THE
SEXTANT
SIMPLIFIED

A practical explanation of the use of the Sextant at Sea

by

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PREFACE

The Sextant is the most important instrument of a Navigator's equipment, and is by custom, usually provided by the individual himself.

It is not suggested, of course, that the whole Art of handling the Sextant can be taught in a book—this is obviously impossible—but one can be made thoroughly conversant with the parts of the Sextant and can learn exactly how to use it before attempting actually to handle the instrument.

In addition, under modern conditions, it is very necessary to use the Stars as well as the Sun for Navigation, but to take accurate" Star Sights requires careful attention to detail with a knowledge of the finer points of the Sextant and its various accessories.

Many Coastal Navigators have every other kind of navigating instrument except the Sextant ; which is so easy to use, and so valuable, that it should be carried in every vessel.

As its usefulness in giving the accurate position depends entirely on the skill of the Observer however, the Sextant should be practised with on every possible occasion.

Apart from the text books for the Ministry of Shipping Examinations which cover the subject of the Sextant well (though largely from a theoretical standpoint) ; there does not appear to be a simple book on the Sextant to help the young Merchant Navy Officer.

The importance of an extensive knowledge of the Sextant is indicated by the fact that the highest marks are given to candidates for Mates' and Masters' Certificates for the Oral Examination on this instrument.

It is to rectify this omission, and also to assist the hundreds of peacetime amateur Navigators who are now serving afloat in the R.N.V.R. that this little book has been written.

My best thanks are due to my friends, W. J. Chandler, for his splendid illustrations used throughout the book, and also to H. H. R. Etheridge, for his cover drawing and Star observation diagrams.

I would also like to thank Heath & Co., for supplying a number of the blocks, also Henry Hughes & Son, Ltd., for supplying blocks, photographs and for the excellent drawings of the Vernier readings, especially drawn by them for the benefit of seamen generally.

For the convenience of the user of the book a plate showing a modern Micrometer Sextant with all the parts named, has been provided at the back which may be folded out when reading the book, to save turning back to consult the photograph of the Sextant.

London, *September,* 1942. OSWALD M. WATTS.

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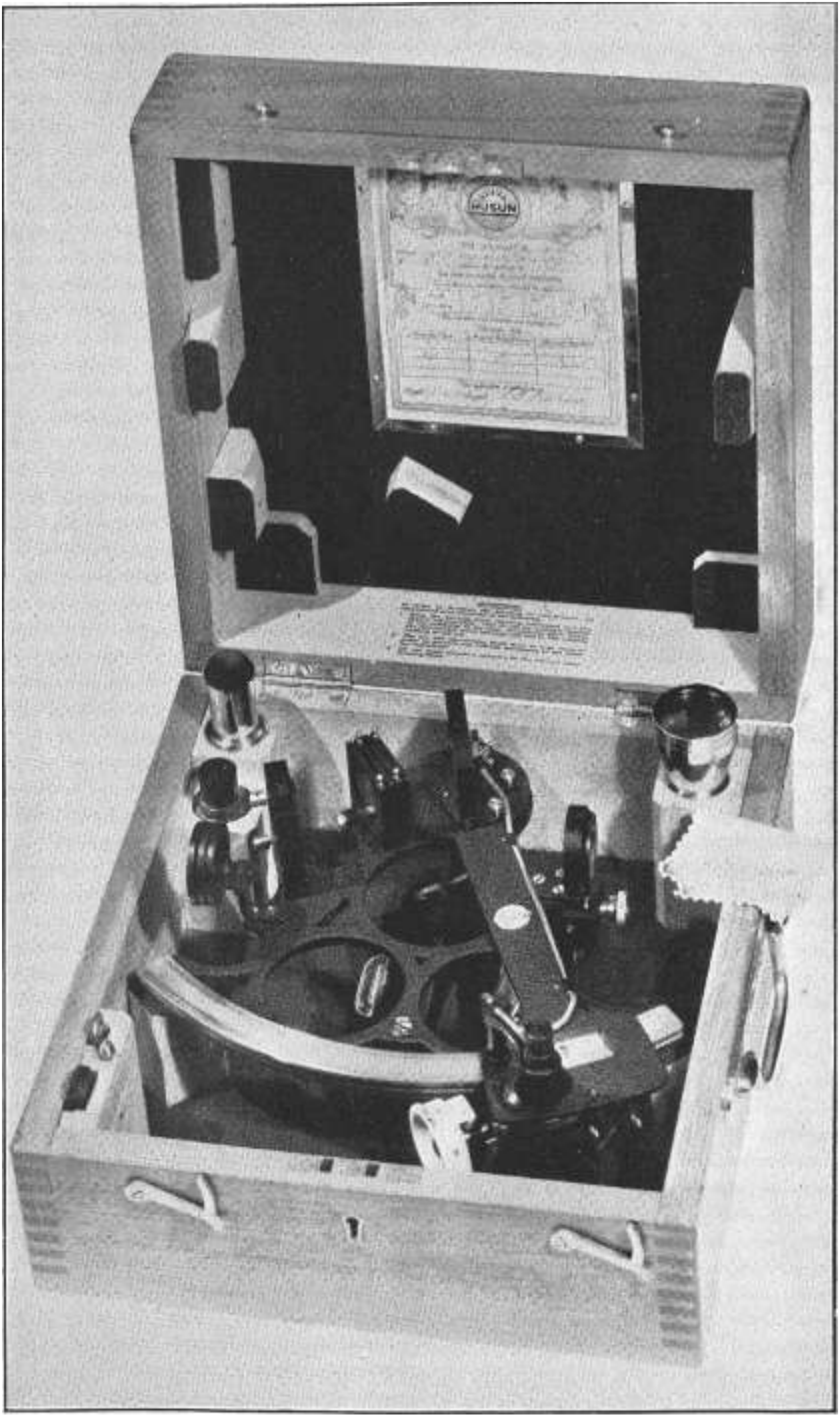


Fig. 2. A "3 Circle" Micrometer Sextant stowed in its Case.

The well-known "3 Circle" Frame is visible plainly. Note the Maker's Certificate, also, the housing for the Star telescope when not in use. The special form of Rising Piece is tightened by a small brass finger screw which may be seen to the right of the Telescope collar.

The Sextant Simplified.

CHAPTER I.

DESCRIPTION OF THE SEXTANT

The Sextant is purely and simply an instrument for measuring angles. It is used in all ships throughout the world, and by its aid the Navigator may find his way across the oceans anywhere out of sight of land.

The instrument is adapted for observing angles in any plane or level and thus vertical, horizontal or diagonal angles may be measured by it. For this reason it is much used in **Coastal Navigation.**

The Sextant is particularly suitable for use at sea in **Deep Water Navigation** for measuring the altitude (that is, the angular distance above the horizon) of heavenly bodies because it may be held in the hand and accurate measurements of the angle obtained even though the vessel be rolling and pitching. This continual movement of the vessel at sea precludes the use of **fixed** instruments (such as theodolites), which require a solid platform—hence the importance of the **Sextant.**

Because of the Laws of Optics respecting the reflection of light from two mirrors, the angle between two objects may be measured with great accuracy, both of the objects being brought into the field of view of the telescope simultaneously.

The Navigator usually possesses his own Sextant which is (especially a modern one) a really beautiful piece of work.

All Sextants are housed (i.e., kept) in a special Case (when not in use), and therefore, as there is even a correct way of lifting the Sextant from its box, it will be advantageous to describe the instrument and its parts right from the time when the possessor of the Sextant opens the Case for the first time to learn how to use it.

It is very advisable for the young seaman to understand all about the instrument he will use several times daily at sea during his whole navigating career.

THE SEXTANT IN ITS CASE

It should be stated right away that all Sextants, whatever their size and price, do fundamentally the same job. The main advantages of the more expensive instruments are that they are larger, are easier to read, also have finer telescopes and various accessories, all of which improvements are directed to the one end—to **make the Sextant easier for the Navigator to use.**

The Sextant Case

Consult Fig. 1 at the front of the book. This shews a modern Micrometer Sextant fitted in its Case; which, incidentally, is usually made of polished hardwood, and is fitted with a brass handle (often countersunk), for carrying. It also has a lock and key; storage for the key when not in use being arranged frequently inside the box.

The Sextant Certificate. Fitted inside the lid of the Case will be seen the Sextant Certificate. In the cheaper models of Sextant this is issued by the Makers of the instrument (as in Fig. 2).

The more expensive types of Sextant, however, are sent to the National Physical Laboratory who test the instrument independently. If it is found to be up to a certain standard they issue a Certificate of Examination for that particular Sextant, which is then permanently fitted in the Sextant Case.

Two classes of Certificate are issued—Class A and Class B—according to the standard of the instrument ; and full details of these tests may be found in Appendix A on page 88.

Such a Certificate is referred to as an **N.P.L. Certificate** and the "hall-mark" of a Sextant is to have an **N.P.L. Class** A **Certificate.** (As shewn in Figure 46 on page 89, and shewn fitted in the Case in Figure 1).

The Certificate shewn in Figure 46 should be read and on it will be seen the Makers' **name and number** of the Sextant. This latter is important, because if the instrument is sent for repairs at any time it is readily traced by this number together with the makers' name. The Sextant in Figure 46 (and Figure 1), would be referred to as No. 23189 by Henry Hughes & Son, Ltd., of London. This number is actually cut on the instrument at the top of the Sextant Arc over the makers' name (shewn clearly as No. 19110 in Figure 3).

The Certificate sometimes states the radius of the Sextant (six inches radius in the case of Figure 2), also the least reading of the Sextant (in this case 10 seconds (10") of arc—see Chapter IV.) ; also the magnification of the telescopes. A table is provided shewing the permanent Errors of that particular Sextant at various angles, which the user must apply. Here in Figure 1 (or Figure 46), the instrument is certified to have errors of not more than half-a-minute (30"). The date of manufacture is also stated on the Certificate.

Today many Sextants have the makers' own Certificate, which is perfectly satisfactory, and may be relied upon implicity ; but if the Navigator buys a new Sextant (and he can usually afford to buy only one—if that— in his lifetime), it is to be recommended for the instrument to have an N.P.L. Certificate.

The Sextant and its Housing. To prevent the Sextant being jarred through being fitted loosely in the case, it is usually firmly held in position by an arm or catch of some sort and frequently this has to be released by a "push or pull" button or arm. In Figure 2 the handle of the sextant fits snugly in a tight handle-shaped support, whilst the two front legs sit in holes in built-up wooden blocks, one on either side. The instrument is thus rigidly held.

Before attempting to remove any Sextant from its case an examination should be made of the exact arrangement of its fitting and securing.

Handling the Sextant

Having released any grip fitting with the right hand, the Sextant should be grasped firmly by the fingers around the frame-work about its point of balance and lifted from the case by the **left hand,** raised up and immediately transferred to the right hand, which grasps the handle at the back of the instrument. **Thereafter the instrument is held in the right hand as shewn in Fig. 11, (page 20), all adjustments to the parts of the Sextant being made with the left hand.**

So that we may now examine the remaining contents of the case, the Sextant should be stood down on a flat surface. It is, of course, set down by again grasping the framework of the instrument with the **left hand,** and placed down on its legs with the handle underneath as in Fig. 9 (page 14).

The greatest care must be taken when lifting the instrument up or placing it down, to grasp the Sextant firmly by the Frame (see Figure 1) ; and never to lift it by the Limb or Arc or to hold the moveable Index Bar (Figure 3) because by so doing it may be strained.

The Accessories in the Case

The number of Accessories naturally depend on the quality of the instrument; those shewn in Figures 1 and 2, however, being more or less universal.

The Sextant is usually provided with a blank tube and two telescopes, one an erect telescope and the other an inverting telescope, all of which will be provided with a proper housing in the Sextant Case (see Figure 1). They are primarily provided to direct the line of sight.

The Blank Tube has no lenses and is merely a sight vane which is used only when taking shore angles, to keep the line of sight from the eye, parallel to the plane of the instrument.

The erect Telescopes represent objects magnified in their natural position, and are provided to render objects and the horizon more distinct, as by the aid of a telescope the contact of the images is more perfectly distinguished. **The Star Telescope** is usually supplied in a modern Sextant. It is bell-shaped and erect and gives a much larger field than any other type and is specially designed to enable the horizon to be distinguished on a dark night.

The Inverting Telescope—a longer one—shews the object upside down or inverted. It is chiefly used for observation of the Sun and has a greater magnifying power than the erect type. It is fitted with two eye pieces, one with higher magnifying power than the other (and consequently a more limited field), preferable for observations on shore ; whilst the smaller powered eye-piece is better suited for sights at sea. Use and experience will soon accustom the observer to the inverted position, and the Sun's Meridian Altitude will be taken easily after practice with it. (See Chapter VII. on Sextant Telescopes).

Telescope Shades (Dark Eye-pieces). One or two Shades of different densities are supplied to fit to the eye-piece of the telescopes as they shade equally the direct and the reflected image of the object. Either one or the other is used for taking sights by the Artificial Horizon on a clear day. One of them could also be used if for any reason the Index or Horizon Shades are not in use or have become damaged.

Apart from the above, more or less standard, accessories (which may be seen standing alongside the Sextant in Figure 3—the Star telescope being shipped) ; the case may be fitted with a screw driver, bottle of oil, camel-hair brush, spanner, etc., and a small ball headed pin lever or other fitting for making the Adjustments to the Sextant.

Stowing the Sextant in the Case

The instrument should now be lifted up and put back into its Case, but before doing so it is **essential** to fold in the Index Shades towards the middle of the instrument in the position as shewn in Figures 1 and 2. If they are left in the position for use as shewn in Figure 11 (page 20), the Sextant will not fit into the Case and the Shades may be knocked and damaged. Now lower the lid gently to see if it will close properly—if not, then the following points should be carefully considered.

The case **should** be large enough to take the Star Telescope (not the long telescope) **focussed ;** (see Figure 1), though it is often impossible to close the Case without pushing in the draw of the telescope or taking the telescope out of the **Collar** (see Figure 3) altogether (as in Figure 2).

Again, the Case should be large enough to take the instrument at whatever position on the Arc at which the moveable Index Bar may be left. This is very important, because it enables the Sextant reading to be checked subsequently, if any error is thought to have been made in the original reading. Frequently it is necessary, however, to move the Index Bar some way along the Arc to allow the Case to close. In this case the ideal position is halfway along the Arc (see Figure 1).

The various wooden chocks, as shewn in Figures 1 and 2, are provided to keep the Sextant and its Accessories tightly fitted in the box. The lid is provided with two strong hooks or other patent fasteners to prevent it flying open when the instrument is being carried.

A piece of **chamois leather** should be kept in every Sextant Case, and used to wipe the instrument carefully after each observation.

THE SEXTANT ITSELF

The **Sextant** derives its name from the extent of its Limb, which is the sixth part of a circle, or 60' (from the Latin *sextans—"* the sixth part").

Types of Sextant. There are really three quite distinct types of Sextant whose difference, however, is **entirely concerned with fixing the Index Bar, and reading the angles observed.** For convenience these three models may be called :—

(a) The Clamping Screw Sextant.
(b) The Endless Tangent Screw Sextant.
(c) The Micrometer Sextant.

(a) The Clamping Screw Sextant

This type of Sextant is still greatly in use and it differs from the other two types in the method of fixing or **clamping** the Index Bar to any required position on the Arc.

When the Index Bar is in approximately the required position on the Arc a finger screw attached to the back of the Arc, called the Clamp or Clamping Screw, is tightened. This holds the Index Bar firmly against the Limb behind the Arc. When this has been done the Index Bar may be moved for a short distance along the Arc by means of the Tangent Screw so that more exact readings may be made (see Figure 19).

The exact reading of the angle observed is performed by a small Arc, adjacent and butting on to the main Arc called a Vernier (to be described fully later), which is fitted in the position shewn in Figure 20.

In this type of Sextant it will be found that the Vernier can only be moved a little way along the Arc (actually just to the limit of the tangent screw). This is extremely inconvenient in practice because it is found frequently that, when observing altitudes, the screw will suddenly get to the end of the thread, when it is necessary to unclamp, turn the screw back to the middle of the thread and resume observation, by which time the Sun has possibly disappeared behind the clouds for good.

(b) The Endless Tangent Screw Sextant

This type of Sextant is a great improvement on the one described above (being really a combined Clamp and Tangent Screw) ; because by pressing (and keeping pressed between the thumb and forefinger) the Quick Release Clamp at the foot of the Index Bar (see Figures 20 and 21), the Bar can be moved by hand anywhere along the Arc and **automatically clamped** by releasing the finger pressure from the Quick Release.

When this has been done the Tangent Screw can be brought into play, and as this is Endless the Index Bar can be screwed along from one end of the Arc to the other without interruption or requiring re-clamping. In other words, the Clamping **Screw** has been eliminated altogether in this model by a **Quick Release** Clamp.

The Endless Tangent Screw Sextant, however, has still to be read by a Vernier.

(c) The Micrometer Sextant

Although generally referred to as the "Micrometer" Sextant, the proper description of this type of Sextant is the "Micrometer Tangent Screw Sextant." The Tangent Screw moves the Index along the Arc to show whole degrees of the observed angle, whilst the Micrometer records the minutes and tens of seconds (which had hitherto been shewn by the Arc and Vernier combined).

This is the most modern type of instrument in which the Index Bar is first of all fixed at the required position in the same way as the Endless Tangent Screw Sextant by a Quick Release Clamp.

The Tangent Screw in addition to being **Endless** is worked, instead of by a brass finger screw, by a Micrometer Screw fitted with a large **Micrometer** head (about an inch in diameter), on which the readings are very clearly marked in black on a white ground (see Figure 18, page 32). As will be seen, this gives a very rapid (almost instantaneous) and easy reading, which is a great advantage ; the graduations being easily discernible at arms length in good daylight and much more easily than usual in poor daylight or in dim artificial light.

The whole degrees are read direct on the Arc and the minutes on the Micrometer head **at sight—thus dispensing with the Vernier and its Microscope entirely,**

A small Vernier is provided to read to 10 seconds (10") if required, but apart from this no usual Arc Vernier in provided or required.

DESCRIPTION OF THE PARTS OF THE SEXTANT

Figure 3 shews a modern Sextant in which the parts have been named to assist the explanation ; which will, of course, be far better understood if the student has an instrument actually before him.

The flat upper surface of the Sextant is called **the plane of the instrument,** well illustrated in Figure 9, and the following are the parts of the Sextant which may be said to consist of three main parts: —

(a) The **Fixed** Parts.
(b) The **Movable** Parts.
(c) The **Removable** Parts.

(a) The Fixed Parts of the Sextant

1. The Frame. The actual metal Frame of the instrument may be one of several patterns, each selected to give the greatest strength and rigidity. Figure 3 shews the well-tried " 3 circle" pattern, whilst Figure 1 depicts the " Diamond-frame " model.

As a general rule there is no advantage in having a very light Sextant as a fairly heavy instrument gives greater steadiness when taking observations in a stiff breeze. The average weight is about 4 lbs.

At the back of the **Frame** is fixed the wooden or Bakelite **handle** of the instrument which enables it to be held in any position between the vertical and the horizontal. It will be seen behind the several illustrations but is best shewn by Figure 3. The handle is important as it must be able to be grasped—possibly for longish periods—easily and without fatigue. **The Sextant should be held only** by **the handle or** by **the Frame.**

The three Legs on which the instrument stands when set down are shewn in Figure 19.

2. The Limb and Arc.

The **Limb** of the Sextant is really the lower margin or the whole of the curved circular portion of the Sextant (A—B in Figure 3) into which the graduated Arc is bedded.

The Arc, on which the graduations are cut, is circular and made of metal with a low co-efficient of expansion. It is usually made of a thin piece of silver (occasionally platinum) let in flush with the face of the Sextant Limb.

The Arc Proper is graduated in degrees from right to left from 0' (Zero Point) to 120^0 (and frequently to 130', 135' or 140'). It should be mentioned that, in consequence of the Sextant being an instrument of double reflection (as explained in Chapter IX. on the Principle of the Sextant), the instrument is graduated to 120° although the Limb is actually only the sixth part of a circle, i.e., 60° as may be seen by Figures 1, 2 and 3.

To the right of 0° or Zero on the Arc, is graduated 5° (sometimes 10°), which is said to be **"off the Arc"** and is called the **Arc of Excess.**

Readings to the left or right of 0° are therefore distinguished by being "**on"** or "**off"** the Arc respectively.

In the case of the Vernier Sextant, each degree on the Arc of the Sextant is divided into six divisions of 10' each (although a few older instruments are still in use that are divided into 4 divisions of 15' each).

In Micrometer Sextants, however, each whole degree is cut boldly on the Arc (see Figure 18, page 32), each 10° being numbered and each 5° being indicated by a longer cut than those marking each degree. Some makers actually number each 5' however. The Micrometer in one revolution of the wheel moves the Index along the Arc one **whole degree,** and sub-divides the Arc to 10' intervals (or 0.2' in the case of Sextants divided to decimals).

3. Horizon Glass

This is rigidly fixed to the Frame perpendicularly to the plane of the instrument and parallel to the Index Glass when the Index is at Zero.

The Horizon Glass is fixed in a metal frame and one half (the half farthest away from the instrument Frame), is plain glass and therefore transparent, so that objects may be seen directly through it by the telescope; whilst the other half (the lower, inner or right hand half nearer the Frame) is a silvered reflector or mirror. This mirror receives the rays of the object reflected from the Index Glass and transmits them to the Observer, through the telescope. It is fitted with **two** small, capped, adjusting screws (A and B) clearly shewn in Figure 4, fitted to the usual rectangular Horizon Glass (back view).

The "Hezzanith" rectangular Horizon Glass is provided hermetically sealed (and therefore impervious to salt water or spray) in the more expensive types, and can be fitted as an extra in the cheaper models. This maker of Sextants has also removed the top bar of the Horizon Mirror, which, besides doing away with the obscuring effect of such a bar, gives easier access to the Horizon Glass silver edge to clean away the salt moisture, which is deposited by the sea air.

Figure 5 shews the "Husun" circular Horizon Glass half silvered as usual (Figure 9 shews this very clearly) ; and fitted with the two small capped, adjusting screws (A and B).

Fig. 4. Rectangular Horizon Glass (Back View).
A is the Second Adjustment Screw
B is the Third Adjustment Screw

A

Fig. 5. Circular Horizon Glass (Back View).
A is the Second Adjustment Screw
B is the Third Adjustment Screw

(b) **The Movable Parts of the Sextant**

4. Horizon Shades of coloured glass (usually three) of different densities are fitted to be turned **up** as required, beyond the transparent part of the horizon glass to "kill " (i.e., tone down) excessive glare on the horizon of the **direct** rays of the Sun or glare of the Moon.

5. Index Bar (or Radius)

The **Index Bar** is really a movable arm being free to rotate on a central axis under the Index Glass, around a point on the Frame which is the centre of the circle of which the Arc is a section.

It is mounted on a round baseplate (see Figure 3), beneath the Index Glass, which is firmly fixed to it at the top of the Bar ; whilst the bottom of the Index Bar (with the Vernier attached) slides along the Arc on the Limb when pushed by hand.

6. Index Glass

This is a reflector or mirror set in a brass frame perpendicular to the plane of the instrument. It is rigidly fixed to the Index Bar at its pivoting point in such a manner that its plane is over the centre of motion of the Index. The Index Glass being fixed to the Index Bar, moves with it and changes its direction as the direction of the Index Bar is changed. The glass is silvered all over, and is designed to reflect the image of the Sun (or any other object) upon the Horizon Glass ; whence it is reflected to the eye of the Observer. It is fitted with a small, capped, adjusting screw at the back.

Figure 6 shews the back view of a rectangular Index Glass of the usual type.

A "Hezzanith" rectangular Index Glass may be made hermetically sealed and impervious to the action of salt spray, and therefore the mirror never needs re-silvering. Whilst this is fitted as standard in the more expensive Sextants, it would have to be fitted specially in the cheaper models.

Figure 7 shews the "Husun" circular Index Mirror, which hermetically seals the mirror from the entry of salt spray, and thus entirely prevents the deterioration of the mirrors from this cause. Figure 7 shews the back view of such a mirror, whilst Figure 9 shews the front view.

A circular Index Mirror has no adjusting screw, being permanently adjusted. This is rendered possible by the frame that holds the mirror being made perfectly perpendicular during manufacture.

Fig. 6. Rectangular Index Glass
(Back View)
Note the First Adjusting Screw
(concealed by a brass screw cap)

Fig. 7, Circular Index Glass
(Back View)
Note that there is **no** First Adjustment Screw provided, as the Index Mirror is **permanently** adjusted

7. Index Shades of coloured glass (usually four) of different densities are fitted to be turned **down** as required between the Index and Horizon Glasses, in order to moderate the brightness of the reflected image of the object—as the Sun or Moon.

8. The Index

The arrow or Zero of the Index Bar is called the **Index,** which in the case of the Vernier Sextant is actually situated at 0' on the Vernier. In Micrometer Sextants, however, it is situated in the **centre** of the blank space (hitherto occupied by the Vernier) as shewn in Figure 3.

9. The Clamp or Clamping Screw

When the Index of the Sextant has been moved approximately to the correct angle, it must be brought into firm contact with the Arc by being fastened at the back of the Arc by a **Clamp or Clamping** (or finger) Screw (see Figure 19, page 34). In the case of the Endless Tangent and Micrometer Sextants this clamping is **automatic** on the release of finger pressure from the **Quick Release Clamp** (see Figure 3).

10. The Tangent Screw

Attached at right angles to the Index Bar is the Tangent Screw (see Figure 19, page 34). which comes into operation only when the Index Bar has first been clamped. It is really a "slow motion" screw, and by turning it the Index Bar is carried backwards or forwards along the Arc. This enables the observer to make the images of the objects come precisely in contact, because, by its use, the Index may be moved with far greater regularity than could be done by hand.

11. The Vernier

The lower end of the Index Bar has a dividing scale cut on it (and therefore moving with it), which slides along close to the Arc—called the Vernier (see Figure 21 and Chapter IV.)

This simply divides the Arc into 10 major divisions, each representing one minute of arc, and enables the reading of the Index on the Arc to be made with accuracy. In the ordinary Sextant the Vernier simply subdivides the 10' intervals on the Arc into 10" intervals by each minute of arc being sub-divided into six divisions of 10" each.

On Admiralty pattern Verniers each minute of arc is sub-divided into five smaller divisions each representing therefore 12 seconds of arc (12"). Thus the Vernier enables the Arc to be read to decimals to the nearest 0.2 of a minute, in accordance with the new practice in Nautical Almanacs of giving Declinations to a decimal point of 0'.1.

12. Microscope

This is a magnifier (see Figure 19), fitted to all Vernier Sextants so that the divisions of the Arc and Vernier may more easily be read. It is fitted on a moveable arm on the Index Bar which may be swung to cover the whole length of the Vernier as illustrated in Figure 19.

Sometimes an opaque glass screen is fitted (also illustrated in Figure 19), with which to regulate the light for reading the Vernier.

13. Micrometer Tangent Screw

This has been described fully on page 32.

14. Electric Light

A small electric bulb is fitted for reading the Sextant in the dark, after taking Star observations, and a dry battery is carried inside (or outside) the handle, which is connected to a press button at the top of the handle. The light itself (see Figure 3) is on a shaded moveable arm which can be swung away from the Arc to read the Micrometer as required.

(e) The Removable Parts of the Sextant

15. The Telescope.

By enlarging the object the Telescope makes accurate observation easier. Also by the place of the image in the field of the telescope it is easy to perceive whether the Sextant is held in the proper plane for observation. The tube or "draw" of the telescope slides in and out to suit different eyesights.

The various telescopes carried have been described in Chapter VII, which also contains a fuller description of the telescopes and their uses.

16. Telescope Collar.

The Telescope Collar is provided so that the Sextant Telescope may be screwed into it and thus kept rigidly in the correct position.

The Telescope Collar is really a double brass ring fitted inside a collar and is so constructed as to furnish means of adjusting the line of sight of the telescope parallel to the plane of the instrument (i.e., the Collimation Error).

It is fixed to a Stem (see Figure 19, Rising Piece), in a direction perpendicular to the plane of the instrument, which in some Sextants is just pushed into a socket and kept in position by a thumb screw and in others is screwed into the Rising Piece but is removable at will.

The Telescope is "shipped" (i.e., screwed) into the Collar by a continuous thread, or as in most modern Sextants by an **interrupted** thread for quickness (see Figure 3).

17. Rising Piece

This is a device by which the telescope in its Collar may be raised or lowered, so as to give more or less light to the direct image, thus equalising the illumination of the reflected and direct objects. It is usually operated by a milled head screw underneath the Frame (see Figure 29, page 47) ; but sometimes the Rising Piece simply slides in a socket and is secured by a small thumb screw (as in Figure 2).

The normal position of the telescope is where equal parts of the plain and silvered parts of the Horizon Glass are visible, but by raising or lowering the Rising Piece the telescope in its Collar can be directed to either the silvered or plain glass portions of the Horizon Glass, and the brilliance of the reflected image be regulated therefore.

As the telescope is raised, less of the silvered part of the Horizon Mirror appears in the field of view and the reflected image will not be so bright. If the telescope is lowered, however (that is, screwed hard **down),** the brilliance of the reflected image will be greatest.

18. Sextant Clip

The Sextant Clip is the small jointed piece of metal fixed to the top of the Index and Horizon Glasses, clearly shewn in Figure 29 at the top of the Index Glass.

This Spring Clip is provided to press the mirror back against the tip of the Adjusting Screw and thus keeps the mirror in its correct position in its frame.

9. Adjusting Screws

An Adjusting Screw is simply a screw which, when it is tightened, pushes the mirror forward against the Clip.

Adjusting Screws are provided at the back of the Index Glass and the Horizon Glass to admit of slight movement of the Mirrors to remove errors of the instrument.

In older instruments two small screws were provided in the Telescope Collar to correct any Collimation Error (see Figure 34).

These Screws are operated by an Adjusting Lever (see Figure 3) ; with the exception of the Telescope Collar Screws (and in some Sextants the screw at the back of the Index Mirror) which are worked with a small screw-driver.

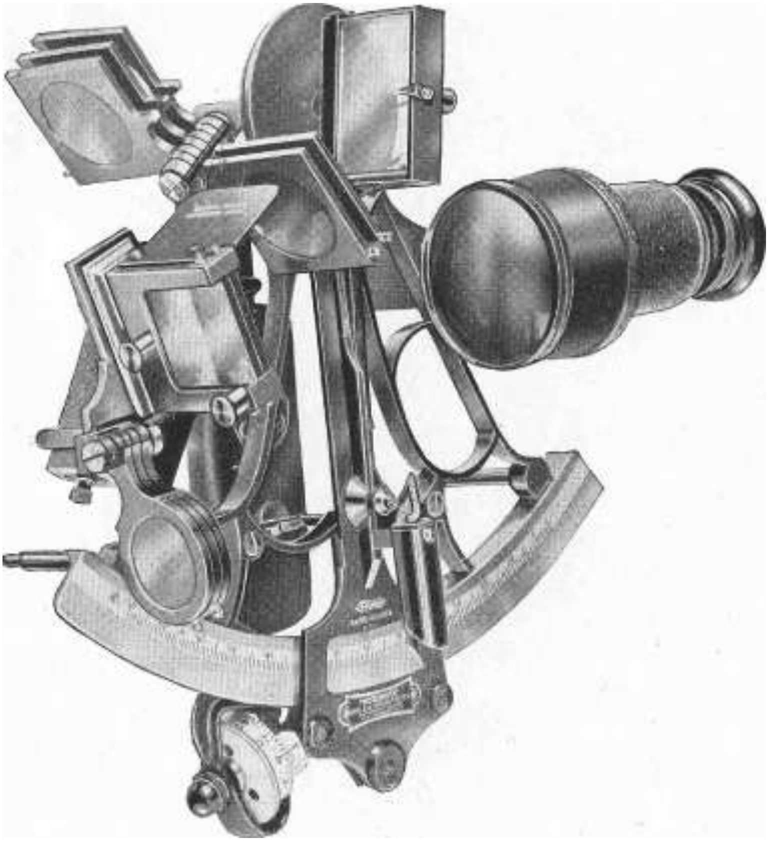


Fig. 8 "Hezzanith" Mark II. Bell Sextant.

This Sextant is so named because the frame is shaped in the middle 'like a bell. Note the large Object Glass Telescope (with screw motion eyepiece) also the absence of "top bar" from the Horizon Glass and the Hezzanith Definition Shade. .

The Quick-Release Clamp is worked by thumb and finger pressure on the button at the extreme bottom of the Index Bar in this Sextant. The oblong vernier light is shewn clearly.

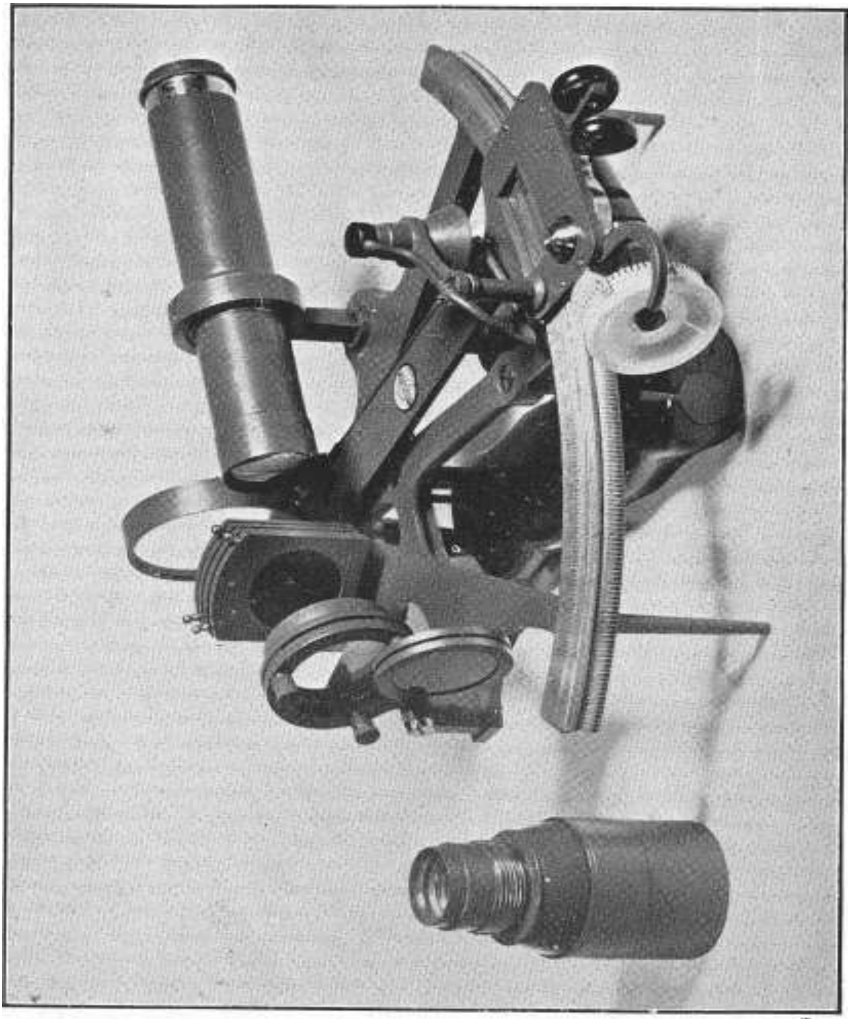


Fig. 9. "Husun" Admiralty Pattern Sextant.

The Inverting telescope is shewn shipped in the collar whilst the Star telescope is standing alongside the Instrument. Note the Circular Mirrors, “Quick-Release Clamp” and the Metal Guard for the Micrometer head. The cap over the hole cut into the bottom of the handle for inserting the electric battery is clearly shewn. Note the teeth on the edge of the Sextant Limb.

CHAPTER II.

SIGHTS

"To sight" is to look at an object with care, and from this is derived the seaman's expression to "take sights."

"Taking Sights" is the nautical term for carefully observing one or more of the heavenly bodies with a Sextant in order to ascertain the vessel's position at sea. As this is done several times a day when out of sight of land, it becomes therefore a highly important part of a vessel's routine.

Whilst the actual taking of the observation is very simple, the results achieved thereby are considerable, so it may be helpful just to see exactly what is done when Sights are taken.

Now an Observer in a ship on looking round, sees a small circle bounding his view, and this apparent meeting place of the sea and the sky is called the Sea Horizon. This appears to him to be flat and he sees it for the whole 360^0 of the circle bounding his view. Looking skywards he sees one half of the heavenly world—called the Celestial Concave-180°, in fact, from any one point of the Horizon to the opposite point.

In the daytime he may see the Sun or the Moon, either or both; and by the use of a telescope he may see one or other of the Planets Venus or Jupiter. These are all the heavenly bodies he has at his disposal during the hours of daylight.

During the night time, however, from dusk till dawn, the Navigator may or may not have the Moon ; some of the four planets Venus, Jupiter, Mars and Saturn are generally available ; and he has literally dozens of Stars which he may bring to his aid from which to " take sights."

Having decided which heavenly body to use, all that the Navigator requires to do is to use the Sextant to measure the angle between the Sea Horizon, generally called the Visible Horizon—and the centre of the Observed Body.

Now this angle—taken with a Sextant—of a heavenly body above the Sea Horizon is called its Altitude, and because various corrections have to be applied later to this, the actual Altitude read from the Sextant is known as the Observed Altitude.

Figure 10 should be consulted as an illustration of what the Sextant actually does. The Index and Horizon Glasses are shewn, also the Sextant Arc ; the Sun is shewn in the Heavens and as this may actually be seen with the naked eye it is generally termed the True Sun.

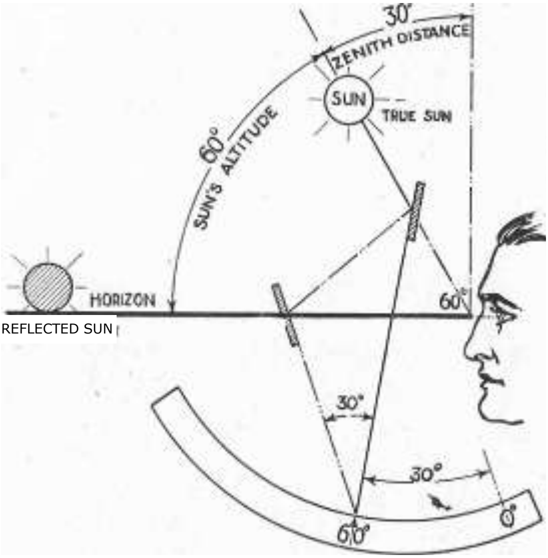


Fig. 10. What Sights give the Observer,

If an Observer places his eye at the end of the Sextant telescope, and looks directly along the thick black line towards the Horizon, when he has moved the Index Bar 30° from Zero (0° on the Sextant) ; owing to the Sextant being an instrument of double reflection, he has really made the angle at his eye 60°, and as this is the Altitude of the Sun, he should just see the reflected Sun on the Horizon.

It should be pointed out that the Direct Image as seen in a Sextant is that seen through the unsilvered part of the Horizon Glass (or over the top of a glass which has no unsilvered part). In this case in Figure 10, the Direct Image is the Sea Horizon, whilst the Reflected Image—in this case it is the Sun—is that seen by double reflection from the Index and Horizon Glasses.

The only other important point for the Mariner is the imaginary one directly overhead to an Observer, called his Zenith—which is naturally 90° from any point of the Horizon. It can be realised therefore that the Altitude and the distance from the Body to the Zenith (called the Zenith Distance) are Complements, or in other words, the Altitude and Zenith Distance being measured on either side of the Body from the Horizon(0°) to the Zenith (90°) must between them always equal 90°. Thus in Figure 10 the Sun's Altitude being 60° (actually measured) gives the Zenith Distance (not measured but theoretical only) as 30°.

It was stated above that the Observed Altitude was the angle of the Centre of the Body above the Sea Horizon, but as the Sun, Moon, and Planets each have a perceptible disc their centres cannot be observed accurately.

The part of the circumference which actually we observe is one of the edges called the Limb ; thus in Figure 10 an observation is being taken of the Sun's **Lower** Limb ; we say we take an " Observed Altitude of the Sun's Lower Limb," sometimes abbreviated to " Obs. Alt. Sun's L.L." but more usually simply by the symbol $\underline{0}$ —meaning that in taking our Altitude we made the Sun's Lower Limb touch the S ea Horizon

On occasions the Sun's Upper Limb is observed whence the symbol 0 would be used. It is important to record this information in the Sights Notebook because when the time comes to make the various corrections to the Observed Altitude mentioned above, it depends on which limb of the Sun has been observed, whether the correction for **Semi Diameter (i.e.,** half the Sun's Diameter) is added or subtracted.

Note that the **Moon's enlightened Limb** is always observed. If for example the Moon's Upper Limb has been observed, this would be recorded in the Sight Notebook as $\overline{(}$ and in the case of the Lower Limb $\underline{(}$.

Here again a correction for Semi Diameter is applied according to which of the Moon's Limbs has been observed.

A Planet's Semi Diameter is so small that it may be neglected in Sea work, so when taking an observation of a **Planet,** to obviate any correction for Semi Diameter the **Sea Horizon should be made to cut through the centre of the Planet.**

Owing to the Earth's daily revolution all the heavenly bodies appear to rise in the East and slowly increase in Altitude until a certain point is reached ; they then decrease in Altitude until they set in the West. This fundamental movement is going on all the time though clouds may obscure the Bodies and daylight of course makes it impossible to see the Stars at this time.

If an observer faces True North or South at Sea, then an imaginary line running from the True North Pole to the True South Pole passing directly overhead through his Zenith is called a Meridian—in this case being known as the **Observer's** Meridian. Now this imaginary line marks the point when the Altitude of a heavenly body ceases to rise and commences to fall, or in other words, when it ceases to bear Easterly at all but bears exactly North or South of an Observer before starting to bear Westerly.

Now when a heavenly body reaches the Observer's meridian, it is said to Culminate, and thus at Culmination attains its greatest altitude. The time of Culmination is called the time of **Transit,** and thus the Nautical Almanac will tabulate the" Times of Transit of heavenly bodies" —meaning the time of the passage of the Body over the Observer's Meridian. More generally however, seamen refer to this time as the time of a Body's **Meridian Passage.** These expressions all have the same meaning, of course.

It should be remarked that the Altitude of a Body depends on the position of that Body and the position of the Observer in relation to it. All Bodies have an Altitude of 0^0 at rising and setting, but their Altitude at the time of Meridian Passage depends on whether the Body will pass almost directly overhead of an Observer or a long way North or South of him.

The Observer cannot influence this Altitude in any way and having decided on a suitable body to observe he must just measure the Altitude as he finds it.

From the foregoing it will be seen that there are two distinct types of "Sights"—one taken when the Body is moving—rising or falling— called simply an **Observed Altitude ;** and the other taken when the Body is stationary—called a **Meridian Altitude ;** and we have seen that this occurs whenever a heavenly body crosses the Observer's Meridian— hence the name.

The speed of the Body's movement and the length of time it is stationary on the Meridian depends entirely on the relative positions of the Observer and the Body. For example, when the Declination (i.e., Celestial Latitude) of the Body is about the same as the Observer's Latitude, the Sun has a long way to climb, because he will be nearly overhead with a Meridian Altitude of about 90^0 at Transit. He will thus appear to rise and fall rapidly and will remain stationary at transit for a matter of seconds only.

On the other hand, if the Observer is in, say, 60^0 North Latitude, whilst the Sun is on the Equator, the Meridian Altitude at transit will be about 30° only, so the rise and fall will appear to be very slow and the Sun will appear to " stand still " at transit for several moments.

As remarked above the Navigator is fortunate in having an endless stream of heavenly bodies from which to obtain Observed Altitudes and Meridian Altitudes by which to find his **Observed Position** at sea.

CHAPTER III.

HOW TO TAKE SIGHTS

In Chapter II. we found that fundamentally there are two types of sights : (1) Observed Altitudes taken at any time the body is visible. (2) Meridian Altitudes taken only at the time of transit of the body.

It is really easier to observe the latter, but they occur only occasionally, (once a day as far as the Sun is concerned). As the novice will probably wish to commence to learn how to use the Sextant at any time the Sun is visible ; the way to take ordinary Altitudes will be described first.

(1) Observed Altitudes taken at any time the body is visible *(a)*

To observe an Altitude of the Sun

The **Beginner** should practice continually bringing the Sun down to the Horizon and at first the telescope may be dispensed with—just look through the telescope collar, thus getting a much bigger field.

A position in the vessel must be chosen where the greatest steadiness will be obtained--generally it is better to be nearer the centre of the vessel as there will be less motion there. The position should also give the greatest comfort and protection to the observer.

First remove the Sextant carefully from its case with the left hand, grasp the handle with the right hand and hold it vertically in the right hand as in Figure 11. Clamp the Index Bar approximately at Zero (or 0') on the Arc.

Before taking any observations of the Sun the **Shades must be used to eliminate glare.** When observing the Sun it is always necessary to use the **Index Shades,** otherwise the Sun's rays, on being reflected back to the Observer's eye, produce such a glare that it is impossible to see the Sun at all. These Shades may be used singly or in combination; and when the Sun is very brilliant, two shades are often necessary. Generally in it best to turn in the lightest coloured Index Shade to commence with.

When the Sextant is pointed directly at the Sun, it is necessary to cover the **Horizon Glass** by **a Shade,** and it is generally best to turn up the lightest coloured shade to start with and replace this by a more dense glass if necessary.

Now, holding the Sextant vertically, point the telescope collar and Horizon Glass **directly at the Sun.** It will be obvious at once whether the correct shades have been used by the Sun's face being clearly defined as a bright coloured circle neither too strong nor too weak. If, however, the glare makes it impossible to see the Sun properly, then turn up " stronger " Shades and again direct the Sextant at the Sun.

We now see the **actual** or True Sun through the unsilvered half of the Horizon Glass, whilst coincident with it (or superimposed upon it)—

Fig. I I. The Sextant held in the normal position for taking sights.

Note the :Index Shade in use, no Horizon Shades being necessary in this particular instance.

but not visible because the Sextant is in Adjustment—is the Sun's **Image** reflected to the eye from the Index Glass via the silvered portion of the Horizon Glass.

The Clamping Screw should now be loosened sufficiently (or the Quick Release Clamp pressed, **and kept pressed),** to allow the Index Bar to slide easily along the Arc ; and it is important to do this correctly. In the Clamping Screw Sextant the Index Bar should be held firmly between the left thumb (nearest the body) and the second (longest) finger resting on the tangent screw. The first or Index finger should be laid out in a natural manner ahead of the Index Bar touching the bottom of the Limb so that as the Index Bar is pushed along the Arc, the Index Finger is "pushed ahead" thus retarding the Index Bar and giving to it a uniform and constant movement.

In the Automatic Clamping Sextant the Quick Release Clamp must be released from the thread by pushing two projecting parts of the Quick Release together. Whilst most observers use the left thumb and index finger to do this, with practice this type of Sextant can be manipulated exactly as described above for the Clamping Screw model.

Now keeping the eye fixed on the Sun, by applying gentle pressure to the Index Bar the True and Reflected Suns will separate rapidly (this of course does not matter, as all we are concerned about is to bring the Sun's Image down to the Horizon).

By this time we shall have to give up looking at the True Sun direct and gradually lower our line of sight (and, therefore, the angle of the whole telescope). We now follow the Sun's Image (seen in the reflected part of the Horizon Mirror), which will descend at the same speed that the Observer pushes the Index Bar along the Arc, the pressure being applied **slowly and smoothly** as described above.

When the Image is at or near the Sea Horizon, which can be seen through the plain part of the Horizon Glass the angle on the Sextant will be, of course, the approximate Observed Altitude. The Index Bar should now be tightened by the Clamping Screw or by withdrawing the finger and thumb pressure from the Quick Release Clamp (when it will automatically become Clamped).

Unless the Altitude is low, there will probably be little glare on the Horizon so the Horizon Shades may be dispensed with and folded back out of the way so the Horizon may be seen more easily. These Horizon Shades are most useful at low altitudes after sunrise or before sunset, if the Sun's rays are strong, and should be employed until all water-line glare is eliminated without unduly dimming the Horizon line.

When the Sun has been reflected down to the Horizon, each of the Index Shades should be folded in in turn so as to find which is most suitable. The whole object being, of course, to get the Sun's limb defined clearly but without glare.

This operation should be repeated frequently until it can be done quickly and accurately.

Experienced Navigators, however, generally dispense with the above method and simply point the Sextant **at the Horizon as directly as possible underneath the Sun.** Then having turned in, say, the least dense Index Shade, move the Index Bar away slowly until the Sun is seen in the silvered (reflected) part of the Horizon Glass near the Horizon (which is seen in the plain glass part of the Horizon Mirror).

At first you may have to move the Index Bar backwards and forwards several times, until you see the Sun, as probably you will find at first that you have not got the instrument pointed directly underneath the Sun. (It generally saves time to sweep continuously round the Horizon a little to the right and left of the estimated descending path of the Sun to avoid missing it).

Now as we are preparing to take a Sight properly, we must insert the Telescope—the ordinary erect or Star Telescope should be used as illustrated in Figure 11. The most important point to be careful about is not to burr the thread when screwing the Telescope into the Collar ; and it will generally be found most satisfactory when doing this to hold the Sextant with the arc vertically so that the weight of the telescope is downwards and will thus help the thread to engage correctly.

Modern Sextant Telescopes usually have interrupted threads (shewn in Figure 3), which are fixed in the collar simply by a half turn of the telescope in the thread—a very convenient arrangement. There is generally a small portion of the rim of the telescope cut away to form a flat surface to act as a guide to insert the interrupted thread in the correct position.

Having fixed the Telescope—which should be left in the Sextant thereafter and put away in the Case in this position—the eye piece should be pulled out until the Telescope is focussed to suit the eye of the Observer. It is best to focus it on a distant vessel, land or the furthest point away in the ship.

When using the Telescope the eye not being used for sighting the object is generally closed (although some Observers always keep both eyes open, see Figure 11). If the blank tube is being used however, both eyes should be used (this is really preferable anyway—two eyes being better than one when they are both being used under the same magnitude).

Adjust the Index Shades to tone the Sun's reflection down so it may be seen clearly without glare, and turn up a Horizon Shade if there is a glare on the Horizon. In Figure 11 the Observer is using one Index Shade but no Horizon Shade—generally the latter are unnecessary when the Sun is high in the heavens.

Now direct the Sextant straight at the Horizon beneath the Sun, and move the Index Bar along the arc until you see the Sun just near the Horizon as already described. Clamp the Index Bar.

As explained in Chapter II., it is customary to observe the Sun's Lower Limb on the Horizon. Having got the approximate Altitude clamped on the Sextant as described above, **exact contact** is made by means of the "slow motion" screw (called the Tangent or Micrometer Tangent Screw). When the bottom of the Sun just touches the Horizon it is termed "kissing" the Horizon.

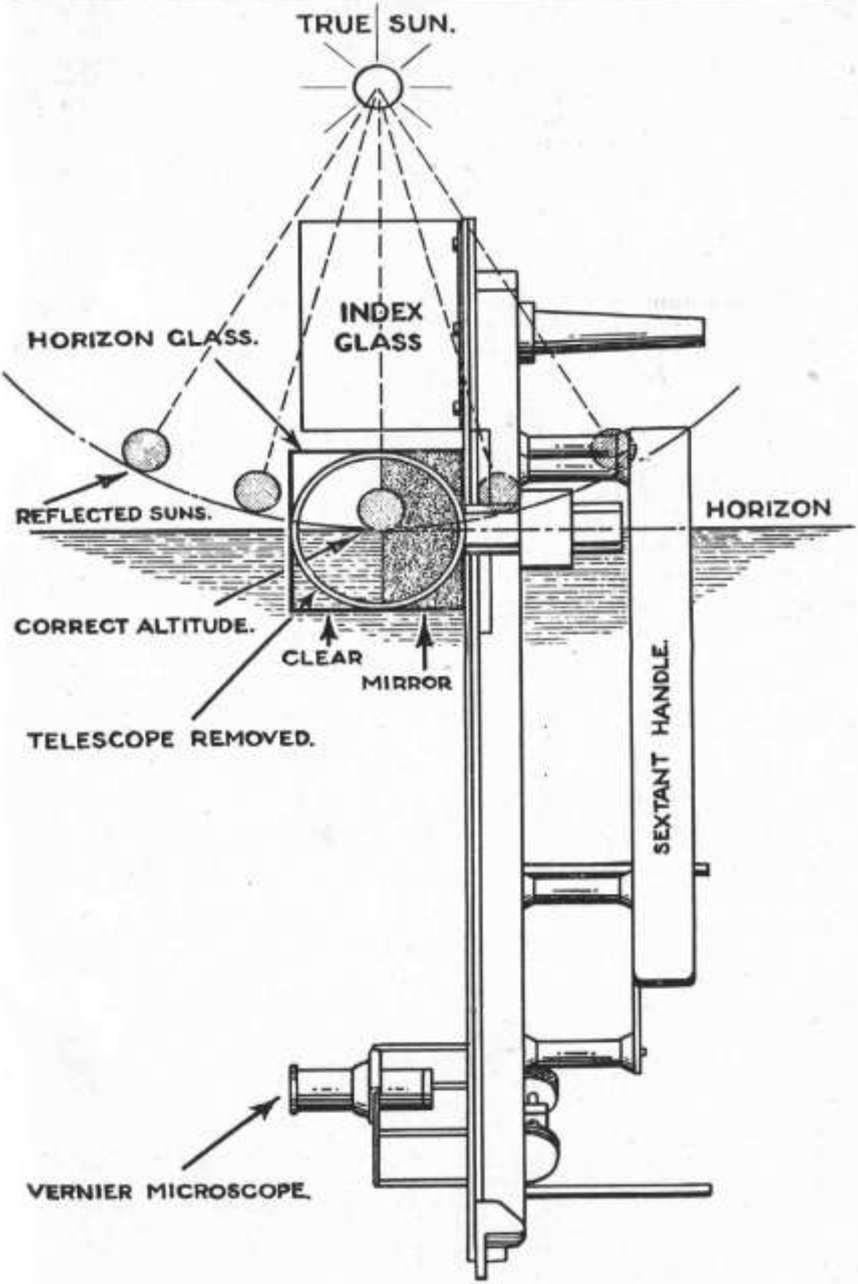


Fig. 12. Observing the Altitude of the Sun.
The reflected Sun as seen in the Horizon Glass.

We know that when taking an Observed Altitude the Body is rising or falling, so it can only " kiss " the Horizon momentarily. In fact, the Observer really has to turn his Tangent Screw at the same speed (but in the opposite direction) as the movement of the Body ; so as to make certain that the Sun's Lower Limb is **just touching** the Horizon when the observation is made and recorded.

It is important also that the reflected Sun be brought down **exactly** underneath the actual Sun and the angle measured vertically, **otherwise a wrong reading will be made.**

Only constant practice will give completely reliable results, but a careful study of Figures 11 and 12 should be of great assistance. Figure 11 shews how the Sextant should be held for making the final adjustments. The thumb and fingers of the left hand turning the Tangent Screw wheel slowly to counteract the Sun's movement.

Figure 12 shews really what the Observer sees whilst holding the Sextant as in Figure 11. The Sextant is illustrated " sideways-on " straight ahead of the Observer and the large circle shews the Line of Sight through the Telescope (which is removed), and shews what the Observer sees in the Horizon Glass. The True Sun is overhead and has been reflected down to the Horizon—just kissing it as shewn, one half visible on either side of the line joining the plain and silvered glass portions of the Horizon Glass (labelled " Clear" and Mirror" in Figure 12).

Now the Observer will see that the Sun's Lower Limb **could** be made to " kiss " the Horizon at a number of places so the Sextant must be rotated slightly to the right and left (pivoted on the handle by the wrist round the Index Glass as centre—pendulum fashion), so that the reflected Sun is made to "lift off the horizon" each side, describing the lower part of a circle exactly as in Figure 12. The altitude should be taken at the lowest part of the swing when the Sun just skims the Horizon, and when this happens the plane of the Sextant **must** be vertical and the point :be directly under the Sun. This action also assists the eye to make sure that the Sun exactly kisses the Horizon as shewn in Figure 12, where the " correct altitude" is indicated.

It should be observed that the Tangent Screw of the Vernier Sextant does not act until the Index Bar is fixed by the Clamping Screw at the back of the lower part of the Index Bar. Care should be taken not to force the Tangent Screw when it reaches either extremity of its thread.

When the Index Bar is to be moved a considerable distance along the arc the Clamping Screw must first be loosened; but when the Index is brought approximately to the division required, the Clamping Screw should be lightly tightened and **exact** contact made with the Index by gradual movement of the Tangent Screw.

Having made a 'good contact" by means of the Tangent Screw (whilst at the same time rotating the Sextant gently pendulum fashion so that the Observer knows he has taken the correct vertical angle) ; at the **Instant** of this "good contact " the Observer must call out " Stop" to another Observer stationed at the Chronometer who takes the exact " Time " when " Stop" was called.

A careful study of Figure 13 *(a, b* and *c)* will be helpful in indicating when the reflected Sun is just kissing the Horizon, as seen in the Horizon Glass.

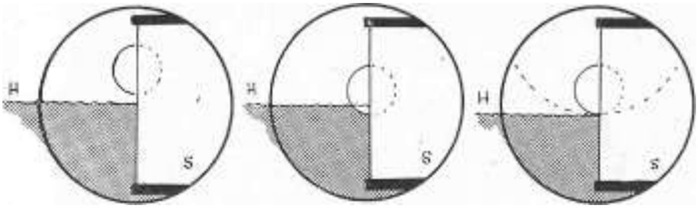


Fig. 13. Observing the Sun's Lower Limb.
(a) The reflected Sun too high. *(b)* The reflected Sun too low.
(e) The reflected Sun correctly kissing the horizon.

Needless to say, of course, the Observer must not move the Tangent Screw again after the " Stop," but must read the Altitude on the Sextant as at this instant (as described in Chapter IV.) to be recorded together with the " time " in the Sight Notebook.

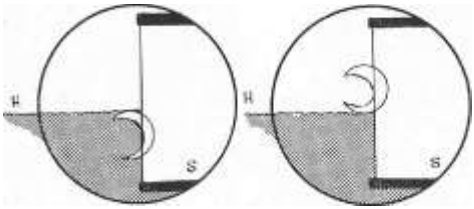
Should the observer feel that the contact was not really very good, he should discard this faulty observation and take another and better observation, if possible.

Remember practice makes perfect.

(b) To Observe an Altitude of the Moon

Primarily, of course, the Horizon must be clearly defined or an Observation of the Moon cannot be taken ; therefore, the best time to take the Moon is during daylight, and at dawn or dusk ; though frequent opportunities occur to get observations during the night.

The observation should be made exactly as described for the Sun, except that the visible Limb of the Moon—called the enlightened Limb is always observed. This may be, of course, either the Lower or the Upper Limb (see Figure 14a and 14b), but this does not matter as long as a note is made in the Sight Notebook of which Limb has been observed.



Fig, 14. Observing the Moon.
(a) The Moon's Upper Limb. *(b)* The Moon's Lower Limb.

(c) To observe an Altitude of a Star

Stars should always be observed during morning and evening twilight, when the Horizon is clearly defined. Although occasionally during the night the Horizon can be so clearly seen that Star sights may be taken, it is rarely possible to be **certain** you can define the Horizon exactly—hence for all practical purposes Stars may be said always to be " taken" at twilight.

The procedure for observing Stars is somewhat different from that adopted for the Sun. When taking sights at dusk only the **brightest** Stars will be visible before the Horizon is " lost " (i.e., too dark to be clearly defined). At dawn, however, the Stars have probably been visible to the observer for some time, so one may have been able to take the approximate altitude sometime previous (although cloud may, of course, prevent this being done). In any case at dawn, provided there is clear visibility, the Navigator can more readily decide what Stars to use and see their position.

There are really two ways of observing Stars, (1) when you can see the star easily, **and there can be no mistake in its identity,** and (2) when the Star is invisible or ill defined.

No Sextant Mirror Shades are required for Star work, so they should be folded back out of the way.

(1) **When you can see the Star easily**

In this case the Sextant is clamped at Zero and the Star Telescope inserted and focussed. The Rising Piece should be screwed well down to the frame as this tends to increase the brightness of the image.

Now a bright Star **can** be brought down to the Horizon in the same way that has been described for the Sun ,and the three stages of doing this are shewn clearly in Figure 15 *(a*, *b* and *c)*.

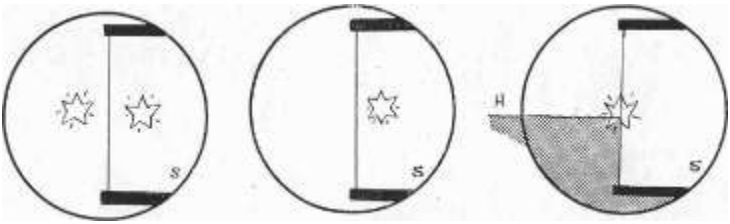


Fig. 15.

Observing a Star with a Sextant in the normal upright position.

(a) Looking directly at the Star. *(b)* The Star coming down.
(c) The Star exactly cutting the horizon.

It is much simpler and saves time however to **"take the Horizon up to the Star."** This is especially valuable with a high altitude Star or a second or third magnitude Star or an older Sextant with small mirrors.

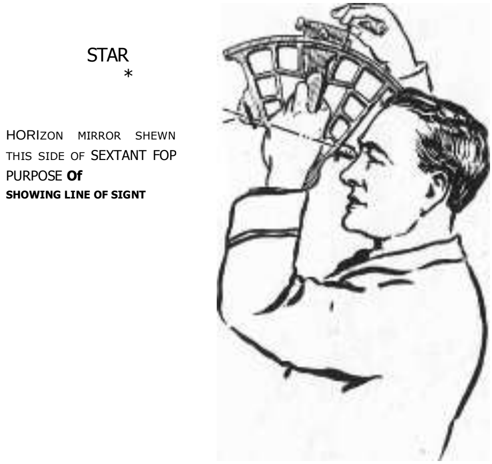


Fig. 16.

The Observer with the Sextant in the reversed position for Star observations.

The Sextant is held in the left hand (with Index Bar about Zero), simply reversed " arc up" (as in Figure 16), with the end of the arc resting on the forehead and the telescope pointed straight at the Star so that **the Star is actually seen in the plain portion of the horizon glass.** Now keeping the Star fixed in sight in the plain glass all the time, unclamp the Index Bar (not too much) with the right hand, and move the Index Bar away until you see the Horizon " arrive" near the Star. Clamp the Index Bar, reverse the Sextant to the normal position (as in Figure 11), and then make exact contact with the Horizon using the Tangent Screw as described for the Sun.

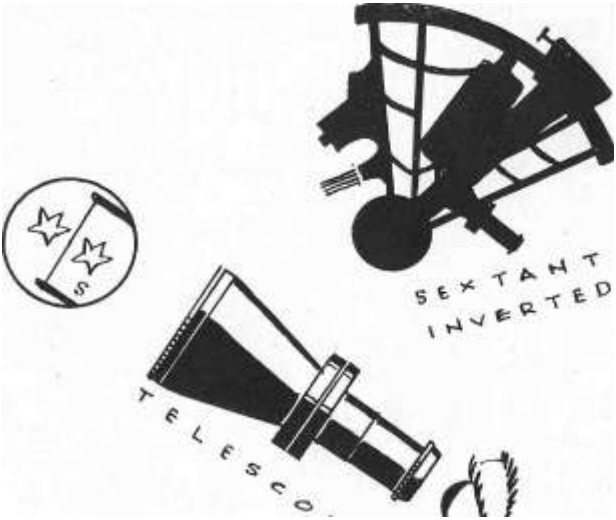
Although this may appear a little complicated in print, it is really very easy and will well repay any Navigator to use for all Star work. It is quick, and as the Star is kept in sight the whole time, **the mistake cannot be made of using the wrong star.** Also as the Horizon is a long continuous black line, it is very easy to see when it " arrives" up at the Star. This procedure **can** be adopted for the Sun but it is unnecessary.

Figure 17 shews the various stages in Observing a Star with the Sextant in the reversed position, which should make the procedure perfectly clear.

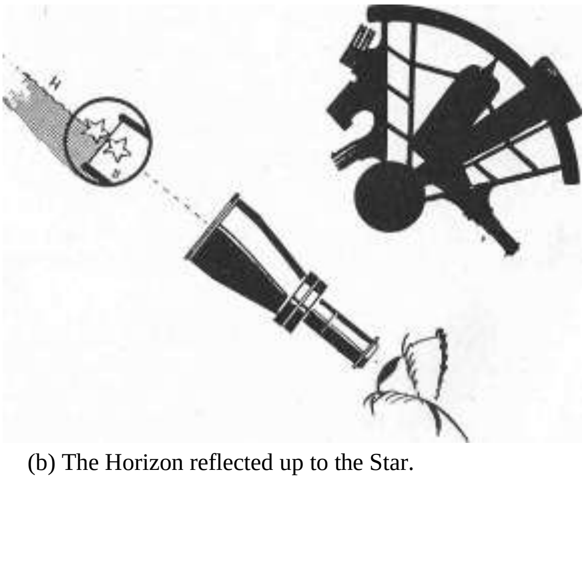
Figure 17(a) illustrates that when looking directly at the Star, one sees the True and Reflected Star exactly at Zero. Figure *17(b)* shews the next step when the Horizon has been reflected up to the Star, whilst Figure *17(c)* shews that on reversing the Sextant the right way up, the reflected Star is at once seen on the Horizon vertically under the Star's position in the heavens.

Fig. 17

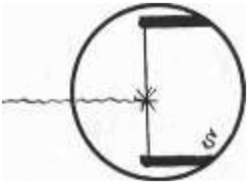
The stages of observing a Star with the Sextant in the reversed position



(a) The Sextant inverted with Index at Zero and Telescope directed towards the Star.



(b) The Horizon reflected up to the Star.



(c) The Sextant reversed and directed at the Horizon in the norma way.

A Star, of course, has no appreciable " Limb," so the centre of the Star itself is brought to the Horizon and made to cut as accurately as possible.

(2) When the Star is invisible or ill defined

When Star observations are required at dusk, one may not be able to recognise the smaller Stars before darkness falls, and renders the Horizon too ill defined for accuracy. In this case the **approximate** altitude of the Star (or Stars) should be calculated in advance and the Sextant set to this angle.

Although the average Navigator prefers to glance around, choose the brightest Stars, (or the most suitable ones), and immediately ascertain their altitudes (with times, of course) ; if there is an urgent need for obtaining good observations it is a very wise precaution to calculate the approximate altitudes in advance—just **in case.**

If the instrument is now directed towards the point of the Horizon directly underneath the Star then, by " sweeping round" a little to the right and left the Star should be seen near the Horizon, when exact contact may be made with the Tangent Screw in the usual way.

The point of the Horizon at which to look may be already known or may be found from a Star Globe, Atlas or Map, or from Azimuth Tables.

(d) To observe an Altitude of a Planet

Observations of Planets are dealt with in exactly the same way as With Stars, except that as the Planets Venus and Jupiter are so bright, it is generally unnecessary to calculate their altitude in advance. The Horizon should be " reflected up " to a Planet exactly as described above for a Star. To obviate any correction for Semi-Diameter, the Horizon should be made to cut through the centre of the Planet.

If it is desired to take the altitude of Venus in the daytime, then the approximate altitude **must** be calculated in advance and clamped on the Sextant. Provided there is little or no cloud (and and Body is not too close to the Sun for it to be blotted out), if the Horizon is " swept" at the correct time in the direction of its bearing, Venus will be picked up as a small bright white speck in a blue background. In bright sunlight by standing in the shadow of the deckhouse or a sail, it will be found considerably easier to pick up the object.

Jupiter may sometimes be observed in the daytime, but this depends largely on the strength of the Star Telescope.

(2) Meridian Altitudes taken only at the times of Transit of the Body

(a) To observe the Meridian Altitude of the Sun

As far as the **Sun** is concerned, we know that it appears to climb continuously from the time of Sunrise until Noon during the A.M. (or Ante-Meridian) hours ; after which time it appears to " dip" and continues to fall to the westward until Sunset. **Noon** is the instant that the Sun reaches its highest altitude when it is on the Observer's Meridian (i.e., the instant of time when A.M. changes to P.M.)

This highest altitude which occurs when it is on the Observer's Meridian in called the **Meridian Altitude** of the Sun and occurs thus only once daily.

It is customary some little time before noon, generally at "one bell" (i.e., 15 minutes to 12, if keeping Apparent Time), to bring the lower limb of the Sun in contact with the Horizon. At this time the Sun should bear a little to the Eastward of True South or True North (depending of course on whether the Observer is South or North of the Sun).

The Sun's slow upward progress can now be watched, following it by slight alterations of the Tangent Screw so that the Sun's Lower Limb is kept constantly kissing the Horizon. Every few moments we may note the increased reading on the Sextant.

Eventually the Sun appears to stop rising, and there will be no visible change in the altitude for a minute or two (as explained in Chapter II.) Now when the Sun appears to stop rising a little before noon (this is Sun Time—called Apparent Time, remember), the main point to remember is **on no account to reverse the motion of the Tangent Screw,** but to watch the Sun intently whilst it remains stationary—until the Sun suddenly " dips "—that is, when it commences to fall and laps over the line of the Sea Horizon and the altitude starts to decrease.

The instant that the Sun appears to " dip " is accepted as "noon and the ship's clock should show 12 o'clock (if it is set to Apparent Time). The Captain or Navigator will probably remark "she's away—make 8 bells," and read the Sextant angle which will be the **Meridian Altitude.**

It should be noted particularly that as the Altitude is required when the Sun is perpendicular to the Observer's Meridian (and not to the east or west of it) ; the Meridian Altitude must be observed by rotating the Sextant in the usual way as illustrated in Fig. 12.

It will be observed, of course, that the Sun is on the Meridian at 12 o'clock **Apparent** Time—which, for convenience sake, is the time kept by the average vessel at sea in the Merchant Navy.

Many small vessels however, keep the ship's clock at Greenwich Mean Time (G.M.T.) or British Summer Time (B.S.T.), whilst vessels of all sizes in the Royal Navy and in convoy probably keep Zone Time (Z.T.) In such cases, of course, the Sun would not be "on the Meridian" at 12 o'clock (Ship Time) ; but the time by the Ship's clock when it would be 12 o'clock noon (Apparent Time) should be calculated from the Chronometer.

The Observer may thus find the Apparent Time is e.g., lb. 10m. later than the British Summer Time being kept by the ship's clock, so that the Meridian Altitude would, therefore, be taken at 1 h. 10m. P.M. **Ship Time** and observations commenced at the usual time prior to this.

(b) **To observe the Meridian Altitude of the Moon, Planets and Stars**

As far as the Moon, Planets and Stars are concerned, the Meridian Altitude should be observed exactly as described above, following the procedure regarding the use of the Sextant described earlier in the Chapter. The times when these other heavenly bodies will be on the Observer's Meridian, of course, vary, and must be ascertained in advance from the Nautical Almanac.

It may be observed that (except in the case of fast vessels sailing on Northerly of Southerly courses), **time** does not enter into the Meridian Altitude problem except to tell **roughly** when to observe the body. It is the maximum **altitude** that matters, not the **time** of this occurrence in the average vessel. With fast vessels moving rapidly towards or away from the Sun (i.e., on Northerly or Southerly courses), the time of noon should be calculated however, then the altitude observed at this time. This should be considered to be the Meridian Altitude.

In every case when an object is on the Meridian, it **must bear South (True) or North (True),** depending, of course, on whether the Declination of the body shews it to lie to the North or South of the Observer's Latitude. Therefore, when desiring to pick up an unseen Planet or Star to ascertain its Meridian Altitude, once the approximate altitude has been clamped on the Sextant this should be directed towards the True North or True South points at the Horizon.

When wishing to observe a second or third magnitude Star at twilight for the Meridian Altitude, it is generally necessary to work out the approximate Altitude in advance in this way.

To Sum up

The following are the requirements of the Navigator (in their correct order) when taking the observation for Meridian Altitude of the Sun.

First ascertain the Height of Eye of the Observer for the position to be used ; and test for Index Error by the Sea Horizon (fully described in Chapter V.)

Then bring the Sun's Lower Limb to the Horizon and read the Altitude. By moving the Tangent Screw slowly, keep the Sun exactly kissing the Horizon, and keep recording the Altitude to make sure it is still increasing. When the Sun dips, make a note of the greatest altitude observed as the Meridian Altitude ; and also whether you are looking Northwards or Southwards to the Sun. If, for example, you are looking southwards and the Altitude at noon was 51° 30', this should be recorded as 51 30'S. Obs. Mer. Altitude (i.e., *0* 51' 30'S. **in** the Sight Notebook).

CHAPTER IV.

HOW TO READ THE SEXTANT

In every case after having obtained the Observed Altitude of the Sun or other body, care must be taken not to move the Tangent Screw again until the Sextant has been read. Having written down the Altitude (or called this out for your Time-keeper at the Chronometer to record) then **always check again most carefully to make sure that you have not misread the Sextant.** It is very easy to do this and many mistakes were made in reading the older Vernier Sextants, a source of error that has been almost eliminated by the adoption of the Micrometer Tangent Screw.

The Micrometer Tangent Screw Sextant

The Micrometer Tangent Screw Sextant is so easy to read that little explanation is required ; it has, of course, no Vernier (except a simple one for seconds) ; but a large Micrometer head instead.

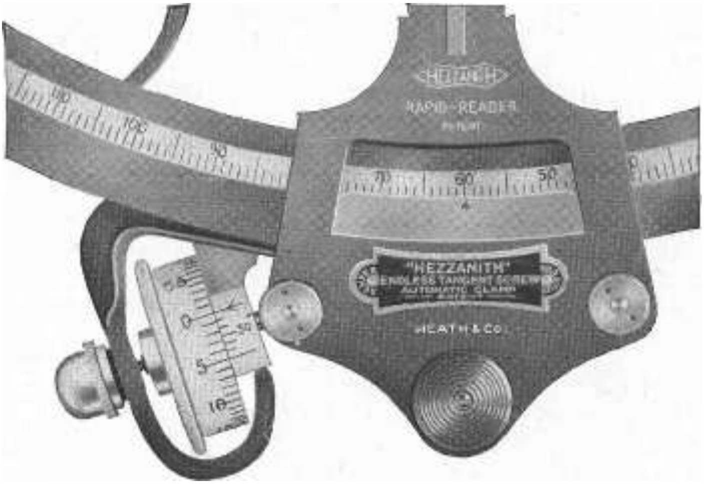


Fig. 18. The Hezzanith Micrometer Tangent Screw--" Rapid Reader:'

Figure 18 shews a "close up" of a " Hezzanith " Sextant Arc and Micrometer Head, whilst Figure 18a shews the underneath view. As can be seen the arc has accurately cut teeth which engage with a worm (also accurately cut), with such a pitch and radius that one turn of the Micrometer Screw corresponds with an angle of one degree on the arc.

The Arc will be seen to be graduated to whole degrees in a most legible manner, whilst the Tangent Screw is fitted with a large head which is divided into 60 parts and reads, therefore, **to one minute of arc.**

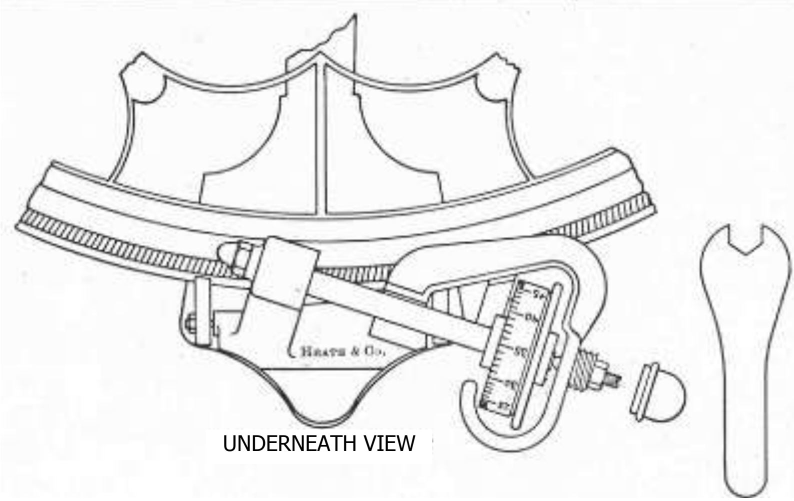


Fig. I 8a. The Hezzanith Micrometer Tangent Screw--Underneath view. Note the bearing screw, clamp nut, cap cover and spanner for simple adjustment

Although the seaman rarely requires to read his Sextant nearer than to the nearest half minute, a simple Vernier is provided against the Micrometer Head so that the minutes may be sub-divided to 10 second (10") intervals if required.

The degrees are read where the Index (indicated by the arrow) cuts the Arc—in this case (Fig. 18) exactly 60°. The minutes are read on the large Micrometer wheel where the small Vernier arrow cuts—in this case 0°—and the tens of seconds are read where one of the lines on the small white Vernier (to the right of the Micrometer) coincide with one of the minute lines on the Micrometer head.

The angle of the Sextant in Figure 0 is, therefore, 60' 0' 0"— simplicity of reading that it would be difficult to improve upon.

If Figure 3 is examined closely the Index will be seen to cut a little past 21° on the arc, and the small arrow on the Vernier is seen to cut the Micrometer wheel between 7 and 8 minutes. The nearest to coinciding lines will be found to be at the fifth cut on the little Vernier panel. As each of these cuts is 10", the Sextant in Figure 3 is therefore reading 21° 7' 50s.

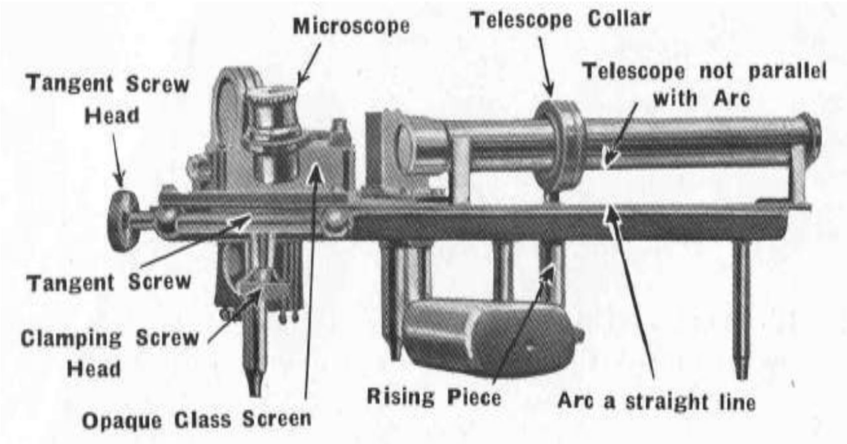
Owing to the other factors involved in taking sights, such as the vagaries of the Horizon, the practical Navigator realises **it is needless to read the Sextant quite so accurately ; so the custom at sea in the Merchant** Navy **is to read the Sextant to the nearest half minute of arc.** In the above case (Figure 3) the reading would be said to be 21° 8'.

In the Micrometer Sextant the reading may be made during daylight, almost at arm's length ; but for the dark hours a small electric light is provided as illustrated in Figure 3. The light is operated (by the fore-finger of the hand grasping the handle) by a small push button at the top of the wooden handle. On the finger pressure being released the light

•

from a small battery—generally concealed in the handle—is at once extinguished. The bulb is mounted in a movable arm (shewn in a "neutral position" in Figure 3), and by swinging this up, the degrees on the Arc may be read, and by swinging it down over the Micrometer wheel, the minutes and tens of seconds may be read with ease.

The Clamping Screw—Vernier Sextant



Fig, 19.The Clamping Screw—Vernier Sextant.

This shews how to hold the Sextant to examine whether the teli-,scope is parallel to the Arc; which appears to the eye as a straight line. It is about 1' in error in the Figure and can be seen easily.

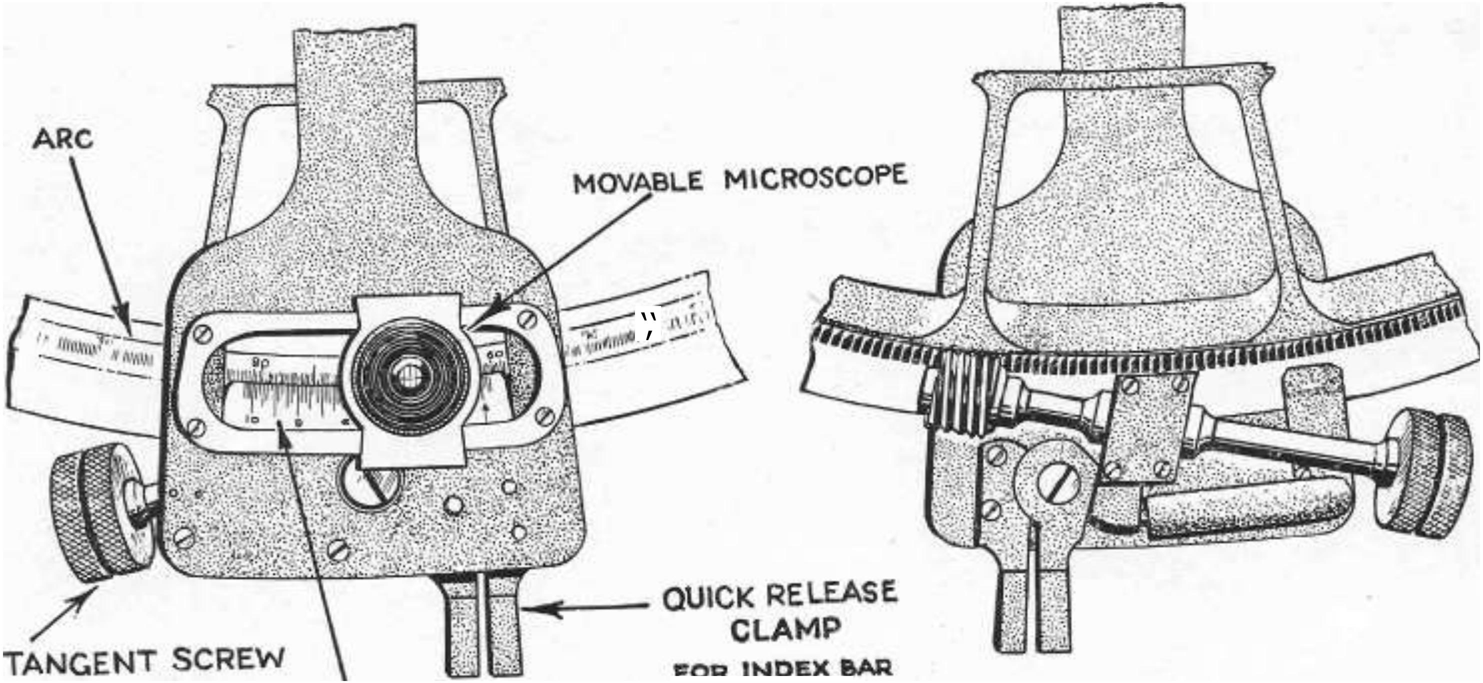
This is illustrated by Figure 19. As described in the Chapter on " How to take Sights," when the approximate angle is obtained the Clamping Screw is first screwed up finger tight by the milled head and then exact contact is made by the Tangent Screw. The Altitude on the Sextant may now be read in the daytime by the aid of the Microscope (as the cuts on the Arc are very small for the naked eye), shewn in Figure 19. At night the same procedure is adopted, but it is necessary to take the Sextant to a light so that this shines on the reading.

The Endless Tangent Screw Sextant

Figure 20 shews the" Husun," whilst Figure 21 shews the" Hezzanith" Endless Tangent Screw Sextants. In the Husun type, when the approximate angle has been obtained, by releasing the finger pressure on the " Quick Release Clamp," the Index Bar becomes automatically clamped to the Arc. As with the Micrometer head exact contact is then made by the Tangent Screw.

In Figure 21 the Quick Release Clamp is a button which is pressed to release the Index Bar and then this pressure is withdrawn, to clamp it automatically ; otherwise it is used exactly as the model illustrated in Figure 20.

The valuable feature of the Endless Tangent Screw is that, whereas the Tangent Screw in Figure 19 can only run to the limit of its thread before it has to be screwed back—thus losing valuable time—the Tangent



VERNIER

Fig. 20. `` Husun " Endless Tangent Screw—front and back view.

Note the Microscope which moves along a fixed stand. Note the "Quick Release" Clamp.

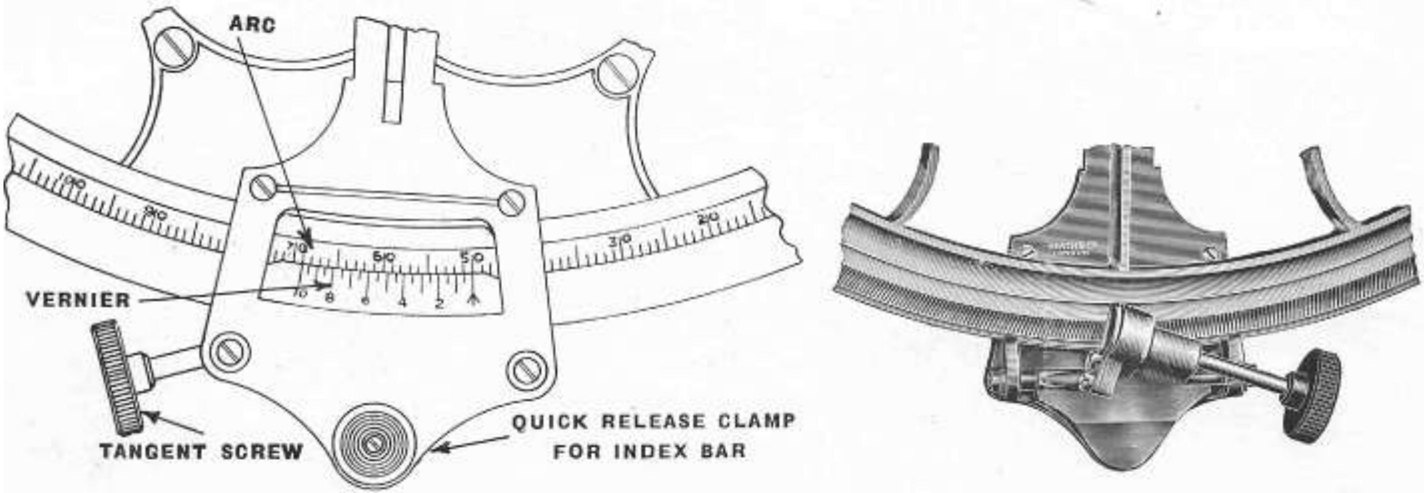


Fig. 21. Hezzanith Endless Tangent Screw.—front and back view.

Note that the 10' divisions on the Arc and the 10" divisions on the Vernier are not shewn.

Screw shewn in Figures 20 and 21 is **Endless. By turning the Tangent Screw with the fingers the Index Bar may be screwed along the entire length of the Arc.**

The Vernier Sextant

Figure 21 depicts a typical Vernier Sextant showing how the Vernier is arranged in relation to the Arc and shews the position of the Index (or arrow) indicating Zero on the Vernier. In modern Sextants (which are usually cut to 10"), each cut on the Arc represents 10 minutes (10'), and each cut on the Vernier represents 10 seconds (10"). The usual Vernier markings are 2, 4, 6, 8, and 10 minutes, as shewn in Figure 21. Actually in the illustration only each degree is cut on the Arc, and each half minute on the Vernier the smaller cuttings being omitted for the sake of clarity. The Sextant in Figure 21, reads exactly to 50' with no extra minutes or seconds.

It should be pointed out right away that it is extremely difficult to describe accurately on paper how to read the Vernier Sextant. The best way is to handle the instrument and practice numbers of different readings. If you can get these checked by an experienced Navigator the rest will be simple.

THE VERNIER

A Vernier is simply a small scale (or auxiliary arc) attached to the lower part of the Index Bar (and sliding in contact with the Arc), by which more accurate readings may be obtained than by a direct reading of the Arc alone. In practice this means that the Vernier enables readings of less than 10' to be made. It is inclined slightly to the face of the instrument and moves, with the Index Bar, in close contact with the graduated Arc.

To form a Vernier for any instrument—take any number of divisions from the scale of the instrument as the length of the Vernier and divide this space into a number of equal parts, differing by 1 (one) from the divisions taken on the scale.

The degree of accuracy to which it is possible to read off by means of a Vernier is always equal to the length of a division on the scale of the instrument divided by the number of divisions on the Vernier.

The Arc of a Sextant is divided at every 10', and the degree of accuracy required of the Vernier is 10". To obtain this, usually 119 divisions are taken from the Arc and divided on the Vernier into 60 equal parts and by this means the Vernier is increased in size and made easier to read without loss of accuracy.

To read the Sextant "On the Arc"

In reading off, whether by day or night, be careful that the Microscope is properly focussed to the eye and is immediately over the line of coincidence ; also that the light does not fall on it sideways but comes in a direction straight down along the Index Bar to the reading.

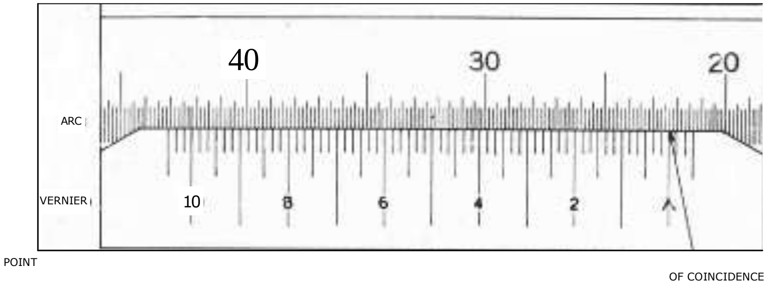


Fig. 22. How to read the Vernier Sextant 22 20' "on the Arc.

Consult Figure 22 and it will be seen that along the Arc only each 10 degrees is actually numbered, each 5 degrees being marked by a very tall line. **Each cut on the Arc represents 10',** and each third cut (that is a half a degree-30') is marked with a slightly taller line, whilst each degree-60'—is marked with an even taller line. (A careful study of Figure 22 should make this quite clear).

Now to read the Sextant, you observe where the **Index,** that is the Zero or Arrowhead, of the Vernier cuts the Arc. **Be careful to make sure you see where the Arrowhead cuts because there are usually two or three cuts to the right of Zero on the Vernier which might be used by mistake (see Figure 22).**

Figure 22, is a large scale drawing of the Vernier and a portion of the Arc above it, a small enlarged piece of which may be seen through the Microscope. It shews the Index to cut the Arc at the second division past 22°—that is 22° 20' exactly. If it cuts exactly at a whole division on the Arc, then as both ends of the Vernier cut exactly there is no further reading required on the Vernier.

Figure 23 shews the same reading on the Micrometer Sextant. The Index shews the reading to be past 22° on the Arc, and the small Vernier arrow cuts at 20' exactly on the Micrometer head so the Sextant reading is therefore 22" 20'.

Figure 24 shews that the arrowhead cuts very nearly at the 5th cut past the 36°. As the reading is always taken from the **lower** cut (the 4th cut in this case), then this would most certainly be 36° 40' **and some more.** A quick glance at the Arc shews that the Arrow cuts about three quarters of the way between the 4th and 5th cut (i.e., 40 and 50 minutes), so the experienced man would say, "it will be **about** 47 minutes."

It should be noted that the beginner would simply write this down as 36° 40'—that is all the Arc tells ; except that as the Arrow does not cut exactly at a whole division we have **also** to look at the Vernier for the "plus something" extra to the Arc reading.

In other words :—

The whole numbers, of ten minutes (10') are read on the Arc and the sub-divisions of these are read on the Vernier.

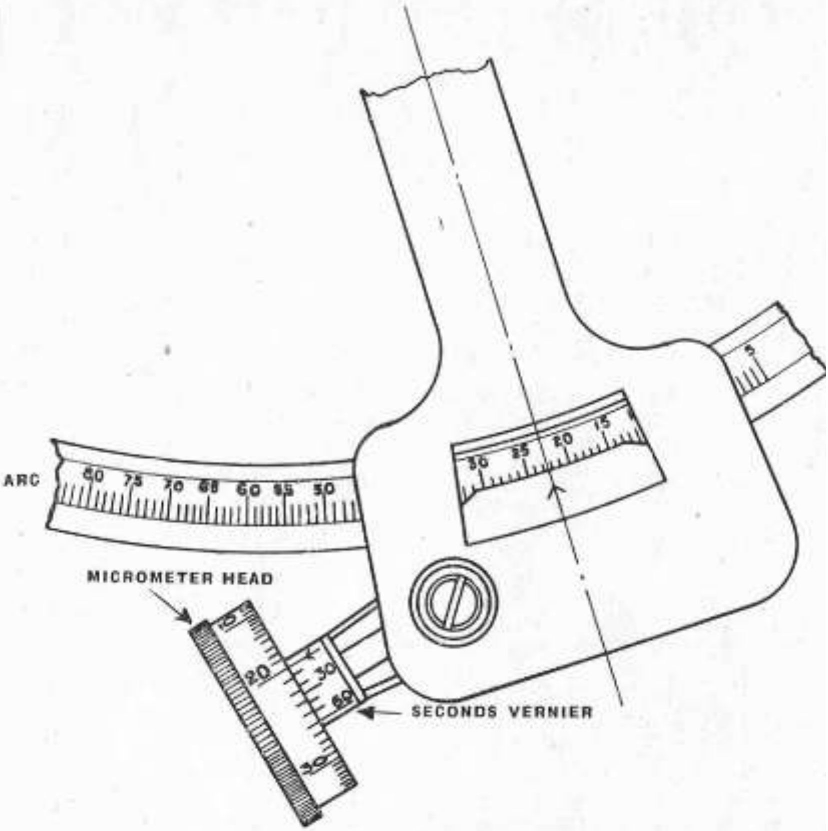


Fig. 23. How to read the Micrometer Sextant 22° 20 "on" the Arc.

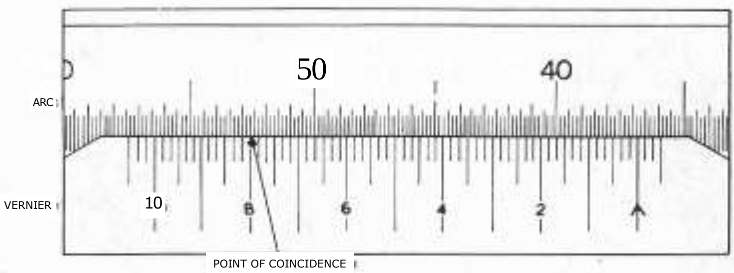


Fig. 24. How to read the Vernier Sextant 36° 48' " on " the Arc.

It does not matter what the Arc reading is—the Vernier reading is ascertained simply and added to it.

Now look through the Microscope at the Vernier and a beginner should start at 0° and move the Microscope along towards the left slowly until he finds where **some** Vernier mark co-incides with an Arc marking (that is, the lines meet vertically). The experienced man, however, knowing from the above that it is going to be **about** 7 more minutes on the Vernier (i.e., 40 on the Arc and therefore 7 more on the Vernier), looks immediately along to about 7 on the Vernier. (If you have already consulted Figure 24, you will have seen that 7 minutes being an odd number is marked only by a long stroke).

Figure 24 shews that a graduation on the Vernier and one on the Arc are co-incident however at 8 minutes, which is, of course, an extra 8 minutes to add to the reading on the Arc. A glance is now given to the Arc Proper again to check this reading of 36' 40'; this is found to be correct, so the 8 minutes is added mentally and the Altitude called out to the Timekeeper as "Thirty-six degrees, forty-eight minutes (36°48')."

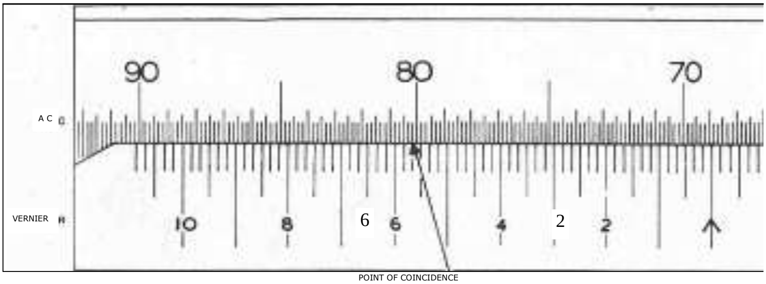


Fig. 25. How to read the Vernier Sextant 68° 55' 40" "on " the Arc.

In Figure 25 the Arrowhead will be seen to cut just past 60° 50' on the Arc. On the Vernier a closer inspection shews that the second cut to the right of 6 minutes (i.e., 5' 40" as each cut is 10"), is the nearest coincident cut of the Vernier with the Arc ; so this must be added to the reading on the Arc giving a final reading of 68° 55' 40". In practice this would be given as 68° 55i'.

It should be noted that about 3 cuts on the Vernier will appear almost to coincide with the Arc cuts and two observers will not always read the Sextant exactly to the same 10 seconds ; whereas all observers would agree to the nearest half-minute.

To read the Vernier Sextant " off " the Arc

When ascertaining the Index Error or taking a Vertical Angle of a shore object " on " and " off " the Arc, readings are required **"off the Arc"** (Proper), and the student must be able to ascertain these readings along the Arc of Excess without mistake.

When reading "off the Arc," however, the 1' and 10" intervals must be counted from the **left hand end** of the Vernier.

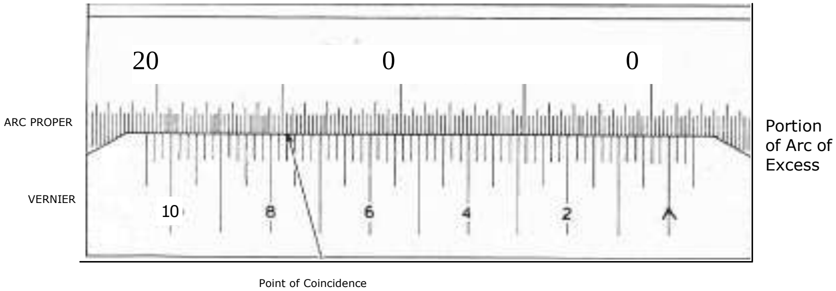
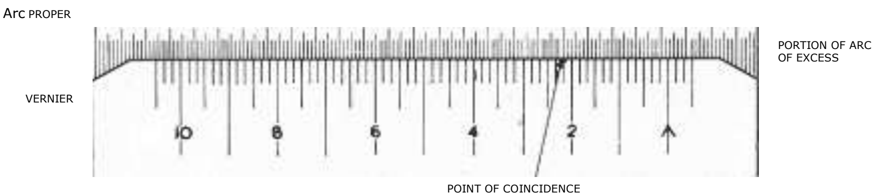


Fig. 26. How to read the Vernier Sextant 0° 42' 20" "off" the Arc.

The Arc reading is taken in the same way as described above, that is, where the Arrowhead cuts at the lower 10 minutes. In Figure 26 this would be 0° 40'; as, however, it cuts more to the right this shews the reading to be **more** than this and about a quarter of the way between 40' and 50', say about 43'.

Now, as we are reading "backwards," i,e,. to the right, the Vernier should be read backwards (to the right) from 10'. In this case coincidence will be found to be (counting downwards) at 2' 20" to the right of 10'— so that the whole reading will be 0° 42' 20" **off the Arc.**

An alternative way to read the Vernier off the Arc is to read it in the usual way and subtract the reading mentally from 10. In the case of Figure 26 the reading on the Vernier is 7' 40" so 10' — 7' 40" = 2' 20", therefore, this gives 42' 20"—the same result. **This alternative method is probably preferable because the Vernier is then always read the same way from the same end**



Fig, 27. How to read the Vernier Sextant 3° 17' 50" " off " thelArc,

As a further example, Figure 27 should be consulted and it will be-seen to read 3° 17' 50" off the Arc.

To read the Micrometer Sextant " off " the Arc

Suppose there is an angle " off the Arc" which on examination is found to be between 1^0 and 2' to the right of Zero (or 0°) and looks to be about Now the Micrometer wheel will be observed to be cut by the small arrow at about 91°, which is, of course, 501 from the other end of the wheel. The reading, therefore, is 1' 50' " off" the Arc (ignoring the 2_T-' as in practice).

Suppose, however, it was desired to read the Micrometer Sextant to the nearest 10", then the seconds Vernier must be examined horizontally in the same way that in the Vernier Sextant we saw where a Vernier cut and an Arc cut coincided vertically. Each cut will be 10" more to add to the reading where the Arrow cuts the wheel.

When using a Micrometer Tangent Screw Sextant " off" the Arc, therefore, you **must** take the wheel reading from 60' in order to get the minute and seconds reading.

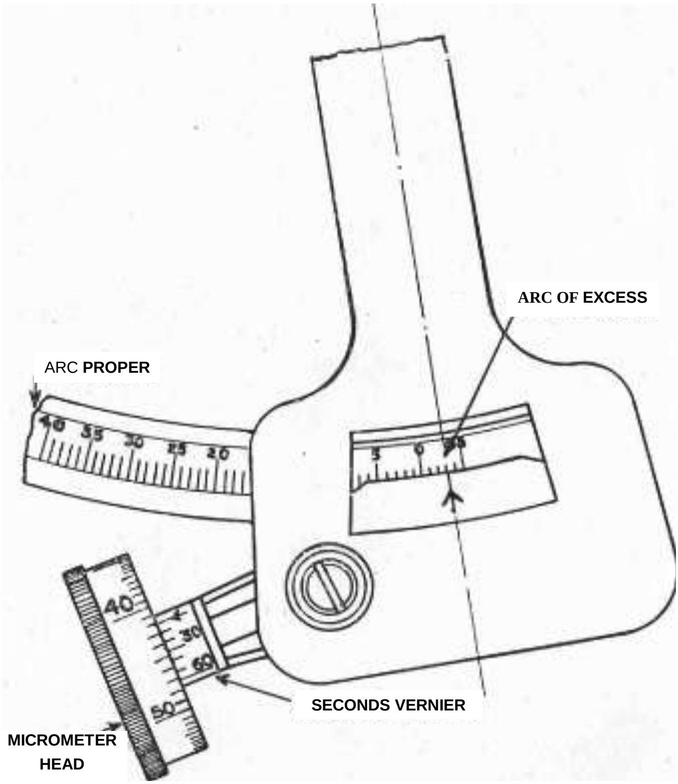


Fig. 28. How to read the Micrometer Sextant 3'17'50" "off " the Arc.

Figure 28 shews the Index to cut to the right of 3° " off " the Arc, whilst the Vernier arrow cuts the Micrometer head at just a fraction more than 42', so a glance down the seconds Vernier shews the first cut coincides horizontally with a marking on the wheel so this is 10" more, in other words 42' 10". Now as we are reading " backwards " this is 17' 50" from the other end of the wheel.

The reading of the Sextant is, therefore, **3' 17' 50" " off " the Arc.**

It is hoped that the above examples have made the method of reading the Sextant perfectly clear, but it may be stressed once again that **only practice will give confidence** to be able to read the Sextant quickly and accurately.

CHAPTER V.

ERRORS & ADJUSTMENTS OF THE SEXTANT.

Just as a Compass must be adjusted so must a Sextant, with this difference, that the Sextant is always adjusted by its owner.

Although the average Navigator takes good care of his Sextant, it is often not realised—probably because it has been his good companion in fair weather and foul—that its very construction makes it, after all, quite a delicate instrument. The successful Navigator is he who keeps his instrument in the best working order and the highest state of Adjustment.

The **Errors** of the Sextant are all concerned with the **Optical** parts of the instrument, a fact which will be further appreciated after Chapter IX. on the Principle of the Sextant has been read.

All parts of the Sextant should be well joined together—the Index Glass, Horizon Glass, and all Shades should be perfectly flat and smooth, whilst the sides of these glasses should be parallel to each other.

The Arc should be perfectly graduated and the Index Glass perfectly centred.

These Errors will be more readily understandable if they are divided into two parts which may be termed **Non-Adjustable Errors** (or those which the seaman is unable to correct for himself) and **Adjustable Errors** (which he should always have under his control and be able to correct by the Adjusting Screws provided).

Non-Adjustable Errors

The Errors, which are all really Errors of construction, that may be classed under this heading are :—

1. Graduation Error.
2. Centering Error.
3. Shade Error.

1. Graduation Error

The Arc graduations of the Sextant may be inaccurate through faulty cutting, but in any case this is an Error that would be impossible for a seaman to discover being really a fault in construction that cannot be remedied. It may be taken for granted that modern Sextants, which practically all have an N.P.L. or Maker's Certificate, are immune from this Error.

2. Centering Error

This is an Error of manufacture, and no means of ascertaining it or adjusting it are provided. It is caused by the centre of the Arc not coinciding with the centre of rotation of the Index Bar, in other words, when the Index Bar does not pivot at the centre of the Arc. Such an error varies at different positions of the Index Bar generally increasing with the angle measured, but it is a very small error if it exists at all, and has no appreciable effect on small angles. It would be tabulated on the N.P.L. or Maker's Certificate.

3. Shade Error

This Error is caused if the two faces of the Shade Glass are not ground exactly parallel. It cannot be adjusted but if suspected it may be ascertained by taking an observation with the particular Shade, and noting the reading, and then taking an observation without the Shade, and comparing the reading. Any error found should be carefully recorded, If a combination of shades is habitually used, observations should be taken with these in a similar way.

Both the Index Shades and the Horizon Shades may be examined in this way by making contact with the direct and reflected images of the Sun, using the inverting telescope and the darker eye-piece(not forgetting to adjust the Rising Piece to make the two images equally bright). If, on removing the dark eye piece and turning in the Shade to be tested (fitting the lighter eye-piece, if necessary), the Sun's images remain in contact, the Shade is accurate. If, however, the images of the Sun do not remain in contact then the difference in the Sextant readings of their being in contact with and without the Shade is the Shade Error for that particular Shade or combination of Shades.

The question of whether the Error in each case is positive or negative must be carefully considered. If the Index Bar has to be moved higher on the Arc Proper to obtain contact with the faulty Shade, then this error, being, so to speak " more," is to be **subtracted** and is a minus (—) error. If, however, the angle to obtain contact with the faulty Shade is lower (i.e., towards Zero), then this error is, so to speak, " less," so is to be **added** and is a plus (H-) error.

It should be pointed out that in modern Sextants Shade Error is rare, and can certainly be ignored in any Sextant with a N.P.L. Certificate, and probably in all Sextants with a Maker's Certificate. Modern manufacturing method has eliminated this error.

Shade Error can, of course, be caused by the Shades becoming loose or damaged by twisting, but such a condition should be apparent at once to the careful observer. In this case the use of the Shades should be discontinued until they may be properly tested and repaired and one or other of the dark eye pieces fitted to the telescope and used. It is important to do this, as by using the telescope eye piece any Shade Error is eliminated. Do not forget to move the up and down screw—the Rising Piece—until the images are equally bright.

The Sextant Certificate

If the Sextant Certificate (shewn on page 89) is examined it will be seen to contain the following statement :—

" The dividing has been examined at a number of points along the Arc and found free from material error. The following corrections, **in addition to the Index correction,** should be applied to the readings of the Arc."

From this it can be seen that the residue of all these **non-adjustable Errors,** if any, is tabulated on the Sextant Certificate inside the Sextant Case Lid.

For an N.P.L. Class A Certificate these errors are tabulated for every 15' of Arc, and must not exceed 40". For an N.P.L. Class B Certificate there errors are tabulated for every 30' of Arc and must not exceed 2'. If the Errors exceed 2' the N.P.L. will not issue a Certificate.

Adjustable Errors

The **Errors** of the Sextant which the Navigator can control himself by Adjustment are termed **Adjustable Errors,** and are familiar to seamen of all ages as the **Four Adjustments of the Sextant.**

1. First Adjustment. Error of Perpendicularity

The Index Glass must be perpendicular to the plane of the instrument.

2. Second Adjustment—Side Error.

The Horizon Glass must be perpendicular to the plane of the instrument.

3. Third Adjustment—Index Error

The Horizon Glass must be parallel to the Index Glass when the **Index** is at Zero.

4. Fourth Adjustment—Collimation Error

The axis of the telescope when shipped must be parallel to the plane of the instrument.

To make the Adjustments

1. First Adjustment—Error of Perpendicularity

The **First Adjustment** (which is known as the **Error of Perpendicularity)** is to set the Index Glass (or movable reflector) perpendicular (or upright) to the plane of the instrument.

To carry this out, place the Index Bar to about half-way along the Arc (approximately 60'), hold the Sextant horizontally face up with the Index Glass close to the Observer's eye and the Arc of the instrument **away** from the Observer. Remove the telescope.

Now direct the eye obliquely into the lower portion of the Index Glass and observe whether the reflected Arc as seen in the mirror to the left is in the same plane as the Arc seen by direct vision close outside the mirror to the right (in other words, are the Arcs continuous in one straight line ?)

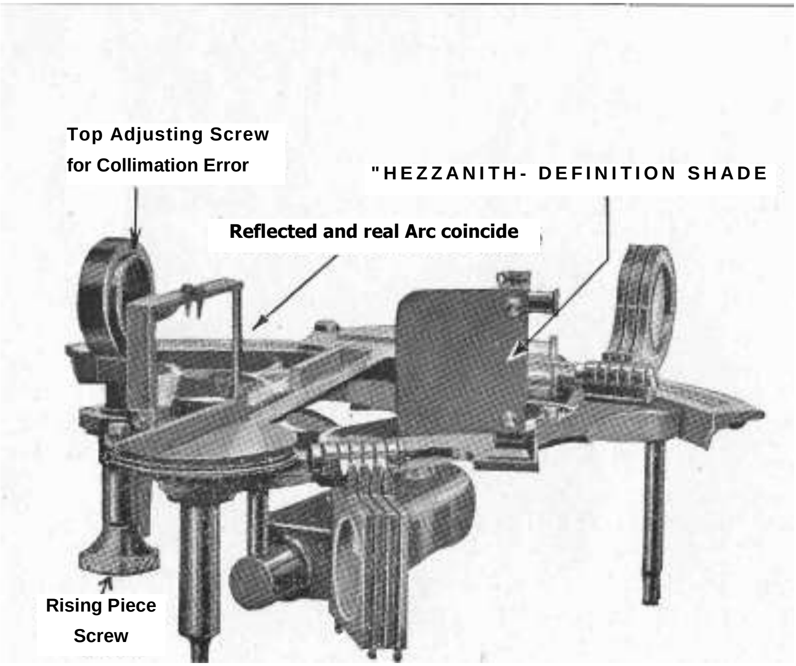
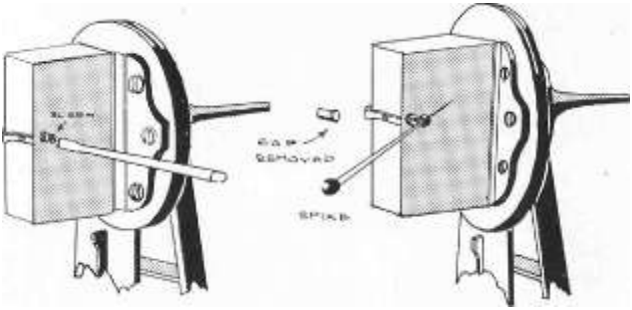


Fig. 29. First Adjustment—Error of Perpendicularity.

This shews the Sextant in position for testing the perpendicularity of the Index Mirror, and also that of the centre-axis. Note also, the Definition Shade fitted on the Horizon Mirror which is a safeguard against glare caused by a large telescope picking up rays of sunlight.

Figure 29 shews the Sextant in the position for testing the First Adjustment (except that the instrument is held actually in the hand), the arrow indicating quite clearly the position where the true and reflected Arcs should coincide. If the true and reflected Arc is continuous in one straight line (i.e., there is a single unbroken Arc as in Figure 29), then the **Index Glass is perpendicular,** and, therefore, reflecting correctly. If, however, the Arc appears broken where the images meet, that is the line of the reflected Arc is seen in the Mirror **higher** or **lower** than the actual Arc, then there is **"Error of Perpendicularity,"** and the ray of light from the observed body is not being reflected to the horizon glass parallel to the plane of the instrument. To rectify this the observer would tilt his Sextant and thus the angle obtained would not be properly perpendicular to the horizon. If the reflection seems to droop from the Arc itself, the Index Glass leans backward, but if it seems to rise, then the Index Glass leans forward. To rectify this, the adjusting screw at the back of the Index Glass must be tightened or loosened and by pressing against the back of the mirror, bring the true and reflected Arcs into line again.



30b

The First Adjustment Screw oper–
ated by a small screw driver.

30a

The First Adjustment Screw oper-
ated by the ball-headed lever or spike.

Fig. 30. The First Adjustment Screw.

To make the Adjustment, the cap covering the Index Glass Adjusting Screw, if fitted (shewn in Figure 6) is first removed. Now there are two types of Screws that may be fitted, the first as shewn in Figure 30a, which is turned by an ordinary small screw driver and the more usual type shewn in Figure 30b, which has a head with several holes drilled through it into which the small ball headed adjusting lever is inserted as illustrated.

The Sextant should now be returned to its original horizontal position (as in Figure 29), and held up to the eye again. Then by gently turning the lever (or screw driver) one way or the other the True and Reflected Arcs may be brought into one continuous straight line.

It will be remembered that, as stated on page 9, Circular Index Glasses are **permanently** adjusted and no Adjustment Screw is fitted to such Mirrors.

This First Adjustment should always be made first. 2.

Second Adjustment—Side Error

The **Second Adjustment** (which is known as **Side Error)** is to set the **Horizon Glass (the fixed reflector) perpendicular** (or upright) to the plane of the instrument.

By a Star. The error produced is similar to that of the First Adjustment (which is presumed to have been made already).

The best way in which to carry out this Second Adjustment is by using a fairly low-lying star that is not too bright. First clamp the Arc about Zero, ship the inverting telescope, and holding the Sextant vertically in the usual way for observations (as in Fig. 11), look direct at the Star and move the Tangent Screw or Micrometer wheel across the Zero of the Arc, that is, alternatively a little on **and** off the Arc. The reflected image should exactly pass over the direct image of the Star, so if the true and reflected images of the Star coincide exactly as they appear to pass one another—on contact being made—then no Second Adjustment is required. If, however, they appear to pass to the side of one another as in Figure 31 and do not coincide, then there is Side Error.

Fig. 31. Second Adjustment—Side Error.

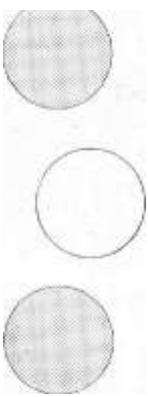
This must be corrected by setting the Index Bar exactly at Zero (not forgetting to set the Micrometer wheel or Vernier exactly to Zero also), and adjusting the Mirror (loosening or tightening it exactly as in the First Adjustment with the spike or lever, first having removed the brass cap) by the screw at the back of the Horizon Glass until the true and reflected Stars are brought into coincidence. (They may be then, of course, one above the other but not one to the side of the other).

As there are two Adjusting Screws at the back of the Horizon Glass (and they may not always be fitted in the same position), it is important to remember what we are doing. We are making the Horizon Glass perpendicular, and, therefore, as we have to push the glass forward or back a little, obviously the screw in the centre line (either top or bottom) of the Horizon Glass must be used (A in Figures 4 and 5).

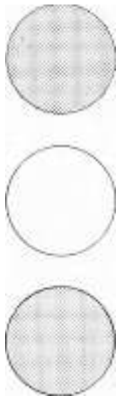
The Sun, Moon or other object may be used for the same purpose in the daytime but are not in any way so satisfactory as using a Star.

By the Sun. It may of course be necessary to make this Adjustment by the Sun, so in this case, fit the dark eye piece to the inverting telescope— this avoids using the Shades in case these cause Shade Error.

Fig. 32. Second Adjustment—Side Error.



32a. Side Error exists.



32b. No Side Error.

Now hold the instrument vertically and look directly at the Sun with the Index at Zero. Now move the Tangent Screw "handsomely" backwards and forwards, and if the image of the Sun passes directly over the actual Sun there is no Side Error. If, however, it passes either side there is Side Error (see Fig. 32a), which must be eliminated as described above.

By the Sea Horizon. In cases where the Sea Horizon is available, the following method may be used, but is not recommended for accuracy.

Set the Sextant **exactly** to Zero on the Arc (and Tangent Screw also), insert a telescope, and, holding the Sextant horizontally, look at the Sea Horizon. Now both the reflected image of the Horizon and the true Horizon on either side of the mirror should be in line, but, if not, then the Adjustment should be carried out as described above to put them in line.

The reason why this method of Adjustment is not recommended is because the Sextant has to be held horizontally which (except in the case of surveying Sextants or Sextants used chiefly to observe horizontal angles) is not the position in which it will be normally used.

Third Adjustment—Index Error

The Third Adjustment is to set the Horizon Glass parallel to the Index Glass when the Index is at Zero

By a Star. Clamp the Index at **exactly** 0 degrees on the Arc, and **exactly** 0 minutes on the Vernier or Micrometer Head, and observe a Star with a low altitude using the high power inverting telescope, holding the Sextant vertically in the usual way.

Fig. 33. Third Adjustment—Index Error.

Now the coincidence should be perfect, vertically and horizontally, but if the reflected image of the star is above or below the true image (that is, a double Star is seen), as shewn in Figure 33, there is Index Error (remember we have taken out any **Side** Error by the **Second Adjustment)** so the true and reflected Stars must be brought into coincidence by movement of the Adjustment Screw set on the **edge** of the Horizon Mirror (B in Figures 4 and 5).

It will be easy to decide which of the two Adjustment Screws on the back of the Horizon Mirror should be used if we consider that as we are trying to make the two glasses parallel (with the Index at Zero), the edge of the glass must be moved **round** to achieve this end—which is the opposite to what was done in the Second Adjustment—therefore, we use the screw on the **Side** of the Horizon Glass.

The Sea Horizon may also be used for this adjustment exactly as described for the Second Adjustment but by holding the Sextant **vertically.**

Special Note

Owing to the danger of the instrument being put out of adjustment by the Adjustment Screws working loose, unknown to the Observer, it cannot be too often emphasized that the screws should be used as little as possible. Also it must be remembered that the Second and Third Adjustment Screws work on the **same** Mirror, that is, the two motions are dependent one on the other, so that having made the Second Adjustment correctly, after the Third Adjustment is made, it may be found on re-checking the Second Adjustment that it has been thrown a little out of Adjustment. Thus the screws on the Horizon Mirror may have to be worked on alternatively (gently) before both Adjustments are completed and even so it may not be possible to eliminate both Errors completely.

The best way to do this is by halving the Errors. After having set the Index at Zero take out half the Side Error by the proper screw—this will probably alter the Index Error so take out half the Index Error : then half the remaining Side Error and continue this until both have been eliminated.

It is important not to neglect to do this as otherwise **Side Error** may be left in the glass.

For the above reasons then, unless the Third Adjustment is considerable —say more than 3 minutes (3')—it is very advisable not to correct for it at all, but to ascertain its amount as described on page 53, under " To Find the **Index Error,"** and allow for this at each observation.

Fourth Adjustment—Error of Collimation

The Fourth Adjustment is to set the line of sight (through the telescope) parallel to the plane of the instrument.

The Line of Collimation in an inverting telescope is the imaginary straight ray which passes through the centre of the telescope, the object glass and the eye glass and intersects at right angles a system of spider threads (cross wires) placed at the focus of the eye piece. It is the optical axis of the telescope and must be parallel to the plane of the instrument.

The elimination of the Collimation Error is the one that has presented. most difficulties to the seaman in the past owing to the somewhat complicated way of testing the Error and adjusting it. This error is due to the fact that the reflected ray from the silvered part of the Horizon Glass is not received in the same vertical plane as that from the Horizon. It will cause the observed angles to be too great.

Fortunately, however, this Error is rarely seen and in **modern well-made Sextants it is almost impossible for the telescope to get out of Collimation,** unless, of course, the instrument has been knocked and the Rising Piece bent, which would be obvious to a careful Observer. If the axis of the telescope is not parallel to the plane of the instrument, then if this condition was so small as to be unnoticeable, it would be a small error indeed, probably under about a minute.

Before adjusting for Collimation Error, Perpendicularity and Side Error must be eliminated.

To make the adjustment, the two cross wires of the inverting telescope must first be placed parallel to the plane of the instrument. This is done by observing a low-lying Star and placing the Index 3 or 4 degrees on either side of Zero, thereby separating the two images of the Star, so one is seen near the top of the field of view and one near the bottom. Bring the edge of the vertical wires into contact with the top image and by revolving the eye piece in the telescope, the two images of the Star should be made to appear in contact with the same edge of the wires. **The cross wires should now be parallel to the plane of the instrument,** and the tube and draw of the telescope may be marked for future reference if desired.

Now with the cross wires in the position described above, select two Heavenly Bodies, preferably two Stars about 90^0-120^0 apart, and bring the reflected image of one and the true image of the other into coincidence **on** the wire nearest the instrument (the lower wire).

Clamp the Index and by slightly moving the position of the Sextant make the coincident Stars appear on the wire farthest away from the instrument (the upper wire). If the Stars still remain in contact no error exists, but if not **Collimation Error** does exist.

To Adjust for Collimation Error

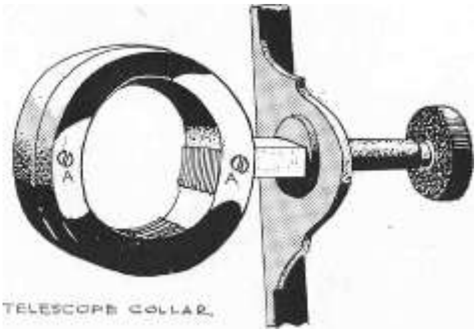


Fig. 34. Fourth Adjustment—Collimation Error.

If the two images appear to separate when transferred from one wire to another, then the Object Glass is too near the frame so the Fourth Adjustment should be made by the two opposing screws (A in Fig. 34) in the double collar of the Sextant (which hold the collar against the exterior ring), by slackening the screw farthest from the frame of the Sextant (the top screw), and tightening the other one (the bottom screw). On the other hand, should the two images overlap this procedure should be reversed. See Fig. 34.

The above test, of course, cannot be made with the Star or Prismatic telescope, which are not fitted with cross wires. Also some Sextants have no screws provided to adjust this Collimation Error.

The Sun and the Moon when at a considerable distance from one another are excellent heavenly bodies to use on occasion for the Adjustment of this Error. The method is as follows :—

Bring the darkened image of the Sun to touch the Moon, which is viewed directly at the middle point of the lower wire. Then by moving the Sextant, bring the point of contact to the middle point of the upper wire, where there should be exact contact also. If the images appear separated at the upper wire, the eye piece end of the telescope rises up, if they overlap it droops down. In the first case, ease the top screw and tighten the lower screw—and do the opposite if the two objects appear to overlap at the top wire.

Short Method

Screw the Inverting Telescope in place, and hold the Sextant carefully in such a position that an inspection will show clearly if the telescope is parallel with the plane of the instrument. A close examination of Figure 19 shews quite clearly that an error of ^{10} may be seen easily by the eye.

Whilst there are several other methods of testing for the Collimation Error, the above methods should be quite sufficient. Some modern Sextants have no means of carrying out this Adjustment, it being regarded by the makers as unnecessary.

TO FIND THE INDEX ERROR (Generally written I.E.)

The Index Error is the amount of Error left on the Sextant after the foregoing First, Second, Third and Fourth Adjustments have been carried out. As mentioned under the Third Adjustment, if the Error is found to be considerable, say more than 3', then the Adjustment is carried out ; but if not, the screw is left untouched and the Index Error ascertained and allowed for.

It is highly important always to know the Index Error of a Sextant and whilst the Navigator would only check over the Adjustments occasionally, he should constantly check his Index Error. Although strictly speaking, this should be done at each observation, the Observer should certainly check it every two or three days at most.

It should be understood that, whenever a Sextant has an Index Error, this must be added to, or subtracted from, every altitude or angle taken with the instrument, regardless of the body observed or the altitude obtained.

If this Adjustment is not made, there will be an error in the place of the beginning of the graduation, although this error will affect all observed angles alike.

For various reasons, some already outlined, it is customary to admit the existence of this source of error, determine its amount and apply a correction for it, which is called the **Index Error.**

There are three ways of finding the Index Error, namely : —

(a) By observing a Star.

(b) By observing the Sea Horizon.

(c) By observing the Sun's Diameter " on " and " off " the arc.

The first and best way is to observe a Star with a low altitude ; the second and usual way is to use the Sea Horizon, and the third way is by the Sun, which is, of course, not always available.

If the weather conditions are such that all three methods may be employed, the same result should be obtained in every case. The best results will be found by using a Star, because as a Star has no appreciable diameter no correction for semi-diameter is necessary, and no Shades need by used—therefore Shade Error should not arise.

(a) To find the Index Error by a Star

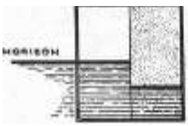
With the Index set approximately at Zero (a few minutes one way or the other off Zero), direct the inverting telescope at a low-lying Star ; make exact coincidence with the true and reflected Stars and read the Vernier or Micrometer head. If the reading is exactly Zero, of course, there is no Index Error. (The Star and its super-imposed image being seen as one). Should the reading be " on " the arc, e.g., 2' 20", then this would be 2' 20" to be subtracted. It would be written as I.E.— 2' 20". Should the reading however be 2' 20" " off " the arc, then this would be 2' 20" to be added to observed angles—written as I.E. + 2' 20".

Fig. 35. Side and Index Errors

If Side Error has not been entirely eliminated then the Stars will appear at an oblique angle to one another as in Figure 35. An endeavour• should be made to eliminate Side Error, but if this is not possible the reflected Star should be brought down dead alongside the direct Star, and any angle on the Sextant would then be the Index Error.

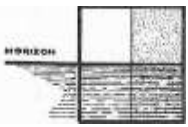
(b) To find the Index Error by the Sea Horizon

Set the Index approximately at Zero, using the inverting telescope, and, holding the Sextant vertically (perpendicular to the Horizon), look. direct at the Sea Horizon. Should the true and reflected Horizons appear to form one continuous line as in Figure 36b, then no Index Error exists—but should they not be in line, then by moving the Vernier or Micrometer wheel, make an exact continuation of the reflected with the true Horizon. Read the Sextant and ascertain the Index Error (if any) which must be allowed for exactly as described above.



INDEX ERROR EXISTING.

Fig. 36a



NO INDEX ERROR.

Fig. 36b

Figure 36a shews the Horizon viewed direct through the plain part of the Horizon Mirror, and the reflected Horizon outside this—clearly the two are not in line and Error exists. Figure 36b shews the true and reflected Horizons now brought into line when the reading of the Sextant would be the Index Error.

To ensure accurate results, care must be taken to see that the Sea Horizon is clearly defined. Finding Index Error by the Sea Horizon should be used only as an " everyday " check or when heavenly bodies are not available.

(c) **To find the Index Error** by **the Sun**

The Index Error may be found both by vertical and horizontal angles in which we measure the Sun's diameter both " on " and " off " the arc.

It will be found generally more convenient to observe the **Horizonal** diameter because it is not so easy to observe the Sun at high altitudes and at low altitudes the vertical diameter may be distorted by Refraction.

Now if the Index be placed at 0' when there is no Index Error, the centres of the reflected and direct images of the Sun will be coincident and when there is an Index Error the centres will not coincide.

If we could exactly superimpose one image upon the other, the reading would give the divergence of the Sun's centres or the Index Error of the Sextant. This cannot be done correctly however, so the following method is adopted.

Using the inverted telescope, and the necessary Shades, set the Index about 32' **on** the arc (which is approximately the diameter of the Sun). This is much quicker than clamping at Zero, and moving the Vernier along to 32' by the Tangent Screw which may come to the end of its thread.

Let the left limb of the reflected image of the Sun be brought into exact contact with the right limb of the direct image as shewn in Figure 37a.

Fig. 37. Index Error by the Sun at low Altitudes

Fig. 37a. Real Sun Reflected Sun
ON the Arc

Fig. 37b. Reflected Sun Real Sun
OFF the Arc

Read the angle on the Sextant and note it down. Now bring the reflected Sun across the actual Sun until the opposite limbs are brought into contact, that is, the right limb of the reflected image into exact contact with the left limb of the direct image (at about 32' off the Arc). See Figure 37b. Read and note down the angle once more.

If, as is generally the case, one of these readings is on the Arc Proper and one on the Arc of Excess, **half their difference is the Index Error.** If the greater of these two angles is **on** the Arc, then the Index Error must come off and is subtractive (—) ; but if the greater of the two angles is **off** the Arc, then the Index Error must come on and is additive (+).

Should the readings be both on or off the Arc, then half their sum will be the Index correction, **subtractive** when **on** and additive when **off** the Arc Proper.

Several Sights (say three) should be taken **on** the Arc, and the same number **off** the Arc, and a mean of the readings used. It is difficult to get these angles correct so the limbs should be placed by hand, before using the Tangent Screw, alternatively a little open and a little overlapping so that in making the contact the Tangent Screw may be turned different ways.

Figures 38, *a* and *b*, illustrate the observing of the Sun's vertical diameter at higher altitudes in exactly the same way as has already been described.

Fig. 38. Index Error by the Sun at higher Altitudes.

38a. ON the Arc. 38b. OFF the Arc.

If the sum of the two readings is taken and divided by four, this should agree with the Sun's Semi-Diameter for the day—as given in the Nautical' Almanac—and be a good check on whether the readings have been taken correctly.

Example of Index Error by the Sun

Reading " off" the arc		31' 40"
" " on " "		32' 40"
	2)	1'0"
		0' 30"

Index Error, 0' 30"

Off the arc	31'	40"
On "	32'	40"
Sum 4	) 64'	20"
Semi-Diam.	**)16**	5"

Index Error is, therefore, ½' **to be subtracted.**

which agrees with the actual Semi-Diameter of 16'.1 given in the Nautical Almanac for that day.

In this case all readings by this Sextant must have a minute Index Error deducted from them.

From the above remarks it will be seen that it is preferable however to use a **Star** for ascertaining the Index Error, but if none of the above methods are available, a distinct mark could be used.

Finally, to sum up, therefore, we may say that the whole of the Non-Adjustable Errors may be ignored in any modern Sextant of good make (bearing in mind the preceding remarks), applying only the remaining Errors of the Sextant (that is, the correction stated on the Sextant Certificate for the appropriate altitude), and the Index Error as observed at the time.

If an Observer, however, constantly gets different readings from a second Observer after all the Adjustments have been made, and the known Errors applied, he should have the Sextant overhauled by the makers or a reliable Nautical Optician.

CHAPTER VI.

THE ART OF TAKING SIGHTS

The art of taking sights cannot be learned from books ; only actual practice at sea in fair weather and foul, in daylight and in dark, will give the experience necessary to make an efficient Navigator.

Consideration of the following points, however, should enable the young Navigator to understand thoroughly how to use his most treasured possession at sea—his Sextant—to the best advantage.

Preparation for the Sight

The Sextant should always be kept in its case with, if possible (when the lid is closed) the erect telescope in the collar and the drawpiece focused so that the instrument is ready for immediate use. An efficient Navigator would then get a sight in a few seconds. It is extremely important not to lose valuable sights through unpreparedness.

Whilst waiting for the Sun to appear from behind a cloud bank, the Sextant should be kept handy in a position where it will not slide about. In a small vessel probably in a bunk is best and in a larger vessel on the chart room settee.

It is necessary to know the height of the Observer's eye at each observation. This should be measured periodically, remembering in a cargo vessel the difference in height between being " light " and "loaded." If the sight is being taken away from an Observer's customary position, remember to use the different height of eye (if it is different).

When estimating the Observer's H.E. (height of eye), which is calculated as in smooth water ; if the Observer takes the sight when the vessel is on the crest of a wave he should add half of the estimated height of the wave to his still water height of eye.

As a general rule the Sextant Telescope should be used as follows.

In daylight, under all usual conditions when observing the Sun, use the Erect Telescope. If the weather is calm and the vessel steady, the lower power inverting Telescope should be used to secure greater magnification.

At dawn and twilight. For morning and evening Star observations use the Erect Star Telescope under all usual conditions. With experience, however, and calm conditions, use the **higher** power draw of the inverting Telescope when there is still considerable light, i.e., very early evening and late morning sights. This gives the maximum brightness to the Stars.

For late evening and earliest morning sights, i.e., when there is considerable darkness, use the **low power** inverting Telescope. This gives the maximum brightness to the Horizon.

TAKING SIGHTS GENERALLY

The Sextant measures the angle between the Sea Horizon (called the Visible Horizon) and the heavenly body.

Remember that the altitude of a heavenly body will continue to get larger whilst the object is to the east of the Observer's Meridian, but will get smaller when to the west of it.

Care should be taken to be sure that the Horizon is defined clearly, and to ignore sights taken when this is not the case, as, unless there is a " true " Horizon the results may be considerably in error.

In gloomy weather it is better to take sights from as low a position as possible as then the Horizon should be more clearly defined.

When observing with the Sextant endeavour always to get the observed objects in the centre of the telescope field.

With a Clamping Screw Sextant always keep the slow motion Tangent Screw about the centre of its run, so as to have plenty of play and avoid spoiling a sight through the Screw jambing in the middle of the observation.

Always test for Index Error every time sights are taken. Observers should accustom themselves, automatically, to apply any Index Error before calling out the Altitudes to be entered in the Notebook. This avoids any subsequent question of the amount allowed.

It is best however to have the Sextant adjusted (provided you are not doing this continually), so that there is **no Index Error to allow.**

Do not forget that both Index Error (if any) and the Error for the particular Altitude shewn on the Sextant Certificate (if any), must be applied to every Altitude taken with the Sextant. Always be careful your Clamp Screw cannot slip.

It is preferable for a beginner to learn to use the Sextant by taking sights when at anchor in a known position, as a check. If the calculated position is within 2 or 3 miles, it is an excellent result. But it is better still to take actual sights with an experienced Observer and compare altitudes. In this way only will it be found whether sights are being taken properly or not.

Then, sights should be practiced under way in fine weather near the coast, and the position of the vessel fixed at the same time by bearings of shore objects. The two positions may then be compared. In good weather with modern instruments and accurate working the position should be obtained within one or two miles.

In actual practice, of course, especially when nearing land, no opportunity should be lost of obtaining a sight. Everything must be in readiness and then when the Sun shews signs of appearing, " shoot" it quickly. The efficient Navigator will have the Sun on the Horizon and obtain a 'sight "—possibly an invaluable sight—whilst an inefficient man will still be fumbling with the telescope or shades.

It is distinctly preferable to allow contact to be made by the motion of the objects themselves—if this is possible. In other words, say the Sun is rising, it should be screwed down a little **below** the Horizon and careful watch kept until it rises (and the time taken), when it just makes exact contact. In the case of a falling body, screw it just above the Horizon and watch its fall until it is exactly " kissing **"—in both cases without using the Tangent Screw.**

A more reliable fix can be had always from sights taken on either side of the Meridian than when both sights are taken on one side of the Meridian.

When taking the Meridian Altitude of an object it **must** then bear either North or South (True) or be directly overhead in the Observer's zenith.

When a heavenly body has a low Meridian Altitude, that is, it is a long distance from the Observer, then it will appear to remain stationary on the Observer's Meridian for several minutes. When the Meridian Altitude is high, however, this apparent " stand" of the object will be of short duration.

When the Meridian Altitude is nearly 90°, i.e., when the object is nearly overhead, the Sun will " swoop " across the Meridian, and appear to touch the Horizon all round, so rapidly that it is difficult to decide on an accurate Meridian Altitude. So observe the North or South (True) point of the Horizon, direct the Sextant towards this and the Altitude should be taken at noon at this point. In this case, remember to take Stellar Observations as a check.

An Ex-Meridian Altitude may be taken of any heavenly body within the limits specified in the the Ex-Meridian Tables, both when the body is rising and falling. The actual observation is taken as already described for each body earlier in the Chapter, and at the same time the **exact chronometer time must be noted to the nearest second,** so that the Hour Angle of the body from the Meridian may be ascertained.

To observe the body (after having clamped the approximate altitude on the Sextant) ; this should be directed towards the True North (or South) Horizon—a little to the **eastward** in the case of a **rising** body, and a little to the **westward** is the case of a falling body.

Any altitude over about 65 ' may be observed from the opposite Horizon if the direct Horizon is obscured by land or any other reason. In any case both of these altitudes may at any time be taken when half the two readings is the zenith distance of the centre. This, therefore, eliminates Dip and Index Error. If the body is not on the Meridian then the times must be taken of the two observations and meaned to correspond with the zenith distance.

Maximum and Minimum Altitudes

This problem has assumed great importance of late years, owing to the increased speed of modern steamers.

On any course other than East or West, but especially on Northerly and Southerly courses, if approaching the Sun, the altitude due to the Observer's motion increases, and if receding from the Sun the altitude decreases. This is readily understood.

The Sun comes to rest when the change of the altitude of the Observer (due to this motion) is equal and opposite to the rate and change of latitude due to the rotation of the earth.

If the vessel is approaching the Sun, it appears to rest after its Meridian Passage, but if receding from the Sun it appears to rest before its Meridian Passage.

Therefore on any Northerly or Southerly courses the maximum altituded is not the Meridian Altitude.

To obtain this, the clock must show apparent time at ship as accurately as possible for the Meridian Passage at noon, and the altitude taken at this time, **regardless of the fact that the Sun may be still rising or falling.**

The minimum altitude is the altitude below the Pole, when the reverse to the above takes place.

TAKING THE TIME

With regard to this " Different ships—different fashions."

Although in small vessels a single Observer may **have** to do the whole operation himself, it is the custom in the Merchant Navy for a fellow Officer (any quartermaster, seaman or apprentice will do, of course, if properly instructed in advance and supervised), to take the " time " for the Observer using the Sextant.

In the Royal Navy, owing to the fact that the chronometer may not be situated close to the Observer on the bridge, the time is usually ascertained from " a deck watch."

Except in the case of the Meridian Altitude of a body (when the time is not required), an Observer should ask his timekeeper to prepare to take his " time." i.e., the time of the observation. This means that the timekeeper should station himself at the open chronometer with the Sight Notebook open and pencil ready. He should also for example leave the chartroom door ajar and generally make the best arrangement to be certain he will hear the Observer's call.

When the Observer has the object close to the Horizon, he should call out "stand by " ; **which should be answered by his timekeeper** (this is important), who should then stand with his eyes fixed on the chronometer face, and count round with the seconds. As the Observer makes exact contact and feels he has a " good" sight—that is, he feels the object is exactly kissing a well defined Horizon—he should shout " stop " (this should be answered by the timekeeper), who will then record the exact **second** of hearing this call, **then** the minute and finally the hour. He should then **immediately** check this, especially the minute—to make sure that this has not been read in error. When the second hand points to about 50 seconds it is extremely **easy to read the next minute** by mistake. As one minute of time means an error of 15 miles great care must be taken to avoid this. The **Ship Time** should also be noted.

The Observer should then (having by this time read his Sextant) call out the name of the body observed and the altitude **with its approximate bearing in the case of a Star or Planet.** Before moving the Index Bar of the Sextant, the Observer should **again check the altitude** (which the timekeeper should **repeat** as a check). The next call should be to " stand by again "—when the same operation should be repeated as many times as necessary. Should the Observer not be heard he should blow a whistle or make some other arrangement.

The Patent Log reading should always be taken at the same time, so that the Dead Reckoning positions may be calculated. In vessels where the speed and distance run is calculated from the Engine Revolutions, it is important not to omit to record the **Ship Time.**

If no more sights are to be taken then the altitude observed should not be altered on the Sextant—you may have read it wrongly—but left for reference.

Generally, however, you wish to observe either the same or another object immediately, so again read the Sextant to make quite certain of your altitude. This is highly important as reading the Sextant incorrectly is a very frequent source of error.

If you have not got an experienced man taking the time, then always glance at the Chronometer yourself—before reading the Sextant—and note especially whether the minute has been noted down correctly.

If single handed the best way is to count the seconds in the head from the time you say" stop " (to yourself), till you have walked to the Chronometer; then subtract these seconds from the reading.

In taking sights, it is best to observe three altitudes in succession, and take the exact chronometer time in every case. Then take the mean of these three altitudes (by adding them together and dividing by three and the mean of the three times and use the **means** for working out the sight. Should the observer have reason to doubt the accuracy of any one altitude or time either ignore this observation or plot them all down and draw a curve through them and see if it is a fair one. If not, discard the faulty observation.

One good sight cannot be improved upon, but in any but the calmest weather, it is best to take three sights and times and use their means.

The aim should be to get the sights in as short a time as possible, say three Sun sights in three to five minutes, and two or three Stars in this time.

The Sight Notebook

Accurate results depend to a great extent upon a proper method being used so a notebook called a **Sight Book** should be ruled up and every sight taken entered into it, including all necessary particulars. This is, therefore, a permanent record of all " sights " taken. The following specimen columns and entries show a convenient form.

Date	Ship Time	Object	Chronometer Time h.	m.	s.	Altitude	Compass Bearing	Observer
6th Mar.	1032	O	14	17	34	52° 07'S.	S22°E.	3rd Officer
	1220	Ex-Mer O	15	49	25	65° 28'S.	S30°W.	3rd Officer
	1801	♄	20	15	00	83° 20'S.	S89°W.	Chief Off.
7th „	0504	C	08	47	08	40° 10'N.	N72°E.	2nd Officer
31st „	1908	*Achernar	18	27	53	47° 45'S.	S24°E.	2nd Officer
	2256	*Vega	22	19	43	51° 38'N.	N71°W.	2nd Officer

The recognised symbols as shewn above should be employed ; the horizontal stroke below the symbols indicating that the lower limbs of the Sun and Moon had been observed. The bearing—to the nearest 10° or so is sufficient—is obtained approximately by looking at the Compass.

Taking Sights in Rough Weather

In a small vessel, using the Sextant is not an easy matter in rough weather. The eye is only situated a few feet above the sea, and as the Horizon is not far away it is frequently obscured by waves. Care must be taken that the reflected image of the Sun is brought down to the actual Horizon and not to a false Horizon or to an intervening wave.

In a rough sea, the actual "sight" should be, taken just when the vessel is on top of a wave, and as the tops of waves make a false Horizon, sights should be **taken from as high a point as practicable.** When ever possible, bring the Sun or Star nearly ahead or astern as a vessel usually pitches less than she rolls. If the converse is the case, however, then bring the object abeam.

Shorthanded in a small vessel it may frequently be best to heave to.

In rough weather, 3 or even 5 sights should be taken, and the mean of the altitudes and the times used. Any obviously bad sights should be neglected.

When observing the **Meridian Altitude** in a very small vessel such as a ship's lifeboat or yacht in rough weather, the rise and fall due to the waves causes the Sea Horizon to fluctuate by the small amount due to the alteration in height of the Observer's eye. As it is impossible to keep the Sun's Limb in constant contact with the Horizon, it is preferable to take a number of observations close to noon in quick succession, continuing to do so until it is obvious that the altitude is decreasing. Whilst generally the mean of these observations would be taken as the maximum or Meridian Altitude, if the mean of the highest and the two altitudes on either side be taken as the Meridian Altitude, the greatest accuracy will be obtained.

OBSERVATIONS OF THE SUN

Sun sights may be taken at any time after the Sun has risen about 10° above the Horizon. Observations nearer to the Horizon than this should not be taken because of **Refraction** (which is the " bending " that rays of light are subjected to when passing through layers of atmosphere of different densities).

At other times, Refraction must be guarded against most carefully, as heat waves frequently put sights many miles out. Little is known about this abnormality that displaces the apparent Horizon (up to 17 miles is recorded), but remember it as a possibility. The value of Stellar observations is thus much increased.

When deciding on the appropriate time to take a second sight (for Double Altitude), frequently, owing to cloud or bad weather, we may have to be quick and " snap " the Sun when the chance arrives. In good weather, however, the Azimuth or A.B.C. Tables tell us when the Sun has changed its bearing enough (more than 20°), and then we can decide when to take the second sight.

When the sun appears from the clouds and shews no appaent "limb," but is just a blur—sailors call this " a ball of wool "—then, if particularly anxious to obtain a sight, take the centre of the Sun, but do not apply any correction to it. If this is worked out it will be found to give a good **approximate** result within several miles, which is all that is required under these circumstances.

In case of cloud obscuring the Sun's Lower Limb, the Upper Limb may be " shot," in which case subtract **twice** the Sun's Semi-Diameter (given in the Nautical Almanac for the day) ; and then apply the Sun's Total Altitude correction from the Table in the usual way.

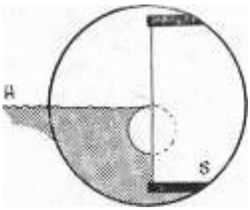


Fig 39. Observing the Sun's Upper Limb

When the Sun is at a low altitude, it is most likely to be affected by Refraction so in this case also observe the **Upper** Limb.

It is important to use the correct Shades for the Sun and never to use too bright a Sun. It is always best to use **one** Shade if possible, and never more than two should be used.

Since we know that when the Sun is on the Observer's Meridian, it must bear True North or South ; the Compass bearing should always be taken at this time when the Altitude is not more than about 40'. The difference between these two bearings is, of course, the Compass Error (for that particular direction of the vessel's head).

OBSERVATIONS OF THE STARS

When observing Stars, beware of a false Horizon—the evening Horizon is usually to be relied upon, more than the morning Horizon.

If desiring to observe Stars during the hours of darkness (not at twilight), it will be found that the Planets and bright Stars of the first magnitude throw a reflection or halo on the Horizon, which makes it extremely difficult to get proper contact. It is much better to observe smaller Stars of the second or third magnitude, as on a dark but clear night, a smaller Star is more easily defined on the Horizon.

When taking Stellar observations, if a Star is not on the Meridian at the best time for seeing the Horizon, **do not wait for the Meridian Altitude** (because by waiting the observation may be missed if the sky becomes clouded over), but take the observation at once (noting the exact time by chronometer) and work this as on Ex-Meridian.

Generally about twilight there will be one Star or more on **or near** the Meridian, so try to observe one to the northward and one to the southward. If, of course, 3 or 4 Stars are within the Ex-Meridian limits **shoot them all.** The calculations needed to find the latitude from the average Ex-Meridian Tables (especially Reed's Ex-Meridian Tables. compiled by the present author, which are extremely simple) are so few that the latitude may be found thus by **several independent Stars in a few moments.**

If the **mean** of the latitudes is taken as the correct latitude of the ship errors will be eliminated, and an extremely accurate position line thus obtained.

Whether working the intercept method or the longitude by chronometer method, it is in the writer's opinion highly desirable to secure the **latitude** by Meridian or Ex-Meridian Altitudes in any case. If Stars are then taken bearing about East and West for position line (or longitude), any error of one Star should counteract the other.

When taking Stellar observations, it is best to take the Meridian Altitude observations first (as this will take longer) ; and then "knock down" the other Stars as rapidly as accuracy allows. Such observations may, therefore, be called " simultaneous" if observed within 2 or 3 minutes of one another.

When observing Stars in bad or cloudy weather, do not worry if the particular Star cannot be identified, but snap it at once (noting the time and altitude in the usual way). The Star may be identified later at leisure, if the bearing has been taken.

The new electric light fitted by battery to Sextants is a great boon to enable the reading to be taken out on deck.

Otherwise the Observer must, after having taken the sights, enter the Chart room or a cabin (which may be lighted brightly), in order to read the Sextant and it will be some little time before his eyes again become accustomed to the dark. On occasions it may be necessary to hand in the Sextant to someone else to read, but as this may lead to errors it is not to be recommended.

LATITUDE BY PLANET IN DAYTIME

Venus—and sometimes Jupiter—is frequently available from which to obtain a latitude during the day. If at the same time (as soon as the Meridian Altitude of Venus has been obtained), the Sun is observed for a position line a most excellent fix is obtained rivalled only by a " cross " from the Sun and the Moon.

On account of the orbit of Venus being between the Earth and the Sun, Venus never recedes far from the Sun. So throughout several months anyway, in most navigable latitudes, it is in a good position to obtain a latitude when another object is available to cross with it during the afternoon.

Of course, the sky must be clear blue—even slight haze will cover the Planet and the Sextant must be taken behind a deckhouse out of the Sun's strong glare. The approximate altitude is calculated (as with a Star), and clamped on the Sextant, which is directed towards due North or South—always South in the United Kingdom, of course.

OBSERVATIONS OF THE POLE STAR

If the Star Polaris—commonly called the Pole Star—were situated exactly at the North Pole, then its true altitude at any place in the Northern Hemisphere would be the latitude. For instance, on the Equator the altitude would be 0° and at the North Pole 90^0.

The Pole Star moves slightly each year, however, and revolves around the Pole daily at a distance of about 11° from it. The problem thus becomes really **a special case of an Ex-Meridian.**

The latitude may be obtained from the Pole Star at any time it is visible (and the Horizon defined clearly) to an Observer in the Northern Hemisphere. In Northern latitudes the Pole Star should be observed **always** at dawn and evening twilight—thus **getting one position line in the simplest manner possible.**

Polaris is not a very bright Star—being of the second magnitude only —and if the Star is visible then the altitude should be observed in the usual way for Stars. No Sextant Shades are, of course, necessary in any case.

When observing Polaris at dawn or dusk, however, it will be invisible so then the approximate altitude should be clamped on the Sextant, which should be directed towards the True North point of the Horizon. The Altitude may be obtained accurately by working back from the D.R. latitudes or as it may **be assumed to be the same as the D.R. latitude** —a quick "rough and ready" supposition, e.g., in Latitude 51°N. the altitude of Polaris will be approximately 51'. Having picked up " the Star in this way, exact contact may be made with the Horizon by the Screws. Then by a **single correction** table (see Reed's Nautical Almanac) the **latitude** may be found.

OBSERVATIONS OF THE MOON

Observations of the Moon are neglected quite frequently, but most unjustly so. One of the reasons for this is probably because of the several corrections that have to be applied, but in modern practice only **one total correction** is required.

The Moon may, of course, be observed during the night, but such sights must be made **carefully and treated with caution.** In cloudy weather the dark shadows projected on the water below the Moon render the actual Horizon uncertain ; in clear weather the upper edge of the illuminated portion of the sea is the Horizon.

When observing the Moon on the wane, as it disappears from the bottom upwards, we must observe the Moon's **Upper** Limb.

When the Moon is near the Equator the rate of change in the Declination is so rapid that it is improbable that the actual Meridian Altitude could be observed.

For much the same reason, and because great exactness would be required, the Moon is generally unsuitable to observe for a Meridian Altitude.

During the daytime it may be preferable to take the Horizon up to the Moon as described already for Star sights.

SIMULTANEOUS SIGHTS

"Simultaneous" sights of two or more bodies are, of course. not necessarily simultaneous as a short interval elapses usually between observations. So if three of four observations are taken within say, five minutes, they are **assumed to be Simultaneous,** for plotting purposes, (though each one is calculated with its own respective chronometer time).

Any vessel's position should be ascertained by observation, at least twice daily, and the following are the several methods available in the order of preference :—

(1) Sun and Planet, Moon and Planet or Sun and Moon in the daytime

During daylight, simultaneous sights of any two bodies are most valuable, and the beginner will find this a good time to commence taking sights, because at this time the Horizon is usually clearly defined. Also it may be borne in mind that if the sights fail to work out correctly— **they may be repeated—an** important point. A cross with the Sun and Moon or Venus and the Sun are probably the finest astronomical
Fixes" there are.

(2) Simultaneous Stars ; Stars and Moon ; Stars and Planet or Planet and Moon

The best time to observe Stars is undoubtedly at dawn directly the Horizon is clear enough. These are easier than twilight (evening) sights, as the whole night watches have been available to identify the Stars and decide which ones to secure. In the evening Stars are frequently not recognisable until the Horizon is too dark for accuracy.

Heavenly bodies must be specially selected for observation and, in practice, where possible, three or four Stars (one in each quarter of the Compass) are taken in case it is found that the position of two Stars is a long way from the D.R. ; the third Star can be worked out then to prove it. Three or four Stars may cross in what is known as a "**cooked hat"** and if this is small assume the vessel to be in the centre of it. Another frequent source of error is to read the Sextant one or five degrees wrong, so if you have a third or fourth Star "up your sleeve," it is very comforting, and gives the "check " **which seamen employ at each and every opportunity.**

Remember that the ideal sight is that in which the position lines cut at **right angles.** This is manifestly impossible when more than two Stars are used, so when taking three or more, try to pick ones with about 45° to 60° difference of bearing between each successive one, and so avoid taking Stars the position lines of which will be parallel to one another and not **cut when plotted.**

(3) "Running Fix" from the Sun in the daytime or the Sun and a Star at twilight or dawn

Whenever two sights are taken of the same or different bodies with a run between it must be borne in mind that accuracy depends upon the run between sights and the allowance for current having been made correctly. This method, therefore, is not specially accurate in a small vessel.

SINGLE POSITION LINE

When approaching land at the conclusion of a passage ; or when the land in obscured ; or when coasting some distance off shore single sights of the Sun or other object should be frequently taken on such bearings that the resulting position line lies parallel with the shore—thus giving the vessel's off-shore distance ; and also at right angles to the shore—thus indicating what point the ship is opposite.

For example a noon sight in the English Channel gives you **latitude,** and would give you the ship's distance from the coast, whereas a sight of the Sun when on the Prime Vertical, would give you a position line running North and South and thus show your **approximate longitude.**

The great value of a single position line cannot be too strongly emphasized.

P.V. SIGHT

A " P.V." sight is one taken when the object is on the Prime Vertical that is when it bears due East or West (True).

We know that, if the object bears due North or South, the position line runs East or West, that is, the position line corresponds exactly with a Parallel of Latitude, and this, therefore, is the reason why the most accurate latitude is obtained from a Meridian Altitude.

Now when the Sun bears due East and West (True), the position line must run North and South, or, that is, the position line corresponds exactly with a Meridian of Longitude, and this is therefore the reason why a P.V. sight gives the most accurate longitude.

It can be realised that within reason, no matter what latitude was used in the compilation the same position line or Meridian of Longitude will be obtained.

In every other case, of course, it is necessary to have a correct latitude or, in other words, obtain a secord sight.

The value of the P.V. sight must not be overlooked, as one sight **then gives us one definite element—but only one, remember.**

Hints on obtaining position lines

In bad or long continued cloudy weather, no opportunity must be lost of obtaining a sight. It will at least give a position line.

If the vessel is running North or South ; the observation should be taken, if possible, of an object bearing about East or West, as this will give **a line of position running in the direction of the vessel's Course.**

If the ship is steering N.E. or S.W., then select some body bearing N.W. or S.E., so as to obtain **a position line in the direction of the Course Line.**

FINALLY

When learning to use the Sextant, an ideal arrangement, if possible, is to take " sights " with an experienced Navigator and compare your Sextant readings. (In the Merchant Navy it is usual for nearly **all** the Officers to take observations independently and the Meridian Altitude in company at noon).

Once the beginner has "got the hang" of the Sextant, and can manipulate it with ease and accuracy—this will never be forgotten—like riding a bicycle.

CHAPTER VII.

SEXTANT TELESCOPES AND OTHER ACCESSORIES

SEXTANT TELESCOPES

In order that the best observations may be made in the the easiest manner, a number of telescopes are included in each Sextant Case, to be used under varying conditions. The more expensive the instrument the more telescopes there are provided.

Manufacturers go to considerable trouble to furnish the best telescope for the particular purpose but, unfortunately, it is not always well understood amongst seamen exactly when and how these should be used.

No attempt will be made to go into the "theory " of the construction of the different kinds of telescopes, but comments will be made on the various practical points that arises, for the use of the Navigator who desires to get the best out of his Sextant, thereby, of course, securing better observations for the safer navigation of his vessel.

In any telescope the end farthest from the Observer (the larger end), is called the **Object Glass,** and the end towards the Observer (the smaller end) is called the **Eye Piece.** The lenses in this eye piece are fixed in a separate tube—generally called the " draw " of the telescope which slides in an outer tube. It may thus be drawn in or out so that the telescope may be focussed for different eyes.

When the telescope has been focussed and the objects have been made to appear well-defined and distinct to an individual Observer, it is desirable to make a circular pencil ring round the " draw" at the correct position for his eye. Then when experience has shewn that this mark represents the best position for this particular Observer's eye, the pencil mark should be permanently "cut in" with a sharp knife, so that this may be felt with the finger nail, to ensure correct focussing of the telescope when taking Star sights in the dark. It simplifies daylight observations also, as it may be seen easily and avoids the necessity of the telescope requiring to be focussed each time. All the draws of the various telescopes should be marked in a similar manner.

Blank Tube or Sight Vane

In Figure 1, this will be seen to be stowed in its place in the case, but in Figure 3, it is standing close to the bottom of the Index Bar. As stated in Chapter I., this blank tube is merely a sight vane, which is used only when taking shore angles, to keep the line of sight from the eye, parallel to the plane of the instrument.

TELESCOPES

There are really three principal types of telescopes used with Sextants— the **Galilean** (which shews objects the correct way up), the **Inverting Telescope** (which shews objects upside down), and the **Prismatic.**

The image seen by a Galilean telescope is erect and is thus known to seamen as the **Erect** telescope, also frequently called the "Star" telescope. Such a telescope cannot be fitted with "cross wires."

The image seen by an astronomical telescope is upside down or inverted, and this type of telescope is known to seamen as the **Inverting** telescope. Because it can be fitted with cross wires, it may be known as a Collimation Telescope.

These two distinct types of telescope are supplied with most Sextants, and cover all usual requirements, which are for a **low power** telescope with a wide field and good light and for a **high power** telescope for special purposes.

Power of a Telescope

The Magnification or Power of a telescope is generally written as, for example, 2 x ; this (the multiplication sign) meaning that any object is magnified twice the size. So as to have a fair sized field of view, the magnification of telescopes is kept low and seldom exceeds 5 x (5 times).

The (Low Power) Erect Telescope or (Star Telescope)

The low power telescope is the short conical bell-shaped telescope (seen shipped in the collar in Figures 3 and 11), and is used for all general observations. In older Sextants, of course, the Erect telescope was purely a straight one and was employed for Sun sights almost entirely. Since it was recognised that Navigation by Stars was in every way more desirable than using the Sun exclusively ; this low power telescope has been improved to make it of the best possible utility for Star work. Consequently, it is generally now called the **Star Telescope.** Its power is usually 2 x, 3 x or 4 x

The main improvement has been in making the **Object Glass** as **large as possible.** Figure 9 shews a Star telescope standing on its Object Glass which is bigger than that shewn in Figure 2 (about 1 inches). Figure 8 shews the Hezzanith large Object Glass Telescope, which is much larger still. This telescope, incidentally, is not focussed by an ordinary draw piece but by a revolving adjustable eye piece. Its magnification is about 4 X. Such a telescope (also called a Monocle) has an Object Glass of about 2 inches diameter.

The purpose of the large Object Glass is to overcome the restriction of the field of view which results from the Erect eye piece, and to give increased illumination.

It should be pointed out that a high-powered telescope is of no special value at night, because a fixed Star's image cannot be magnified—it appears to be a mere point of light—so for this reason the magnifying power of the Star telescope is not high.

The use of a large Object Glass Telescope, however, is very helpful in illuminating both the Star **and** the Horizon, but care should be exercised, if using such a telescope in bright sunlight, that rays of sunlight are not picked up to dazzle the eye. (The Hezzanith Definition Shade is fitted to Heath & Co.'s Sextants to prevent this). If no special Prismatic telescope is provided, the Star telescope should also be employed when observing angles between two terrestrial objects.

Therefore we may say that for ordinary Sun and Star observations the Erect (Star) telescope would be used.

The (High Power) Inverting Telescope

The **Inverting** telescope is shewn shipped in the Sextant collar in Figure 9 (the eye piece, or " draw," will be seen to be slightly withdrawn). It may also be seen standing upright in Figure 3, close to the Index Shades. An Inverting telescope always has an extra " draw" (eye piece) of a different power to the other and this is shewn standing upright in Figure 3 on the extreme right, close to the blank tube. (These two are termed the high and low power eye pieces or draws.)

Each one of the draws is fitted with cross wires at its focus to define the line of collimation, which is the line joining the focus to the centre of the Object Glass. The high power eye piece generally has two cross wires and the low power eye piece has four.

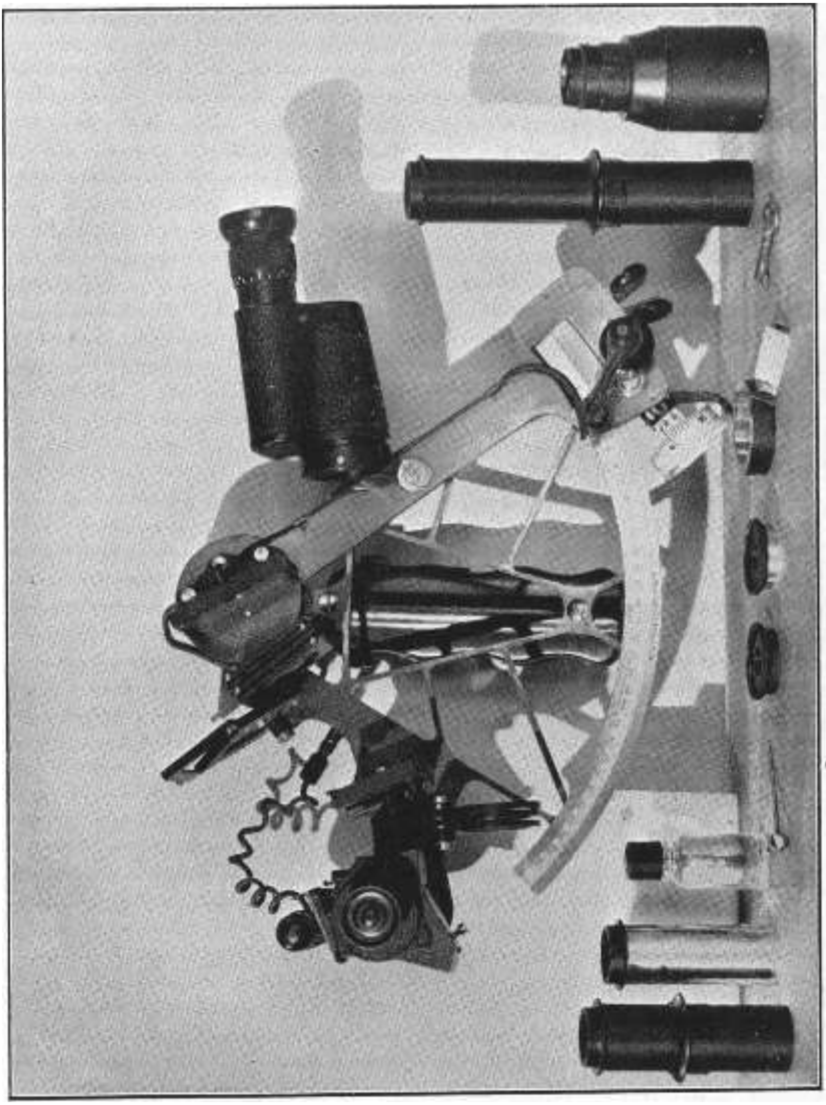
The **high power** telescope has fewer lenses than the erect telescope, and thus transmits more light ; and since it is only used for observations of the heavenly bodies (or the Horizon) the fact that it shews things upside down or inverted does not matter.

It is especially useful for making the Adjustments of the Sextant—using the higher power draw—and would be employed also if using an Artificial Horizon on shore. The higher power draw used for this purpose would be 9x or 10x.

The lower power draw (generally bx magnification) has a wider field and gives greater light so would be employed for all observations of the Sun where the deck is steady enough for the observer to use it.

It gives a much larger image of the Sun than the Star telescope and therefore should always be used (under favourable conditions) for taking the Sun's Meridian Altitude because by its use the Sun's limb is so clearly defined.

With a steady deck an experienced Navigator will use this inverting telescope for ordinary observations of the Sun when conditions are favourable—the high power eyepiece being used when the horizon is bright and the ship steady.



Husun Gothic Bubble Sextant—in use

The Prismatic Telescope.

The **Prismatic Telescope** (shewn shipped ready for use in Fig. 40, page 73) gives the same benefits as are to be had from the Inverting telescope, but it gives an **erect** image. For this reason, therefore, it is of special use for taking horizontal angles of terrestrial (or shore) objects. It should also be used with the Bubble Artificial Horizon. Its power is usually 6x. Giving the image " erect" like the star telescope, it is easy for the observer to change from one " erect " telescope to another.

Binoculars.

Binocular glasses (having two eye-pieces like ordinary binoculars) are fitted to some Sextants, especially for taking observations of stars. They do not appear to be popular with seamen, however, who prefer the telescope they are used to. If binoculars **are** used, however, care must be taken to fit them correctly to the collar or errors of collimation may
OCCI1r.

SEXTANT ACCESSORIES.

There are one or two accessories that may be used with the Sextant, and when purchasing a new Sextant consideration should be given to the fitting of one or more of the following accessories which are not really refinements, but are of considerable practical utility.

Sextant Mirrors.

It is important when observing Stars to have large mirrors to increase the field of view. Most modern Sextants have large sized mirrors, and it is a point that should be considered when purchasing Sextants.

Rectangular and circular mirrors are fully described in Chapter I.

Blank Tube (or Sight Vane).

This is supplied in every Sextant case, but, as stated in Chapter I., this blank tube is merely a sight vane which is used **only when taking shore angles,** when the telescopes are not required for magnification. Its purpose is to keep the eye parallel to the plane of the instrument and it is much more accurate to use this sight vane therefore than merely to look through the telescope collar and take observation.

Fig. 1 shews this Blank Tube stowed in its place in the Sextant case ; Fig. 3, shews it again standing next to the bottom of the Index Bar.

The Wollaston Prism.

The Wollaston Prism is of great practical utility when taking Star observations, especially with a somewhat hazy or cloudy horizon. By its use the star image is split into **two** bright reflections of the star, separated by about I- of a degree, one above and one below eQui-distant from the star's original position. Fig 41 shews that the Prism is fitted in the same position as the Index Shades and when observing a Star this Prism is turned in like a Shade. Fig. 42 shews the Path of the Ray.

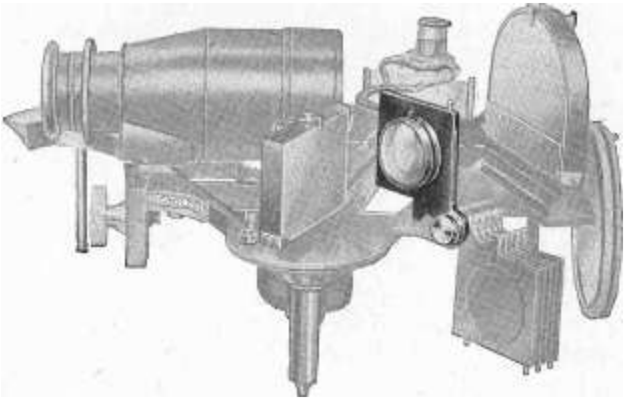


Fig. 41. The Wollaston or Double Star " Prism on Sextant

When taking an observation of a Star with the Wollaston Prism, the observer, of course, sees two stars, one above the other, and the horizon is brought dead between the two stars' images so that perfectly correct altitudes are obtained. Accurate observations may be obtained by its use even when the horizon beneath the star is not well defined.

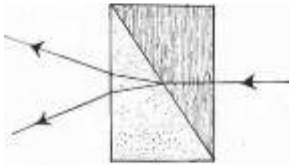


Fig. 42. The Wollaston Prism illustrating Path of Ray **The**

Double Star Prism.

This is stated to be similar to the Wollaston Prism, but is less expensive.

Hezzanith Nicol Prism.

Its purpose is to eliminate horizon glare and for giving a clear definition of the horizon. It is fitted to the telescope like an eye shade.

Hezzanith Polariser.

It is for the same purpose as the Nicol's Prism but is more compact.

Husun Mackenzie-Nicol Prism.

For eliminating horizon glare and defining the horizon. Fitted to the telescope like a shade head.

Elongating Lens for Star Observations (Hezzanith Sextants).

As the stars appear to us simply as a point of light, there is no way of magnifying a star image, but it may be elongated, that is, made into a horizontal line.

This lens is mounted like one of the Index shades and has the property of elongating a star-image into a streak.

As the elongation is horizontal it is also a means of ascertaining that the portion of the horizon used is vertically below the observed star.

Stellar Lenticular (Husun Sextants).

For elongating the image of a star. **The**

Artificial Horizon.

The Artificial Horizon is used for making observations on shore and for school work.

Generally, it consists of a metal trough filled with mercury and covered with a glass cover to protect it from the wind, but the more modern instruments are circular with internal storage capacity for the mercury.

The angle observed in the artificial horizon is twice the angle between the object and the horizon. Half the reading is therefore the observed altitude.

As this is not a practical accessory that can be used at sea, it will not be described at all but full details of it and its use may be found in any text book of navigation.

The Bubble Artificial Horizon.

The best Horizon for the observer at sea when using the Sextant, is undoubtedly the natural one ; but very frequently the horizon is not defined sufficiently clearly to use it as a datum line, though the body may be clearly visible.

In order therefore that the Navigators could overcome the difficulty and obtain sights, even without the natural horizon, the Bubble Horizon has been produced. This has the added advantage that observations of the Moon, Planets and Stars may be taken during the night.

The Booth Bubble Horizon is detachable from the Sextant and is shewn in Fig. 40 fixed to the insi rument.

Under favourable conditions and with constant practice and experience considerable accuracy may be obtained by using it when the sea horizon is obscured or doubtful.

Owing to the quite considerable cost of the Bubble Horizon, relatively few navigators have experience with it.

Those who are interested, however, may obtain full particulars of the Bubble Artificial Horizon from the manufacturers.

It is well to practice using the various telescopes, because an important observation may depend upon using a suitable powered telescope.

CHAPTER VIII.

PRACTICAL NOTES ON THE CARE OF THE SEXTANT

The Sextant, as will have been gathered from the foregoing pages, is a most important and somewhat delicate instrument, requiring great personal care and attention.

It is hoped that the following notes will supply the Navigator with hints and tips on all the points which will assist him to take the greatest care of his Sextant and keep it in the best adjustment.

As this is your best friend at sea, always treat it with the greatest respect.

Never lend your Sextant.

Buying a Sextant.

When buying a new Sextant, the maker's name will be sufficient guarantee of the quality and accuracy of its construction.

If procuring a second-hand instrument, on no account buy it because **it** "looks all right." Get someone to help you to select it. Many a dirty-looking sextant covered with verdigris will, by spending a few shillings to have it cleaned, be made to look far better and may turn out an excellent "gun." Whilst the good-looking sextant may have a flaw that cannot be easily detected.

In selecting a second-hand instrument, several points should be watched. Firstly, the vernier must be correct. If one end cuts a division on the arc the other end should also. See the glasses in the shades are not slack. Reverse the instrument and see if the true and reflected arcs are in the same continuous line. Note whether the arc is well cut, as this is often worn by constant polishing ; if it is, reject the sextant at once. See that the screw at the back of the top (Index) glass is workable. Also examine the other screws for the same reason, because, sometimes, if the metal has not been too good, the thread of the screw is so worn that a screwdriver will not grip it. Make sure also the mirrors are not slack ; bad silvering alone will not matter, as you can have them re-silvered at a marine optician's for a small sum.

If required for deep-sea work and the sextant is not fitted with a telescope of sufficient power to be able to observe stars easily, ask an optician's advice as to the cost of fitting one, for, unless your sextant telescope will pick up stars without difficulty, it is no good nowadays.

Far the better way is to get a brand new one. Buy a good priced instrument, it will last your lifetime if you take care of it.

Using the Sextant.

When holding the Sextant many men prefer to grasp the frame of the Sextant around the handle as well, thus getting a firmer grip.

When clamping the Index Bar, the Clamp Screw should not be forced down hard, but just tight enough to prevent the Index Bar slipping so that the Tangent Screw will act.

Do not strain the Tangent Screw by allowing it continually to get to the end of the thread.

Always rub over your Sextant lightly after use—more especially in damp weather—with a piece of chamois leather (kept specially in your Sextant box). This will prevent the silvering being damaged and keep your Sextant in good order and condition for years. Be careful to rub the arc dry at the same time.

When taking sights in rough weather be careful to clean off the salt spray. After sunset and at night moisture may form on the mirrors which should be removed. Remove all moisture from **the dividing line between the plain glass** and the silvered glass, otherwise the silvering will soon deteriorate and make Star sights much more difficult.

Be careful not to apply excessive pressure on the mirrors or the adjustments may be upset.

The instrument should never be left exposed to the Sun for longer than necessary, and between "sights " it is very admirable to stow it away in its box, or it may get a knock when you are not there.

When using the Micrometer Sextant this must be carefully handled. Very firm pressure must be applied to the Quick Release Clamp, disengaging this carefully by firm pressure of the thumb and finger on the clamp. **Do not push the Index along the Arc.**

The Arc and Micrometer teeth must be kept clean in order to prevent any stiffness occurring in the movement of the Index Bar.

The working parts of the Micrometer Sextant should be lubricated with the special oil provided. This should be used sparingly to the underside of the large Micrometer pivot screw, the Micrometer screw bearing, and also to the rubbing surfaces of the arc.

In addition to adjusting the Sextant and finding the Index Error a periodical examination should be made as follows :—

(1) See the Index Bar moves freely along the arc—if not send it to the maker for overhaul.

(2) Holding the Sextant arc away, as for the 1st adjustment, see if the true and reflected horizons are in line, if not note the difference. Now move the Index Bar round the Arc from one side to the other and see if there is any variation in the distance between the true and reflected arcs. If there is, the Index Mirror must be bent and the instrument should be sent to the maker for overhaul.

(3) Examine the Sextant and see if the telescope is parallel with the Arc (as illustrated in Fig. 19), if not it should be sent to the maker for overhaul.

(4) The Vernier should be examined to see whether when Zero exactly cuts a division on the Arc the 10' division on the Vernier **also** coincides with another division on the Arc. It should do this at several different places along the Arc otherwise the Sextant should be sent for overhaul.

Keep your Sextant stowed away from damp and vibration.

Do not keep your Sextant in a drawer where the constant jolting will probably alter the Adjustments. If possible get a special shelf built fitted with side battens to prevent the box getting any play when the vessel is rolling.

An occasional rub up of the Arc with the bare finger will enable the reading to be made more easily. Be careful not to use anything that will cut the Arc.

It may sometimes be necessary to rub it gently with a little lamp black and sweet oil and then wipe it off. This, in addition to generally cleaning the Arc, makes it much more legible. Never polish the Arc with any abrasive substance.

Never put your Sextant down where a lurch of the ship will knock it or where a shipmate may kick it accidentally

To keep mirrors clean and bright use alcohol, fresh water and tissue paper.

If the Sextant is being stowed away for a long period, the Arc should be coated lightly with vaseline.

ADJUSTING THE SEXTANT.

Although the Sextant is very strongly made, yet it is of necessity a delicate instrument and must be handled carefully. Nevertheless, bearing in mind the conditions under which it is housed, it may at any time receive some accidental damage. A light blow is liable to put out the Adjustment.

Never adjust your Sextant too much. If there is an Index Error, leave it (and, of course, allow for it), until you get a calm night—one spent at anchor is best—and then correct the adjustments by a star. You will be repaid by letting the screws set well, and then, when once adjusted, the Sextant will probably stay so for voyages

Use the highest power of the inverting telescope for the final adjustment of Index Error and Side Error.

The practical Navigator tests rapidly for Index Error by setting the Index Bar exactly at zero and observing the Sea Horizon both vertically and horizontally. If no error is apparent then for Sea horizon observations the Sextant may be considered to be in Adjustment.

When the Index Error has been corrected, if there is any small quantity remaining, this should, if possible, be made "off the arc" (therefore a plus correction) ; because an additive Index Error is much simpler to apply than a subtractive one.

Never adjust your Sextant by a **near** object, because owing to Parallax the results will be quite unreliable.

When using a Star to adjust the Sextant do not use one too bright. It is preferable to use one of the Second Magnitude, such as Alpha cca, Deaebola or Dubhe.

Finally.

"Tormenting " the Sextant is the term applied to "over-adjustsment" of the Sextant, therefore **do not torment your Sextant,** as if the adjusting screws once get loose they will never be reliable.

REED'S—THE SEXTANT SIMPLIFIED 81

CHAPTER IX.

THE PRINCIPLE OF THE SEXTANT

In Chapter I.—Description of the Sextant—we found that a small piece of glass gg' (a movable reflector called the Index Glass) see Fig. 43, is placed at I at the centre of the arc AC and is attached to a movable radius IB (the Index Bar). By moving the Radius or Bar the plane of its surface (which is perpendicular to the arc AC) may be made to cut at any required point, e.g., B. Another piece of glass hh' (the lower half only of which is silvered) is a **fixed** reflector (called the Horizon Glass) and is placed at H—perpendicular to the plane AC.

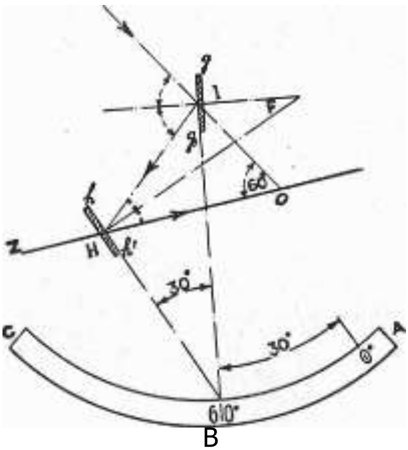


Fig. 43. The Principle of the Sextant

Now suppose a ray of light proceeding from the object Y in the direction YO hits the movable reflector I at the angle YIg, then by a well-known optical law (described below) the ray will be reflected back in the direction IJH making an angle HIg' with the movable reflector (Index Glass) equal to the angle YIg.

Also at the fixed reflector H the ray IH will suffer another reflection in the direction HO making with the reflecting surface hh' the angle 0Hh' equal to the angle IHh.

Now if we suppose an Observer's eye be placed at 0 and another ray of light to proceed from the object Z along the same line ZHO the two objects Y and Z will thus appear to come to the observer from the same

point Z; the image of the object Y having been transmitted to him from the silvered part of H and the direct image of Z through the upper part of H which is made transparent for this purpose.

The angular distance between Y and Z which is what is required is the angle 0 (60^0 in Fig. 43) and this angle by a second optical law is double the angle AIB (301 measured along the Arc AC.

Thus if the arc AC, which may be supposed to be the sixth part of a circle or to contain 60°, is so graduated that it reads twice that number or 120°, then the reading off along the arc AC will be the value of the angle at 0, and this is the method adopted in dividing the arc of the Sextant.

To observe therefore the angle between any two objects such as Y and Z the observer at 0 looks directly at the left hand object Z through the fixed reflector H, he then moves the radius IB attached to the movable reflector I in the plane passing through 0 and the two objects Y and Z until he sees the ray proceeding from Y in the same direction as the object Z. Then the reading off on the arc AC measures the angle at 0 the angular distance between the two objects Y and Z.

It should be pointed out that the observer's eye is seldom at 0 exactly but at some other place in the line OH. When the objects such as the Sun, Moon or Star are at a considerable distance from the observer, however, this will make no appreciable difference.

OPTICAL LAWS.

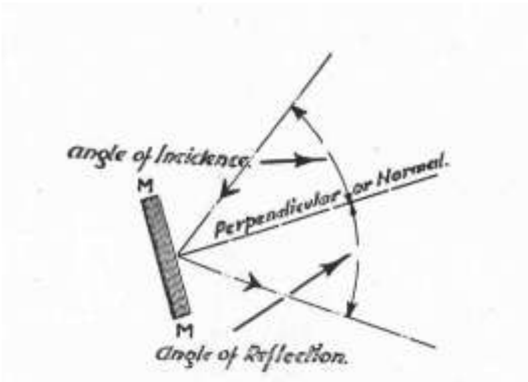


Fig. 44. Law of Optics

The two important optical laws used in the construction of the Sextant are as follows :—

1. The Angle of Incidence equals The Angle of **Reflection.**

In Fig. 44 a ray of light from the Star strikes the plane polished surface MM and the angle which this direction makes with the perpendicular (or normal) to the surface is called the angle of **Incidence.** Now when this ray of light is turned back or reflected from the polished surface the angle which its ray makes is called the Angle of **Reflection,** and the law of optics is that these two Rays always lie on either side of the perpendicular to the surface and equi-distant from it—therefore the two angles are equal. Thus the angle of Incidence equals the Angle of Reflection. This occurs in the Sextant as described above when the ray hits the Index Mirror I and the Horizon Mirror H (see Fig. 43).

2. If a ray of light is reflected twice at the surface of two Plane Mirrors, the angle between the planes of the Index and horizon glasses is half the angle between the objects observed, or it may be put that " the angle between the first and last directions of a ray is double the angle of the inclination of the reflecting surfaces to each other."

In Fig. 43, YIHO is the path of the ray of light from an observed object reflected from two mirrors I and H (the Index and Horizon Mirrors) which are perpendicular to the plane of the instrument.

YI meets HO at 0. The angle 0 is therefore the angle between the first direction of the ray and the last direction, that is the angle at the observer's eye.

The angle F between the normals (or perpendiculars at I and H) equals the angle between the planes of the Index and Horizon Glasses HBI. Now by law of optics above mentioned this angle is half the angle between the objects observed. Therefore in order to avoid doubling the angle HBI to get the correct angle, the Sextant is graduated to double its actual reading as shewn in Fig. 43.

No attempt has been made to prove the above. Those who are interested, however, are referred to any text book on navigation.

Fig. 10 may, with advantage, be consulted.

CHAPTER X.

THE SEXTANT AND COASTAL NAVIGATION

The Sextant is of the utmost value when in sight of land, because, by measuring the **"angular height"** of a lighthouse or a mountain (or any object of which the height is known), the " Distance off" may be found. This operation is termed **"Taking the Vertical Angle."**

The vessel's position can also be Fixed by measuring with the Sextant the angle between 3 or more lights or points of land. This operation is termed **"Taking the Horizontal Angle."**

Taking the Vertical Angle.

Set the Index Bar at zero and use the Star Telescope or simply the Blank Tube. Look direct at the object and by moving the Tangent Screw (or Micrometer Wheel), bring the reflection of the upper part of the object (seen in the silvered half of the horizon glass) down to the level of the lower part of the object (seen through the plain glass in the horizon mirror)—generally the horizon.

When observing the Sextant angle of a lighthouse, it must be borne in mind that it is the centre of the glass lamp that must be reflected down to the sea (high water-mark to be strictly accurate) and not the top of the lighthouse—exactly as shewn in Fig. 45.

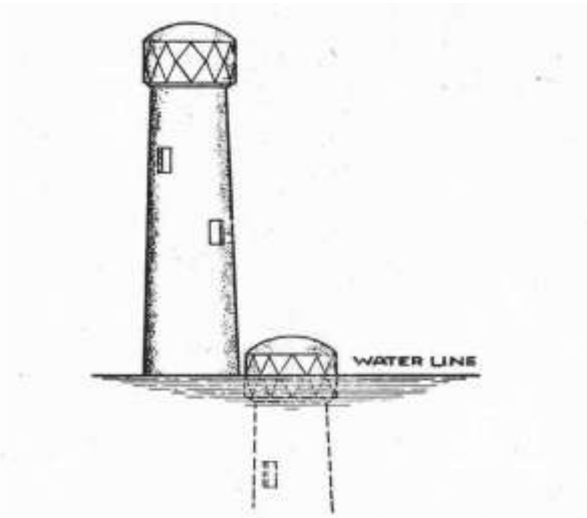


Fig. 45. Taking the Vertical Angle

In practice no allowance is made for height of tide or height of eye, as by ignoring these the observer is led to believe he is closer to the object than he really is and therefore in most cases is given an added margin of safety.

As very small angles are being observed and as accuracy is usually desired, always take the mean of the readings both "on and off" the arc. This eliminates any sextant index error. The height of the lighthouses and headlands—above high-water—are shewn on the chart in the Light Lists or in Reed's Nautical Almanac.

Position by Vertical Sextant Angle.

For the benefit of those who are not familiar with this method of Fixing a Vessel's Position, it should be explained that if the height of any object is known, the distance off may at once be found in the day time by taking a sextant angle of it. If at the same time the bearing of the object is taken by compass **the vessel's position is ascertained exactly.**

This method gives an **ABSOLUTE FIX** and should, when practicable, be used in preference to all other methods of Fixing the Position when in tidal waters, as it gives the position at once without the possibility of error that may occur with the 4 point and other Running Fixes.

In modern navigation whenever possible, in the day time, especially when passing abeam of an object (i.e., 90^0 from the Ship's Course) when it is customary **always to Fix the vessel's position ;** the distance off an object is found by taking a Sextant angle of it.

At sea "**Lecky's Danger Angle"** is generally used. This is a little book giving in column under every 10 feet of height, the distance off in miles and cables corresponding to the sextant angle in minutes. The procedure is to look out the column representing the height of the lighthouse or object to be observed before hand and have the book lying open at this page. **Having ascertained the Sextant Angle,** a glance in the book will give the distance off. A quick and simple procedure.

The reason " **Lecky's Danger Angle"** is used is because it has an extension for finding the distance off from "long range" of mountains, etc., of use for example when passing 20 miles or so from an outlying island, such as Teneriffe.

When coasting, however, and being less than 5 to 7 miles off, an excellent table is given in Reed's Nautical Almanac for finding the distance off **by inspection,** without calculation of any sort. Most volumes of Nautical Tables contain a similar table.

Rough Method.

In practice, if you have no Tables at all, an excellent rough and ready rule is to :—

Multiply the height by 0.565 and divide by the Sextant Angle in minutes to get the distance off.

Up to 5 miles distance this will be approximately correct and as the height can be multiplied by the constant **beforehand,** it is very simple to divide by the angle so the "distance off" is obtained in a few seconds

Example.

The vertical Sextant Angle of Buchan Ness Lighthouse (130 ft. above H.W.) was taken and found to be 0'24'. Required the distance off.

```
         130 feet.        Angle 24')73.45 (3.06 miles.
   Constant 0.565                   72.
            -----                   ---
            650                     1.45
           780                      1.44
          650
         ------
         73.450
         ------
```

Distance off 3.06 miles which is practically the same as may be found by the table in Reed's Nautical Almanac.

It can be seen that the result is accurate and that you would get the correct answer if you used this rough method.

The Vertical Danger Angle.

Here the problem is that, e.g., knowing there is an outlying danger off a point, we decide to keep definitely 2 miles off the lighthouse (200 ft. high) whilst we round it. So reversing the procedure, we look for this distance off under the height and find the **angle** to which we must set the sextant.

The distance off varies as the vertical angle so when approaching the object the sextant angle becomes greater then the danger angle, and this would be a warning to haul out a little. If the sextant angle is smaller than the danger angle then the vessel is safely outside the danger circle indicated by the danger angle on the sextant.

This can be remembered easily because the nearer you approach an object the larger the angle between the observer's eye and the top of the object must be.

If you have not got " Lecky's," "Burton's," or " Norie's " Tables available, then the .565 method may again be used ; working this method for the above Example.

```
Height of Lighthouse   200 feet
            Constant   .565

                         1000
                       1200
                      1000

       (Miles) 2)113.000
```

Required angle in minutes 56.5'

The "Vertical Danger Angle Table" in Reed's Nautical Almanac, gives under 200 feet and abreast of 2 miles, 057• The answer obtained by calculation is 056.5', and is almost the same as found by the Tables.

As can be seen, this procedure is almost exactly the same as finding the distance off, except that you divide by the miles instead of the sextant angle.

The Horizontal Sextant Angle.

Three objects are required that are marked on the Chart and the horizontal angle measured between the middle one and that on either side of it. This gives, or course, a" Fix" **independent of the compass and deviation—hence** its value.

To take the " horizontal angle" between two objects, hold the Sextant horizontally (flat), mirrors upwards, and bring the reflection of the right hand object directly below the left hand object, when the latter is seen through the plain part of the horizontal glass. To pick up the reflection of the right hand object, the Index Bar should be at zero, and the observer looks directly towards the object.

If it is necessary to reflect the left hand object over the right hand object, the Sextant must, of course, be held upside down.

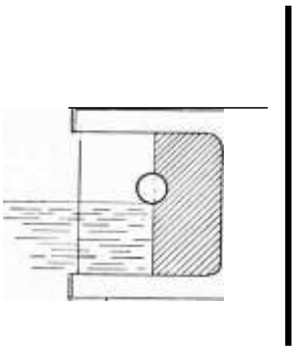
Do not forget also always to first **set the Index Bar at zero.**

These horizontal angles should be plotted on tracing paper or by the **Station Pointer.** The practical use of these horizontal angles and The Horizontal Danger Angle are given in all Navigation Books.

Danger Angles.

Navigation by Danger Angles is little practiced in Merchant vessels, as it is preferable and safer to set a course well clear of an object than to attempt to pass very close to it. (In almost all cases there is room to seaward, and it is better to be sure than sorry).

When coasting in a small vessel with an inaccurate compass, however, an experienced observer may find it highly advantageous to use horizontal sextant angles to fix the vessel's position.



Appendix A.

The National Physical Laboratory.

SEXTANTS

Sextants are not engraved with the Laboratory mark, but a certificate is issued giving the main results of the tests and indicating that the required standard has been attained. The Laboratory regulations provide for two classes of tests, viz. :—

CLASS A. For normal type instruments of the highest class.

CLASS B. For normal type instruments of a standard lower than is required for Class A.

Among the various requirements are the following :—

Class A **test**

General Construction.—The mechanical construction of the instrument must be satisfactory, with regard both to the workmanship and the suitability of the materials employed.

Graduation.—The range of graduation should enable the instrument to be read from 5 degrees below zero to 125 degrees above. It should be possible to read directly to 10 seconds (or 0.2 minutes in the case of instruments with decimal sub-division). The combined graduation and centering error should nowhere exceed 40 seconds (or 0.8 minutes in the case of instruments with decimal sub-division).

Telescopes.—The Instrument should normally be supplied with a minimum of three telescopes, viz. :—

(i) A telescope of minimum magnification 9 and minimum" apparent" field 25°.

(ii) A telescope of minimum magnification 6 and minimum " apparent " field 25°.

(iii) An erecting "star" telescope of magnification about 3 and minimum " apparent" field 15°.

The telescopes must give good definition, with absence of colour, over the greater part of the field. The telescope mounting should carry a satisfactory rising piece, or its equivalent, and should be such that the axis of the mounted telescope is reasonably parallel to the surface of the limb.

Mirrors and Shades.—With all mirrors and shades the surfaces must be so nearly plane and parallel that light passing through is not deviated by more than 5 seconds. In order to ensure the perpendicularity of the mirrors to the plane of the arc graduation both mirrors must be fitted with a satisfactory adjustment for the removal of perpendicular error. The horizon mirror must also be fitted with a satisfactory adjustment for side error. The density of the shades should be suitably graded.

Class B Test

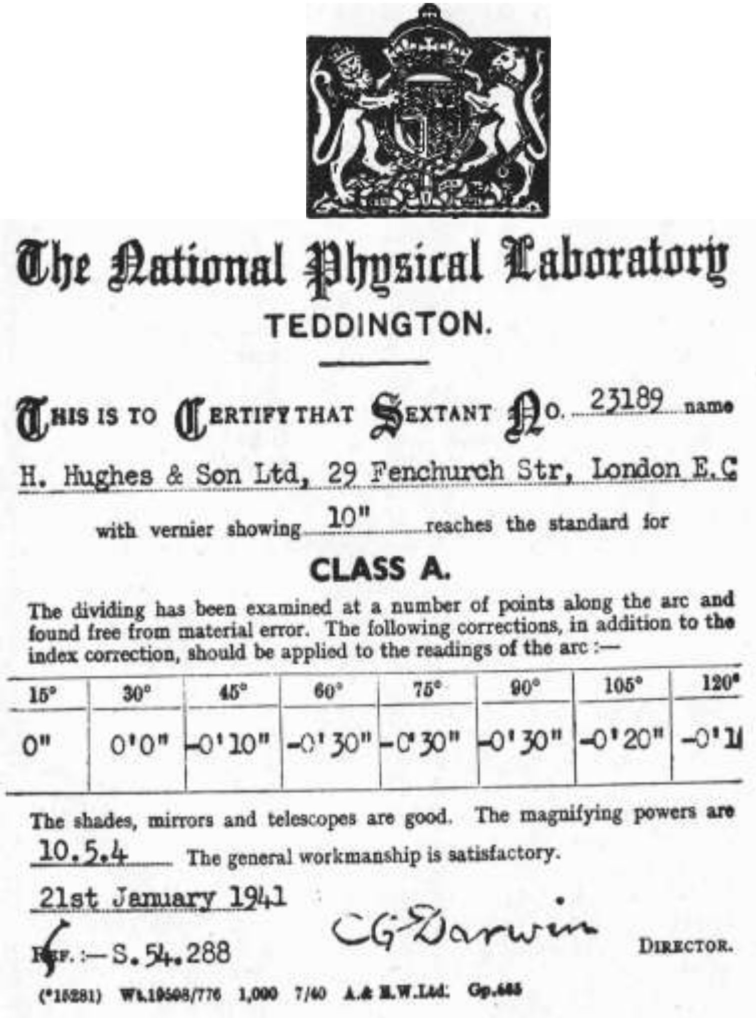
; The requirements are similar to those enumerated above for Class A, but the standard is not so high. For instance :-

Graduation—It should be possible to read directly to 20 seconds, and the combined graduation and centering error should nowhere exceed 2 minutes.

Telescopes.—The instrument should have at least two telescopes which should correspond to telescopes (ii) and (iii) of the Class A requirements.

Numbering.—It is invariably required that each instrument shall be engraved with a distinguishing number for the purpose of identification.

Certificates.—A certificate is supplied with each instrument which has passed the tests to which it has been submitted. The certificate shews the class of test and gives figures for the value of the smallest direct reading, the magnification of the telescopes, and the errors observed at the various angles.



The National Physical Laboratory

TEDDINGTON.

This is to Certify that Sextant No. 23189 name

H. Hughes & Son Ltd, 29 Fenchurch Str, London E.C

with vernier showing 10" reaches the standard for

CLASS A.

The dividing has been examined at a number of points along the arc and found free from material error. The following corrections, in addition to the index correction, should be applied to the readings of the arc :—

15°	30°	45°	60°	75°	90°	105°	120°
0"	0'0"	-0'10"	-0'30"	-0'30"	-0'30"	-0'20"	-0'1

The shades, mirrors and telescopes are good. The magnifying powers are 10.5.4 The general workmanship is satisfactory.

21st January 1941

Ref. :—S.54.288

CG Darwin DIRECTOR.

(*15281) Wt.10508/776 1,000 7/40 A.& E.W.Ltd. Gp.685

Fig. 46. The National Physical Laboratory Certificate Class A.

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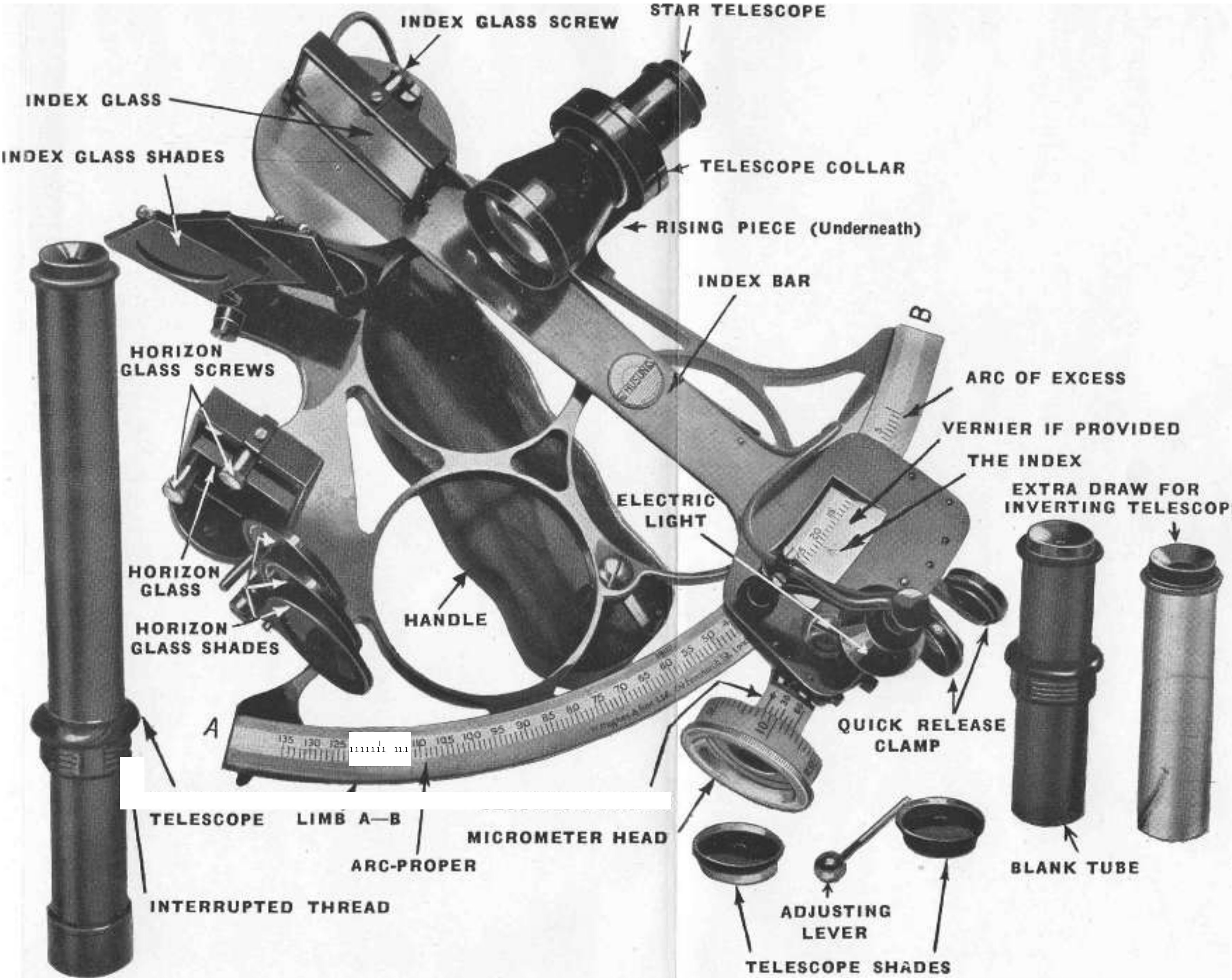

Fig. 3. A "3 Circle" Micrometer Sextant with the parts named.

Fig, I. A Diamond Frame " Micrometer Sextant stowed in its case.

Note the position of the Index Bar (about half way along the Arc) and the Erect Telescope shipped in position.