EEP18 Input paper

Agenda item 11.1

Task Number 2

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Amendment to IALA Guideline 1041 on Sector Lights

# Summary

At EEP17 the author was given an action (95) to review the Recommendations and Guidelines that have been produced by the EEP Committee’s WG4 Light and Vision (Reference EEP18/11/1). As a result of the review, section 5.4 of the above mentioned guideline requires expanding.

## Action arising from the input of the document

The text in 2 for inclusion in section 5.4 of the IALA Guideline 1041 on Sector Lights with a view to issuing Edition 3 as an output paper from EEP18.

# adittional text to section 5.4 of Guideline 1041

## Measurement

The measurement of a stand-alone marine AtoN omnidirectional sector light is best carried out by using a technique called gonio-spectroradiometry. This is described in detail in IALA recommendation E200-3 [x] but will be briefly described here. Essentially, it is a method of measuring the colour of a light against a horizontal, or azimuthal, angle of rotation.

### Measurement Equipment

The measurement equipment comprises a goniometer, which is a device that can tilt or turn the light through measured angles and a spectroradiometer, which is an instrument that can measure the spectral content of a light source.

The goniometer has an angular scale with the zero or datum in line with the direction of the measuring instrument and its scale is ±180 degrees in both horizontal and vertical directions as shown in figure x.



Figure x Goniometer Angular Coordinate System

A spectroradiometer gives a measure of the spectral power distribution (SPD) of a light source. It is this distribution of spectral power that determines the colour of the light perceived by the eye.



Figure x Spectral Power Distribution (SPD) of a White LED

The SPD can be converted into colour by using a colour chart. A colour chart wraps the wavelengths from the SPD x axis around a locus from a two dimensional colour chart with x and y axes, known as a chromaticity diagram. Chromaticity x and y values are used to pinpoint the coordinates of a colour. CIE provide a standard chromaticity diagram for use with coloured lights, shown in figure x.



Figure x CIE Chromaticity Diagram showing Spectral Locus and Approximate Colours

*Note: Reproduction of colours may not be accurate*

The colour chart given in IALA Recommendation E200-1 "on Marine Signal Lights - Colour" [ref], shows the recommended colour regions for marine AtoN lights outlined on a CIE chromaticity diagram, as shown in figure x.



Figure x CIE Chromaticity Chart showing IALA Recommended Colour Regions

Therefore by measuring the SPD at angular increments, the colours of the light all round its azimuthal plane can be determined. Across sector boundaries, the change of colour from one IALA region to another can be plotted in detail. The angles at which the light does not fall into a recommended IALA colour region can be assigned to the angle of uncertainty.



Figure x A Series of x, y Plots at 1/100th degree Intervals on a Chromaticity Diagram showing Colour Change of a Sector Light from a White Sector to a Red Sector

The mean of the two angles at either side of the angle of uncertainty can be taken to be the sector boundary. In the case of the plotted data in figure 7, the angle at which the light leaves the white region is -109.43 degrees. It enters the red region at -109.00 degrees. The sector boundary is therefore -109.215 degrees and the angle of uncertainty is ±0.215 degrees. The quoted sector boundary, according to the goniometer horizontal angular scale, is therefore -109.215 ±0.215degrees.

The relative accuracy of the goniometer is ±0.01degrees, which can be included in the uncertainty budget, but it is insignificant compared to the uncertainty of aligning the sector light datum mark (usually due south) with the measurement device. This is typically ±0.5mm on the perimeter of the sector light. Therefore, if the sector light diameter is 350mm, the angular uncertainty is ±0.15 degrees.

The measurement angle of the measurement device should also be considered. For example a 50mm measurement aperture over a 65.5m measurement distance, gives a measurement angle of 0.04 degrees.



Figure x Diagram depicting Measurement Angle

### Measurement Procedure

* The sector light should be placed on the centre of the goniometer and the spectroradiometer aligned with the light at a given distance
* A measurement datum point should be marked on the perimeter of the light that is in line with the spectroradiometer measurement aperture. This datum corresponds to zero degrees on the goniometer angular measurement scale [ref]. The alignment can be done with a line laser or projector shone from the measurement head to the light on the centre of the goniometer table. This casts the shadow of a plumb-line across the centre of the table in line with the measurement axis and the shadow can be clearly seen on the perimeter of the light under test.
* Once datum is marked, the sector light should then be turned through incremented horizontal (or azimuthal) angles. At each incremented angle, the visible spectrum should be recorded. From each spectral recording, intensity and colour information can be derived and plotted against horizontal angle on a Cartesian graph.



Figure x Cartesian Graph of Intensity and Chromaticity vs Horizontal Angle

* The intensity data should be used to determine the nominal range of each sector in accordance with IALA Recommendation E200-2. The x, y chromaticity can be plotted on a chromaticity diagram to determine the sector angles with respect to the datum point (zero on the goniometer scale). They should also be used to check that the colour in each sector falls within the recommended colour region according to IALA Recommendation E200-1.
* Once the sector boundary angles have been determined, these need to be converted from the goniometer scale to a compass bearing and reciprocal compass bearing. This will enable the sectors to be checked with figures published in the Admiralty List of Lights or with the navigational requirement.

|  |  |  |
| --- | --- | --- |
| **Goniometer**  **Angle** | **Compass Bearing (lighthouse)** | **Reciprocal Bearing**  **(ship)** |
| -180 | 0 | 180 |
| -170 | 350 | 170 |
| -160 | 340 | 160 |
| -150 | 330 | 150 |
| -140 | 320 | 140 |
| -130 | 310 | 130 |
| -120 | 300 | 120 |
| -110 | 290 | 110 |
| -100 | 280 | 100 |
| -90 | 270 | 90 |
| -80 | 260 | 80 |
| -70 | 250 | 70 |
| -60 | 240 | 60 |
| -50 | 230 | 50 |
| -40 | 220 | 40 |
| -30 | 210 | 30 |
| -20 | 200 | 20 |
| -10 | 190 | 10 |
| 0 | 180 | 0 |
| 10 | 170 | 350 |
| 20 | 160 | 340 |
| 30 | 150 | 330 |
| 40 | 140 | 320 |
| 50 | 130 | 310 |
| 60 | 120 | 300 |
| 70 | 110 | 290 |
| 80 | 100 | 280 |
| 90 | 90 | 270 |
| 100 | 80 | 260 |
| 110 | 70 | 250 |
| 120 | 60 | 240 |
| 130 | 50 | 230 |
| 140 | 40 | 220 |
| 150 | 30 | 210 |
| 160 | 20 | 200 |
| 170 | 10 | 190 |
| 180 | 0 | 180 |

* When the measured sector boundary angles have been converted, they should be examined to see how closely aligned they are with the goniometer datum. It should be remembered that the sector boundaries are accurate to within ±0.01 degrees with respect to each other but only to within ±0.15 degrees with respect to datum.
* Adjustments should then be made to find the most appropriate position corresponding to true North on the perimeter of the sector light assembly.
* The goniometer should then be rotated so that the appropriate true North position is aligned with the measurement aperture and the shadow-casting technique used to mark that position on the sector light perimeter.

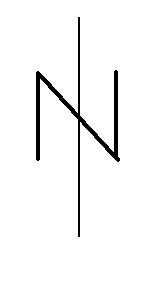


Figure x True North mark on the Sector Light Perimeter

The true North mark would normally be placed on the uppermost perimeter of the light under test, unless otherwise requested.

Some manufacturers mark their sector lights with true North and/or South. A manufacturer’s datum mark can be used as the goniometer datum, thus alleviating the need to find and mark true North upon completion of the measurement.

### Typical Uncertainties in Measurement

* Relative sector angle (sector to sector) – 0.01 degrees (insignificant);
* Concentricity of light source to goniometer table axis of rotation – 0.08 degrees (0.5mm in 375mm radius of goniometer table);
* Goniometer datum alignment – 0.15 degrees (0.5mm in 375mm radius);
* Sector light datum alignment – 0.3 degrees (1.0mm in180mm);
* True North transfer from sector positions – 0.3 degrees (1.0mm in180mm);
* Combined uncertainty by root sum of squares (RSS) – √(0.082 + 0.152 + 0.32 + 0.32) = 0.46 degrees.

Please note that the measurement uncertainty does not include the "angle of uncertainty" between the different colours at the sector boundaries. These will be stated for each boundary in the measurement results.

## Installation

The installation engineer should receive the stand-alone sector light after it has been measured on the light range. It should come with a mark on the perimeter denoting true North and a test sheet showing the relative positions of the measured sectors. During installation, there are essentially three stages of alignment: rough alignment of the lantern to true North; alignment of the lantern with a known landmark using the gunsight; further fine adjustment of the lantern with a projected image of a sector boundary using the gunsight. Each stage is a refinement of the previous one, thereby improving accuracy.

### Installation Procedure 1 (for Sabik LED 350 ODSL)

Figure 11 Left: Sabik LED 350 ODSL LED Sector Light on site

Right: Sabik LED 350 ODSL LED Sector Light with snow cover removed

* Before installation commences, measure and note down two or three true bearings from the light to conspicuous landmarks on a chart of the area of interest.
* If replacing an existing light, mark the sector boundaries from the old light on a convenient existing structure. This can be used for confirmation after installation of the replacement light.
* This installation should be carried out in clear dry weather.
* Check that the serial number on the light agrees with the serial number on the test sheet.
* Check that the sectors shown on the test sheet agree with the navigational requirements of the station on which the light is being installed.
* Place the light in its assigned position, roughly aligning the true North datum mark on the light perimeter with true North using a magnetic compass or similar.
* Use three bolts to loosely secure the light pedestal in place, bearing in mind that the light will have to be turned to finely adjust its position.
* Remove the snow cover (Sabik LED 350 ODSL).
* Ensure the light is fitted concentrically to the mounting/register plate.
* Ensure the light is level by using a spirit level across the top fastening bolts of the light assembly.

**Using the traditional gunsight mechanism**

The (gunsight) assembly consists of:

* An adaptor ring. This is fixed to the top of the lantern.
* A compass ring (360 degree). This is mated with the fixed adaptor ring and can be revolved and locked as required.
* A gunsight. This is mated to the compass ring and can be revolved and locked as required. There is a sight-glass at the rear of the telescope that is used to read the gunsight reciprocal bearing relative to the compass ring.

Figure x Gunsight - Component Parts (left) and Assembled (right)

Using the gunsight, carry out the following:

* Fit the adaptor ring to the top of the light and fasten securely.
* Bolt the compass ring section onto the adaptor ring. Then position the gun sight to mate with the compass ring.
* Remove the lens cover(s) on the gunsight.
* Look through the 'wrong end' of the gunsight and align the vertical cross hair with the true North datum mark on the sector light perimeter and lock the gunsight in position.
* Rotate the compass ring so that 0 degrees is aligned with the sight-glass at the rear of the gunsight.
* Lock the compass ring.
* Unlock the gunsight and rotate it so that the sight glass is aligned with the reciprocal bearing of one of the conspicuous landmarks previously taken from the appropriate chart.
* Lock the gunsight.
* Rotate the sector light assembly until the conspicuous landmark is aligned with the cross hairs of the gunsight.
* Tighten the fixing bolts on the sector light pedestal.
* Check the level and concentricity once more.
* Unlock the gunsight and check the bearings of other conspicuous landmarks.

The gunsight is a useful visual alignment tool. However, if access to all sides of the sector light is restricted, the ability to use the gunsight through all desired angles may not be feasible. In this case, some of the alignment may be carried out by mechanical rather than visual methods – e.g. an engineer’s square and straightedge.

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Figure x Mechanical Alignment of Gunsight Ring to true North using Engineer’s Square and Straightedge

**Optional further improvement of sector accuracy**

The sector accuracy may be improved by using a projected image of the sector edge, but this may not always be practicable. Where practicable, to improve the sector accuracy:

* Wait till dusk and switch on the light
* Set the rhythmic character to fixed light.
* Use a large piece of white card as a screen on which to project the light emanating from the apparatus. Try and get the screen as far away from the light as possible whilst still maintaining a clear projected image. An assistant or a stand may be needed to hold the screen (choose a non-windy time).
* Move the screen around so that it shows a sector boundary.
* Align the cross hairs of the gunsight with the sector boundary and lock the gunsight. This may need to be done with the 'wrong end' of the gunsight if it cannot be focussed to a short distance.
* Check that the bearing shown through the sight glass agrees with the navigation requirement for that sector edge. The reading through the sight glass may need to be a reciprocal bearing depending on whether the 'wrong end' of the gunsight was used or not.
* Check the remaining sector boundaries in a similar fashion.
* Once all sectors (or those able to be checked) have been checked, adjust the rotational position of the light if necessary and recheck against conspicuous landmarks.
* On completion, return the rhythmic character to that assigned to the AtoN.
* Replace the snow cover (Sabik LED 350 ODSL).

A theodolite or builder's level may be used instead of a gunsight but a 'transit' type is recommended, i.e. one where the sight can be swung vertically to view along a reciprocal bearing. It is preferable to choose a sight with a short focal distance to enable it to be focussed on the true North datum mark a few centimetres away. It is important to level the light accurately and then level the theodolite/builder’s level. Theodolites in particular are quite tall and any non vertical component will result in an angular error.

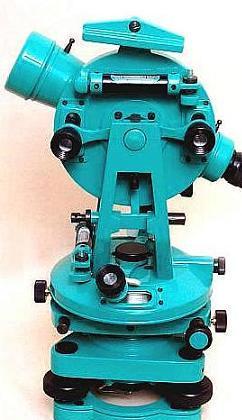
 

Figure x Transit Theodolite and Builders Level

### Installation Procedure 2 (for Vega VSL-73)

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Figure 15 Vega VSL-73 LED Sector Light

**Using the register plate method**

The design of the register plate should include slotted fixing holes to enable it to be rotated about its vertical axis so that it can be aligned with the relevant landmarks and/or references. It should also include markings pertinent to the station on which the sector light is to be fitted as follows:

* a true North mark;
* a diametric line at the relative bearing of a previously agreed landmark or landmarks;
* radial lines at the relative bearings of the sector boundaries;
* colour identification of the sectors
* note: the thickness of the line markings on the register plate should be no more than 0.5mm.

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Figure x Vega VSL-73 LED Sector Light mounted on a Register Plate

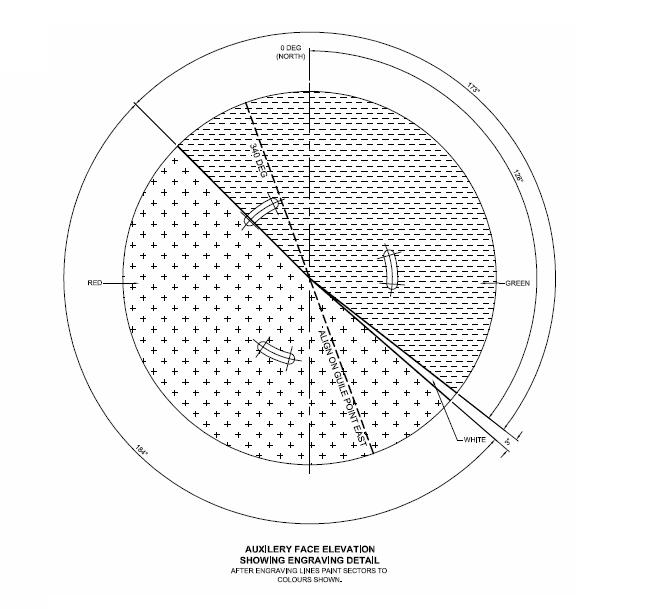


Figure x Drawing of Register Plate

*Please note that if the slotted hole for mounting is in line with the landmark bearing line, the nut and bolt may obscure your view along the line (across the plate).*

* Before installation commences, check the bearings from the light to conspicuous landmarks on a chart of the area of interest.
* If replacing an existing light, mark the sector boundaries from the old light on a convenient existing structure. This can be used for confirmation after installation of the replacement light.
* This installation should be carried out in clear dry weather.
* Check that the serial number on the light agrees with the serial number on the test sheet.
* Check that the sectors shown on the test sheet agree with the navigational requirements of the station on which the light is being installed.
* Place the register plate on the pedestal mounting plate, roughly aligning the true North radial mark on the register plate with true North using a magnetic compass or similar.
* Using three nuts and bolts, loosely secure the register plate in its approximate position on the mounting plate (bearing in mind that the plate will have to be turned to finely adjust its position).

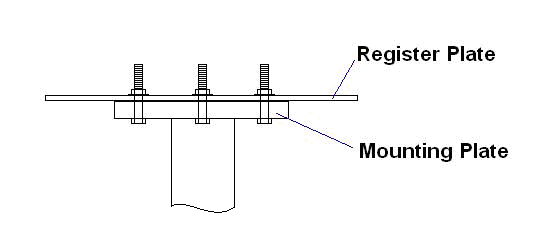


Figure x Mounting Details of Register Plate

* Look along the diametric landmark bearing line marked on the register plate in the direction of its respective landmark and rotate the plate until the diametric line is aligned with the landmark.
* If there are other landmarks, check their respective lines for correct alignment and adjust to get the best compromise between all landmarks.
* Tighten the three nuts and bolts carefully and recheck the landmark alignments.
* Mount the sector light assembly above the register plate using the same three bolts (see figure x) and loosely secure (bearing in mind that the light will have to be turned to adjust its position).

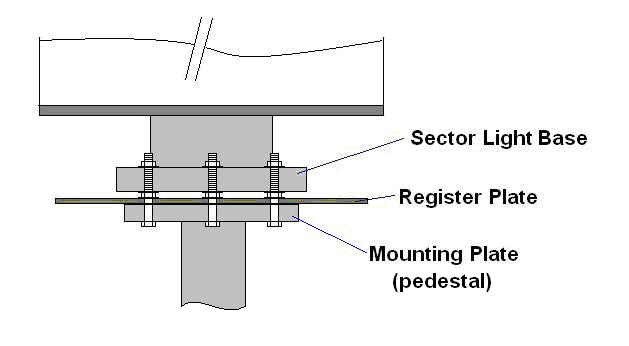


Figure x Drawing of Mounting of Sector Light and Register Plate

Note: This mounting method results in a gap between the sector light base and the register plate due to the thickness of the nut. This will increase the uncertainty of alignment between register plate and lantern.

* Ensure the light is level by using the integral level or a spirit level across the top of the light assembly.
* Rotate the light assembly until the true North datum mark on the sector light base (marked during the light range measurement procedure or by the manufacturer) is aligned with the true North radial mark on the register plate.
* If appropriate, ensure all other marks on the lantern perimeter are aligned with their corresponding radial marks on the register plate.
* Ensure that the light is fitted concentrically to the mounting/register plate.
* Tighten the three nuts carefully and recheck the alignment with the register plate.

The installation procedure should now be complete but further adjustment or alignment may be necessary during commissioning. For most lanterns this will entail rotation of the whole sector light assembly and/or register plate; however, for the Vega VSL-73 sector light, adjustment can be made using the secondary mounting frame. It can be seen from the picture in figure x that a graduated scale has been marked on the secondary mounting arrangement to facilitate adjustment. When commissioning is complete, a note or photograph should be taken of the graduated scale setting for commissioning documentation.



Figure x Close-up of Vega VSL-73 Mounting on a Register Plate



Figure x Graduated Scale marked on the Secondary Mounting Arrangement

### Uncertainties in Installation

Installation uncertainties will include measurement uncertainties, as described in 4.1.3., because the reference is true North (marked scribed on the lantern perimeter).

Typical uncertainties associated with the angular positioning of a sector light are as follows:

**Gunsight Method**

* Measurement uncertainty from light range – 0.46 degrees (from 4.1.3)
* Concentricity of gunsight to lantern housing – 0.15 degrees (0.5mm in 175mm radius of lantern housing);
* Concentricity of light sources to lantern housing – 0.15 degrees (0.5mm in 175mm radius of lantern housing);
* Setting accuracy of compass ring – 0.2 degrees;
* Setting accuracy of gunsight sight-glass – 0.1 degrees;
* Transit accuracy of gunsight (true to reciprocal bearing) – 0.25 degrees;
* True bearings from the light to conspicuous landmarks on a chart (assuming one metre accuracy for each landmark at 2 kilometres) – 0.05 degrees;
* Combined uncertainty for installation by root sum of squares (RSS):
  + initial set up - √(0.462 + 0.152 + 0.152 + 0.22 + 0.12 + 0.252 + 0.052) = 0.6 degrees
  + checked against sector edge - √(0.152 + 0.152 + 0.22 + 0.12 + 0.052) = 0.3 degrees

**Register Plate Method**

* Measurement uncertainty from light range – 0.46 degrees (from 4.1.3)
* Concentricity of register plate to lantern housing – 0.2 degrees (0.5mm in 120mm radius of lantern base);
* Concentricity of light sources to lantern housing – 0.15 degrees (0.5mm in 175mm radius of lantern housing);
* Alignment accuracy of register plate with landmark – 0.75 degrees;
* Alignment accuracy of sector light assembly with register plate – 0.2 degrees (0.5mm in 120mm radius of lantern base);
* True bearings from the light to conspicuous landmarks on a chart (assuming one metre accuracy for each landmark at 2 kilometres) – 0.05 degrees;
* Combined uncertainty for installation by root sum of squares (RSS):

√(0.462 + 0.22 + 0.152 + 0.752 + 0.22 + 0.052) = 0.9 degrees

## Commissioning

Final commissioning of the sector light should be carried out by a vessel. The task is to sail round all sectors and sector boundaries to ensure that the light complies with the navigational requirement. This requires the mariner to carefully observe the change in colour of the light at each sector boundary and recognition of colour change may best be achieved if a fixed light is exhibited for the duration of the commissioning procedure.

Some vessels are equipped with a dynamic positioning (DP) system which has an ‘anchor point’ facility. This enables the bow of the vessel to point directly at a set position. For sector light alignment, the ‘anchor point’ should be set to the position of the light being commissioned. The vessel can then be moved from side to side through a sector boundary with an angular resolution of 0.1 degrees relative to the position of the light.



Figure x Screenshot of the Dynamic Positioning (DP) system showing the Anchor Point facility

At each sector boundary, the commissioning officer should take a bearing of the light from the ship and record it. The bearing may be taken by the use of the ship's compass or, perhaps more accurately, by plotting the DGPS positions of the light and the ship on an electronic chart, thereby determining the bearing.

Each sector boundary should be transited in one direction, then the other. For sector boundaries with a narrow angle of uncertainty, a mean should be taken of both recorded sector bearings. If the recorded bearings for a sector differ by more than 0.5 degrees, a further two bearings should be taken, first in one direction, then the other. The mean of four readings should then be taken.

For sector boundaries with a wide angle of uncertainty, the bearing at which the change in colour is perceived in one direction may be significantly different to that in the other direction. In this case, each direction should be treated separately and a mean of several recorded bearings for each direction taken. This will result in two mean values, the mean of which can be taken as the sector boundary bearing and the difference of which can be taken as the angle of uncertainty of the sector boundary.

For example, in one direction the change of colour from red to pink may be recorded three times and the mean taken. In the other direction, the change of colour from white to pink may be recorded three times and the mean taken. The mean of these two means would be the sector boundary bearing. The difference between the two means would be the sector boundary angle of uncertainty.

Each mean sector boundary bearing should be compared with the published data for that station and reported accordingly.

It should be borne in mind that on most stand-alone sector lights there is no readily available means of adjusting a sector boundary. Therefore, if there is a significant departure from the published bearing, either the whole beacon has to be turned, which will affect all other sector boundary bearings, or the equipment will have to be returned to shore to be adjusted on a light measuring range. If necessary, the whole light assembly can be rotated to seek an all round compromise between the errors at all sector boundary bearings.

### Uncertainties in Commissioning

The uncertainties for the process of commissioning are perceived as follows:

* Sector light "angle of uncertainty" [2] – this is the angle over which the colour of the light is indeterminate (e.g. neither white nor red but somewhere in between). Each sector light and even each sector boundary of that light may give a different angle of uncertainty. The uncertainty contribution should be taken from the measurement results for that particular light and that particular boundary (see 4.1.2);
* Visual observation of the sector boundary from two or more readings – for a sector boundary with a sharp cut between colours, this should be taken as the 'standard error' of all the readings for that boundary. The standard error can be calculated by taking the root sum of squares of all readings minus the mean, then dividing by the square root of the number of readings minus one. The uncertainty can be taken to equal the ‘standard error’.



Example: four recorded bearings 180, 180.2, 180.4, 179.8 – Mean = 180.1





= √{(0.01 +0.01 + 0.09 + 0.09)/3}/2

= √(0.2/3)/2 = 0.26/2 **= 0.13**

For a sector boundary with a large angle of indecision, the ‘standard error’ needs to be calculated for two sets of readings and the greater of the two taken as the uncertainty.

Typical uncertainties associated with the commissioning of a sector light are as follows:

* Taking a bearing by ship's compass – 0.25 degrees
* Taking a bearing by satellite navigation (DGNSS) and electronic chart –
  + Positional error of lighthouse at the distance observed (say 5m at 2000m) – 0.15 degrees;
  + Positional error of ship at the distance observed (same as above) – 0.15 degrees

Typical examples of combined uncertainty for installation by root sum of squares (RSS):

* By compass –

|  |  |
| --- | --- |
| Measured angle of uncertainty of boundary | 0.25 |
| Uncertainty at edge of angle of uncertainty | 0.13 |
| Compass bearing uncertainty | 0.25 |

Combined uncertainty = √(0.252 + 0.132 + 0.252) = 0.38 degrees

* By DGNSS –

|  |  |
| --- | --- |
| Measured angle of uncertainty of boundary | 0.25 |
| Uncertainty at edge of angle of uncertainty | 0.13 |
| Positional error of lighthouse | 0.15 |
| Positional error of ship | 0.15 |

Combined uncertainty = √(0.252 + 0.152 + 0.152+ 0.152) = 0.35 degrees

However, each uncertainty contribution should be considered carefully for each station and each sector. When using an electronic chart and positioning by DGNSS, the greater the distance between light and vessel, the more accurate the bearing and consequently the lower the angular uncertainty. This increased accuracy is offset by the ability to observe a change of colour in a light when it is much smaller in the eye (smaller subtense angle) and much dimmer. In the case of white/green boundaries, there is potential for colour confusion at low levels of observer illuminance, particularly for flashing lights. At greater distances of observation therefore, the change from white to green, or vice versa, might not be easily distinguishable.

# Discussion

The text in section 2 may be better as an appendix to the guideline, but it does fit in section 5.4

# References

1. GLA R&RNAV Report RPT-01-IT-10.

# Action requested of the Committee

The Committee is requested to:

1. Review and comment on the text in section 2.