INSTRUMENTS

THE JÄDERIN BUBBLE SEXTANT

by

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In some previous issues of this Review descriptions have been given of several types of bubble-sextants, and it is believed that it might be of interest to describe a type which is already 30 years old and was designed by the late Professor Edvard JÄDERIN of the Stockholm Technical University for the ill-fated ANDRÉE balloon polar flight, and was used to some extent during that flight, according to the records found in 1930 on White Island (Kvitöya) by the AHLMANN Expedition.

Since the year 1897 it seems that it has not been used except by the present writer, who had an instrument made for an arctic cruise of which a short description has appeared in this Review (*). The results obtained in the ice were all that could be reasonably expected with a bubble-sextant, and were very useful in many cases. To the already pretty lengthy discussion regarding the possibility of using the bubble-sextant at sea no contribution will be given here, but it appears that the successful use of bubble-sextants at sea would depend on a certain knack in observing which cannot be acquired easily by everybody. For observations in the air however the instrument described might prove of value, as its accuracy is sufficient and the construction simple.

JÄDERIN has given a description in Swedish (**) of his trials with the instrument, evidently stimulated by Adolf ERIK NORDENSKIÖLD, who still showed great interest in every investigation referring to the polar regions or to geography in general.

JÄDERIN'S invention passed through two stages. The first of these led to the instrument actually used by ANDRÉE and his companions, and later a second and more perfect design was produced in the following year for use by an expedition in 1897 in the steam-corvette *Freja*.

The appliance includes a reflecting prism and below this a spherical level attached to a common mariner's sextant (Fig. 1). Already in the first stages JÄDERIN had laid down two main conditions to be satisfied, *viz.*

1st. — That the unsteadiness of the bubble in the field should give it a movement in the same direction as the movement of the doubly-reflected image of the sun, and

2nd. — That the radius of curvature of the level should be such that the movements of these two images in the field should be equally great.

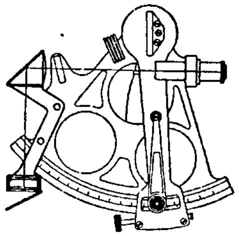
(*) *Hyd. Review*, Vol. VII, N° 2, pp. 37-43.

(**) Ofversikt af Kongl. Vetenskaps-Akademiens Förhandlingar, Stockholm 1897, N° 9, pp. 493-505.

These two conditions, if satisfied, would give the same relative immobility of the two images as that described by Sir Isaac Newton in his inventor's description of a reflecting sextant.

In the first stage of the instrument the prism was a simple rectangular glass prism with plane faces. With this type Jäderin made many determinations of error on land and in a boat. On land he found the probable error of one observation to be about 1' and in a small boat about 2'. Nils Strindberg, the young physical student who was lost with Andrée, on one occasion determined the latitude of Stockholm by observations from a cab in motion and is said to have obtained a result 10' in error. It is with this instrument that the observations from the balloon *Ornen* were carried out.

In the second stage Jäderin had realized the importance of a collimator lens to be placed between the tube and the prism, or a Wollaston prism, with one face spherical and serving as a lens. This throws the image of the bubble optically to infinite distance, and thus it may be seen clearly beside the image of the sun with or without the tube.



Nivåsextant, Prof E. Jäderins konstruktion, användes med fördel, då sjohorisonten är täckt av dimma, ehuru himmelen är klar, då horisonten begränsas av land, vid observationer nattetid etc. Konstruktionen, bestående av ett rätvinkligt prisma med linsförstoring A och dosvattenpass B, kan med lätthet anbringas å vanlig sextant och hastigt åter avlägsnas. Därigenom att vattenpassets krökningsradie är gjord lika med linsens brännvidd, ernås fördelen; att solbilden i synfältet och nivåns runda blåsa orubbligt följas åt, ehuru instrumentet ej kan hållas stadigt. Härvid kunna lika noggranna observationer erhållas som vid användning av artificiell horisont.

Fig. 1

Fig. 1 gives a diagrammatic picture of the instrument, as at present provided by the instrument-makers, Messrs. Nya Instrumentfabriks A. B. Lyth of Stockholm. The price is low and the bubble appliance may easily be adapted to any instrument; it is fixed or removed by two screws operated by hand. It may be of interest to give some results obtained with the instrument during the arctic cruise mentioned above, in order to enable the reader to form an opinion of its order of accuracy. It may be pointed out that the observations were made from a sealing-vessel ((Björnöy) 20 meters (65 ft.) long the movements of which were very jerky, but all observations were made within the drift-ice region, and none in the open sea.

Of some 140 altitudes of the sun, 17 sets or series were taken with the Jaderin sextant. Their results were in good agreement with the altitudes from the natural horizon.

When using bubble-sextant altitudes, a series always consisted of five or more separate observations, which were plotted against the times of observation on squared paper (*). This was necessary in order to be able to estimate the value of the results. A single observation was found liable to an error of from 3' to 10'. If the individual observations gave large discrepancies, a series of 15 to 25 altitudes was taken, but if the agreement was good, about five observations were found sufficient in order to reduce the uncertainty of the results to 2' or 3'. These statements are illustrated by figures 2, 3 and 4.

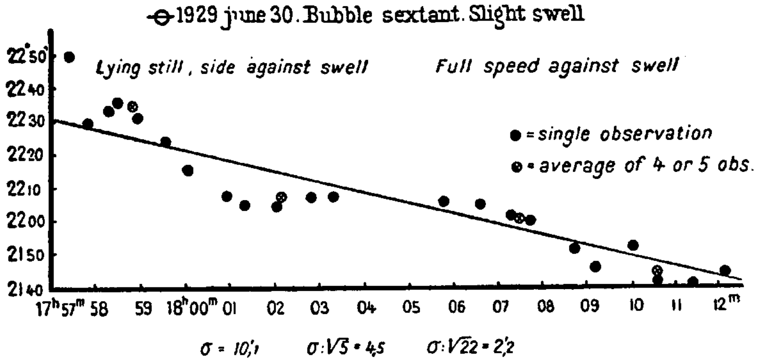


FIG. 2

The observations on 30th June (Fig. 2) are of some interest. The altitudes before 18 h. 04 m. were taken while the vessel was lying still, broadside on to a slight swell. At such times the small vessel made very short and jerky movements, with a period of only a few seconds for a whole oscillation. The last ten observations shown on figure 2 were taken with the vessel at full speed into the swell. This gave smoother movements of the vessel and a longer pitching period, about 10 seconds for a whole oscillation. It may be seen from the diagram that the accuracy of observation became two to three times greater.

The mean error of one of the single observations given in figure 2 was found to be 10.'1; the mean error of an average from five observations 4.'5 and of the whole series of 22 observations only 2.'2.

Figure 3 represents a series of nineteen individual altitudes observed near the meridian (the sun culminating at 1220 Zone time), in very smooth water within the drift-ice limit and close west of Hope Island. The agreement between the individual values is far better in this case, the mean error of one observation being only 3.'0.

(*) This method is described in a paper by M. FAVÉ : Le point sans l'horizon de la Mer. Paris, 1910, Chapelot, p. 58, 92.

Instead of the table of M. FAVÉ, any table giving the variation of altitude with time or of time with altitude may be used.

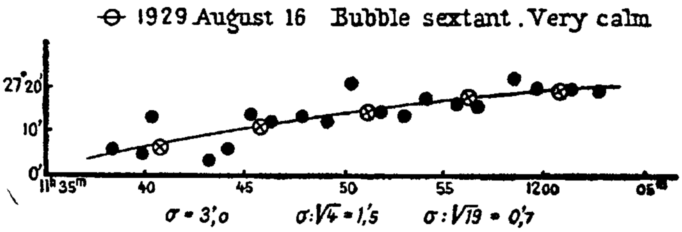


Fig. 3

Another set of observations in smooth water showed that if one of the crew was passing to and fro on deck it was sufficient to increase the mean error perceptibly. This must evidently be due to the smallness and form of the vessel.

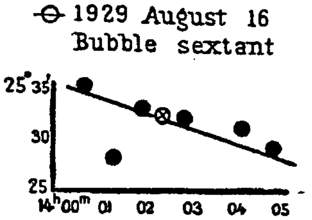


Fig. 4

Figure 4 gives a series of six observations which may be regarded as fairly typical for a good set of altitudes. The accuracy of the average should be about 1'.

Bubble index error. — In the same manner as ordinary altitudes, those taken with bubble sextant must of course be corrected for index error. This is determined by bringing the bubble and its circle in coincidence with the horizon and reading the micrometer.

A series of fifty such readings was observed on 30th June. The frequencies of the different readings are given on the diagram, fig. 5.

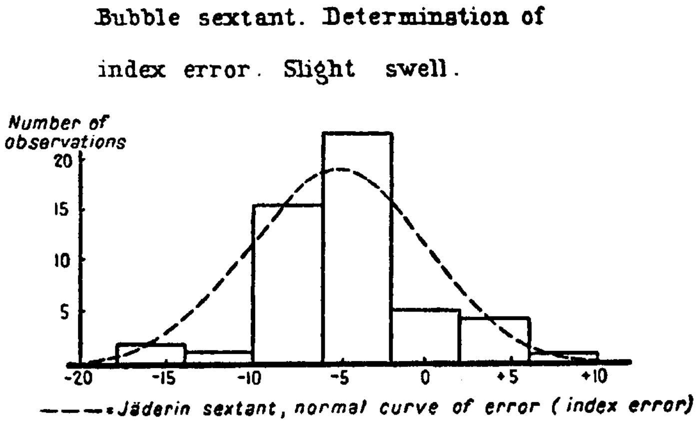


Fig. 5

At the time of observation there was slight swell, which is shown also by the quantity σ, i.e., the standard deviation or "mean error" of one observation, being as high as ± 4.'5. The index error was found to be — 4.'9 from an average of the 50 observations. The dotted line shows the normal curve of error, calculated to fit the observations according to the methods of mathematical statistics.

It evidently is not possible, from the restricted experience referred to above, to make any general statements regarding the usefulness of the bubble sextant as a navigating instrument. The use of the bubble sextant on board the "Björnöy" however goes to prove that there is no danger in using such an instrument and that when navigating in ice, it is often of considerable value.

If the vessel is unsteady, a greater number of observations is of course necessary, if the sea is smooth, a small number. By plotting the altitudes against time the observer may then judge the reliability of the observations, and he uses the sloping altitude-time curve mentioned above or an average altitude for the average time of observation, obtained graphically or numerically. In all cases it will be of value to plot the single observations by some graphical method in order always to be quite sure of the accuracy of the data used for calculating the line of position.

Successful observations with the bubble sextant on board such a vessel as the "Björnöy" seem to depend to a considerable degree on experience. Even for an observer well used to the ordinary sextant, readings on the bubble are very difficult at first. As is well known, a steady movement of the vessel does not affect the bubble. When a vessel is rolling in a seaway, the altitude should be taken either while the vessel is comparatively at rest, or approximately at a moment when the vessel is moving at its fastest sideways, i.e., somewhere midway between two subsequent turning points in the rolling movement. These turning points, when the vessel is relatively at rest, should be the most dangerous for bubble-observation, for then the vessel has its greatest acceleration and the bubble, although it may appear steady, will be at its maximum deviation.

These considerations are of a theoretical nature. They should be valid on larger ships with considerable rolling period. The theory could not be tested on board the "Björnöy", as the vessel was too small and too stiff. The rolling period consequently was very small and the lurches violent, so that the bubble never came to rest between successive rolls; thus observations were not possible in anything more than a fairly light swell, when a bubble-sextant would probably have rendered useful service on board a larger and less stiff vessel.

However the experience of the present writer goes to prove that during navigation in ice, where fog and low mist are often prevalent, the bubble sextant is a navigation instrument of considerable value even on board a vessel of the dimensions and type of the "Björnöy". The navigator need not fear that he will be led into error, as the graphic method provides an easy means of testing the accuracy of the results.