targeted mixing we can also acquire coloured light. The disadvantage when acquiring the white light by the RGB technology consists in its demandingness. It requires a lot of know-how because the management of the coloured LED with various values of luminance is demanding and the white light produced often achieves lower values of the colour rendering index CRI 70 – 80. If we consider changes of the correlated colour temperature of the white light when solving the illumination in the industrial spaces, it is suitable to combine the coloured chips with white LEDs. In this way optimal CRI values are obtained.



White light can be produced by combining blue and yellow light only. Sir Isaac Newton discovered this effect when performing colour-matching experiments in early 1700s.

SPECTRA OF WHITE AND COLOURED LEDS



LEDs do not require colour filters. The colour tone of the light is determined by the semiconductor material used and the dominant wavelength.

COLOURS STRAIGHT FROM THE SEMICONDUCTOR

Colours straight from the semiconductor

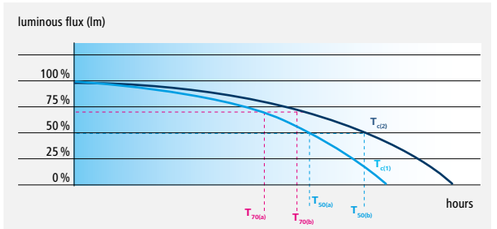
LEDs do not require colour filters: their light comes in different colours produced directly by different semiconductor materials. Secondary colours are also possible. The major semiconductors are:

Semiconductor material	Abbreviation	Colour(s)
Indium gallium nitride	InGaN	green, blue, (white)
Aluminium indium gallium phosphide	AlInGaP	red, orange, yellow
Aluminium gallium arsenide	AlGaAs	red
Gallium arsenide phosphide	GaAsP	red, orange, yellow
Silicon carbide	SiC	blue
Silicon	Si	blue

The lifespan of the LED sources moves in the values of up to 50,000 hours which represents 18 years for 11-hour-operation daily, 250 days a year.

From the point of view of the lifespan the LED light sources achieve above-average parameters. Their lifespan moves in the values of up to 50,000 hours which represents 18 years for 11-hour-operation daily, 250 days a year. The drop of the light source performance to 70 %, in some cases to 5 % is introduced as the LED lifespan end. It means that the LED failure rate is substantially lower compared to the conventional sources. However, appropriate cooling of the light source is a necessary condition for maintaining the lifespan parameters.

DEFINITION OF LIFESPAN



LEDs do not fail but the intensity of the light they produce diminishes over time. The lifespan (L) of an LED thus needs to be defined for different applications. For emergency lighting, for example, rating up to L80 ore more are required, this means that the LED reaches the end of its service life when the luminous flux falls to 80 percent of the original flux measured. For general lighting, values of L50 or L70 are defined. The lifespan of an LED depends to a large extent on ambient and operating temperature. Where an LED is operated at a high temperature (Tc1) or with poor thermal management, its life is shortened.

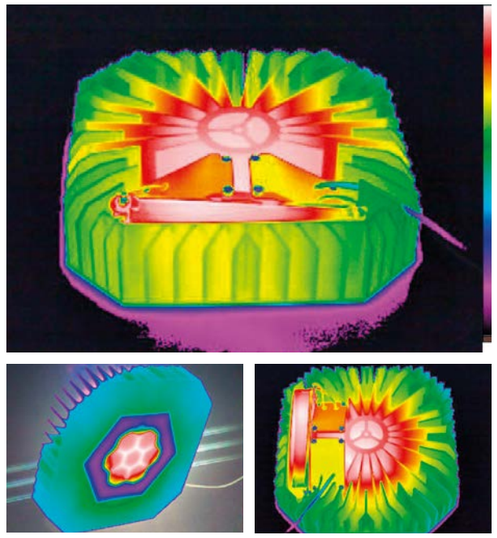
In spite of higher purchase costs the LED sources represent in a longer-term horizon the most effective and economical light solution. The experts estimate that if we replaced all existing light sources for the LED ones today, the energy savings worldwide could reach the amount of 30 %. If we realise that the artificial lighting consumes up to one fifth of the energy produced, this amount is not negligible at all. When we take into account a smaller area illuminated by obsolete conventional sources, we would be able to save up to 75 % of lighting system input power by the controlled LED illumination. All light sources also produce the IR radiation during the change of the electric power into the light which the human organism perceives as heat. However, the LED light sources produce it in a negligible amount compared to the conventional sources and thus they do not increase the inadequate costs for the air-conditioning power consumption. The lifespan and failure rate of the LED sources reduces the lighting system maintenance costs as it does not require any regular interventions of service staff and purchasing new light sources.

The LED source saving potential can be maximised by installing the intelligent lighting management which enables adjusting the radiation intensity of every luminaire in the lighting system automatically in dependence on the availability or intensity of the daylight.

The environment-friendly approach is a topic also for the producer of the light sources today. The reality is that the majority of the conventional light sources cannot be produced without using the toxic heavy metals – lead and mercury. The users of the premises equipped with this type of light sources have an additional burden when they replace them as they are compulsory to remove the used or damaged sources in compliance with the law about disposal of the toxic waste and on the other hand they are exposed to the risk of breathing the toxic vapours when the light source is damaged. In this respect the LED sources represent an incomparably lower risk. Though they contain a small amount of heavy metals, they are in solid state and so there is no danger of breathing in the toxic vapours when the LED source is damaged.

Thermal management

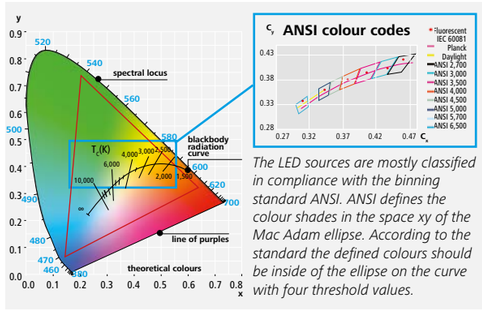
Similarly as in the case of other light sources, the temperature significantly affects the performance of the LED light source. Without any adequate thermal management overheating of the LED source can develop and it reduces its lifespan and the risk of its damage is also increased. Implementing a suitable cooling system we achieve maintaining the declared lifespan of the LED light source and its high efficacy. From this point of view the thermal management represents the most critical factor for the luminaires with the LED source.



Thermal output of Grafias

Binning

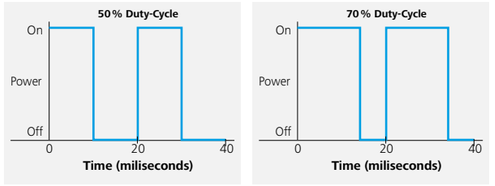
During the industrial production of LEDs deviations of the key parameters arise in the individual batches. In the framework of one batch the parameters are generally the same, but when we compare two various batches, the LEDs differentiate e.g. in colour or the luminous flux. To ensure the constant quality of light with the same level of luminance and colour of the light, it is inevitable to sort out every batch according to the value of individual parameters. This sorting is called binning. The main criteria taken into account when binning are as follows: the luminous flux measured in lumens (lm), the correlated colour temperature measured in Kelvins (K), the forward voltage measured in volts (V). The LED sources are nowadays classified according to the binning standard ANSI. This standard defines the colour shades of LED by the MacAdam ellipses which depicts the colour deviation on the axis X and Y. The MacAdam ellipses shows how the colour of the individual LED modules can differ. The binning standard ANSI recommends for the resulting colours to be inside of the ellipse on the curve with four threshold values. The binning groups of the LED sources which show minimal differences of the values measured will produce the light of the same colour.



The LED sources are mostly classified in compliance with the binning standard ANSI. ANSI defines the colour shades in the space xy of the Mac Adam ellipse. According to the standard the defined colours should be inside of the ellipse on the curve with four threshold values.

PWM control

The Pulse Width Modulation (PWM) represents the most effective method how to check the intensity of the LED light source. The PWM principle is based on periodical switching on and off of the constant current directed to the LED. The resulting intensity of the LED light source is characterised by the ratio between the state of switching on and off. The frequency of switching on and off is adjusted for the human eye to perceive the emitted light as a continuous luminous flux. Its intensity depends on the adjustment of the PWM cycle (0 % to 100 %). The advantage of the impulse width modulation is the maintaining of the constant correlated colour temperature in the whole range of dimming.



Compared with the conventional light sources the LED light sources reach the full luminance immediately. The immediate start of the LED source is a benefit from the point of view of safety and comfort. At the same time compared to the conventional sources, frequent switching on and off does not make any damage to the LED source and does not reduce its lifespan as well.

BASIC TERMS

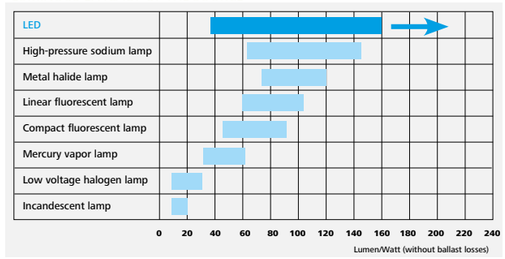
LUMINOUS FLUX Φ

The luminous flux is a physical quantity which states how much light in total a light source emits to all directions. It is the radiant power of the light source assessed from the point of view of the human eye sensitivity. The luminous flux expresses the ability of the radiant flux to cause a visual perception. The unit of the luminous flux is lumen (lm).

EFFICACY η

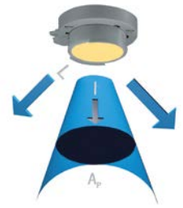
The luminous efficacy states with what efficiency the electric power is changed into the light, i.e. what proportion of the luminous flux is produced from the input power (W) delivered to the light source. The unit is lumen per watt (lm/W).

LUMINOUS EFFICACY OF THE SOURCE



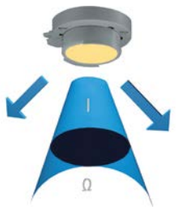
LUMINANCE L

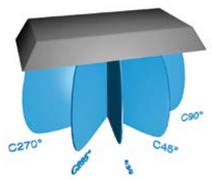
The luminance is the gloss of the shining or illuminated surface as the human eye perceives it. The unit is candela per square metre (cd/m²). This quantity gives the level of the luminous intensity over the specified surface area. The luminance of the illuminated surface depends in a great extent on its reflectance.



LUMINOUS INTENSITY I

The luminous intensity is a physical quantity which states what volume of the luminous flux the light source (or luminaire) emits to the elementary solid angle in the direction evaluated. The unit of the luminous intensity is candela (cd).

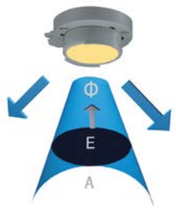




intensity distribution curve

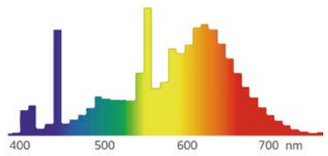
ILLUMINANCE E

Illuminance is a vector quantity which states what amount of the luminous flux falls to the illuminated surface. The unit of the illuminance is lux (lx).

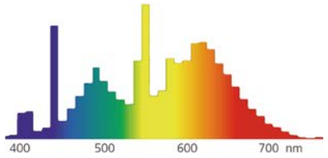


GLARE

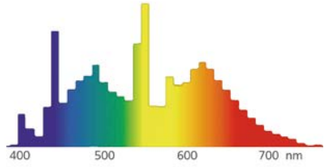
If too great luminance occurs in the field of vision of the eye, its differences or the spatial or time contrasts which exceed the vision adaptability, the glare arises. During the glare the activity of the visual system is deteriorated.



2,700 K



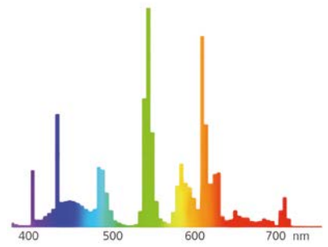
4,200 K



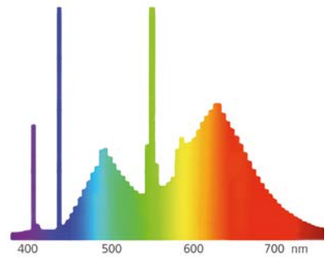
6,500 K

CORRELATED COLOUR TEMPERATURE (CCT)

The correlated colour temperature of the light source determines the atmosphere in the room. It is defined by the correlated colour temperature of the light source expressed in kelvins (K). Low temperatures create a warm light, the high ones the cooler ones. The most used light colours are the warm white (below 3,300K), the neutral white (3,300 to 5,300 K) and the day white colour (over 5,300 K). The warm white colour is predominantly used for emphasising the red and yellow colour. The blue and green colours become apparent at higher temperatures.



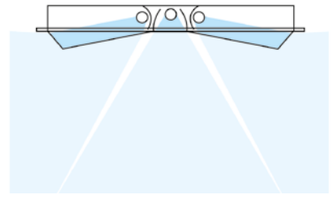
CRI 70



CRI 95

COLOUR RENDERING INDEX (CRI)

The properties of light source colour rendering are given in the levels of the general index of colour rendering – Ra. The CRI gives the rate of the congruence of the object surface's real colour illuminated by the considered light source under stated conditions of comparison. The smaller this difference is, the better the property of the colour rendering of the given source is. The light source with Ra =100 renders all colours completely equally as a standard light source. The lower the index Ra is, the worse the colour rendering is.



LIGHT OUTPUT RATIO (LOR)

The Light Output Ratio is the ratio of the luminous flux coming out of the luminaire and the sum of the luminous fluxes from all light sources.