Professional Sextant

Operations Manual

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First Use

Before the first use check and correct the mirror position.
Mirrors may be deadjusted by shock during transport.
Refer to Chapter: Adjustment of Horizon and Index Mirror

Application

The sextant is used for astronomical position finding at sea.
In coastal waters horizontal angle measurements can be carried out for terrestrical navigation.
With a sextant the navigator measures the vertical angle between the visible horizon and a celestial body. From this apparent angle one can calculate the true star height as required for astronav calculations by applying different corrections to be found in the nautical almanach.
At the same time of star observation the Greenwich time (world time or UTC) has to be determined. Star altitude, UTC and the dead reckoning position allows calculating a line of position (LOP). The intersection of two LOPs gives the true position or FIX.

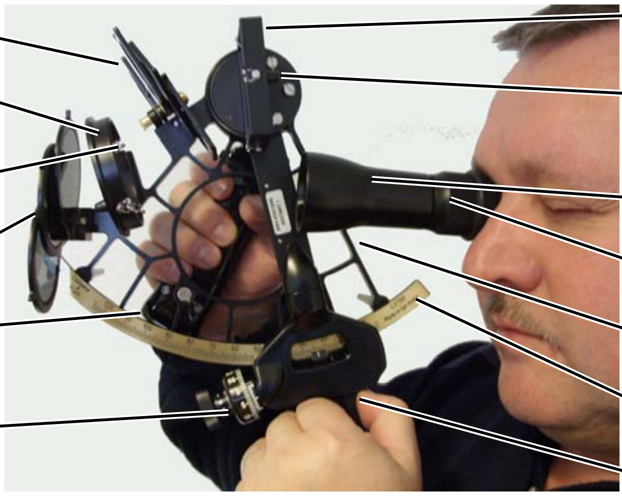
Technical Data

Angle range	-5° ... +125°
Instrument errors	< +/- 5"
Reading accuracy	> 10" or 0.17`
Weight	1.8 kg
Batteries type AA or R6 (1.5 V)	2
Horizon Mirror	traditional split view or full view
Dimensions of index mirror	56 x 42 mm
Dimensions of horizon mirror	∅ 56 mm
Material storage box	wood
Frame material	brass seawater resistant coated

<u>4 x 40 Telescope:</u>

Principle	Galilei, upright picture
Magnification	4 x
Objective diameter	40 mm
Aperture	8°
Field of view	131 m/1000 m
Exit pupil	5 mm
Luminosity, geometric	100
Twilight factor	12.7
Focussing	rotatable eyepiece

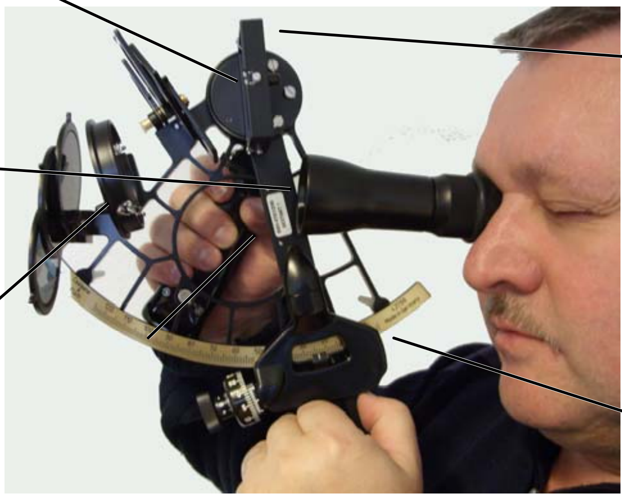
Design



At its lower end the sextant frame carries the arc or limbus with a graduation from -5° to +125°. An angle of more that 90° can be used to check an unusual horizon dip. The alidade or index arm is pivoted to the frame by means of a specially designed bearing that grants a minimum of slack. Attached to the upper end of the index arm is the index mirror. The lower end of the index arm supports the graduated drum with knurled knob and tangent screw, the vernier, the lever and the index mark to read off full degrees. The drum has scale units of 1`. Decimal minutes may be read from a vernier scale.
The telescope is detachable, and is fixed by a knurled screw to the body of the sextant.
The eyepiece is rotatable for focussing. The 4 x 40 mm optical system grants sufficient brightness for twilight observations as well as enough magnification for coastal horizontal angle measurements.
The horizon mirror is mounted in front of the telescope. And in front of this a set of 3 differently tinted horizon glasses (circular) is installed to dim the sun´s reflection on the water surface. A set of 4 differently tinted index shade glasses (rectangular) is located between horizon and index mirror. These shade glasses are for light dimming of the doubly reflected celestial body (sun). In order to ensure equal brightness of both images -especially during sun observation- the tinted glasses are all of systematically graduated transparency and can be moved into the path of light singly or in any required combination from either set of filters. All shade glasses stop transmission of non visible (ultra violet) light so that no harmful effects will be caused when looking into the sun through these shade glasses.
The reverse side of the frame carries the handle with batteries for illumination and the legs.

The full-vision mirror extends the field of vision along the horizon by 95 %, and, depending on the wavelength of the light, meets with the needs of the human eye concerning the light reflection/transmission ratio.
The traditional split view horizon mirror on the other hand, allows direct, not attenuated horizon view. This can be advantageous under poor visual conditions like in twilight. The vertical silver/transparency limit makes the vertical finding at observation easier.

How a Sextant Works



The principles of measurement may be outlined as follows:
Index mirror A reflects the light from the star to the internal surface of horizon mirror B. This reflects the light into the objective of the telescope. Thus the navigator observes the star through the telescope doubly reflected.
As the horizon mirror also allows the light from the horizon to transmit this will be seen directly through the telescope by the navigator.
So one has to distinguish between direct vision of horizon and doubly reflected vision of the celestial body.
The index mirror A can be adjusted by moving of the alidade.
If the index of the alidade points to zero of the limbus, mirrors A and B are parallel. So the observer sees two images (the directly seen one and the doubly reflected one) of the same object. Both should be exactly superimposed if the mirror positions are error free. If these two images do not exactly coincide along the vertical, then there is an index error (either + or -), which requires correction in all measurements. If these two images do not coincide along the horizontal, then there is a tilt error which also requires correction. Usually one will find a combination of both errors.
To measure the vertical angle between the horizon and a star the observer should move the alidade along the limbus until the reflected image of the star is superimposed on the direct image of the horizon. The method of sighting will be explained in detail later. By the law of light reflection the angle which the index mirror has been turned, is half the angle between star and horizon. For this reason the limbus of the instrument has been graduated so as to allow the user to take a reading without having to make a conversion. The total measuring range of a sextant is ≈120°, so that the angle of the arc is ≈60° only. This gives the sextant the name because 60° is the sixth part of a complete circle.

Sextant in the Box

Before laying the sextant into the box move the alidade to the zero position.
When the instrument is being placed in its case, make sure that the instrument is dry, because otherwise humid air inside the case may cause fungus attack.

Batteries for light are already inserted into the sextant handle.

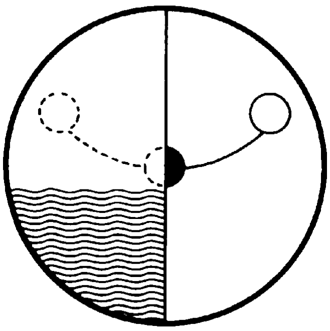
You will find the following items in the box:
User`s manual
Certificate
Mirror adjusting wrench
Cleaning brush (for cleaning the toothing at the arc from dry salt)

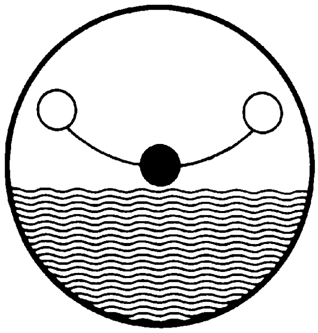
Celestial Observations

Carefully watch not to look into the sun without applying shade glasses of necessary light reduction!

The sextant has to be held vertically.

1. Prepare observation by choosing the right shade glass if moon or sun shall be measured. This can be done by direct observation of a celestial body through a shade not using the telescope. Combine the shades as required. The circular horizon shades are to reduce light reflection on the sea surface. Even these have to be adjusted to the brightness of the sun if the following method should be used.
2. Check index and tilt errors (ref. to chapter: Adjustment of Horizon and Index Mirror). Note index error, if any, for later calculations or correct the mirror position as described in the above mentioned chapter.
3. Move the index arm to zero and observe the star. You will see the star twice: the doubly reflected image and the directly seen through the horizon mirror.
4. Bring down the star to the horizon. To do this, loosen the lever and move the index arm slowly forward. The directly seen and the reflected image of the star will separate. Follow the lower image (reflected image) of the star by moving down the sextant synchronously. When the horizon appears in the field of view from below engage the lever. Now carry out fine adjustment by rotating the drum until the star touches the horizon (the star “kisses“ the horizon).

a) 

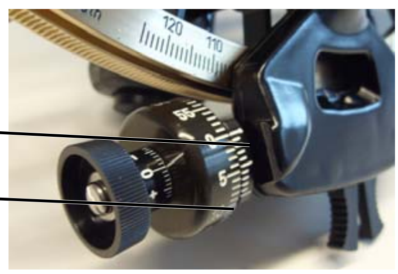
b) 

5. The sextant must be exactly vertical when measuring the star altitude. If not, the measured altitude will be too high. To avoid this swing the sextant around the axle of the telescope. The star will describe an arc (“Swinging the arc“). The lowest point of it just has to touch the horizon. Refer to the above illustration: a) traditional split view horizon mirror, b) full view horizon mirror.
6. Read the whole degrees of star height at the index of the alidade and the minutes and decimal minutes at the vernier as shown.

Index for degrees

Vernier for decimal minutes

Drum for minutes



Alternative Methods
There are two popular alternative methods of star sighting :

1. Adjust index shade glasses to diminish light transmission as mentioned above. Horizon shade glasses have to be adjusted only to reduce brightness of reflections on the water. Face to the direction of the celestial body. Observe the horizon through the horizon mirror. Move the alidade up and down (accidental) until the image of the star appears. Now engage the lever and carry out fine adjustment and proceed as mentioned above.
2. Adjust index shade glasses to diminish light transmission as mentioned above. Horizon shade glasses have to be adjusted only to reduce brightness of reflections on the water. Precalculate the star height and move the index arm to this angle. As the field of view of the telescope is about 9° the intended star can easily be found.

Finding the Position
The apparent height measured as written before has to be corrected before starting the mathematical treatment. The correction can be found in the nautical almanach. In addition at the same moment of altitude measurement the Greenwich time (world time or UTC) has to be filed. Both -star height and UTC- will give one line of position (LOP). The intercept of two or more LOPs will give the true position, the FIX.
The mathematical procedure cannot be explained here. Refer to the relevant literature, like: American Practical Navigator by Nathaniel Bowditch et al., U.S. Defense Mapping Agency or others.

Terrestial or Horizontal Angle Observations

This measurement can be used to find a position near to the coast.
Swing out all shade glasses and set the alidade to zero. When the instrument is held horizontally, the right-hand object will be sighted first. One can see simultaneously the directly seen (through the horizon mirror) and the doubly reflected (reflected by horizon and index mirror) picture. Move the alidade forward. Simultaneously turn yourself to the left and keep the doubly reflected picture in view. The second left object will appear from left and can be brought exactly in line with the first right-hand object.
Reading of angle will be carried out same as described above.

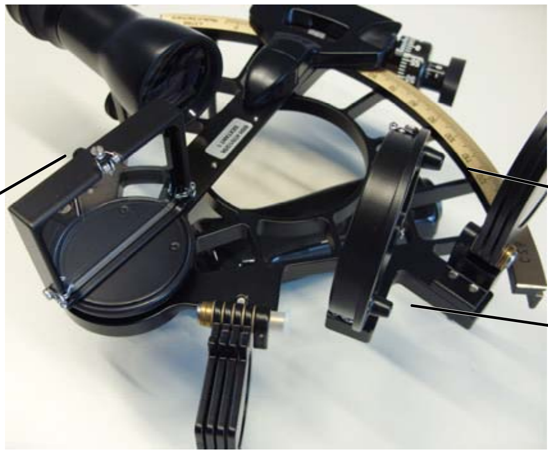
Range Finding

The distance to a terrestial object of known height can be calculated by measuring the apparent height with a sextant. The nearer the object the heigher will be the apparent angle between top and bottom. One has to distinguish between objects in front of or behind the visual horizon. The relevant formulas will be found in the nautical literature.
There are special sextant-like instruments called stadimeters with an expanded scale for small angles especially for this application.

Adjustment of Horizon and Index Mirror

There are two different kinds of sextant errors: the so-called small errors (mirror position errors) and the large errors (caused by excentricity of the index arm pivoting, errors of graduation ...). The small mirror errors can be recognized and must be corrected by the navigator himself. The large errors, however, cannot be recognized and cannot be corrected by the user. If the navigator thinks that there could be such a large error he should contact a qualified workshop. Reasons for large errors are bad workmanship, heavy knocks, shock or drop of the sextant.
When the sextant is in use, the small mirror errors may become apparent in the course of time. Also here the possible reasons may be knocks or shock.
It is therefore necessary to ensure the following:

1. The index mirror must be at right angles to the plane of the instrument. Any inclination against the vertical is called <u>tilt error of the index mirror</u>.
2. The horizon mirror must be at right angles to the plane of the instrument. Any inclination against the vertical is called <u>tilt error of the horizon mirror</u>.
3. The <u>index error</u> must be 0.



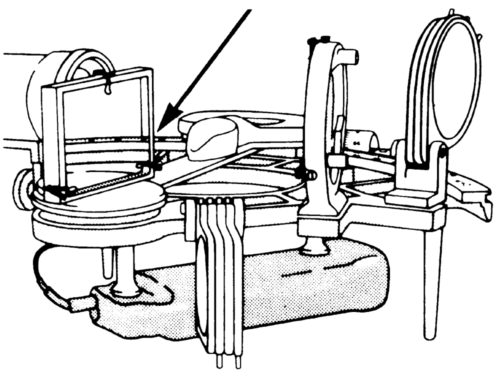
Tilt errors produce a lateral displacement of the directly seen and doubly reflected image, index errors produce a vertical displacement. It is very important to correct index errors as they will cause erroneous observations which will result in wrong positions. Therfore index error should be checked before each observation. The mirrors fixed within the frames tend to have stable set points. If these set points are not at positions of zero error it can be advantageous not to adjust the mirror by the correction screws but to adding or subtracting the error value from the observed height. This is recommended for smaller errors because this will prevent loosening of the correction screws within their threads.

Too frequent adjustment of these mirror adjusting screws should be avoided, particularly as tightening and loosening will work out their threads.

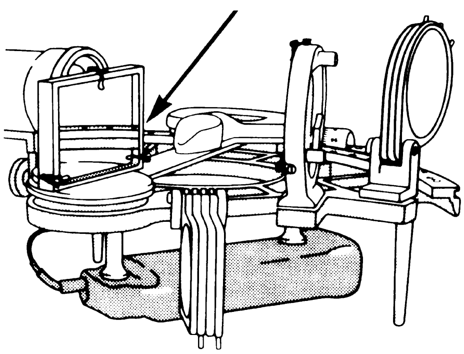
Tilt Error of the Index Mirror

The index mirror must be at right angles to the plane of the instrument.
In order to determine whether the index mirror is perpendicular to the plane of the instrument, the alidade should be positioned approximately at the centre of the graduated arc. Now look from direction of the index mirror, passing the inner edge of this mirror, at the zero point of the graduated arc. Next to this, reflected in the mirror, the opposite end of the graduated arc will become visible. If the two images are level, the index mirror is correctly positioned. If the two images are not level the index mirror has to be adjusted by means of correction screw as shown in the following illustration.
Smaller differences are tolerable because these errors do not directly affect the measuring accuracy.

Take the sextant this way to identify and correct tilt error of index mirror



a)



b)

ilt Error of the Horizon Mirror

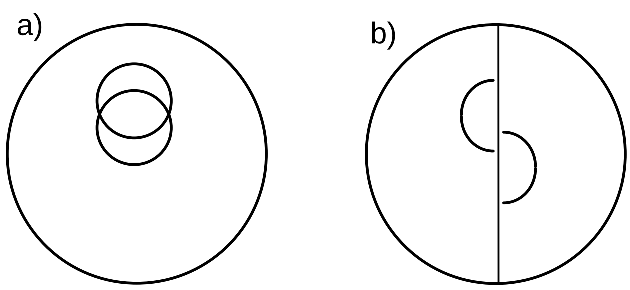
The horizon mirror must be at right angles to the plane of the instrument.
Set the alidade to the zero point of the graduated arc and the drum as well. If the horizon mirror is parallel to the (corrected) index mirror, then the reflected and the directly seen image of an object will coincide (if the object distance is over 3 nm). If the images do not coincide the horizon mirror has to be adjusted. There are the two following methods to do this:

1. Superimposition check (for fullview horizon mirrors only)
   The sun (make sure applying the right shade glasses!), a fixed star, or a distant terrestrial object has to be observed. If the superimposition of reflected and directly seen image is exact, the horizon and index mirrors are parallel. If the sextant is held vertically in the right hand and the images appear laterally displaced then the horizon mirror is tilted. Correct this by using the screw as shown in the illustration on page 11.
2. Visible-horizon check (for traditional split view and fullview horizon mirrors)
   To begin, the instrument is held vertically as it is held for celestial observations. Move the alidade so that the image of the directly seen visible horizon is made to coincide with its reflected image. The instrument is then, for example, turned clockwise round the axis of the telescope through an angle of approximately 45°. If the directly seen visible horizon and its reflected image still coincide, the horizon mirror is correctly positioned. If both images move up and down to each other, the horizon mirror is tilted. The necessary correction can be made by adjusting the screw as shown in the illustration on page 11.

Index Error

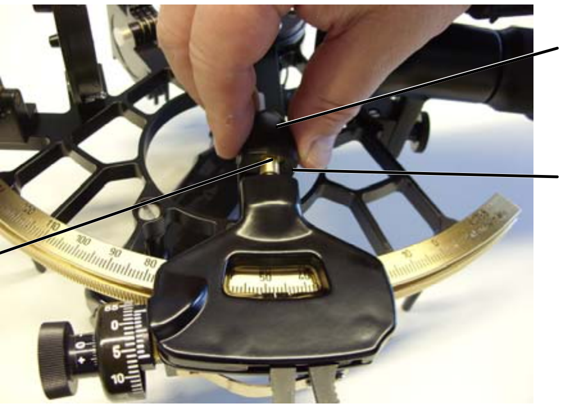
If the index mark and the drum as well of the alhidade points to zero of the arc then both mirror should be parallel (tilt errors are already removed). This cannot be reached in every case so the angle reading will require correction.
This is known as the index correction. Proceed as follows to correct:

1. Set the alidade (index arm) to zero. It is necessary to make a fine adjustement using the drum.
2. Observe the celestial body (make sure applying the right shade glasses!) through the horizon and index mirrors. Both pictures coincide more or less. In case of the fullview horizon mirror a) both pictures of the sun are superimposed, in case of traditional split view horizon mirror b) half of the celestial body is on the right and half of it on the left side of the field of view. Carry out the correction by adjusting screw as shown on page 11.



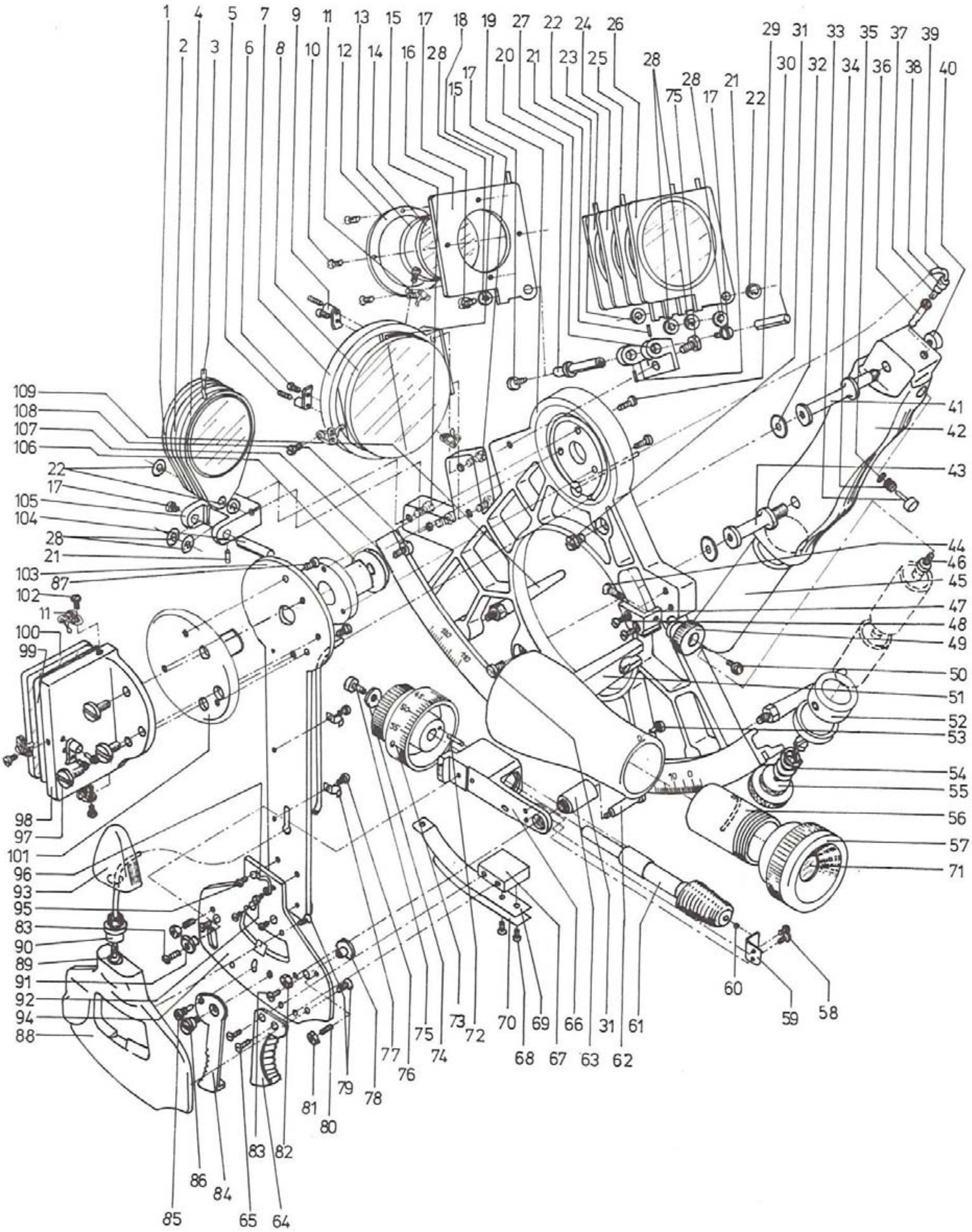
Changing the Telescope
The telescope is fixed to the sextant by a knurled knob.
No adjustment is necessary in order to exchange one against another telescope. But care must be taken to ensure that it is screwed securely to the frame.

Illumination and Replacement of Batteries
The illumination lights up the index mark and drum with vernier. This simplifies measurement readings at night. Open the sextant handle by using of the knurled knob to change the batteries (2 off type R6 or AA).
The bulb can be replaced by pulling out the illumination cap of the light leading frame as shown in the following picture.



Care and Maintenence
Precision mechanical instruments must be treated with extra care. They should never be knocked or dropped. The instrument should either be held with the right hand gripping the handle, or, when it is being taken out of its case or handed to someone else, with the left hand holding the frame of the instrument.
A fine hair brush should be used to clean the mirrors, tinted glasses, telescopic lenses and the graduated arc from dry salt caused by spray water or dust. In case the mirrors are cleaned this way or if they are touched accidentally one has to re-adjust them. If these parts are wet, they should be cleaned carefully with a soft chamois leather of fluff-free linen cloth. A chamois leather or linen cloth should be used to dry the body of the instrument if it has been exposed to rainwater, spray or moisture in any other form.
The glass components should not be exposed to direct sunlight if they are wet, as this will cause brownish stains. A cotton-wool swab soaked in pure alcohol should be used to remove salt residue from the mirrors and glass components.
Exposing the sextant unnecessarily to direct sunlight should be avoided at all times. Heat from the sun may cause the cement between the lenses of the telescope to cumble, which will result staining the lenses (sun spots).
Acid-free oil (non resinous) should be applied sparingly to the screw of the drum from time to time.
When the instrument is being placed in its case, make sure that the instrument is dry (otherwise humid air inside the case may cause fungus attack), swing the shade glasses in storage position, alidade to zero and close the case carefully.

Exchanging the Mirrors
Generally the exchange of the traditional split view mirror with frame against a fullview horizon mirror with frame or the other way round is not critical and can be done by the navigator himself. After installation the mirror position has to be corrected carefully (ref. to chapter Adjustment of Horizon and Index Mirror).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