A SIMPLE DAY AND NIGHT ALIDADE FOR TELESCOPIC USE

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Alidades used in the Navy and Mercantile Marine are mostly minute and expensive instruments. The reason is that a good alidade must have a cardanic suspension and a lighting device. It thereby becomes unwieldly and frequently unsuitable for small coasting craft. In spite of their complicated construction most alidades possess only the possibilities of a dioptric glass. The inaccuracy of this hydrographical dioptric surveying is only allowable generally in peace time for coasting navigation on account of the presence of many lights and marks. In war time and in a great many sea parts also in peace time, considerable difficulties arise from the small number of lights which can be surveyed and their often very much diminished range, especially in misty weather. It is then impossible to do without an alidade fitted with a telescope, because a telescope allows an accurate survey of lights and marks, when these are not or hardly visible with the naked eye, without mentioning the more accurate determination of angles with a telescope than with a diopter.

In order to do away with the above mentioned difficulties, many mariners have recourse to a night telescope fitted on the compass, to take bearings. This method of taking bearings has the advantage of identifying really more lights when strong night glasses are used, but the lack of a close connection between compass and bearing telescope entails large errors in angles. It should be added that a good many of these night glasses are not made out of non magnetic material but of iron. In consequence, the magnetic compass is disturbed by the proximity of the glass and bearing taking involves a new source of errors.

With small vessels, next to simplicity the waterproofness of the lighting device as well as protection against damage play an all-important part. On small vessels the alidade stands a far greater risk of being washed away by the sea than on big ships with high lying surveying bridge. Moreover, the force of the striking sea against a small craft on account of the low position of the surveying instrument is greater than against a big craft.

For these reasons, a small simple alidade for night and day use was devised and is described hereafter.

This alidade is normally constructed without a cardanic suspension, but can of course be used with one. It consists, as shown in Fig. 1 of a Plexiglass plate with an engraved scale lined with luminous colours as well as of a contrivance for dioptric bearing taking and the addition of binoculars.

The different component parts are described more accurately in what follows :—

1. — THE PLATE PROPER AND THE SCALE

It was necessary to construct an alidade that could be used under all lighting conditions and whenever possible independently of artificial lighting. For this reason the scale was provided with a self lighting luminous colour. There is considerable advantage in using this colour which amply justifies its high cost price. A plate of this kind can easily be constructed. It does away with delicate wires or sources of light as well as with the necessity of cleaning and the risk of sea water penetration. This plate can also be made solid and shock proof. The material selected was a Plexiglass plate 10 mm. thick and 210 mm. in diameter. Large holes were drilled in four places, in order not to increase unnecessarily the weight of the plate, on the one hand and on the other hand, to prevent the penetration of sea water when the plate is drenched. The plate edge is provided with a ring on which degree figures and lines are engraved. This ring bears a groove underneath into which a radio-active luminous substance is poured. The groove is made completely water and air-tight by means of a

Plexiglass ring. The luminous colour can therefore be damaged neither by sea water nor sea air. When so protected the life time of the radio-active luminous colour amounts to several years. The figures and lines engraved on the upper side are inlaid with black colour that can stand sea water. Therefore they look black on a greenish background in the day time and black on a whitish background at night.

It is obvious that lighting technical requirements for the visible reading of a scale of this kind are important :— At sea, the lighting power fluctuates between about 100.000 lux in bright sunlight and about 1/100.000 lux downwards at night.

The luminosity of the scale must always be such that lines and degree figures can be read beyond all question, under all lighting conditions. Still it must not be so great as to be blinding, which means that it must not impair the perceptibility of the sighted object. It must be somewhat higher than that of still standing instruments, as the ship swinging motion reduces legibleness to a considerable extent (1).

In war time, should be added to these considerations, the necessity of being invisible to other ships and airmen.

The legibleness of figures and lines is determined by the well known sensitiveness of the eye to forms. It depends in the first place on the size of the signs to be read, on their luminosity or their surrounding and on the contrast between signs and what is around them. It is obvious that figures and lines must be as large as possible and their shape as simple as possible. Special care must be taken that figures should be read upright and not upside down; all flourishes and superfluous signs should be omitted. Practical experience shows that the thickness of figures must be about from 1/10 to 1/5 of their length.

The brighter the luminous surface and the darker the figures, the greater is the contrast between the figures and their surrounding. It is proper that figures and lines should be deeply engraved and laid in very black colour, in order to intensify the effect of contrast through the dark hollow space thus created. In order to ensure a good legibleness of 5 mm. thick figures and lines also on a ship in motion, if such size be utilised, the scale brilliancy must not be less than 50 Milliapostilb. The highest limit of brilliancy is determined by blinding and visibility from the air and can by a simple calculation be estimated at about 250 milliapostilb (2).

The scale brilliancy mentioned here, corresponds, by way of comparison, to the brilliancy of white paper, on a full moon night with a slightly over-cast sky.

A few words should be devoted to blinding, as this question plays a part to which so far too little attention has been given as yet in connection with most nautical instruments.

The discernibleness of signs, when not of too small a size, in relation to their surrounding, is determined by the so-called Weber-Fechner law. The difference of luminosity between signs and surrounding, according to this law must amount to about 10%, for the sign to be perceptible in its surrounding. Should a source of light stand in the field of vision, with a somewhat higher brilliancy, it is to this source that differences must be ascribed. For this reason, a too-brilliantly lighted scale can impair the bearing of a weak light, on account of blinding. The difference between a weak light and its surrounding, as far as the eye is concerned, is ascribed not to the dark night sky but to the luminous scale surface. It can then sink to less than 10 %. This is all the more remarkable with night observations and in very bright sunshine, as the Weber-Fechner law no longer holds good for very high or very low brilliancies. Even then, the difference of luminosity, to be perceptible, must amount to more than 10 %. An example should be briefly considered. The contrast between the black printed type and the white paper of a book, independently of the lighting power, amounts to about 30 %. It is therefore possible, without special difficulty, to read a book under all medium lighting conditions, because the contrast amounts to more that 10 %. Directly the light becomes very weak (night) or very strong (blinding summer sunshine) the given contrast of 30 % is no longer sufficient, because the Weber-Fechner law does not apply :— reading becomes difficult or even impossible.

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(1) It is generally assumed that greater luminosity is required on moving ships than on motionless ones. According to the kind and force of the vibration, a double and even treble minimum lighting power must be adopted, as compared with still conditions, to allow accurate reading.

(2) P. Bauma: *Philips techn. Rundschau* 4, 1939, p. 16 and following.

Here also arises the often broached question whether or no, dark figures on light back ground should be preferred to light figures on dark background. According to the laws of physiology and optics and from many practical tests this question can unequivocally be decided in favour of dark figures on light background. It is therefore wrong to use black scales with light inscriptions. They are subject to greater risk of blinding not to mention the risk of halation, as light colored figures require a greater luminosity and consequently undergo an apparent enlargement and an impaired legibleness.

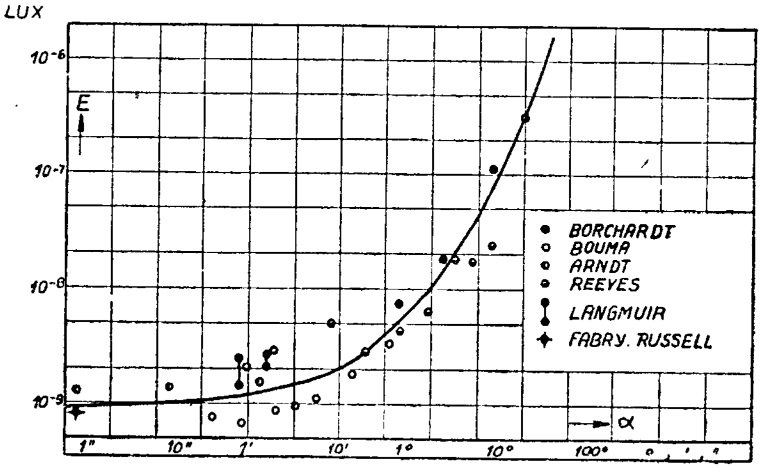

FIG. 2

Lighting power E in lux with the naked eye, which must produce a circular spot of light, to be just still perceptible, as a function of the size of the spot of light, measured in angles of its largest expansion (after Bouma, *Philips Tech. Rundschau* 4, 1939).

More over, the worst conditions of visibility are not generally experienced during pitch dark nights, but in twilight and moonlight with a torn blanket of clouds. It is therefore the right time, under such conditions, to test the efficiency of night instruments. The reason for this may well be that on the one hand blinding phenomena occur through the broken luminosity structure of the sky and sea and that on the other hand, the human eye possesses two separate instruments of vision for night and day use and, under the just mentioned lighting conditions, acts as a sort of commutator.

Fig. 2 shows the connection between the size of an object to be observed and the minimum lighting power to be exercised on the eye by this object to make itself perceptible. The measuring points originate from different observers and have been obtained through physiological, astronomical, nautical and purely laboratorial investigations. So long as the objects are small, their visual angle lying under about 1 minute, the curve runs horizontally, that is, E remains constant and independent of the visual angle α (Ricco's law). With this visual angle increasing, it may be assumed as a first approximation that E is proportional to α (Piper's rule). For very great visual angles somewhat over 10°, E is proportional to α^2.

Fig. 3 gives the connection between the luminosity B of the object in terms of Apostilbs, the visual angle α, the distance r between the alidade and the eye in meters, the luminous surface f of the alidade plate in square meters, the radiation angle ε and the lighting power exercised on the eye measured in lux.

That is to say :—

$$E = \int\int \frac{B \cos \varepsilon \, df}{r^2}$$

In the case of vertical radiation, therefore, when this somewhat occurs as an airplane flies over the alidade, $\cos \varepsilon = 1$ and as besides $\frac{df}{r^2} = \alpha^2$, the formula becomes more simple :—

$$E = B \alpha^2$$

Two important results may be inferred from this formula and Fig. 2, namely the point whether being seen from airplanes at night is to be feared and also for this reason, if light signs on dark background or dark signs on light background are to be preferred.

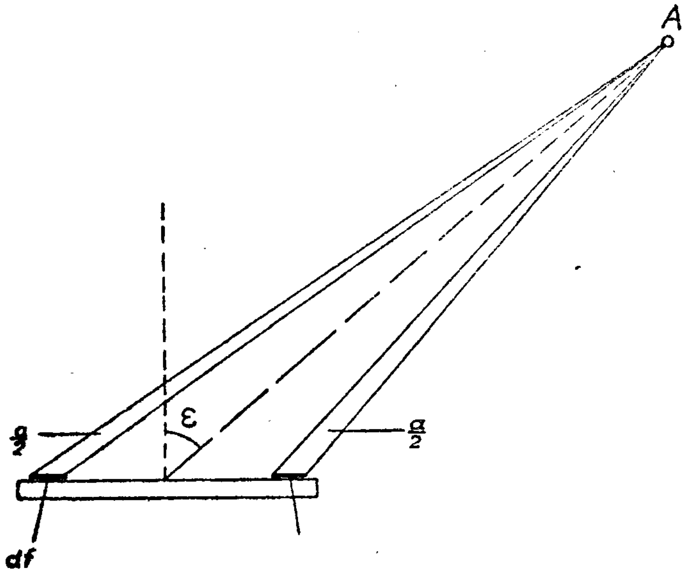

FIG. 3

Image of an alidade plate on the eye, r *is the distance to the observer,* df, *the surface element of the lighted ring,* α *the angle under which this element is seen and* ε *the angle of incidence.*

As regards being seen from the air, the visual angle is very small. It is then the first horizontal part of the curve that comes in. The minimum lighting power then perceptible to the eye amounts to 10^{-9} lux. This figure has, of course, only a laboratorial value. Experiments at sea have given a 200 times greater minimum lighting power namely 2×10^{-7} lux. As the above mentioned luminosity of the plate amounts of 250 milliapostilbs at the most and its surface does not exceed 77 cm^2, by introducing in the formula 100 m., as the distance from the plate, we obtain

$$E = 250.10^{-3}.\ 77.10^{-8} = 1.9.10^{-7} \text{ lux},$$

which represents fairly accurately the minimum lighting power. There is therefore no risk of being seen from the air when 100 meters off, if the plate is flown over perpendicularly. If the plate is seen obliquely, the conditions become more favorable in proportion to cos. ε on account of incidence of light rays.

If the luminosity is kept constant, Fig. 2 shows that according to Ricco's law and Piper's rule, the greater surface has the advantage over the smaller one, as E is then proportional to α^2 (Riccò) or at last proportional to α (Piper). The observation of the plate by the reading mariner also falls within this visual angle. If light figures on dark back ground are desired instead of dark ones on light back ground, the luminosity for the same legibleness must be correspondingly increased, because the luminous surface would then be much smaller than in the first case.

2. — BINOCULAR SUPPORTS

As may be seen on Fig. 1 and 4, the alidade is provided with a contrivance suitable for both diopter and telescope use. This contrivance is so constructed that without any impediment to dioptric surveying, most usual binoculars can be hooked on. The fixing of the binocular is made absolutely fast and takes in the binocular bridge so as to secure an accurate control of the optical axis.

The binocular itself can be made to swing round the horizontal axis to compensate displacements of the horizon due to the ship's motion.

In order to take a bearing with the binocular, it is generally sufficient to focus in the middle of the glass field of vision. As, for instance the most frequently used 7 × 50 binocular has an objective field of vision of 7° and the focussing on the middle of field of vision can be done easily even by inexperienced observers with an accuracy of about 5 %, the error of focussing is less than 35 minutes, which is quite acceptable. It is, of course, possible without any trouble to introduce a sighting wire graticule but this method is not advisable for night observations, as a graticule makes it slighty more difficult to look for specially weak lights.

3. — SUMMARY

A simple day and night alidade for dioptric and telescopic use has been described. The plate bears a coating of radio-active luminous colour which does away with all other lighting devices. Ordinary ship glasses can be used for this telescopic sighting.

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