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FOURTH REPORT ON DAYLIGHT OBSERVATION OF STARS AND PLANETS

By

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Report

on

FOURTH REPORT ON DAYLIGHT OBSERVATION OF STARS AND PLANETS

(A sextant with bubble viewed by one eye and celestial body by the other)

NAVAL RESEARCH LABORATORY
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ABSTRACT

Advantages and disadvantages are discussed of a "Two-eye Sextant" with which one eye views the celestial body and the other eye the bubble. Although no extended series of tests were made it was concluded that errors in altitude measurements can be made negligable for a normal observer for a sextant of high magnifying power. The construction of a "Two-eye Sextant" is described. Results of ground and flight tests are given, insofar as they pertain to the two-eye feature of the instrument, and show that a "two-eye sextant" may be practicable.

INTRODUCTION

1. It was suggested by Commander Clyde W. Smith, U.S.N., at a conference on the daylight star project on October 20, 1941, that a sextant in which one eye viewed the celestial body and the other eye the bubble, might offer certain advantages in simplicity of construction. A preliminary investigation of the feasibility of this idea was made at this Laboratory and the results were presented in reference (a). Following this a separate bubble cell to be viewed by the left eye was incorporated into the telescopic sextant being built in this Laboratory.

2. Laboratory and flight tests of this sextant have been made. The present report covers only the aspects of the investigation related to the two eye bubble feature. Description of the mounting and its effectiveness and aspects of the problem other than the two eye bubble will form the substance of another report.

3. The results suggest that the artifice of looking at the bubble with one eye and the celestial body with the other may be practicable in certain cases, in fact, more practicable than one might expect from a priori consideration.

ADVANTAGES:

4. The chief advantage to a sextant with bubble viewed by the second eye instead of introduced into the same eye with the star is in simplicity of construction. A two eye sextant of this kind would probably be less expensive and somewhat lighter in weight, for the case of a daylight star sextant. Furthermore, star visibilities should be somewhat greater for the "two-eye sextant" since no reflector plate need be in the light path. The illumination system for the bubble can be made entirely independant of the star side of the instrument and would have no direct effect on star visibilities.

5. Some increase in star visibility may be produced by the two eye sextant merely because both eyes are illuminated and used, even though the star is seen by only one eye. Data bearing on this point were reported in reference (b).

6. The two eye bubble sextant will give incorrect altitude readings unless precautions are taken to avoid the effects of hyperphoria, if present in the observer's eyes. Hyperphoria is a condition in which the axes of

the eyes of the observer tend to be non-parallel in the vertical plane. Under ordinary conditions the two eyes see the same objects and the axes are forced into parallelism. But if the two eyes view objects which are quite dis-similar, such as a star and a bubble, and which have no fixed position relative to one another, the axes of the eyes may no longer remain parallel.

7. The error introduced into an altitude reading by hyperphoria is equal to the angle between the axes of the eyes, measured in the vertical plane, divided by the magnifying power of the sextant telescope. To estimate the importance of this error, it is necessary to know how much hyperphoria is likely to be present in the eyes of aircraft navigators. The only information available on this point is contained in the Naval Regulations for aviators. A man is disqualified for aviator who shows hyperphoria more than 1 prism diopter, or 34 minutes of arc. Probably most aviators show a great deal less than 34 minutes of hyperphoria.

8. On the basis of this information it may be expected that errors in altitude up to 34 minutes, may occur with "two-eye sextants" of unit magnification. For the Mark IV sextant, whose magnification is two, errors up to 17 minutes might be expected if it were fitted with a bubble to be viewed by the other eye. For daylight star sextants of the "two-eye" type of magnifications 10 and 20, the errors would be 3.4 and 1.7 minutes respectively and would be less serious. Lack of oxygen might increase hyperphoria however, but the magnitude of such an effect is not known.

9. The error due to hyperphoria can be eliminated in either of two ways, as pointed out in reference (a). First, cross hairs or a reticle pattern can be introduced into the field of the left eye and made sufficiently similar to the cross hairs in the field of the right eye so that the two eyes are forced to stay in allignment. Cross hairs of this sort were tried in a laboratory set up but found to distract too much from vision of the star. Second, rotateable prisms, or a decentering adjustment for the eyepiece, or other device can be incorporated into the bubble side so that the effect of hyperphoria can be compensated out for the particular observer. The left eye field would have some inconspicuous allignment marking at the margin of the field to be used for making this adjustment. Such a system requires that the degree of hyperphoria stay fairly constant for an observer. Data on the constancy of hyperphoria were not available, but variations in hyperphoria during the course of an observation are

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expected to be much less than one prism diopter, and probably only a very few minutes of arc.

10. Esophoria and Exophoria, which refer to lack of parallelism of the axes of the eyes in the horizontal plane, cause errors which are probably negligable, but may give rise to difficulty for certain individuals in merging the two fields laterally.

11. If the instrument is in improper adjustment tipping the head sideways so that one eye moves up and the other down a small amount past the eyepieces, causes the star and bubble to go out of coincidence and will give rise to an error similar to that due to hyperphoria. If the images of bubble, crosshairs and star all lie at infinity, no such effect exists and this condition can be secured by proper focussing of the eyepieces.

12. So far as accuracy is concerned it was concluded as a result of the theory described above that a satisfactory two eye bubble sextant can be made in powers of 10 or higher, and probably for lower powers as well.

DESCRIPTION OF INSTRUMENT:

13. An experimental tele-periscopic sextant was constructed with bubble viewed by the left eye and star by the right. The optical system is diagrammed in plate 2 (Fig. 1.) and the portion of the actual instrument containing the two occulars and bubble is shown in plate 1.

14. The magnifying power of the instrument was 20. The sky prism was a 90 degree prism with faces 70 mm. square. The objective was of focal length 50 cm and diameter 50 mm. The eyepiece was a Kellner type of 2.5 cm equivalent focal length. The exit pupil of the instrument depended on the prism setting and was at most 2.5 mm in diameter. The real field of the instrument was 1.8 degrees and the apparent field 36 degrees.

15. The bubble cell was designed so that bubble and star stayed together as the instrument was tipped to or away from the observer. In order for this to take place the proper radius of curvature of the surface against which the bubble rode was selected. The theory is as follows:

16. If the instrument is tipped through an angle a, measured in the plane of star and zenith, the star image appears to move thru an angle given by A. a/f_1. and the bubble thru A. R/f_2,
where f_o, f_1, and f_2 are the focal lengths of objective, star eyepiece, and bubble eyepiece, respectively, and R

is the radius of curvature of the surface over which the bubble moves. For these angles to be equal, the condition is that

$$R = \frac{r_c \; r_y}{\quad}$$

and in the case of the sextant which was constructed

$$R = 50 \times \frac{3.37}{2.54} = 66\text{cm}$$

For bubble chamber a standard Mark III Pioneer cell was reconstructed with a surface of 66 cm radius of curvature. The bubble and star images in the finished instrument where found to follow one another quite well.

17. By placing the bubble cell above the right prism, P_3, as shown in plate 2, the star and bubble were made to move in the same direction for forward and backward tipping of the instrument. For lateral tipping, the two image moved in opposite directions. A roof prism in place of either P_2 or P_3 would have corrected this, but was not available.

18. As usually adjusted a bubble of 2 to 4 mm diameter was used and appeared quite large at the eye, subtending an angle of 4 to 8 degrees. The real angle subtended in the object space was only 0.2 to 0.4 degrees. The bubble period was about 1/2 sec., as would be expected for a surface of 66cm radius of curvature (cf. reference (a)). The motion of the bubble in xylene of 2-4 mm diameter was approximately critically damped. The bubble action was considered satisfactory.

19. Even illumination of the bubble was secured by a 2.8v flashlight bulb L run from two cells. Between lamp and bubble were a ground glass diffusing screen G, and a blue filter F to make the bubble field closer in color to the sky. A rheostat enabled the observer to adjust the bubble field in brightness.

TESTS OF SEXTANT:

20. The two eye experimental sextant was tested from ground and in flight. At Washington on September 22 and 23, 1942, Venus, Arcturus and Procyon were viewed through a full daylight sky from ground. In flight in a JRF plane on September 29 and 30, 1942, Venus, Arcturus and Vega were observed in full daylight at 10,000 feet. With the sextant mounted in a PBY-5a, during flights on January 13, 1942 Venus and Vega were observed at 8,000 feet.

21. No extensive tests of accuracy were made with the sextant. The writer, who has approximately 20 minutes of hyperphoria, was able to repeat settings to 1 or 2 minutes of arc, after adjustments were made to compensate for his hyperphoria.

22. As a result of the tests it appeared that the presence of the bubble in the left eye field distracted somewhat from vision of the star in the right eye. In order to reduce this effect, bubble and background were dimmed until barely visible. A bright uniform blue field with no bubble seemed to be of no harm and probably aided vision of the star. However, a uniform field for the left eye of color quite different from the sky (unfiltered tungsten light) also caused distraction.

23. Further tests are necessary to determine the most favorable type of bubble illimination. It is thought that a system as diagrammed in Plate 2, Figure 2 may be worth trying. The beam splitting prism p superimposes the bubble image on the bright uniform background produced by lamp L_1. Background brightness and bubble brightness and color can be varied independently and any brightness or color contrast produced. It is expected that a very low bubble to background contrast along with a high brightness background would be most favorable.

CONCLUSIONS:

24. It was concluded that a practical and accurate two eye bubble sextant can be made especially if high magnifying power is used. Further work will be necessary to determine the range of errors to be encountered due to hyperphoria and to discover the most favorable type of bubble illumination.

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REFERENCES

(a). NRL Conf. Report. No. H-1825 of 20 December, 1941.

(b). NRL Conf. Report No. H-1780 of 1 October, 1941.

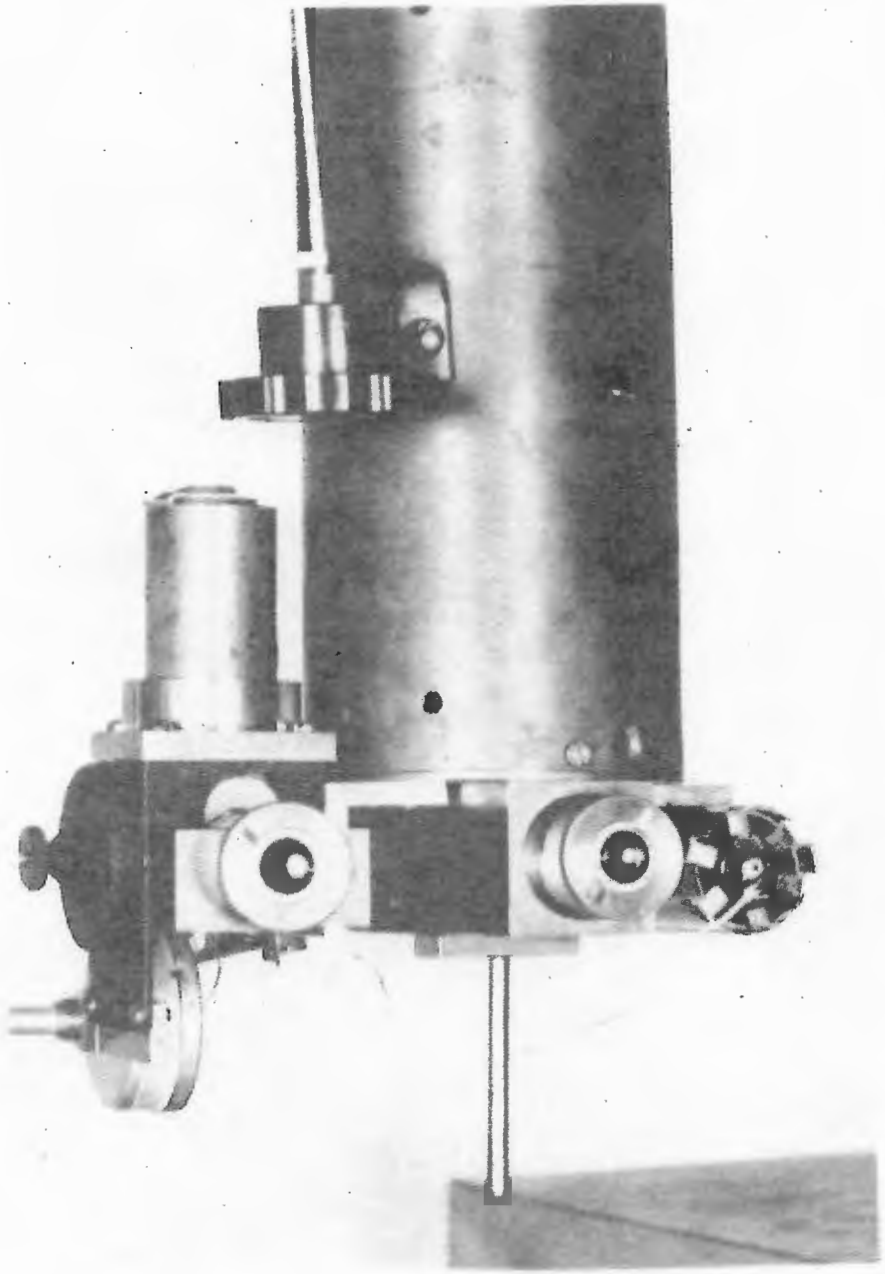

PLATE 1

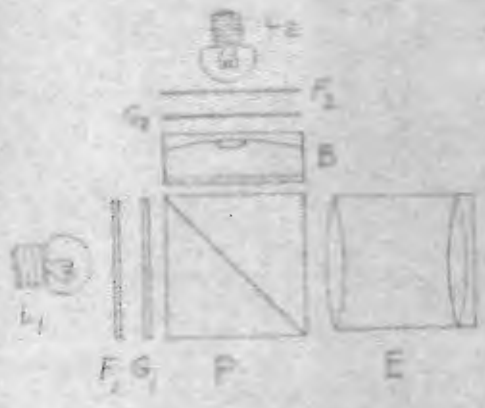

FIG. 2

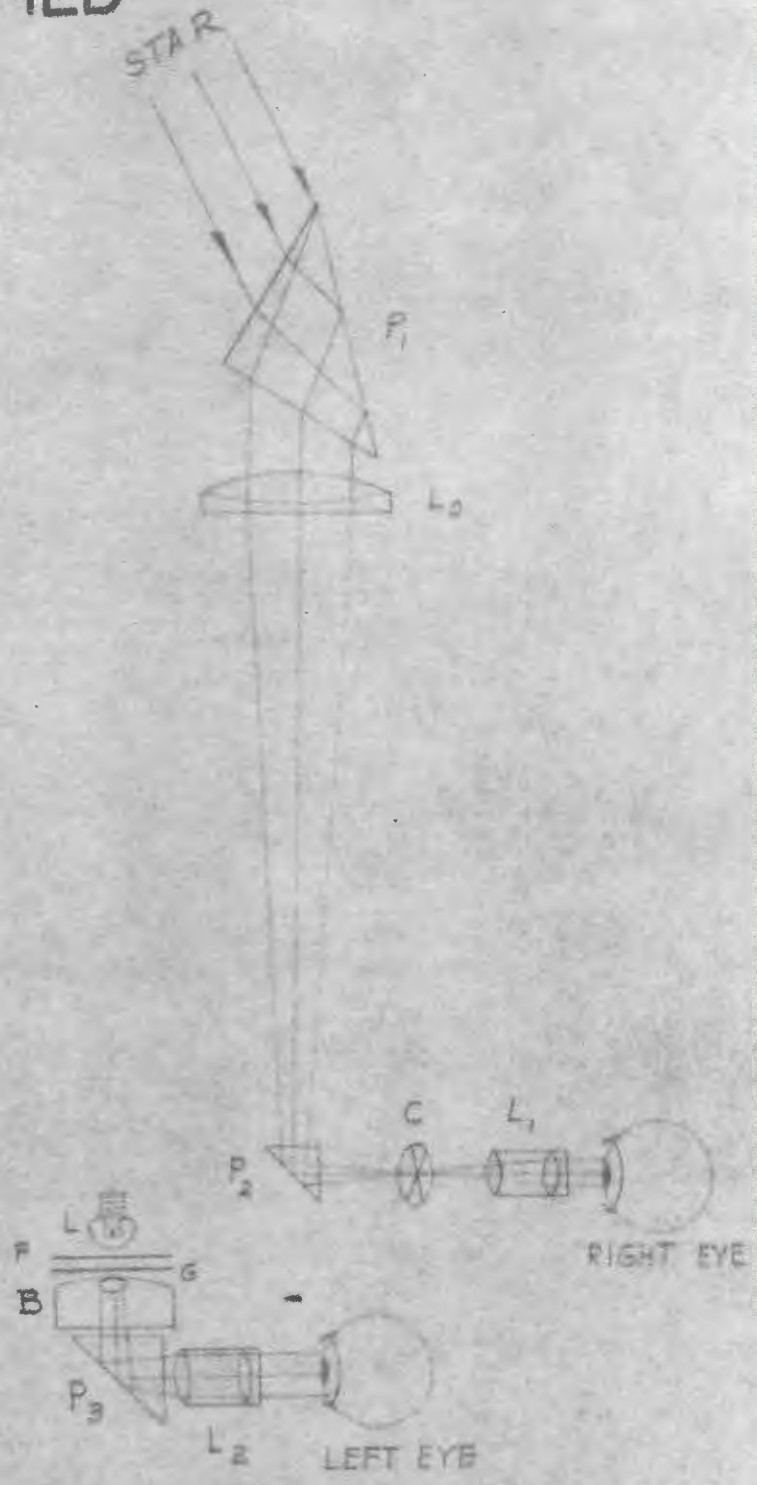

FIG. 1

PLATE 2