

APPLICATIONS IN MEDICAL FIELD



Image quality assurance

Workplace Lighting

IMAGE QUALITY ASSURANCE

IN X-RAY DIAGNOSTIC COMPANIES



- **EU DIRECTIVE 2013/59/EURATOM**

Establishing basic safety standards for protection against the hazards of exposure to ionizing radiation



- **Radiation Protection Act – StrlSchG**

It makes regulations for the protection of people and - as far as long-term protection of human health is concerned - the environment from the harmful effects of ionizing radiation.

- **Radiation Protection Ordinance – StrlSchV**

Regulation on protection against the harmful effects of ionizing radiation. The X-ray Ordinance RöV was integrated and expired on December 31, 2018.

- **Radiological viewing devices and conditions - DIN 6856**

Part 1: Requirements and quality assurance measures in medical diagnostics
Part 3: Viewing devices for dentistry

- **Ensuring image quality in X-ray diagnostic companies - DIN 6868**

Part 157: Acceptance and consistency testing of image reproduction systems in their environment

- **Assessment and routine testing in medical imaging departments - DIN EN IEC 61223**

Part 2-5: Consistency tests; Image display devices (monitors)

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USER



- **Hospitals & Clinics**

Radiology, medical technology, technical department

- **Service companies for medical technology**

Manufacturers of X-ray systems, independent service providers

- **Radiologists**

Independent practices



- **Dentists**

Independent practices



Image display system IDS

Workplace consisting of one or more image display devices (monitors), a display control unit (graphics card), a computer hardware (workstation) and software which can display images.

Image display device IDD - monitor - display

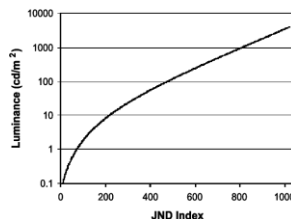
Functional unit of an image display system based on active or passive display elements, which receives signals from an analogue or digital interface and displays them as a matrix of pixels.

Ambient conditions

The ambient conditions are regulated by the room classes and reflect the different operating conditions of the monitors. The activity to be carried out in the room determines the room class and this determines the maximum brightness and the monitor to be used.

luminance curve

The luminance characteristic for image display devices with diagnosis quality was introduced because of the non-linear contrast sensitivity of the human eye. The human eye is more sensitive to small relative changes at higher luminance levels than at lower luminance levels. The Grayscale Standard Display Function (GSDF DICOM) specifies the luminance differences required for the human eye to detect a change (JND). The characteristic curve of the monitor is adjusted to this curve within the measured minimum and maximum luminance. This creates a comparable image impression on different monitors, even from different manufacturers.



GSDF characteristic DICOM 14

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AMBIENT CONDITIONS - ROOM CLASSES - DIN 6868 - 157

GOSSEN

Room class	Type of room	Task	Classification of image display system	Illuminance* lx
RK1	reading room	predominant assessment of radiographs and marker datasets.	reporting quality	≤ 50
RK2	Examination rooms with immediate diagnosis	medical activities in the examination room in which therapy-relevant decisions are made.	reporting quality	≤ 100
RK3	rooms for conducting the investigation	activities in which the investigation is carried out using a dialogue monitor.	reporting quality	≤ 500
RK4	viewing and treatment rooms	activities in which a known and assessed finding has to be reproduced repeatedly.	viewing quality	≤ 1000
RK5	dental diagnostic work station	findings outside the lighting conditions of a dental treatment	reporting quality	≤ 100
RK6	dental treatment room	findings under the lighting conditions of a dental treatment workplace.	reporting quality	≤ 1000
* The illuminance is measured orthogonally to the screen surface when the image display device is switched off.				



MAVO MAX **RK1**



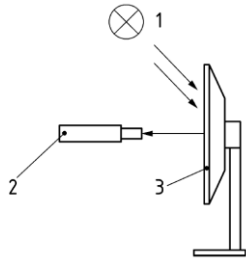
MAVO MAX **RK2 / RK5**



MAVO MAX **RK2 / RK5**

The room light monitor MAVO **MAX** indicates compliance with the permissible illuminance

Method A - Telescope method

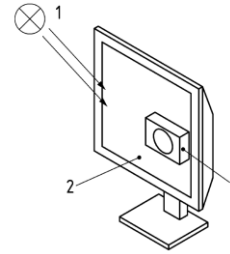


Legend

- 1 Ambient light
- 2 Telescope luminance meter
- 3 Display

- Measurement takes into account the ambient light
- Measuring field must be significantly smaller than the square in the test image
- Focusing on screen surface
- Lens hood or cone in front of the lens to block out ambient light
- Repeatable results only if environmental and measurement conditions are the same

Method B - Short-range luminance meter in combination with an illuminance meter



Legend

- 1 Ambient light
- 2 Display
- 3 Illuminance meter
- 4 Short-range luminance meter

- Measurement does not take ambient light into account, therefore additional measurement of illuminance required
- The measuring aperture of the luminance meter must be significantly smaller than the square in the test image
- Illuminance meter is placed in the middle of the image display device and points outwards
- Luminance values L' must be calculated from the measured luminance value L , the measured illuminance E and the luminance coefficient q

$$L'_{\max} = L_{\max} + E * q \quad L'_{\min} = L_{\min} + E * q$$

- Luminance coefficient q must be provided by the manufacturer of the image display device

IMAGE QUALITY ASSURANCE

ACCEPTANCE TEST - MEASUREMENT TESTS - DIN 6868 - 157

Test	Measuring device	Test images	Measuring method
Minimum luminance $L'_{\min}$	luminance, telescope method	TG18-LN8-01	at the center of the screen
Maximum luminance $L'_{\max}$	luminance, telescope method	TG18-LN8-18	at the center of the screen
Veil luminance L_{amb}	luminance, telescope method	-	at the center of the screen, with image display device switched off
Illuminance E	illuminance meter.	-	at the center of the screen, perpendicular to the surface, with image display device off
Homogeneity of the image display device	luminance, contact measurement	TG18-UN80 (or HG DDL 204) TG18-UN10 (or HG DDL 26)	5 measuring points with IDD diagonal < 23", 9 measuring points with IDD diagonal ≥ 23", $H = 200 \times (L_{\text{highest}} - L_{\text{lowest}}) / (L_{\text{highest}} + L_{\text{lowest}})$
homogeneity of multiple image display devices	luminance, contact measurement	TG18-UN10 (or HG DDL 26)	measuring point z, at the center of the screen of the individual image display device $H = 200 \times (L_{\text{highest}} - L_{\text{lowest}}) / (L_{\text{highest}} + L_{\text{lowest}})$
luminance characteristic*	luminance, contact measurement	18 test images TG18-LN8-01 bis TG18-LN8-18	measurement of the 18 test images at the center of the screen, evaluation with a suitable software tool
* Omitted for RK 5 and RK 6			



Test images in 1024 x 1024 matrix can be downloaded from the DIN Radiology Standards Committee (NAR).

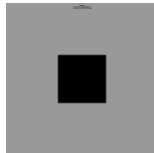
IDD = Image Display Device

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LUMINANCE - MEASUREMENT TESTS - DIN 6868 - 157

Minimum luminance $L'_{\min}$

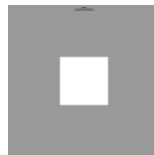
The minimum luminance is measured by displaying the test image TG18-LN8-01 and telescopic measurement to the center of the image display device.



TG18-LN8-01

Maximum luminance $L'_{\max}$

The maximum luminance is measured by displaying the test image TG18-LN8-18 and telescopic measurement to the center of the image display device.



TG18-LN8-18

Maximum luminance ratio r'

The maximum luminance ratio is calculated from the quotient of the maximum luminance and the minimum luminance.

$$r' = L'_{\max} / L'_{\min}$$

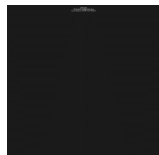
Veil luminance L_{amb}

The veil luminance is measured with the image display device switched off with a telescope measurement to the center.

Homogeneity of the image display device

Depending on the screen diagonal, either 5 or 9 measuring points are measured in contact measurement according to the adjacent graphic. The homogeneity for each test image is calculated from the lowest and highest measured values .

$$H = 200 \times (L_{\text{highest}} - L_{\text{lowest}}) / (L_{\text{highest}} + L_{\text{lowest}})$$



TG18-UN10

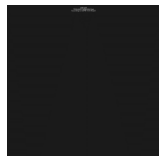


TG18-UN80

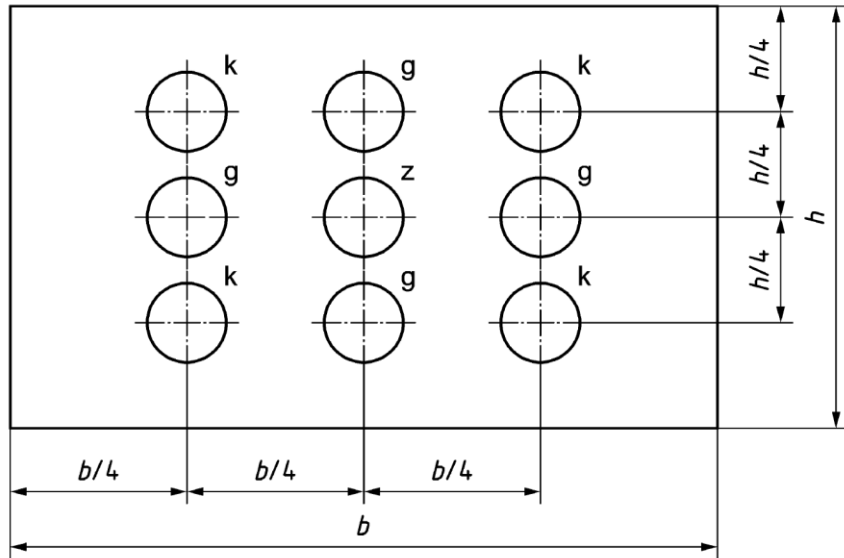
Homogeneity of multiple image display devices

For each image display device, the measuring point z is measured in the center in contact measurement. The homogeneity is calculated from the lowest and the highest measured value.

$$H = 200 \times (L_{\text{highest}} - L_{\text{lowest}}) / (L_{\text{highest}} + L_{\text{lowest}})$$



TG18-UN10



Legend

h height of the screen

b width of the screen

k and z 5 measuring points for image display devices < 23 inches

g, k and z 9 measuring points for image display devices ≥ 23 inches

z Measuring point in the center

IMAGE QUALITY ASSURANCE

LUMINANCE CHARACTERISTIC - MEASUREMENT TESTS - DIN 6868 - 157

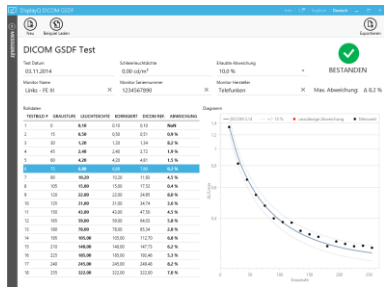
Luminance characteristic

The luminance characteristic is measured by displaying the 18 test images TG18-LN8-01 to TG18-LN-18 and measuring them in the center of the display device. Since a contact measurement is required, the veiling luminance must be taken into account in the evaluation.

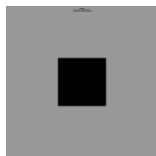
A suitable software tool is required for the evaluation. If no quality assurance software is used, the Monitor Check of the European Reference Organization for Quality Assured Breast Screening and Diagnostic Services (EUREF) can be used.

Quality assurance software

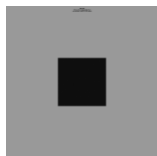
- **PerfectLum**
- ayDisplayQuality Software
- QA Web for DIN 6868 - 157
- QAXRAY Pro
- **RadiCS**
- gFM - dental
- **DisplayQ**
- KPS 2015
- GammaCompMD QA



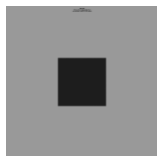
Source : [DisplayQ Expert](#) – Logima Software GmbH



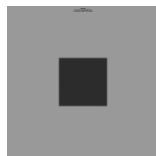
TG18-LN8-01



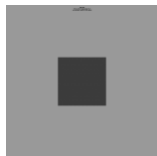
TG18-LN8-02



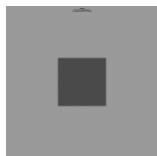
TG18-LN8-03



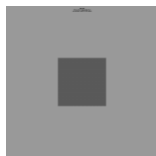
TG18-LN8-04



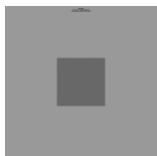
TG18-LN8-05



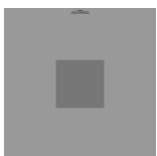
TG18-LN8-06



TG18-LN8-07



TG18-LN8-08



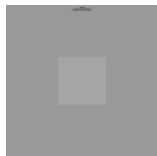
TG18-LN8-09



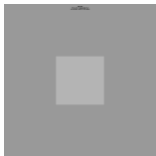
TG18-LN8-10



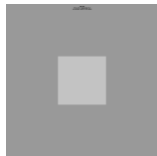
TG18-LN8-11



TG18-LN8-12



TG18-LN8-13



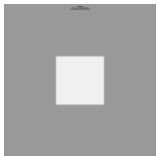
TG18-LN8-14



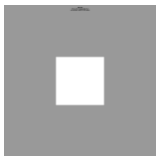
TG18-LN8-15



TG18-LN8-16



TG18-LN8-17



TG18-LN8-18

IMAGE QUALITY ASSURANCE

CONSTANCY TEST - MEASUREMENT TESTS - DIN 6868 - 157

Test	Measuring device	Test images	Measuring method
minimum luminance $L'_{\min}$	luminance, telescopic measurement or alternatively contact measurement	TG18-LN8-01	at the center of the screen
maximum luminance $L'_{\max}$	luminance, telescopic measurement or alternatively contact measurement	TG18-LN8-18	at the center of the screen
veil luminance $L_{\text{amb}}^{a, b}$	luminance, telescopic measurement	-	at the center of the screen, with image display device switched off
illuminance E^a	illuminance meter.	-	at the center of the screen, perpendicular to the surface, with image display device off
homogeneity of multiple image display devices ^a	luminance, contact measurement	TG18-UN10 (or HG DDL 26)	measuring point z, at the center of the screen of the individual image display device $H = 200 \times (L_{\text{highest}} - L_{\text{lowest}}) / (L_{\text{highest}} + L_{\text{lowest}})$
luminance characteristic ^a	luminance, contact measurement	18 test images TG18-LN8-01 bis TG18-LN8-18	measurement of the 18 test images at the center of the screen, evaluation with a suitable software tool
Test interval every six months - exception test interval RK 5 and RK 6 annually .			
^a Not applicable for RK 3, RK 5 and RK 6. $L_{\text{amb can}}$ be neglected as long as the values of the constancy test are below the reference value of the acceptance test. ^b The test is only required if there are abnormalities in the minimum luminance.			



IMAGE QUALITY ASSURANCE

REQUIREMENTS FOR THE MEASURING EQUIPMENT - DIN 6868 - 157

Medical technology - DIN 6868 - 157 Acceptance and constancy test on image reproduction systems in their environment

acceptance test			measuring method A Luminance, 1° ... 5° 0.05 cd/m ² ... 1000 cd/m ² class B, DIN 5032-7 factory calibration		
constancy test	measuring method B,C,D Illuminance 1 lx ... 1000 lx accuracy ≤ 10% repeatability ≤ 5% factory calibration	measuring method B Luminance, essay 0.05 cd/m ² ... 1000 cd/m ² class B, DIN 5032-7 factory calibration	measuring method A Luminance, 1° ... 5° 0.05 cd/m ² ... 1000 cd/m ² class B, DIN 5032-7 factory calibration	extends the test interval for veiling luminance and maximum contrast from 3 to 6 months – for old DIN V 6868 - 57	
test of room lighting (room classes)	illuminance 1 lx ... 1000 lx accuracy ≤ 10% repeatability ≤ 5%		illuminance via luminance class B, DIN 5032-7 + reflectance standard	continuous room light monitoring RK1, RK2, RK5	color temperature (CCT) color rendering (Ra) of lighting defined in DIN EN 12464-1
Measuring device	MAVOLUX 5032 B/C USB MAVOLUX 5032 C BASE MAVOLUX 5032 B/C - Kit	MAVO-MONITOR USB MAVOMONITOR - Kit	MAVO-SPOT 2 USB	MAVOMAX	MAVOSPEC LITE MAVOSPEC BASE



WORKPLACE LIGHTING

HEALTHCARE FACILITIES



EU guidelines



- **Basic Law of the Federal Republic of Germany - GG**
- **Occupational Health and Safety Act - ArbSchG**

This law serves to ensure and improve the safety and health protection of employees at work through occupational safety measures.
- **Workplace Ordinance ArbStättV**

This ordinance serves to protect the safety and health of employees when setting up and operating workplaces. It stipulates the protection goals to be observed for the lighting.
- **Technical rules for workplaces - ASR**

The technical rules for workplaces specify the requirements of the workplace ordinance.

 - **ASR A3.4 Lighting and line of sight** (including emergency lighting) May 2023

The requirements of this ASR deviate in individual cases from standards, in particular from DIN EN 12464 Parts 1 and 2, which only specify the planning principles for lighting systems, but do not take the requirements for safety and health protection of the employees at work into account.
 - **ASR A2.3 Escape routes and emergency exits** (incl. safety lighting) March 2023
- **General recognized rules of technology**
 - **DIN EN 12464-1 Lighting of workplaces - Part 1: Indoor workplaces**
 - **DIN EN 12464-2 Lighting of workplaces - Part 2: Outdoor workplaces**
 - **DIN EN 1838 Emergency lighting**



- **Basic Law of the Federal Republic of Germany - GG**
- **Social Code - Statutory Accident Insurance - SGB VII**

The task of accident insurance is to prevent accidents at work and occupational diseases as well as work-related health hazards, to restore the health and ability to work of the insured by all suitable means following the occurrence of accidents at work or occupational diseases, and to compensate them or their surviving dependents with cash benefits.
- **Accident prevention regulations - DGUV regulations**
 - DGUV Regulation 1 **Principles of Prevention**
 - DGUV regulation 3 **Electrical systems and equipment**
- **Information material – DGUV information**
 - DGUV Information 215-210 **Natural and artificial lighting in workplaces**
 - DGUV Information 215-211 **Daylight in the workplace - performance-enhancing and healthy**
 - DGUV Information 215-410 **Monitor and office workstations - design guidelines**
 - DGUV Information 215-442 **Office lighting - Aid for planning artificial lighting in offices**
 - DGUV Information 215-444 **Sun protection in the office**
 - DGUV principle 315-201 **Requirements for the training of experts for the inspection and assessment of lighting in workplaces**

WORKPLACE LIGHTING

USERS AND AREAS



User

- Hospitals & Clinics
- Nursing Homes & Retirement Homes
- Medical practices
- Rehabilitation

Areas

- Reception & entrance areas
- Corridors & traffic routes
- Treatment room
- Patient room
- Operating rooms
- Autopsy Rooms & Mortuaries



<https://www.saxonia-licht.de/lichting-im-gesundheitswesen>

WORKPLACE LIGHTING

HEALTHCARE FACILITIES - MINIMUM VALUES - ASR A3.4

Working areas, workplaces, activities	Minimum value of illuminance lx	Minimum color rendering index CRI	Remark
Corridors: during the day	200	80	Higher values may be required to carry out the medical treatment.
Corridors: during the night	50	80	
General lighting without employees staying regularly	200	80	
Night lighting, overview lighting in areas that are not regularly walked on	5	80	
low-risk medical or nursing activities without contact with bodily fluids, bodily excretions or contaminated objects	300	90	
Working areas for medical or nursing activities with increased risk potential through handling ▪ bodily fluids, bodily waste or contaminated objects or ▪ with pointed, sharp, moving or hot instruments	500	90	
Partial area for medical or nursing activities with increased risk potential through handling ▪ bodily fluids, bodily waste or contaminated objects or ▪ with pointed, sharp, moving or hot instruments	1000	90	
Monitoring of patients at night	50	90	
Imaging diagnostics with image intensifiers and television systems	50	80	
Medicinal baths, massage and radiotherapy	300	80	
Instrument preparation, duty room	500	80	
health service laboratories	500	90	

WORKPLACE LIGHTING

HEALTHCARE FACILITIES - MINIMUM VALUES - DIN EN 12464-1

Type of room, task or activity	Minimum value of illuminance lx	Minimum color rendering index CRI	Remark
Surgical area			
Preparation and recovery rooms	500	90	
(Wake up room) Wake up phase	100	-	
(Recovery rooms) Additional lighting if required	1000	85	
Operating rooms	1000	90	
Operating environment	2000	90	
Surgical field	40000 ... 160000	90	
Autopsy rooms and morgues			
General lighting	500	90	
Autopsy and dissection table	5000	90	Higher values may be required.

EMERGENCY LIGHTING - MINIMUM VALUES - DIN EN 1838 / ASR A2.3

Security lighting	Minimum value of illuminance lx	Minimum value of color rendering index Ra	Remark
First aid points	≥ 5	≥ 40	within 2 m
Fire fighting or alarm systems	≥ 5	≥ 40	within 2 m
Escape routes	≥ 1	≥ 40	along the center line, uniformity $\leq 40:1$, at least 50% still within 0.5 m left and right of center
Anti-panic lighting *	$\geq 0,5$	≥ 40	free floor space, excluding edge area 0.5 m, uniformity $\leq 40:1$
Workplaces with particular risks	≥ 15 and ≥ 10 % of the maintenance value	≥ 40	Maintenance value related to the visual task
Measuring height DIN EN 1838 ≤ 2 cm ASR A2.3 ≤ 20 cm			

* in Germany, they are usually designed like escape routes (1 lx)



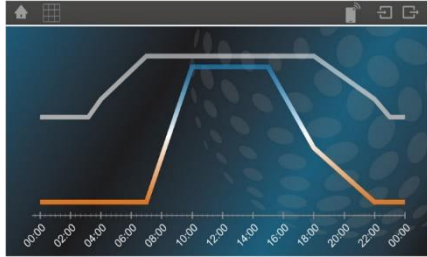
Photoreceptors in the eye

- **Cones** (R, G, B) are responsible for color vision
- **Rods** are responsible for night vision
- **Retinal ganglion cells** are connected to the pineal gland and synchronize the internal clock



Circadian Rhythm (24h) is controlled by hormones

- | | | | |
|-------------------|---------------------|----|--------------------------|
| ▪ Evening: | Melatonin ++ | => | Fatigue, Metabolism -- |
| ▪ 3 h Morning: | Cortisol ++ | => | Awakening, Metabolism ++ |
| ▪ During the day: | Serotonin ++ | => | Mood ++, Power ++ |



Biological influence of light on humans depending on the course of the day.

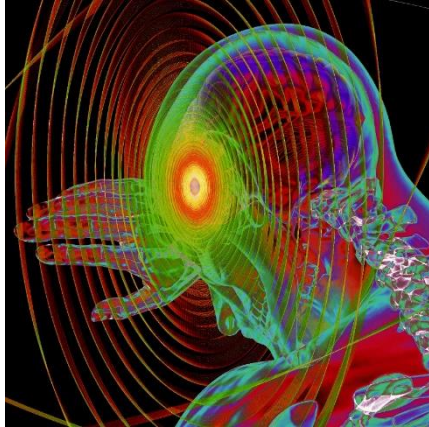
- Activation and increase in concentration
- Increase in motivation
- Reduction of fatigue
- Initiation and optimization of recovery phases
- Improvement of the mood
- Strengthening the immune system

Kurvenwerte		
Uhrzeit	Farbe	Helligkeit
03:10	2700 K	55 %
04:00	2700 K	68 %
07:00	2700 K	100 %
10:00	6500 K	100 %
15:00	6500 K	100 %
18:00	4220 K	100 %
22:00	2700 K	68 %
23:00	2700 K	55 %

Example of a melanopically effective daytime course of lighting -
Source: Trilux

Adjustment of **color temperature** and **brightness** to the natural daily routine, or to achieve a desired effect. **Verification** of the light control function with **MAVOSPEC BASE / MAVOSPEC LITE**, computer and **Excel macro for data logging**.





Temporal Light Artefact (TLA) an undesired change in visual perception induced by a light stimulus (Temporal Light Modulation, TLM) whose luminance or spectral distribution fluctuates with time.

Effects on humans

- **Photosensitive epilepsy** – flashing lights stimulate epileptic seizures
- **Stroboscopic effect** – dangerous when working with rotating machinery
- **Migraine or severe headache** often associated with nausea and visual disturbances
- **Increased repetitive behavior** among persons with autism
- **Asthenopia** (eye strain), including fatigue, blurred vision, conventional headache, decreased performance on sight-related tasks
- **Other:** panic attacks, anxiety, increased heart rate, dizziness
- **Also:** interference with machine vision and imaging devices (video & security cameras, bar code scanners etc.)

Ecodesign requirements for light sources

EU Regulation 2019/2020 since 1.9.2021

Limits **PstLM** ≤ 1, **SVM** < 0,4



PstLM = short-term light modulation measures visible flicker – 0.3 Hz up to 80 Hz

SVM = stroboscopic visibility measure assesses the strobe effect which can occur in conjunction with moving objects – 80 Hz bis 2000 Hz

WORKPLACE LIGHTING

REQUIREMENTS FOR THE MEASURING EQUIPMENT

Lighting of workplaces – Part 1: indoor workplaces DIN EN 12464-1

Lighting of workplaces – Part 2: outdoor workplaces DIN EN 12464-2

Technical guideline for workplaces - Lighting - ASR A3.4 – Employers Liability Insurance Association DE

Technical guideline for workplaces – Emergency lighting, optical safety guidance systems - ASR3.4/3 – Employers Liability Insurance Association DE

	illuminance		glare luminance, 1° ... 5° 0.05 cd/m ² ... 1000 cd/m ² class B, DIN 5032-7 factory calibration	color temperature (CCT) color rendering index (CRI) [flicker]	flicker PStLM, SVM
Emergency lighting - DIN EN 1838					
	safety-, anti-panic- and surrogate lighting at least 0.5 ... 1 lx accuracy ≤ 10% MAVOLUX 5032 B USB		safety signs luminance + contrast accuracy ≤ 10%	color rendering index (CRI)	
Measuring device	MAVOLUX 5032 B USB MAVOLUX 5032 B - Kit		MAVO-SPOT 2 USB	MAVOSPEC LITE MAVOSPEC BASE	MAVOPAD



Thank you for your attention!

If you have any further questions or suggestions, please contact:



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