



Maritime Traffic Technology

Design of Visual Signals Stations



Technical Information

Document

Name: Design of Visual Signal Stations

Type: Technical Information, Input Paper for IALA ENG Committee

Version: 1.0

Date: 2022-09-19

Author: Frank Hermann

German Federal Waterways and Shipping Administration  
 Waterways and Shipping Office Baltic Sea  
 Branch Maritime Traffic Technology

Content

1 Summary 3

2 Introduction 3

3 Lights versus Signals 3

3.1 Lights 3

3.2 Signal Station 3

4 Geometry 4

5 Luminous Range 6

6 Luminous intensity and colour 6

6.1 Harmonisation of intensities 6

6.2 Mesopic vision 7

6.3 Helmholtz-Kohlrausch phenomenon 7

6.4 Cool white light at day 8

6.5 White and yellow lights in a signal board 8

6.6 Summary 8

7 Intensity Control 8

8 Intensity profile 9

8.1 Table-Example 11

8.2 Iso-intensity diagram example 11

8.3 Single luminaire intensity distribution 12

8.4 Signal position 12

9 Backing Board 13

10 Example 16

11 References 18

# Summary

This technical paper describes the photometric and geometric requirements for visual signal stations. The paper is based on the German practice for maritime and inland signal stations. It can be used as a starting point for a future IALA guideline.

# Introduction

IALA has published the codes for port traffic signals in Recommendation R0111 [1]. Until now there is no subordinate guideline.

The German administration published technical regulations on signal stations 60 years ago and these are still advanced due to current developments. The regulations are used for its own signals (e.g. more than 300 locks) and for the permission of signal stations at ports and bridges.

# Lights versus Signals

The International Chart INT 1 [2] and the IHO Chart specifications [3] differentiates lights from signals.

## Lights

A light and its code are described in detail in chapter P of INT 1. Some of these details are covered by IALA recommendations and guidelines (colour, flash characters). The purpose of a light is to find and confirm the position of a vessel (Aids to Navigation).

In most cases a light consists of a single light point visible. The most common exception is a leading line with two different lights (front and rear) at different positions.

There are composite lights which show two or more single lights at the same position but at different heights.

All these lights can be described with the tools of INT 1 chapter P.



Figure 1: Single light, Leading Lights, Composite Lights

## Signal Station

Signals belong to chapter T Services of INT 1. They are called signal stations, which implies that a signal may include several 'lights' (or several luminaires). There is no further information about the code. For port traffic signals the code is defined by IALA R0111. Other signal stations are used at locks, bridge passage, by-ports (waiting area in front of a lock) and sidings (passage area for large vessels in a narrow channel). In these applications the code shown may be different from IALA R0111. Some codes used for maritime signals in Europe are derived from UNECE Resolution 90, SIGNI (European Code for Signs and Signals an Inland Waterways).

The desription of a signal station cannot be published according to chapter P of INT 1 as the code shown is permanently changing and is not covered by INT 1.

However, some IALA documents are applicable for visual signals.

A signal station consists of at least 2 luminaires showing green and red light, with only one of them switched on at a time. In most cases the signal shown has a least 2 'lights' active (IALA Rec R0111: 3 lights) and therefore 4 luminaires (IALA: 9).

Typical arrangements are shown in Figure 2. The central layout can show all the main messages of IALA Rec. R0111. The left layout is for very short ranges only (approx. 200 m).



Figure 2: Some geometrical layouts for a signal station

To give the mariner full information, it is not only necessary to recognize the colour and flash character of a single light. The entire information is provided by a horizontal and vertical arrangement (layout) of several lights.

# Geometry

The recognition of the message, a signal station shows, depends on the viewing angle between the single lights as seen from an observer at distance (Figure 3).



Figure 3: Viewing angle and light separation

viewing angle

separation of the single lights, vertical and horizontal

distance between observer and signal

The eye resolution is assumed to be about 1' (1 arc minute). To provide a secure recognition at the maximum useful distance the viewing angle should be larger than 1'. The German administration has designed its signals with a minimum value of 4' ().

Minimum light separation can be calculated with the tools of Blaise-Equation for of IALA-Recommendation R0112. However, this tool is hard to use and will give similar values (3' ... 5').

A value of 4' as the angular design separation for the maximum useful distance leads to a recommended separation of the single lights according to

.

Typical values are shown in Table 1.

Table 1: Separation of lights of a signal

|  |  |
| --- | --- |
| [m] | [m] |
| 1000 | 1.16 |
| 2000 | 2.33 |
| 3000 | 3.49 |
| 4000 | 4.65 |
| 5000 | 5.82 |

As an example, a German layout is shown in Figure 4, which is designed for some IALA R0111 code plus auxiliary information. A single light is typically designed with two or three luminaires showing different colours. These luminaire should be put very close together. The center between these lights should have the distance vertically and horizontally.



Figure 4: Layout of a signal station (example)

# Luminous Range

"The luminous range is the maximum distance at which a light can be seen, as determined by the luminous intensity of the light, the atmospheric transmission factor and the threshold of illuminance on the eye of the observer" (IALA dictionary 2-1-390, 2021).

Within the luminous range the colour and the flashes of a light should be clearly recognizable. For signal stations the useful range is limited by the angular subtense of several lights shown and not by the luminous intensity.

To publish a range (nominal range) will be misleading as it is expected that the code or message will be entirely recognizable from this distance.

For signal stations, luminous ranges (especially nominal range) should not be published.

This is in accordance with Chart INT 1, where only the purpose and position of a signal station is drawn in the charts.

However, the tools of IALA guideline G1148 may be used to find a suitable luminous intensity for the lights of a signal station.

# Luminous intensity and colour

## Harmonisation of intensities

A signal station will be used for day and night. The message may be presented by a geometrical arrangement of lights with different colours.

To optimize visual perception, two conditions should be considered.

* Mesopic vision (IEC 845-22-018, )
* Helmholtz-Kohlrausch phenomenon (IEC 845-22-066)

Although both conditions are based on sophisticated theories, they lead to simple results, which can easiliy be confirmed by visual trials.

## Mesopic vision

At day, it is assumed that the observer will see with the cones of the eye (photopic vision IEC 845-22-016). There is full colour perception.

At night, scotopic vision (IEC 845-22-017) is active. There is no colour perception and the visual sensitivity function is shifted towards shorter wavelengths.

For lights and signals, it is clear that the colour will be seen by the observer at night. So the perception of an AtoN light is never based on scotopic vision alone.

The region between full photopic and full scotopic vision is named mesopic vision.

In this region, the weighting function is between the photopic luminosity function and the scotopic luminosity function .

CIE defines a mesopic weighting function with a 'not well defined' parameter .

Although this function is very hard to handle in practice, it can be used to explain, why 'cold white light' appears much brighter at night compared to a 'warm white light': The shift to amplifies the perception of the blue part of the white spectrum.

According to the theory of mesopic vision, 'cold white light' appears extraordinary bright at night.

## Helmholtz-Kohlrausch phenomenon

IEC-definition: Change in brightness of perceived colour, produced by increasing the purity of a colour stimulus while keeping its luminance constant within the range of photopic vision.

The result from Helmholtz-Kohlrausch phenomenon is that an observer, who sees white and high-purity coloured lights of same luminous intensity, will perceive the coloured lights much brighter than white.

In European standard EN 12966 for road vertical signs, the phenomenon is already considered. On a board with lights of different colours, each colour is shown with a different luminance.

When the luminance of the red light is scaled to a value of 1 (dimensionless), the ratio to the other colours are:

Table 2: Colour ratio from EN 12966

|  |  |  |  |
| --- | --- | --- | --- |
| White | Yellow | Green | Red |
| 4 | 2,4 | 1,2 | 1 |

As an example, the white part of a signal board should be 4 times brighter than the red one, to produce a harmonized signal.

The long-time experience at German waterways have shown that the colour ratios of Table 3 are sufficient for marine signals. Germany does not use yellow for signal stations and has no value for this colour .

Table 3: Colour ratio from TFV-08 (German standard for waterways)

|  |  |  |  |
| --- | --- | --- | --- |
| White | Yellow | Green | Red |
| 2 | - (\*) | 1 | 1 |

(\*) Remark: I assume that the factor 2 works pretty good for yellow.

## Cool white light at day

Although not covered by any theory the situation at day is totally different. The background light is the sky or some reflection of it, which is said to have a colour temperature of about 5500 - 8000 K. The most convenient standard is D65, which is 6500 K.

At day, a cool white light does not appear very conspicuous.

## White and yellow lights in a signal board

The IALA code for port traffic signals has four colours.

Older CIE papers proposed to limit the number of colours in a signal system to a maximum of three colours to avoid mix-up. In some cases warm white and yellow light are hard to distinguish.

To improve perception of white and yellow, warm white should not be used.

## Summary

The requirements above to optimize the perception of the different colours of a signal station can be summarized to:

* White (and yellow) colour should be brighter than red and green.
* White colour should not be 'cool white' to prevent glare at night.
* White colour should not be 'warm white' to provide sufficient colour difference from yellow.

The luminous intensities of the lights of a signal station should have the follwing ratios:

White : (Yellow) : Green : Red = 2 : (2) : 1 : 1.

The white light should have a colour temperature of approx. 4000 k (neutral white).

# Intensity Control

A signal station (INT1 T) is assumed to work at day and night, whereas most of lights (INT1 P) are for night time only.

According to IALA Rec R0202, intensity calculations are based on Allard's Law ().

The required illuminance at the eye of the observer is explained in IALA Guideline G1148 and has strong influence on the resulting intensity.

The international accepted values for the required illuminance are:

* for all lights except leading lights / night, no backround luminance
* for leading lights / night, no backround luminance
* for all lights / night, minor backround luminance
* for all lights / night, substantial backround luminance
* for all lights / daytime

From these values it seems that the control ratio should be , but in practice this is not needed and may cause technical problems.

* In nearly any case, a signal station (e.g. port traffic signal) is in the vicinity of a strong illuminated area and minor or substantial background illuminance can be presumed.
* The daytime value for the required illuminance was established for the meteorological condition that the light appears in front of 'bright cloud or clear sky' [5]. At many signal stations we find man-made-structures or dark panels as background, so that a lower value for the required illuminance at day might be acceptable.
* The preferred tool to realize an intensity control is 'pulse-width modulation' (PWM). It is not recommended to use a PWM duty cycle lower than 5%. For lower duty cycles the PWM results in very short electrical pulses, which may cause parasitic electromagnetic radiation and stress to electronic components.

At IALALITE/IALABATT 2012, the German administration presented a control procedure derived from the european standard EN 12966 Variable message traffic signs [6].

The sign luminance is adjusted according to the measured horizontal illuminance .



Figure 5: Intensity control procedure for signal stations

This procedure can be used for all signal stations. The station needs a luxmeter and a controller which calculates and sets the luminous intensity. At bright sunshine the intensity is 100 % and when the illuminance decreases (cloud, sunset), the intensity is set to a lower value x % (Figure 5).

EN 12966 proposes 6 steps for controlling the intensity.

For marine signal stations the following steps have been found to be sufficient:

Table : Intensity steps

|  |  |  |
| --- | --- | --- |
| Step | Illuminance | Intensity |
| Day |  |  |
| Twilight |  |  |
| Night |  |  |

# Intensity profile

The code of a signal station has to be recognized from very different positions. In Figure 6 two situations are shown.

1. A large vessel with high observer position:  
   The distance between observer and signal may be several kilometres and a high intensity is required.
2. A small vessel with low observer height:  
   A signal should provide sufficient recognition for short observer distance. The distance may be about 100 m and large angular divergence may be required. The intensity should not be too high, to avoid glare.



Figure 6: Different positions in a vertical plane

The same situation occurs in the horizontal plane (Figure 7). For short distances (waiting area), large viewing angles and low intensities are required. For long distances (approach area) the angles are smaller and high intensities are needed.



Figure 7: Different positions in a horizontal plane

As a consequence of the viewing positions described above, it is not suitable to reduce the luminous intensity distribtution to a single nominal intensity value and horizontal and vertical divergence.

Instead, the required luminous intensity distribution should be defined by a two-dimensional function with horizontal angle and vertical angle according to CIE Publication No. 43 Photometry of Floodlights.

A two dimensional function to describe the intensity distribution is commonly used for road traffic lights (EN 12368), ICAO aviation lights (approach lighting system, see [7]) and the German standard for signal stations (see [8]).

It can be used for the presentation of a measured intensity distribution and for defining the required intensity distribution.

The two dimensional function can be published by a table (example EN 12368) or an iso-intensity diagram (IEC 845-29-042).

## Table-Example

**'Signal head type W, categorie 2/1 of EN12368'**

The luminous intensity distribution is then defined by the percentage of at / .

Table 5: Relative intensity distribution, Signal head type W 2/1

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| () |  | ± 5° | ± 10° | ± 20° | ± 30° |
| () |  |  |  |  |  |
|  | 100 % | 85 % | 55 % | 3 % | 1 % |
|  | - | - | - | - | - |
|  | 80 % | 75 % | - | - | - |
|  | 60 % | - | 35 % | - | - |
|  | 30 % | - | - | 8 % | - |
|  | 2 % | - | - | - | 2 % |

Remarks:

* The standard is for red, yellow and green lights (white excluded). For these three colours, the same minimum luminous intensity is defined.
* The vertical position of road traffic signal heads is the maximum observer hight usually presented by a truck driver. The luminous intensity is therefor defined in and below horizon only.

## Iso-intensity diagram example

**'German standard TFV-08 for signal stations at Kiel Canal (locks, by-ports and sidings)'**

The luminous intensity is referenced to the minimum required value at the optical axis of the lantern and given in percentage.

In the angular region enclosed by the coloured rectangles, the luminous intensity should be higher than the percentage value listed in the diagram (Figure 8).

For example, in the rectangular region and the luminous intensity should be equal or higher than of the value .



Figure 8: Iso-intensity diagram

## Single luminaire intensity distribution

It should be mentioned that each luminaire used for the different colours need to have the same relative intensity profile. Otherwise it may be possible that, for a single position, the observer sees only one luminaire because the other two luminaire are in the dark part of their intensity profile, which means that the observer sees a different code.

This requirement seems to be redundant, but in practice it is not. Many LED lanterns are assembled with a combination of standard secondary optics and different coloured LED. As the light emitting LED chip differs in size from colour to colour, the angular divergence of the profile differs as well.

## Signal position

The recommended signal position depends on the intensity distribution of the lantern and the observer positions. In the horizontal plane the signal station may be rotated, to give best visual perception for the relevant observer positions (see Figure 7).

For the height of the lantern there are two different solutions. For maritime applications the height of the signals is set to the average of the maximum and minimum observer height (Figure 9).

This will give moderate heights and the vertical intensity distribution is symmetrical. However, it should be confirmed that there is no superstructure or container on the vessel, that obstruct the viewing line at relevant distances.



Figure 9: Moderate height example

Especially when the maximum observer height is not too large, the signal height may be choosen equal to the maximum observer height (Figure 10). This design has the advantage that a horizontal screen can be attached above the signal, which reduces false signal from incident sun light. The vertical intensity distribution is defined only in and below the horizon. For road traffic and inland waterways signs this is the standard design in Germany.



Figure 10: Maximum height example

In some case it is better to have two signals (Figure 11). One is of high intensity and little divergence for vessels at great distance, the other is for small ships with low observer height and has low intensity but high divergence. Normally the message of both signals should be the same, but it may be possible to give different messages to ships of different sizes. For example, small ships should wait until large vessel has passed.



Figure 11: Application of two different signals

# Backing Board

The nominal daytime range of marine signal lights was published by IALA in 1974 with a separate recommendation. The recommendation included an equation for the required illuminance at the eye of the observer.

Luminance of the background

Minimum required illuminance at the eye of the observer

(I assume that this equation is just another famous Blaise-equation.)

This equation was used to estimate the visibility of a light at day depending on day time meteorological conditions.

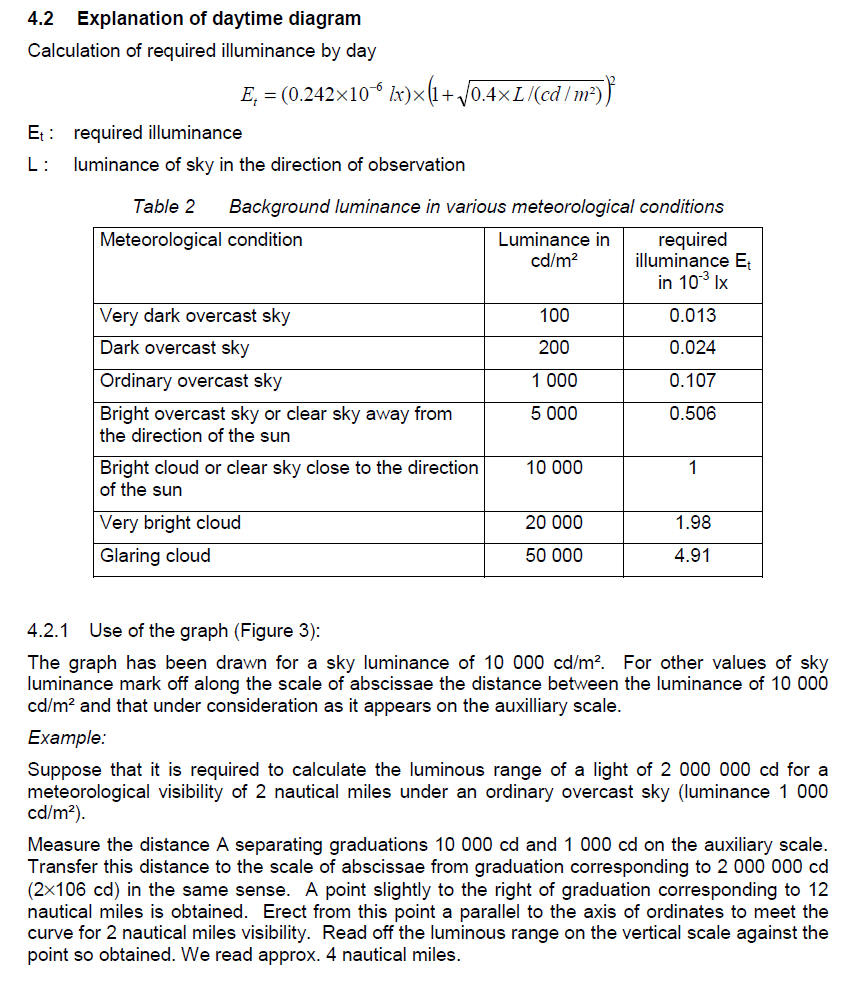


Figure 12: Extract from IALA Recommendation E-200 Part 2

The equation was kept in IALA E-200-2 in 2008, but got lost in the current R0202.

The main output of this equation was that the expected sky luminance for nominal daytime range of a light was set to 10 000 cd/m² ('bright cloud or clear sky close to the direction of the sun').

The required illuminance became then .

The nominal day time range for lights is then based on the value .

This is true for an AtoN light with a background near the horizontal line between the water and the sky, when the supporting structure of the light is below eye resolution (Figure 13).



Figure 13: Day time light with clear sky and bright clouds

For signal stations, the background is usually a building or other man-made structure behind.



Figure 14: Day time signal station

In these situations the background luminance will be significant lower than and it can be expected that the required Illumination at the eye of the observer at day may be about or even less.

To improve visibility at day, it is recommended to use a backing board (IEC 845-31-100) with black colour.

An example for backing boards is shown in Figure 4. If the signal station is fixed at a building, the part of the building surrounding the signal should be painted black as well.

# Example

In this chapter a typical design of a signal station is specified. The height and the geometrical layout is useable for a range of about 3000 m. Alle codes of R0111 can be realized.



Figure 15: Typical layout of a signal station

The minimum luminous intensities of the luminaires at daytime (, ) are

The angular intensity distribution is described by an iso-intensity diagram (Figure 16). The intensity is controlled according to the measured illuminance (Table 6).

Table : Typical dimming values

|  |  |  |
| --- | --- | --- |
| Step | Illuminance | Intensity |
| Day |  |  |
| Twilight |  |  |
| Night |  |  |

The colour of the luminaire is exactly R0201 for red and yellow (Figure 17). As the use of a '4 colour system' for signal station is not recommended by CIE, green B from R0201 should not be used. As explained before, the white region is cut off from x = 0.34 to x = 0.41, which lead to neutral white of about 4000 K. With these measures the colour difference between the four colours used is increased for safe recognition.



Figure 16: Typical angular intensity specification (Day, 100%)



Figure 17: Colour specification for a signal station

# References

1. IALA R0111 (E-111) Port Traffic Signals
2. International Chart Series INT 1, German edition see BSH, [www.bsh.de](file://Wsa-whv-dc03.wsa-whv.wsv.de/user/Frank.Hermann/3_IALA/visual-signal-station/www.bsh.de)
3. Regulations of the IHO for International (INT) Charts and Chart Specifications of the IHO, International Hydrographic Organization
4. IALA R0202 (E200-2) Marine Signal Lights - Calculation, Definition and Notation of Luminous Range.
5. IALA G1148 Determination of Required Luminous Intensity for Marine Signal Lights
6. Variable Message Signs, Presentation at IALABATT/IALALITE 2012 IALA-Workshop in Brest, France
7. The Convention on International Civil Aviation, Annex 14, Aerodromes, International Civil Aviation Organization
8. TFV-08 Lichtsignalanlagen, <https://izw.baw.de/publikationen/verkehrstechnik/0/TFV-08-Lichtsignalanlagen-20220422.pdf>
9. International Electrotechnical Commission, Online Electrotechnical Vocabulary, [www.electropedia.org](file://Wsa-whv-dc03.wsa-whv.wsv.de/user/Frank.Hermann/3_IALA/visual-signal-station/www.electropedia.org), 845 Lighting