IALA GUIDELINE

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LIGHT APPLICATIONS - ILLUMINATION OF STRUCTURES

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1. SCOPE

This Guideline does not address architectural lighting; instead, it focuses on illumination for navigational aspects. Illumination can provide an important Marine Aid to Navigation (AtoN) function. This Guideline may assist the service provider in considering and implementing illumination of AtoN structures.

Illumination of fixed structures is frequently called flood-lighting or facade-lighting.

2. OBJECTIVES

Illumination of fixed structures means that the supporting structure of a navigational light or a navigational obstacle is illuminated or floodlighted with a fixed light of non-glaring properties.

The purpose of this illumination is to enable the mariner to positively identify the object and to allow estimation of distance and relative position to the object.

3. TECHNICAL CONSIDERATIONS

The main application is for close range navigation such as in ports and restricted waters on typical structures as follows:

- Offshore structures, beacons
- Piers, jetties, breakwaters, dolphins
- Locks, bridges, signs.

The illumination must not interfere with any navigational light. Good vertical separation between the two types of lights is necessary, if mounted on the same structure.

The risk of creating glare to the observer must be considered. This is a common mistake that should be avoided. Screening of the light sources is often required.

Normally the illumination system does not have a backup system, due to heavy power requirements by the fixed light. However, with the introduction of LED technology (LED-tubes), this can be achieved.

White light is commonly used, but lateral red and green can be used particularly by means of LED.

3.1. BASIC PRINCIPLES

There are two ways to achieve illumination of structures, the traditional in-direct illumination or by direct emitted light towards the observer.

Figure 1 Minor Light, Sweden

3.2. INDIRECT ILLUMINATION

In-direct illumination means that a lamp illuminates an object, and the observer sees the reflected light from the object (figure 1). This method has low efficiency, as only a fraction of the emitted light is radiated towards the observer. This method is simple to apply by the use of standard light fittings and normally requires mains electricity. An advantage is that the whole structure can be illuminated and also its surroundings. The indirect light can help the observer to identify the structure (e.g., fixed lighthouse) by illuminating identifying text (or identification number).

Using the same colour of indirect light as the illuminated area, the conspicuity may be enhanced.

3.2.1. DIRECT ILLUMINATION

Direct emitted light towards the observer is a fairly newly adopted method making the use of diffused LED to create the impression of a weakly illuminated area resembling flood light. The light directed to the observer is usually emitted from vertical tubes arranged around the structure. From a distance, these lighted tubes form a strip band of light. The light efficiency is high as mainly all light generated is directed towards the observer (figure 2).

Figure 2 Almgrund Lighthouse,Sweden, equipped with LED pipes

3.3. TYPES OF ILLUMINATION

3.3.1. SEALED BEAM LAMPS

The most robust illuminator is the sealed-beam lamps, which also have a long life if run at a lower voltage than marked. They are used for indirect illumination.

3.3.2. SODIUM AND MERCURY LAMPS

Sodium (Na) and mercury (Hg) lamp are frequently used for indirect illumination and have the advantage of long life. Sodium emits yellow light, and mercury emits white light. These are often used to mark opposite sides of channels with yellow and white side marks.

3.3.3. LED LIGHTS

LED lights can be used with varying colours for indirect illumination. LEDs are an efficient producer of coloured light – sometimes called “colourwash”.

3.3.4. LED PIPES

LED-pipe light is designed to address problems associated with traditional AtoN floodlights without the need for mains electricity, high power consumption and maintenance. These direct light emitters rely on a low voltage supply which means that solar PV systems can be utilized.

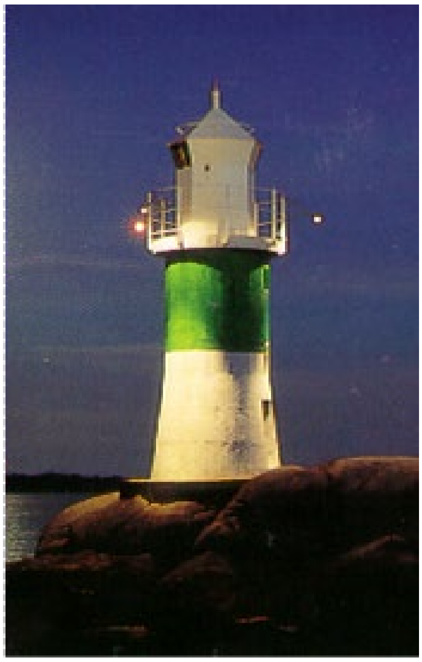

Figure 3 Floodlit lighthouse, Sweden

4. TYPICAL APPLICATIONS

4.1. LIGHTHOUSES AND MINOR LIGHTS

Floodlit lighthouses can provide enhanced visual identification and may be considered as important as the traditional flashing light of the lighthouse. The floodlight has to be considered as complementary to the main AtoN light.

It helps the mariner to keep track of the bearing to the lighthouse in the eclipsed period by having a permanently illuminated object to look at. It makes the AtoN easily and quickly recognizable.

The light source in these constructions can be sealed beam lamps. To prolong the lifetime of the lamps they can be run on a lower voltage. Normal use is 4 lamps on a beacon (2m in diameter) and 8 to 12 lamps on larger lighthouses.

A lighthouse with white and black banding can show its white band at night. These bands are illuminated from the inside by 18W fluorescent lamps (figure 4). In the event of fog, floodlights with low pressure sodium lamps on the top of the tower are switched on to illuminate the tower and the breakwater structure as well. By using the yellow light, the breakwater is also highlighted as an obstacle.

Figure 4 Nordermole, Travemünde, Germany

Another example of the use of backlighting can be seen below (figure 5) when the structure is made from transparent material such as fibreglass or glass blocks.

Figure 5 Tamamo, Japan

4.2. OBSTACLES

4.2.1. BEACONS AND MARKS

For this application, fixed or flashing lights are not applicable. By illuminating a beacon or a mark the mariner will be able to have a better appreciation of the distance and the relative position to the AtoN.

Marks may consist of a plastic cone, which is illuminated from the top downwards (figure 6). When yellow light is required, a low pressure sodium lamp is used. Alternatively, a mercury vapour lamp is used when white light is needed.

Figure 6 Illuminated mark in Göta Canal, Sweden

4.2.2. BREAKWATER LIGHTING

Important features like breakwaters that need to be defined for the mariner as an obstacle can be marked with a white plate that is illuminated by a luminaire with a low pressure sodium lamp (figure 7). The yellow light indicates this point as an obstacle.

Figure 7 Plate size: 1050 x 760 mm: low pressure sodium lamp 90W

4.2.3. MARKING OF A DOLPHIN

At the Kiel Canal, the dolphins are marked by night with backlighted yellow pyramids using a low pressure sodium 35W lamp (figure 8).

Figure 8 An acrylic pyramid illuminated from the inside to mark a dolphin

4.2.4. BRIDGE COLUMN LIGHTING

If necessary, the columns of a bridge may be illuminated. For these purposes, low pressure sodium lamps could be used. These yellow lights mark the columns as an obstacle for the mariner. The illumination is mounted on the columns and emits its light downwards to the base of the column. By carefully adjusting the amount of light, reflection on the water surface can be minimized. Lateral colours can also be used.

4.2.5. CONTOUR LIGHTING

In this particular case, lighting strips can be positioned along the edges or around the structure to improve its visibility by night (figure 9).

Figure 9 Contour lighting on a floating aid, Japan

4.2.6. ILLUMINATION FROM DISTANCE

Figure 10 Sadamisaki Japan

For this application, the traditional way of marking, e.g., lantern or beacon, the location is not practically or economically feasible. Illumination from an alternative location is possible to highlight the hazard by night (figure 10).

4.2.7. PIPE LIGHTING LED FLOODLIGHTING

An LED pipe light is designed to address problems normally associated with traditional AtoN floodlights, e.g., lack of mains electricity, high power consumption, high cost of sub-sea electricity cable and maintenance difficulties (figure 11).

Figure 11 LED-floodlighting in the busy approach to Gothenburg, Sweden

4.2.8. EXTENDED ILLUMINATION AREA

Conventional flood lights are normally fitted with standard mercury or sodium vapour lamps to illuminate the mark. The drawback of this method is the potential confusion with background lighting from urban areas, roads and bridges, especially at port entrances or other heavily populated areas.

To increase the conspicuity in areas where background lighting presents a problem, e.g., at breakwater lights, additional measures need to be considered. One example is the use of aluminium sheeting covered with coloured fluorescent film together with LED strip lighting. An illuminated area of 1.2m2 (0.2m x 6.0m) is provided on a lattice mast (figure 12).

With LED technology, it is also possible to flash the whole lighted area, which would further increase the conspicuity with respect to the background lighting.

Figure 12 Extended Illumination Area, Sweden

4.2.9. LOCK ENTRANCE NAVIGATION AID

To assist the mariner when approaching a lock, special marks are provided near the gate - entrance navigation aids. Different solutions are possible. One solution is to provide a sign with a white rectangle with a black contrast border around it (figure 13). At night, the white part is illuminated by a luminaire with a fluorescent lamp, which is of the same length as the white rectangle. As it is mounted on the left and right side of the gate, it shows two white lines at night to guide the mariner to the lock entrance.

Figure 13 Entrance lock navigation aids (Germany) can be seen to the left and right of the lock gate

4.2.10. ILLUMINATION OF LOCKS

To ensure navigation during the night through locks, especially on inland waterways, the locks are illuminated during the night. For this purpose, the plant and its parts like gates, chamber walls and platforms are illuminated to make them visible to the mariner (figure 14). As the lock represents an obstacle and colour vision is not necessary, the yellow light of the low pressure sodium lamp is used.

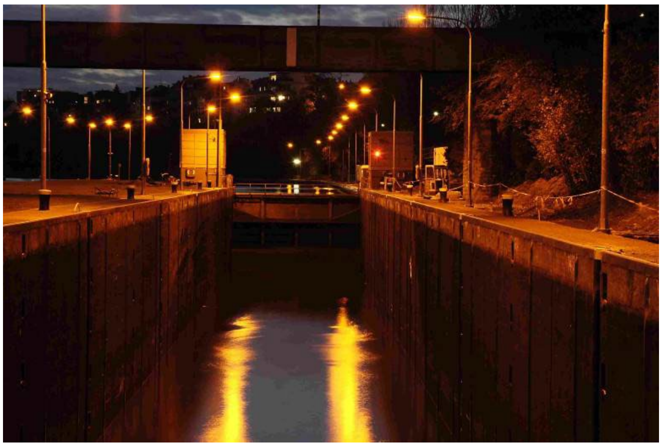

Figure 14 Illumination of a lock at night, Germany

4.3. SIGNS

4.3.1. ILLUMINATION

Countries with extended inland waterways may wish to provide the mariner with additional information by installing relevant signage (figure 15). These signs can be in different colours, sometimes with a pictogram and may also include additional text information e.g., “400”. If necessary, the sign can be illuminated by a luminaire to highlight the information at night.

Figure 15 Typical sign with luminaire at the top (Germany)

4.3.2. BACK LIGHTING

Back lighting of signage can be used to assist the passage of ships through bridge openings (figure 16). One possible solution is to use coloured acrylic panels, which are illuminated from behind, to define the safe channel. This technology can achieve a high uniformity and a defined level of luminance contrast between the different colours.

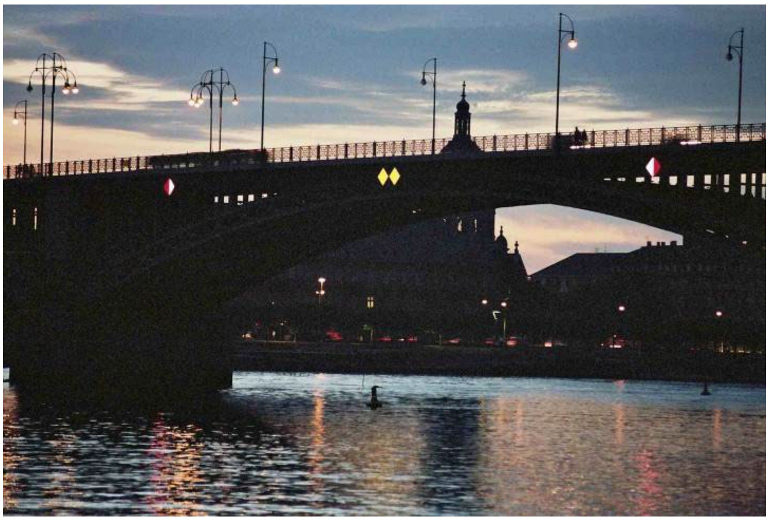

Figure 16 Coloured signage on a bridge, Germany

5. DESIGN CONSIDERATIONS

Flood-lighted, back-lighted, LED-pipe or contour lighted objects are normally used within a distance up to 1NM. Beyond this range, the flood-lighted or back-lighted structure tends to become more like a point source and the luminance becomes too low to be detected. It has to be kept as a lighted area giving a minimum of 3 minutes (0.05 degree) of arc subtended by the eye of the observer.

For the contoured lighted structure, it is somewhat different. It is necessary to recognize or define the individual contours within the lit area. Therefore, a greater subtense angle would be required.

General considerations should include the following:

- Direct light should not result in glare to the eyes of the observer.
- Avoid or minimize any direct light on the surface of the water to prevent reflection.

5.1. PERFORMANCE REQUIREMENTS

5.1.1. LIGHT SOURCES

If a surface has to illuminated and the colours of the surface are important to the mariner, a light source with a high colour rendering during the whole lamp life is very important. A high efficacy and long lifetime of the light source is beneficial. Furthermore, the cost for the light source should be low. When comparing these features a fluorescent lamp often shows more advantages than LED-technology.

A low pressure sodium lamp is the light source with the highest efficacy between 100 lm/W and 120 lm/W. It is has a long life span of more than 10,000 hours and is a very reliable, well proven and tested lamp.

For yellow lights, high power LEDs have an efficacy of about half that of a low pressure sodium lamp and can produce a lot of heat. Careful heat management is necessary to optimize efficiency and mitigate early failures. The cost of a low pressure sodium lamp is considerably lower than a matrix of LEDs.

Sealed beam lamps (e.g., PAR 36 SB4589 28V 50W) can be used for illuminating structures. To prolong the lifetime of the lamps they can be run on a lower voltage, e.g., 22 V. Normal use is 4 lamps on a beacon (2m in diameter) and 8 to 12 lamps on larger lighthouses, i.e., total illumination power of 200 W – 600 W.

For the illumination of the white plate to mark breakwaters and to illuminate objects like bridge columns, low pressure sodium lamps between 35 W and 90 W can be used. Alternatively, a mercury vapour lamp can be used when white light is required.

For the illumination of a single sign (typical size 1m^2 to 2m^2) with different colours, a fluorescent lamp with a power consumption of 40W can be used.

To implement a lock entrance navigation aid, a luminaire with a fluorescent lamp of 65 W is used to illuminate the plate. LED-technology may also be possible.

For the back lighting of signs, LED-technology may be used. By using this technology, a high uniformity and a defined level of luminance and contrast between different colours can be archived. This leads to better distance recognition compared with the application of fluorescent lamps.

Refer to IALA Guideline *G1043 Light Sources used on Visual Aids to Navigation* for further information on luminance efficacy, power consumption, life, colour rendition, spectral distribution, intensity, etc.

5.1.2. LIGHT DISTRIBUTION

For the illumination of objects (signs, columns, etc.) a direct, symmetrical or asymmetrical light distribution characteristic should be used for the luminaire. A direct distribution means, 100% of the light is directed downward to the object. Depending on the size of the object to be illuminated, a wide or small beam distribution should be chosen. A flat and clear front glass is recommended.

The light emission of the luminaire to the eye of the observer must be reduced in order to mitigate glare. Furthermore, the scattered light incident on the water surface should also be minimized. Accessories like an adjustable hood (adjustable anti-glare frame) or a louvre (grid shield) may be helpful to reduce or avoid glare.

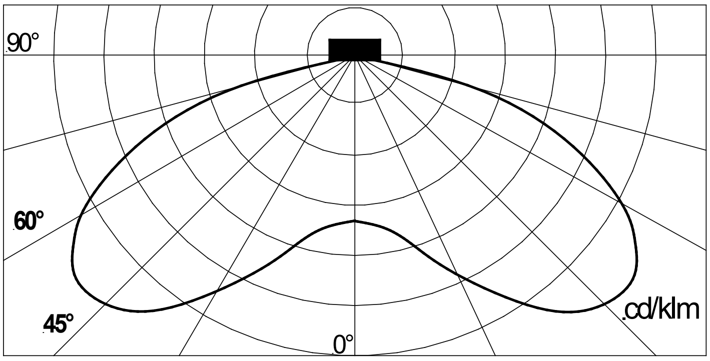

Figure 17 Example for direct, symmetrical distribution, wide beam

5.2. POSITIONING OF LIGHT SOURCES

Ideally, all light sources should be positioned perpendicular to the water surface to avoid reflection or direct light in the direction of mariners. The lower the angle of light is, the higher the probability of direct light or reflection that may cause glare to mariners.

It is important to avoid any interference with the main navigational light

Non-corrosive material should be used for the light housing, and it should be positioned for ease of maintenance. Measures should be taken to protect against water ingress and birds. The weight of the unit and shock resistance

5.3. ILLUMINANCE (ILLUMINATION LEVEL)

The minimum intensity for daytime use should be 1 microlux illuminance at the eye of the observer. For nighttime use, a minimum of 20 microlux and a maximum of 200 microlux illuminance at the eye of the observer is required depending on the level of background lighting.

5.3.1. ILLUMINATION OF SIGNS AND PLATES

For the illumination of a sign or a plate with the size between 1m² and 2m², the following value for luminance (lx) is recommended:

$$Average\ illuminance\ E_{av}: 200lx \pm 10\%$$

Equation 1 Average illuminance (lx)

$$uniformity\ u = \frac{E_{min}}{E_{max}} \geq 1:6$$

Equation 2 Uniformity limit for signs and plates

where:

E_{min} is the minimum illuminance

E_{max} is the maximum illuminance

Reference: *DIN EN 12899-1: Fixed, vertical road traffic signs,* table 22 / class E2 and table 23 / class UE2

5.3.2. Back Lighted Signs using LED-technology

Table 1 Luminance and Uniformity

Colour	Average Luminance L_{av} in cd/m²	Tolerance	u
White	120 cd/m²	± 10%	≥ 0,5
Red	60 cd/m²	± 10%	≥ 0,5
Yellow	60 cd/m²	± 10%	≥ 0,5

$$u = \frac{L_{min}}{L_{max}}$$

Equation 3 Luminance uniformity

where:

L_{min} is the minimum luminance

L_{max} is the maximum luminance

5.3.3. Level of illuminance for locks

Table 2 Illuminance level for locks

Area	Horizontal, Average illuminance E_h	Vertical, Average illuminance E_v	Uniformity u
Approach Area	1 to 10 lx *		≥ 1 : 6
Lock Platform	≥ 10 lx		≥ 1 : 4
Chamber Wall ≤ 10m		≥ 2 lx	≥ 1 : 3
Height:> 10m		≥ 6 lx	
	* increasing to the gates		

$$u = \frac{L_{min}}{L_{max}}$$

Equation 4 Uniformity for locks (3)

where:

L_{min} is the minimum illuminance

L_{max} is the maximum illuminance

Reference: *DIN 67500 Illumination of Locks*.

The eye of the mariner coming from the dark has to be adjusted to the higher level of illuminance in the lock. This process is called adaptation and needs some time - light adaptation takes a few seconds whereas full adaptation can take up to one hour. To achieve good adaptation, the illuminance should increase in the approach area until it reaches its highest level in the chamber.

5.3.4. TYPE OF REFLECTIVITY (LAMBERTIAN OR RETROREFLECTION)

When light strikes a rough or granular surface, it bounces off in all directions due to the microscopic irregularities of the interface. The exact form of the reflection depends on the structure of the surface. One common model for diffuse reflection is Lambertian reflectance, in which the light is reflected with equal luminance in all directions, as defined by Lambert's cosine law.

Some surfaces exhibit retro reflection. The structure of these surfaces is such that light is returned in the direction from which it came. If illumination is used in combination with a retro reflection surface, the position of the light source is very important but there will be no significant gain from the retro reflective material.

5.3.5. RETRO-REFLECTIVE MATERIAL

If the object shows colours that the mariner must recognize, non retro-reflective material is recommended. Retro-reflective sheeting reflects the incident light back to the light source and not to the eye of the mariner, so that the effect of the retro-reflection offers no advantage to the user.

5.4. FLOOD LIGHTING ON DEMAND

Flood lighting is very energy demanding and ideally requires mains electricity supply. Some installations (e.g., LED-pipes) can be operated using a solar Photovoltaic system. In addition, on-demand flood lighting can be switched on using a remote control system by the service provider or the user, as required.

6. DEFINITIONS

The definitions of terms used in this Guideline can be found in the *International Dictionary of Marine Aids to Navigation* (IALA Dictionary) at http://www.iala-aism.org/wiki/dictionary and were checked as correct at the time of going to print. Where conflict arises, the IALA Dictionary should be considered as the authoritative source of definitions used in IALA documents.

7. ABBREVIATIONS

AtoN	Marine Aid(s) to Navigation
Hg	Mercury
LED	Light-emitting diode
lm/W	lumens per watt
m	metre
m^2	square metres
Na	Sodium
NM	nautical mile
u	uniformity
V	volt(s)
W	watt(s)

8. REFERENCES

[1] IALA Guideline G1043 Light Sources used on Visual Aids to Navigation

[2] DIN EN 12899-1: Fixed, vertical road traffic signs

[3] DIN 67500: Illumination of Locks