IALA

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LEADING LIGHTS

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Association Internationale de Signalisation Maritime

DOCUMENT REVISION

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Date	Details	Approval
June 1998	1st issue	
December 2005	Entire document. Reformatted to reflect IALA documentation hierarchy.	
September 2020	Ed. 1.2 Editorial corrections.	

THE COUNCIL

RECOGNIZING the need to provide guidance on leading lights for use during night time and during day time,

RECOGNIZING ALSO that such guidance should include information on the nature and significance of each condition mentioned in the Recommendation as well as the definitions and symbols used,

RECOGNIZING FURTHER that the guidance should also include all Formulae necessary to design leading lights to the recommended standards,

TAKING INTO CONSIDERATION the proposals of the IALA Aids to Navigation Engineering Committee,

REVOKES IALA Recommendation for Leading Lights dated May 1977; and,

RECOMMENDS:

AT NIGHT

that leading lights used at night comply with the following conditions:

1 Illuminance at the eye when in the useful segment

a that at any point the useful segment the illuminance at the eye of the navigator produced by each of the lights be at least equal to 1×10^{-6} lux.

2 Equality of illuminances

b that the illuminances at the eye of the navigator produced within the useful segment by the two lights be as nearly equal as possible.

3 Illuminance at the eye in the acquisition region

a that at any point in the acquisition region the illuminance at the eye of the navigator produced by one of the lights or both lights to be used be at least equal to 0.2×10^{-6} lux.

4 Prevention of glare

a that at any point of the useful segment the illuminance at the eye of the navigator produced by either light must not exceed 0.1 lux; if the background is very dark this figure must be reduced to 0.01 lux.

5 Separation of lights

a that at any point of the useful segment the elevation difference of the lights as seen by the navigator must be at least equal to the following experimentally derived values of γ_m (in radians):

$$\gamma m = (2.4 + 0.2 log E^{+}) \times 10^{-3} \; for E_1 = E_2 \qquad (*)(1a)$$

$$\gamma m = (2.6 + 0.14 log E^{+}) \times 10^{-3} \; for \left| log \frac{E_2}{E_1} \right| = 1 \qquad (*)(1b)$$

$$\gamma m = (3.32 + 0.08 log E^{+}) \times 10^{-3} \; for \left| log \frac{E_2}{E_1} \right| = 2 \qquad (*)(1c)$$

(*) for other values of the ratio E_2/E_1, interpolation formula

Where:

E_1 and E_2 are the illuminances in lux at the eye of the navigator produced by the front and rear lights respectively.

E^+ is the greater of these two illuminances

b that if before adopting the final luminous intensities a preliminary investigation of appropriate sites is undertaken, it should be based on a value of γ_m = 1.5 ×10^{-3} radian (approximately 5 minutes of arc).

6 Sensitivity

a that the standard deviation of the bearing difference of the two lights when the observer has the impression that the two lights are vertically in line, be calculated in radians using the formulae:

$$\Theta_Q = supp(**)(\Theta_1, \Theta_2) \quad (2a)$$

(**) Supp means the larger of the two values

Where:

$$\begin{cases} \Theta_1 = 0.05 \times 10^{-3} + 0.038\gamma \;\; for\, \gamma \leq 5 \times 10^{-3} \;\; radian & (2b) \\ \Theta_1 = 0.31 \times 10^{-3} + 0.09\gamma \;\; for\, 5 \times 10^{-3} \leq \gamma \leq 20 \times 10^{-3}\, radian & (2c) \end{cases}$$

$$\Theta_2 = 0.07\gamma m \quad (2d)$$

b that the magnitude of the minimum value of the bearing difference of the two lights, when an off-axis deviation in a definite direction is considered as detected with certainly by the observer, be calculated using the formulae:

$$\Theta_D = supp(**)(\Theta'_1, \Theta'_2) \quad (3a)$$

Where:

$$\begin{cases} \Theta'_2 = 0.16 \times 10^{-3} + 0.12\gamma \;\; for\, \gamma \leq 5 \times 10^{-3} \;\; radian & (3b) \\ \Theta'_1 = 0.31 \times 10^{-3} + 0.09\gamma \;\; for\, 5 \times 10^{-3} \leq \gamma \leq 20 \times 10^{-3}\, radian & (3c) \end{cases}$$

$$\Theta'_2 = 0.224\gamma m \quad (3d)$$

c that, in the interest of safety, the axis of the leading lights be established in such a manner that for the type of ships and navigation conditions considered, the ship may safely depart from the axis up to a point where the bearing difference as observed by the navigator reaches the following value in radians:

$$\Theta_M = supp(**)(\Theta_1, \Theta_2) \quad (4a)$$

Where:

$$\begin{cases} \Theta'_1 = 0.25 \times 10^{-3} + 0.19\gamma \;\; for\, \gamma \leq 5 \times 10^{-3} \;\; radian & (4b) \\ \Theta'_1 = 0.5 \times 10^{-3} + 0.14\gamma \;\; for\, 5 \times 10^{-3} \leq \gamma \leq 20 \times 10^{-3}\, radian & (4c) \end{cases}$$

$$\Theta'_2 = 0.35\gamma m \quad (4d)$$

γ being the elevation difference of the lights in radians as observed by the navigator.

BY DAY

that the use of leading lights for day time be designed in accordance with the same rules as those for night use with the exception that the luminous intensities derived from these rules be increased by a factor of 2000 to 5000.

DEFINITIONS (see Figure 1 in annex)

a) (System of) leading lights: A group of two lights, or of several lights in the same vertical plane, such that the navigator can follow the leading line by keeping the lights on the same bearing.

b) Line of lights, axis of the lights: On the earth's surface, trace of the vertical plane through the leading lights.

c) Useful segment: That part of the line of lights within which it is intended that vessels should receive guidance.

d) Rear light: That light which is farthest from the navigator along the line of lights.

e) Front light: That light which is nearest to the navigator along the line of lights.

f) Acquisition region: The region in which it is considered necessary for the navigator to be able to see one or more of the lights so that he can enter the useful segment without difficulty.

g) Elevation angle (of a light): At the point of observation, the angle between the horizontal plane and the direction of the light (taken as positive upwards).

SYMBOLS (see Figure 1 in annex)

E_1 Illuminance in lux at the eye of the observer produced by the front light.

E_2 Illumimance in lux at the eye of the observer produced by the rear light.

E^+ The larger of E_1 and E_2

F_1 Front light.

F_2 Rear light.

H_1 Height of the front light above chart datum, in metres.

H_2 Height of the rear light above chart datum, in metres.

H' Height of an obstruction above chart datum, in metres.

H'' Height above chart datum of the light which may be obscured by an obstruction, in metres.

I Luminous intensity of a light, in candelas.

I_1 Value of I for the front light.

I_2 Value of I for the rear light.

M Position of the eye of the observer.

M_0 Projection of M on the chart datum plane.

R Horizontal distance between the lights, in metres.

S Horizontal distance between a light and an obstruction which may obscure the light, in metres.

V Meteorological visibility, in metres.

Va Minimum visibility for acquisition.

Vu Minimum visibility for utilization

a Horizontal distance from the front light to the nearest point of the useful segment, in metres.

b Height of the observer's eye above sea level, in metres.

c Height of sea level above chart datum, in metres.

d Horizontal distance (to a light), in metres.

l Horizontal distance of the front light to the farthest point of the useful segment, in metres.

u Horizontal distance between an obstruction and the observer, in metres.

x Horizontal distance between the front light and a point on the axis of the leading lights (taken as positive towards the useful segment), in metres.

y Off-axis distance in the horizontal plane, in metres.

y_M Off-axis distance that can be reliably detected by the navigator, in metres.

z Dip of the horizon in metres: the distance between the tangent plane to the surface of the sea at the point of observation and the surface of the sea (real or hypothetical) at the point considered, in metres.

z_1 Values for the dip of the horizon of the front light, in metres.

z_2 Values for the dip of the horizon of the rear light, in metres.

γ Elevation difference (difference of the angles of elevation of the two lights), in radians.

γ_m Minimum value for the elevation difference necessary for proper separation of the lights, in radians.

θ Bearing difference (difference between the bearings of the two lights), in radians.

θ_Q Standard deviation of the bearing difference.

θ_1 Intermediate value, function of γ, used for the calculation of θ_Q.

θ_2 Intermediate value, function of γ_m, used for the calculation of θ_Q.

θ_D Safely detected bearing difference.

θ'_1 Intermediate value, function of γ, used for the calculation of θ_D.

θ'_2 Intermediate value, function of γ_m, used for the calculation of θ_D.

θ_M Minimal bearing difference which is recommended at the lateral boundaries of the channel.

θ''_1 Intermediate value, function of γ, used for the calculation of θ_M.

θ''_2 Intermediate value, function of γ_m, used for the calculation of θ_M.

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1. GENERAL

Leading lights allow ships to be guided with precision along a portion of a straight route which is called the "useful segment". As an aid to navigation they are reliable, very sensitive, and very simple to use.

It is therefore common practice to guide ships along natural narrow fairways by means of leading lights or, more generally, by a series of leading lights in succession, the useful segments of which form a continuous series of straight lines. In the same way the centre lines of artificial channels are laid out in a series of straight lines along which ships will be guided by leading lights. The availability of suitable sites for the leading lights may affect in a decisive manner the selection of ship courses in natural narrow fairways or the layout of artificial channels.

In order to reach the first useful segment of leading lights, it will often be necessary to observe at least one of the leading lights whilst in a region to seaward or to the side of it. This has been called the "acquisition region".

When using leading lights, the determination of the width of an artificial channel or of the axis to be marked in a natural channel requires taking account not only of the inaccuracy of the relevant aid to navigation, but also of the different "nautical margins", such as those resulting from the breadth of ships navigating in the channel, the amplitude of possible yaws of those ships, extra widths required for vessels to pass each other, the drift angle between the shipping route and the head of the ship when a ship is submitted to the effect of transverse winds and currents, uncertainties resulting from the location procedure used with soundings, inaccurate soundings or possible changes in the sea bottom since the last soundings, etc.

This recommendation is only related to the inaccuracy of the aid to navigation proper, leaving out the different "nautical margins" which depend on local conditions and can only be determined after considering each particular case.

2. AVOIDANCE OF OBSTRUCTIONS

It has not been felt necessary, within the recommendation proper, to stress the fact that no obstruction should prevent the mariner from seeing the lights from any point of the useful segment. This is, however, a requirement which may be difficult to comply with and sometimes even to state with precision. In particular, moving obstructions should be taken into account, such as vehicles, cranes, and other ships. Future developments should also be considered, e.g., growing trees, new constructions, new plantations, etc

3. METHOD OF OBSERVATION

The recommendation has been prepared assuming observation with the naked eye.

It may not always be possible to use binoculars, owing to inclement weather, to the motion of the sea, or because no binoculars are available.

The most suitable binoculars at night are of the 7 × 50 type i.e.: 7 magnifying power and 50 mm lens; by day 10 × 50 binoculars may be preferred.

The use of such binoculars may result in improving the luminous range of lights. However, they bring about only a limited improvement in the sensitivity of leading lights. A number of observations have shown the reduction of the bearing difference that can be detected with certainty to be of the order of one third. Binoculars would be of greatest use in cases where the eye could not easily resolve the lights.

4. THRESHOLDS OF ILLUMINANCE

Laboratory experiments have shown that at an illuminance of 0.2 microlux (the conventional threshold used in maritime signalling) proper use could not be made of the leading lights. The same experiments have shown that to observe the relative position of the lights easily and to derive the maximum possible accuracy from leading lights, a minimum illuminance of 1 microlux was necessary at the eye of the observer.

This condition is to be met at the outer limits of the useful segment for the minimum meteorological visibility under which the leading lights are to be used. Given leading lights with known characteristics, this same condition determines the minimum meteorological visibility under which the leading lights may be used satisfactorily.

As regards acquisition, an illuminance at the eye of the observer at least equal to the 0.2 microlux conventional illuminance threshold is sufficient. This condition should be met at the outermost limit of the acquisition region in the relevant direction.

In the case of leading lights of limited range and with a high level of shore illumination, the above figures may be found too low.

The variety and complexity of possible conditions do not permit the laying down of precise guidelines for such cases.

It will be possible to limit the necessary increases if the lights are made extremely conspicuous; for example, by the use of a rapid and synchronous rhythm.

5. ILLUMINANCE EQUALISATION

It is advisable to equalize illuminance in order to improve the sensitivity of leading lights and to facilitate their observation and their use. However, it is not possible to achieve equalization at all points and for all possible values of the meteorological visibility. Under favourable circumstances the ratio of illuminances may be permitted to vary between 0.5 and 2.

This ratio may sometimes deviate substantially from unity: from 0.1 to 10 or even from 0.01 to 100 in special cases, for instance when an existing light is used as a part of new leading lights or when the distance between the lights is large when compared to the maximum distance to the front light. This necessitates increasing the minimum values of the elevation difference and affects the sensitivity slightly. The utilisation of the leading lights is not prevented, however.

Experience shows that a distance between the lights on the order of 1/10th of the maximum distance to the front light is often satisfactory. It is possible to deviate appreciably from this value and to accept ratios from 1/2 or more to as low as 1/20 or even less.

6. AVOIDANCE OF GLARE

The condition for the avoidance of glare was determined from the result of a survey conducted among navigators and of tests along the coast.

It will be acceptable to check that it is achieved at the nearest point of the useful segment, assuming an ideally clear atmosphere.

7. SEPARATION OF LIGHTS

For a long time, the condition was expressed on the basis of a minimum angle in minutes of arc; the value of the minimum was taken as 6’, 4.5’ or 4’, depending on the particular lighthouse service, and irrespective of the luminous intensity of the lights. Laboratory experiments have permitted the assessment of the effect of the illuminance at the eye of the observer. The values that have been indicated are those corresponding to twice the elevation difference for which half of the observers experienced some difficulty in using the leading lights. This condition is fairly superfluous when binoculars are used to observe the leading lights.

The condition should be verified at both ends of the useful segment for the lowest tide levels acceptable for safe navigation as well as the lowest heights of the observer's eye above sea-level.

When computing the elevation difference, it is recommended to take the apparent earth curvature into account. A correction coefficient can be introduced so simply that there is no advantage to consider separately the case of the flat sea and the case where the earth radius is taken into account (the formulae 1. 13 refer).

8. SENSTIVITY

Sensitivity has been considered form three different points of view which are complementary.

a The standard deviation θ_Q of the bearing difference of the two lights results from experimentation excluding any subjective appreciation; it is given to be used if necessary, as a basis for probabilistic or statistical investigation.

b The minimum value θ_D of the bearing difference of the two lights, when an off-axis deviation is detected with certainty by the observer in a definite direction, is a notion which is often used in investigations relating to the sensitivity of leading lines though it is somewhat subjective.

c The margin θ_M to be adopted when designing the position of the axis of the leading line has been estimated rather strictly according to the experience gained on satisfactory existing leading lights. Greater margins can be adopted if it is possible to have more latitude in the tracing of the channel or if the conditions for the use of the leading line are unfavourable. This margin is only related to the inaccuracy of the aid to navigation. "Nautical margins" such as those described under the title "General" should also be taken into account. However, their evaluation is out of the scope of this recommendation.

9. THREE-LIGHT LEADING LIGHTS

Three-light leading lights may be justified by special topographical features. It has been thought that three-light leading lights might markedly increase the sensitivity as compared with two-light leading lights. Precise data are not available about this. However, it seems possible in almost all cases to design two-light leading lights that will meet the requirements of navigation as regards precision.

10. DAYTIME LEADING LIGHTS

Available observations show that the sensitivity of daytime leading lights is very close to that of night time leading lights.

The luminous intensities of such leading lights have to be increased in keeping with the IALA" Recommendation for a definition of the nominal daytime range of maritime signal lights intended for the guidance of shipping by day-April 1974".

The indicated coefficient of 5000 is consistent with a luminance of the sky of the order of 10,000 candelas per square metre.

Should it be impossible for technical or economic reasons to achieve the luminous intensities determined in accordance with the above rule, the 5000 coefficient might be scaled down to 2000. A certain reduction in the efficiency of the leading lights would have to be accepted which might be acceptable in certain local situations and operating condition.

11. FORMULAE (SEE FIGURE)

11.1. ILLUMINANCE AT THE EYE (ALLARD)

The illuminance at the eye E measured in lux produced by a light with intensity I expressed in candelas at distance *d* in metres for a meteorological visibility V in metres is given by:

$$E = \mathrm{I}\, d^{-2}\, (0.05)^{\mathrm{d/V}} \qquad (5)$$

Condition A-1 is thus expressed by the combination of the two following expressions, where V is equal to Vu

$$\mathrm{I}_1\, l^{-2} (0.05)^{l/\mathrm{V}} \geq 1\ 10^{-6}$$

$$\mathrm{I}_2\, (l + R)^{-2}\, (0.05)^{(l+\mathrm{R})/\mathrm{V}} \geq 1\ 10^{-6} \qquad (6)$$

Condition A-2 is complied with when the ratio between the following quantities is made as close to unity as possible:

$$\mathrm{I}_1\, x^{-2}\, (0.05)^{\mathrm{x/V}}\ and\ \mathrm{I}_2\, (x + R)^{-2}\, (0.05)^{(\mathrm{x+R})/\mathrm{V}} \qquad (7)$$

whatever the value of *x* between *a* and l and whatever the value of V greater than Vu.

Hence the formula:

$$\frac{\mathrm{I}_2}{\mathrm{I}_1} = \left(1 + \frac{R}{a}\right)\left(1 + \frac{R}{l}\right)(20)^{\mathrm{R/2Vu}} \qquad (8)$$

Condition A-3 is complied with, if in the direction concerned at any point of the boundary of the acquisition region the following expression holds for one at least of the two lights:

$$\mathrm{I}\, d^{-2}\, (0.05)^{\mathrm{d/V}} \geq 0.2\ 10^{-6} \qquad (9)$$

where V is equal to V*a* and *d* is the distance to the light of intensity I.

Condition A-4 is complied with when the two following expressions are simultaneously satisified:

$$I_1 a^{-2} \leq 0.1 \qquad (10a)$$

$$I_2\, (a + R)^{-2} \leq 0.1 \qquad (10b)$$

11.2. SEPARATION OF LIGHTS

For intermediate values of E_1/E_2 between those shown in the recommendation it will be possible to use either a graphical interpolation or a numerical one according to the formula:

$$\gamma_{\mathrm{m}} = [2.4 - 0.06|log\ (E_2/E_1)| + 0.26\ |log(E_2/E_1)|^2 + log\ E^{+}\ (0.2 - 0.02|log\ (E_2/E_1)|$$

$$- 0.02\ \left|\log\left(\frac{E_2}{E_1}\right)|^2)\right]\ 10^{-3} \qquad (11)$$

11.3. ELEVATION DIFFERENCE

The elevation difference γ of two points R apart and with respective heights H_1 and H_2 above chart datum, the nearer being distance *x* from the observer, is given by the formula:

$$\gamma = \frac{H_2 - b - c - 6.75\ 10^{-8}\ (\mathrm{x} + \mathrm{R})^2}{\mathrm{x} + \mathrm{R}} - \frac{H_1 - b - c - 6.75\ 10^{-8}\ \mathrm{x}^2}{x} \qquad (12)$$

The formula assumes that the dip of the horizon *z* at distance d^2 from the observer is 6.75 10^{-8} d^2 as entered in Lists of lights.

The formula can be made simpler as follows:

$$\gamma = \frac{(H_2 - b - c)}{x + R} - \frac{(H_1 - b - c) - 6.75\ 10^{-8}\ R}{x} \qquad (13)$$

Term — 6.75 10^{-8} R is the correction due to the earth curvature; it is a function only of the distance between the observed points.

The condition for separation of lights will thus be written, based on the data shown in the comments: $\gamma \geq \gamma$ m.

N.B. — The formula supplies also the condition for the absence of screening effect due to obstructions.

In this case, if *u* is the distance between the observer and the obstruction, H' the height of the obstruction, H' the height of the light and S the distance between the obstruction and the light the following expression will obtain:

$$\frac{H_2 - b - c}{u + S} - \frac{(H' - b - c) - 6.75\ 10^{-8}}{u} \geq 0 \qquad (14)$$

The design should be checked for lowest tide, minimum ship's bridge height and the points of the useful segment that are closest to and farthest from the obstruction.

11.4. OFF-AXIS DISTANCE

The off-axis distance *y* at distance *x* from the front light is related to the bearing difference θ of two lights R apart by the formula:

$$y = \theta x \left(1 + \frac{x}{R}\right) \qquad (15)$$

The off-axis distance that can be detected with certainty , y_D, may be derived from the bearing difference that can be detected with certainty θ_D according to:

$$y_D = \theta_D\, x \left(1 + \frac{x}{R}\right) \qquad (16)$$

The minimum recommended channel half width, y_m, can be deducted from the minimum bearing difference θ_m by:

$$y_m = \theta_m\, x \left(1 + \frac{x}{R}\right) \qquad (17)$$

11.5. GEOGRAPHICAL RANGE

For a light height H above chart datum and for an observer at height *b* above water level the geographical range in metres is given by :

$$3849 \left(\sqrt{H - c} + \sqrt{b} \right) \qquad (18)$$

It will be useful in the case of long-range leading lights to check that the outermost end of the useful segment and the boundary of the acquisition region are within the geographical range of both lights.

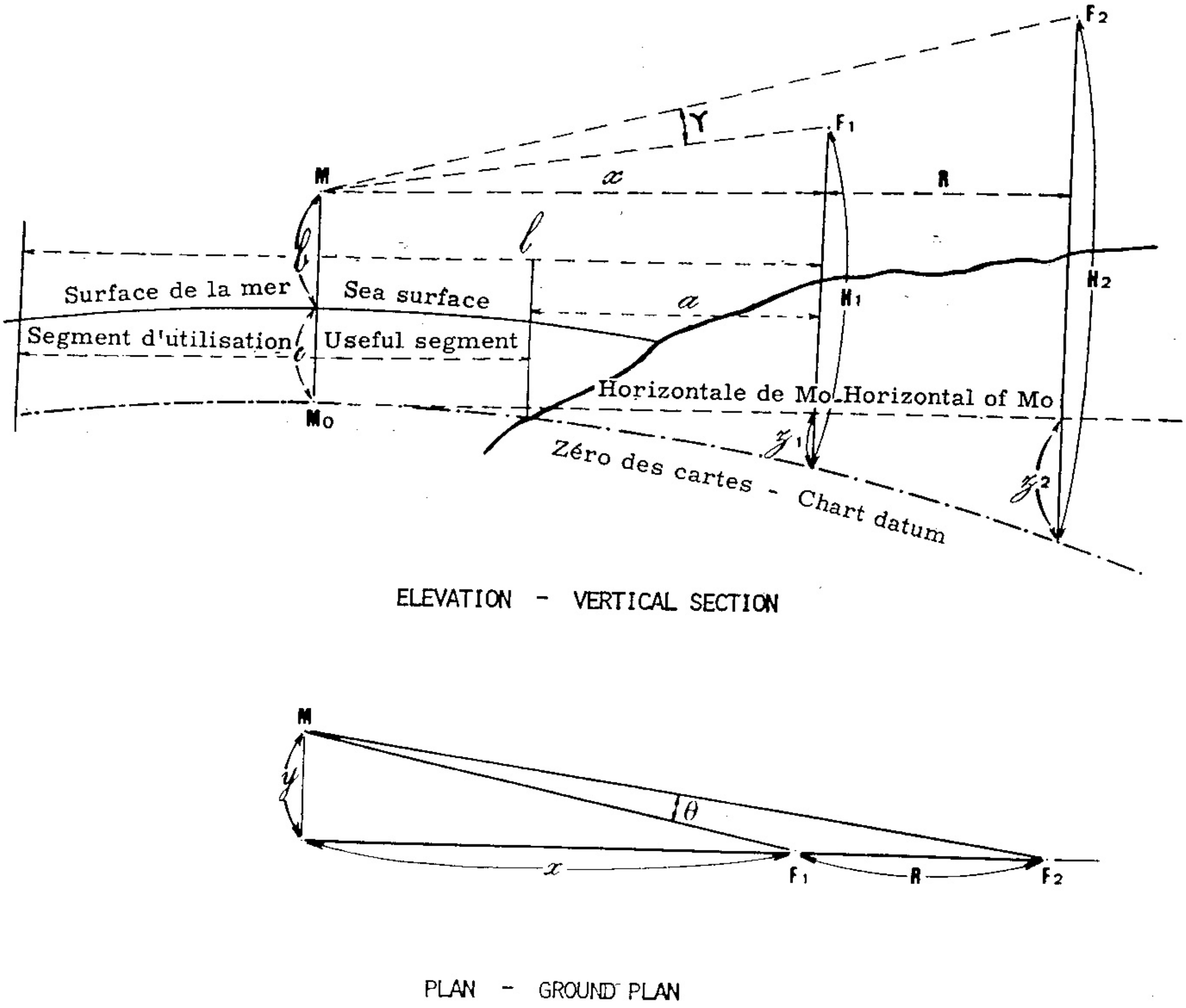

Figure 1 Chart demonstrating terms used in leading lights