ERRORS IN OBSERVATIONS

Errors

Learn how to compensate for all known causes of error. Remember, sextants are delicate and accurate optical instruments, and must be protected.

Never touch the index glass with your fingers or let any object strike it. Touching the glass leaves a film which makes it harder to see the bubble and celestial body while taking observations.

When making sextant observations in the air, you must take into account the following errors:

Sextant Error

There is an error in the instrument which is due to faulty adjustment of the bubble or the index prism. When you have found the error (see NIF 3-3-2), either apply it in reverse to the Hs (sextant altitude), or remove it by zeroing the sextant.

Atmospheric Refraction

This error in the observation is due to the light ray being bent toward the vertical by the earth's atmosphere. It is always a subtractive correction. This correction has been taken care of in the solutions by HO 218, Star Altitude Curves and Astrograph, for flight level of 5,000 feet. If the flight level differs greatly from 5,000 feet, or, if using one of the other solution forms to obtain the Hc, you must apply the correction for refraction to the Hs, using the tables at the back of the Air Almanac.

Dome Refraction

This is an error in observation introduced by shooting through a glass dome. This error usually increases with altitude, from about 0 to 10 minutes. To determine the error for your airplane:

1. Determine the sextant error accurately.
2. Shoot a series of observations through the glass dome. Use a range of altitudes.
3. Plot these shots against a computed curve in which refraction and sextant corrections have been applied in reverse.
4. The difference of altitude between your shots and the curve is the dome refraction. Make a critical table of the corrections similar to:

Hs	Correction
20°	-3′
25°	-4′
35°	-5′
50°	-6′
65°	-7′
80°	

Parallax

This error is introduced by assuming that you are at the center of the earth instead of at the earth's surface. This error is negligible except for observations of the moon. The parallax correction, which is always added to the Hs in observations of the moon, is determined from the tables in the Air Almanac.

Acceleration Error

This is an error in observation caused by the airplane movement which deflects the bubble so that it does not indicate true vertical. You can minimize this error by following these suggestions:

1. Notify the pilot when you are about to start shooting so he will hold the airplane steady.
2. Start shooting on an even minute and continue shooting for two minutes to average out acceleration errors which are due to the motion of the ship.
3. Use bubble about twice as big as the sun. A small bubble is sluggish and gives poor results.

LAT.	GROUNDSPEED						
	100	150	200	250	300	350	400
0	0	0	0	0	0	0	0
10	0.4	0.7	0.9	1.1	1.4	1.6	1.8
20	0.9	1.3	1.8	2.2	2.7	3.2	3.6
30	1.3	2.0	2.6	3.3	3.9	4.6	5.3
40	1.7	2.5	3.4	4.2	5.1	5.9	6.8
50	2.0	3.0	4.0	5.0	6.0	7.1	8.1
60	2.3	3.4	4.6	5.7	6.8	8.0	9.1
70	2.5	3.7	4.9	6.2	7.4	8.7	9.9
75	2.5	3.8	5.1	6.4	7.6	8.9	10.17

CORRECTION FOR CORIOLIS ACCELERATION

Coriolis Force

This error in observation is due to the rotation of the earth. This error increases with latitude and speed of the plane. Take care to determine whether the correction is enough to warrant the additional computation. Remember, the correction is at a maximum on beam shots.

Translate all lines right in Northern Hemisphere, left in Southern Hemisphere, perpendicular to track. Correction is in statute miles if your groundspeed is in statute miles, nautical miles if your groundspeed is in nautical miles.

Note explanation of "Z Correction for Bubble Sextant" which is combined with wander of the airplane caused by gyro precession. This correction is found in the rear of the Air Almanac.

You can overcome personal error only by constant, persistent practice.

Checking Sextant Error

Sextant error is the difference between what the sextant reads and what it should read if the instrument were in perfect adjustment.

1. The simplest and most accurate method of determining the sextant error is by using the collimator. Merely collimate the crosshairs or the star in the collimator with the bubble in the sextant and read the scale. If the scale reads above zero, the error is plus; if below zero the error is minus. Make certain that the collimator is level before checking the sextant.

2. If near a large body of water, you can use the natural sea horizon as a reference. Set the sextant on a stand, table, or place it in a clamp. Determine the height of the instrument above the water level. Split the bubble with the sea horizon. Apply dip correction to the sextant reading (you can find the amount of the dip correction from the back of the Air Almanac, but you must add it, not subtract it). The difference between the corrected sextant reading and zero is the sextant error.

3. If you know the altitude of the natural land horizon (determine it by means of a surveyor's transit or a sextant of known error) you can check the sextant on it. The sextant error is the difference between the sextant reading and the correct altitude of the horizon.

4. Construct a curve of the altitude of a celestial body. Plot Hc plus refraction, and minus parallax when shooting the moon. Compare with the sextant altitudes to obtain the sextant error. This method permits checking the error of the sextant at the altitudes which are most generally used.

5. If you set up a light or a pole at the same height as the sextant, 1,000 or more feet away, by means of a surveyor's transit or by a sextant with a known error, you can find the sextant error.

Remove the Error

After you have determined the sextant error you can remove it partially or completely by the methods described for each type of sextant. You should check the error frequently as it will change from time to time. Apply the sextant error mathematically in reverse to the Hs, if it is impractical to remove it. This is known as sextant correction.

It is a good idea to determine the altitude of some distant point from a place near the operations building and check your sextant just before takeoff.

Place a card with sextant number and error, date of check, and your name and rank in sextant case.

AIRCRAFT SEXTANTS

Know your sextant. The success of a vital mission, the lives of your fellow crew members, and the safety of your airplane are all dependent upon the accuracy of your calculations. They, in turn, depend upon the accuracy of your instruments and the skill with which you use them.

Tips

Always remove batteries from the sextant container as soon as your mission is completed. Corroding batteries ruin the rheostat and vernier-light battery case.

Keep the index mirror clean and free from greasy fingerprints. If the mirror does get dirty, clean it with lens paper or a well-washed handkerchief.

Severe changes of temperature may cause the index mirror to crack or break. Don't leave the instrument near a heating tube and then use it in a cold turret.

When you open the sextant case after a quick drop in temperature, moisture condenses on the sextant mirrors. To combat this, open the sextant case before you climb to a high altitude.

Batteries do not work well in extreme cold, so keep spares in a warm place, such as the pocket of your jacket, and replace them as often as necessary.

Always carry spare parts such as bulbs, batteries, and pencil leads in your sextant case.

Use a collimator tube, a precomputed curve, or a natural sea horizon to determine the amount of index error in your sextant. **Do not attempt to remove the error.** Note it and correct all subsequent observations by this amount. For any adjustments to your sextant consult an instrument specialist.

If your sextant requires the use of recording discs, be sure to keep them away from the heating tube of your airplane. If the case becomes hot, the wax on the discs melts and the whole supply sticks together.

If your sextant has a vapor bubble, be sure to release the bubble from the chamber during ascents, descents, and when you put the sextant away.

A-12 SEXTANT

Operation

There are two methods of using the sextant:

1. When you observe the sun, use the eyepiece and sunshades. You then are observing it indirectly, because the index glass reflects it to your eye.

2. When you observe the stars, use the direct method of sighting. This simplifies star finding and lessens the chance of observing the wrong star.

Median (Average) Sights

Take a series of shots, pressing the marking lever each time the body appears in proper position relative to the bubble. Take these shots only a few seconds apart.

It is good practice to observe a body for a period of one or two minutes in order to obtain the average time of the observation more readily.

Obtain the median reading in this manner:

1. If your shots are evenly spaced, use the middle mark on the rim of the drum. Rotate the drum until this mark is under the marking pencil. Then read the scale.

2. If your shots are not evenly spaced, rotate the drum until the visual average seems to be under the marking pencil. Your ability to estimate the correct median improves with practice.

Bubble

This sextant has a fixed bubble. The bubble assembly includes a bubble housing, two lenses with seals and locking rings, a filler hole, and xylene bubble fluid.

Optics

The index mirror is clear glass and optically flat. A clamp secures it on the same shaft that carries the sextant arm. With proper adjustment there is no lost motion between the arm and this mirror.

The lens tube assembly transmits the image of the bubble downward vertically from the bubble assembly and then up at an angle to the index mirror and your view.

The real field of the sextant is approximately 12°.

See T.O. 05-35-15.

A-7 SEXTANT

Hold the instrument in both hands. Your right hand operates the micrometer drum while your left, besides furnishing additional support, operates the shade glass holder and the astigmatizer knob. When you use the artificial horizon, move the horizon shutter knob to its extreme position in the direction opposite that of the arrow. This keeps any direct horizontal light from entering the telescope.

Operation

1. Before taking a reading with this sextant, be sure to set the ratchet of the averaging device at 0 and adjust the pencil properly to give fine legible lines.
2. Sight through the instrument and bring the image of the celestial body into horizontal coincidence with the bubble.
3. To record the observation, press the trigger by moving your right thumb backwards without taking that hand off the sextant.
4. Repeat this procedure, without re-setting the ratchet, until you have recorded the desired number of observations.
5. Note the number in the ratchet and select the middle reading.
6. Having determined the middle reading, locate its pencil mark on the micrometer drum cover.
7. Align the pencil mark of the average reading with the end of the pencil.
8. Note the reading on the worm scale dial and micrometer drum scale. This quantity is the average angular altitude determined by the observations. The time of the observation is the median time between the start and finish of your observation.

Bubble

The bubble assembly wnich forms the artificial horizon consists of a field lens, bubble chamber, bottom glass, and diaphragm chamber with cap. A vapor bubble forms in the bubble chamber which, together with the diaphragm chamber, is filled with xylene. The bubble is formed and controlled in size by the deflection of a flexible diaphragm, which forms a wall of the chamber on the side of the bubble assembly. Control the deflection by turning the nut on the diaphragm cover. Radioactive luminous material, painted on a metal ring surrounding the bubble, amply illuminates it.

Before you put the sextant away in its carrying case, return the bubble control knob to neutral, loose on the shaft.

Optics

The instrument optics is so designed that the matching of the bubble's image with that of the body does not have to take place in the middle of the field. It is best to use the astigmatizer for accurate work because the way it flattens the image makes it easier for you to estimate the center of the bubble.

The real field of the sextant is approximately 12°.

See T.O. 05-35-4 for additional instructions on operation and care of this sextant.

A-8A SEXTANT

Operation

You can use this sextant for direct or indirect sighting.

1. Before you take any readings you must set the averaging device in the zero position. Do this by turning the vernier disc as far clockwise as possible. Then use the sextant in the usual manner.
2. As soon as you have taken a shot, place your right index finger in the concave portion of the handle and push it as far counter-clockwise as possible. Then return the handle to its original position. This operation moves the vernier disc counter-clockwise an amount equal to one-eighth of the total recording.
3. Repeat this procedure until you have taken a total of eight shots.
4. Then read the counter disc and vernier disc to obtain the average of these eight settings in degrees and minutes.

The average time is the time of the average altitude reading.

If the 0 line of the vernier disc points between two lines of the counter disc, read the lower of the two as the number of degrees. Add to this the reading of the vernier disc, expressed in minutes of arc.

In reading the vernier, follow the vernier disc counter-clockwise until a line of the counter disc appears to be a continuation of a degree line. The number of divisions in the vernier disc from 0 to the point where the lines coincide is the number of minutes you add to the scale reading.

A pencil averaging device is now available. To have your sextant modified, send it to any one of the following service commands:

Fairfield Air Service Command,
Oklahoma City Air Service Command, or
Sacramento Air Service Command.

Bubble

Use the dark field illumination of the bubble at night. This makes the bubble appear as a bright ring in a dark background. You can regulate the brightness of the bubble with the rheostat.

You can see directly through the center of the bubble to sight a heavenly body.

Optics

The focal length of the eye lens is equal to that of the objective lens.

The real field of the sextant is 9°.

See T.O. AN 05-35-7.

A-10 SEXTANT

Operation

Hold the sextant by its frame in the palm and fingers of your right hand. The control knob, which elevates the field prism, is down. Use your left hand to operate the control knob or to adjust the size of the bubble.

To register a line on the recording disc, move the plunger of the marker with your right forefinger.

The middle value of several readings in a series is the average of your observation. To obtain this reading, align the middle line of any group of readings with the index. Then read the counter to obtain this value in degrees and minutes.

If your observations are equally spaced, take a direct average. If they are not equally spaced, devise your own method of averaging them.

Bubble

Only the bubble itself is illuminated. This makes it easier for you to observe dim stars.

If the bubble disappears you can easily re-form it in this way:

1. Turn the sextant until the bubble-size knob faces downward.
2. Turn the bubble-size knob to its maximum INCREASE position, as indicated on the engraved diaphragm housing. Be careful not to force the knob past the limits of this position.
3. If the bubble is not visible, it may be formed in the diaphragm. Turn the knob to near its minimum position.
4. Hold the sextant firmly and snap your arm forward quickly, in order to release the bubble from the diaphragm housing.
5. An alternate method is to hold the sextant with the bubble chamber away from you and whip the sextant downward sharply.

Turn the bubble to maximum size when you put the sextant back in its case.

Optics

The auxiliary telescope and the eyeguard at the glass chamber housing are interchangeable. When you use the telescope you get a two-power magnification and your field is reduced approximately one-half.

The real field is approximately 14°.

The scales are illuminated. Replacement lights are provided, but in an emergency you can use the lamps out of the B-3 driftmeter, radio compass, or some other aircraft instrument.

See T.O. AN 05-35-12.

A-10A SEXTANT

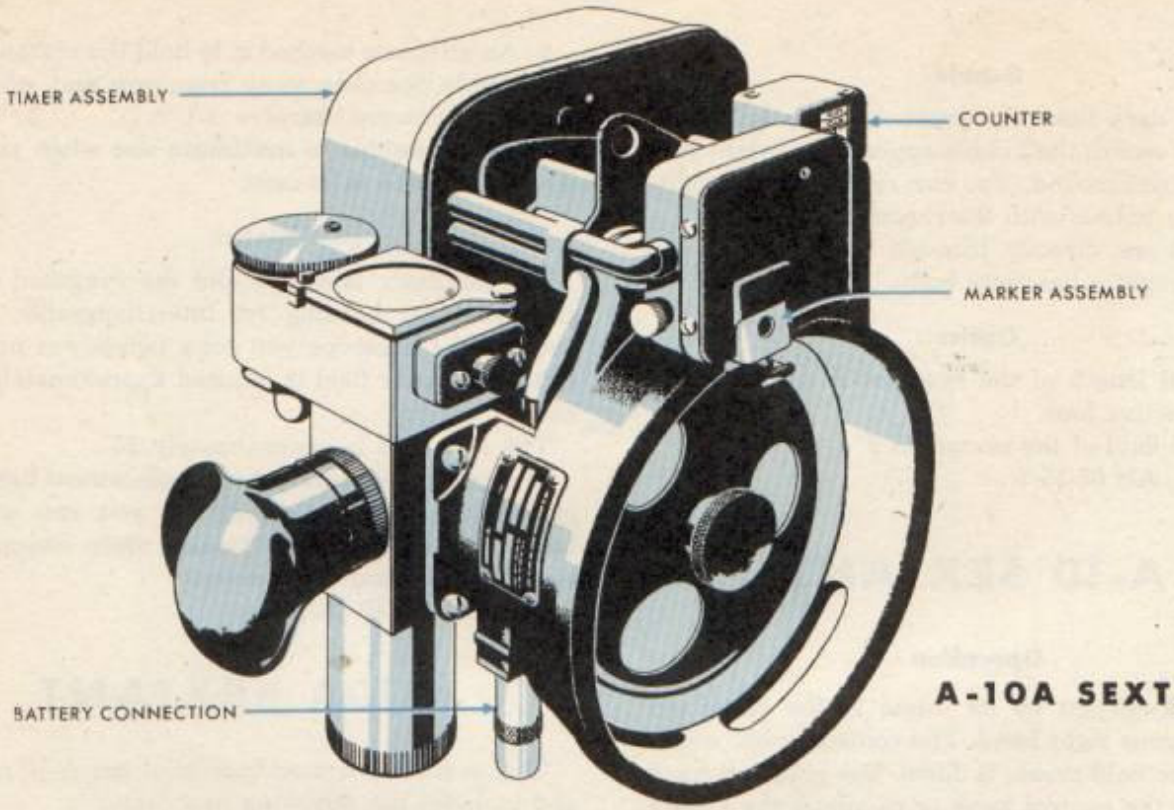
This sextant is a modification of the A-10 sextant and includes the following new features:

1. An automatic marking device operated by a solenoid timing mechanism, which makes a mark on a plastic disc. You can operate the marker manually if the timing mechanism fails.
2. An air-reservoir bubble chamber which permits the bubble to form more easily and produces a bubble which is less affected by temperature changes than the previous vapor-type bubbles.
3. An improved lighting system for the marking disc and counters.
4. A 3-cell battery case which operates the electric timing mechanism and the lighting system.
5. The rheostat which controls bubble illumination is on the sextant instead of on the battery case.

Operation

You must use the battery case to operate this sextant, both day and night. The batteries provide power for a small electric clock in the housing on the left side of the sextant. Approximately once every second, so long as you press the trigger above the marking disc, this clock energizes a circuit which actuates the solenoid marker on the right side of the sextant.

Shake the sextant lightly to make sure that the clock has started; it does not always start when the battery case is connected. As soon as you complete your observations, disconnect the batteries to preserve them.



A-10A SEXTANT

Determine the number of impulses of the marking mechanism per minute. Normally this number does not vary greatly even with extreme changes in temperature. Once you know it, you need only to count the clicks of the solenoid to time an observation.

In the air it may not be possible to hear the click of the marking device, but by resting your right index finger lightly over the marker you can feel its movement and count the number of impulses. At night the bubble light blinks at each impulse and you can use this means of counting them.

The marking device requires careful adjustment of the pencil lead so that there is sufficient clearance between the lead and the disc at the beginning of the stroke to allow the solenoid to gain momentum before the lead strikes the disc. If this adjustment is too close the lead doesn't slide over the disc and, consequently, won't make a mark. If the pencil lead is too far from the disc the mark made is too short. If you adjust it correctly, the lead should last for the entire flight.

You can operate the marking device manually by pressing the flat side of the marker with your right index finger.

General

1. After looking at your hack watch at the start you can time your observation accurately by counting the aural or visual impulses of the marker.

2. You can concentrate on maintaining collimation with the body without having consciously to space your observations at even intervals.

3. The automatic marker makes more uniform marks and eliminates movement of the sextant which occurs when you operate the marker button manually.

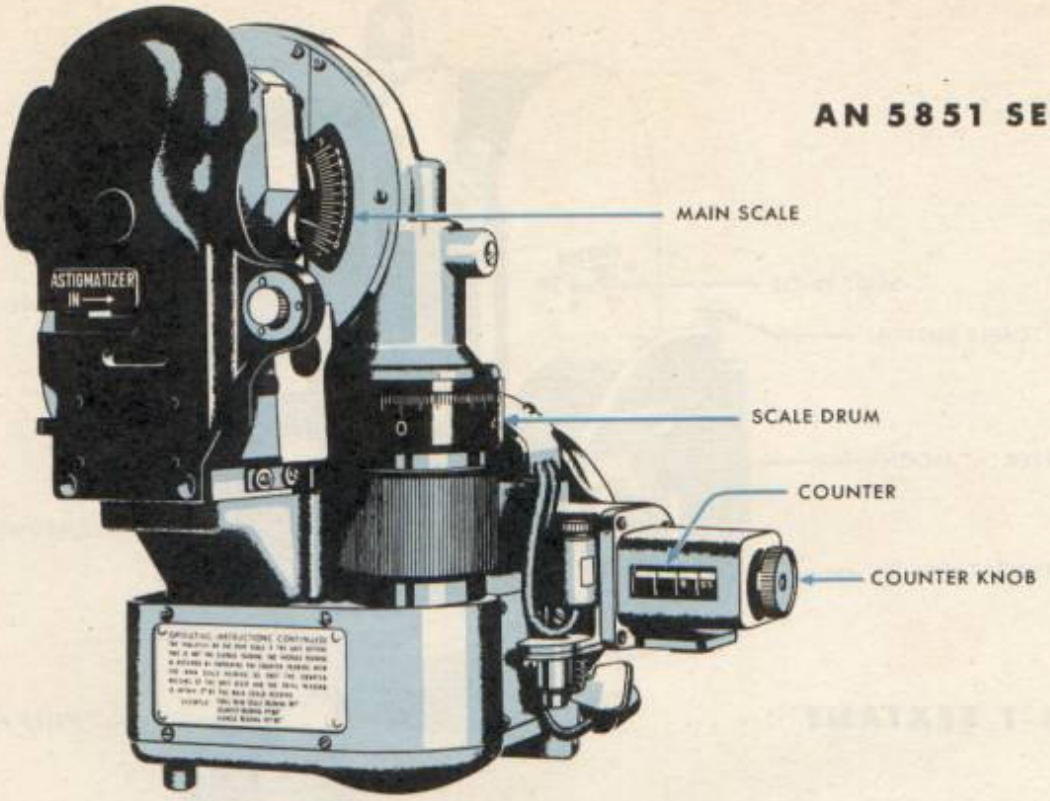
Bubble

The new bubble consists of a double chamber with a large air reservoir. Change bubble size by transferring air from one chamber to the other. The bubble never disappears except through deliberate operation of the diaphragm.

A large change in temperature produces practically no change in bubble size because the reservoir acts as a buffer. If you can't change the bubble size as you wish by rotating the diaphragm control to its extreme limit, level the sextant during the return stroke. You can rotate the diaphragm control back and forth any required number of times.

Optics

The real field of view varies between 12° and 14°, but is reduced one-half when you use the telescope attachment. You sometimes have difficulty in locating the desired star; it happens with all horizontal-viewing sextants. This procedure may help you:



1. Set the instrument to 0° altitude.
2. Pick up the star by direct sighting.
3. Bring the sextant to operating position slowly, keeping the star in the field of view by rotating the index knob.

See T.O. 05-35-33.

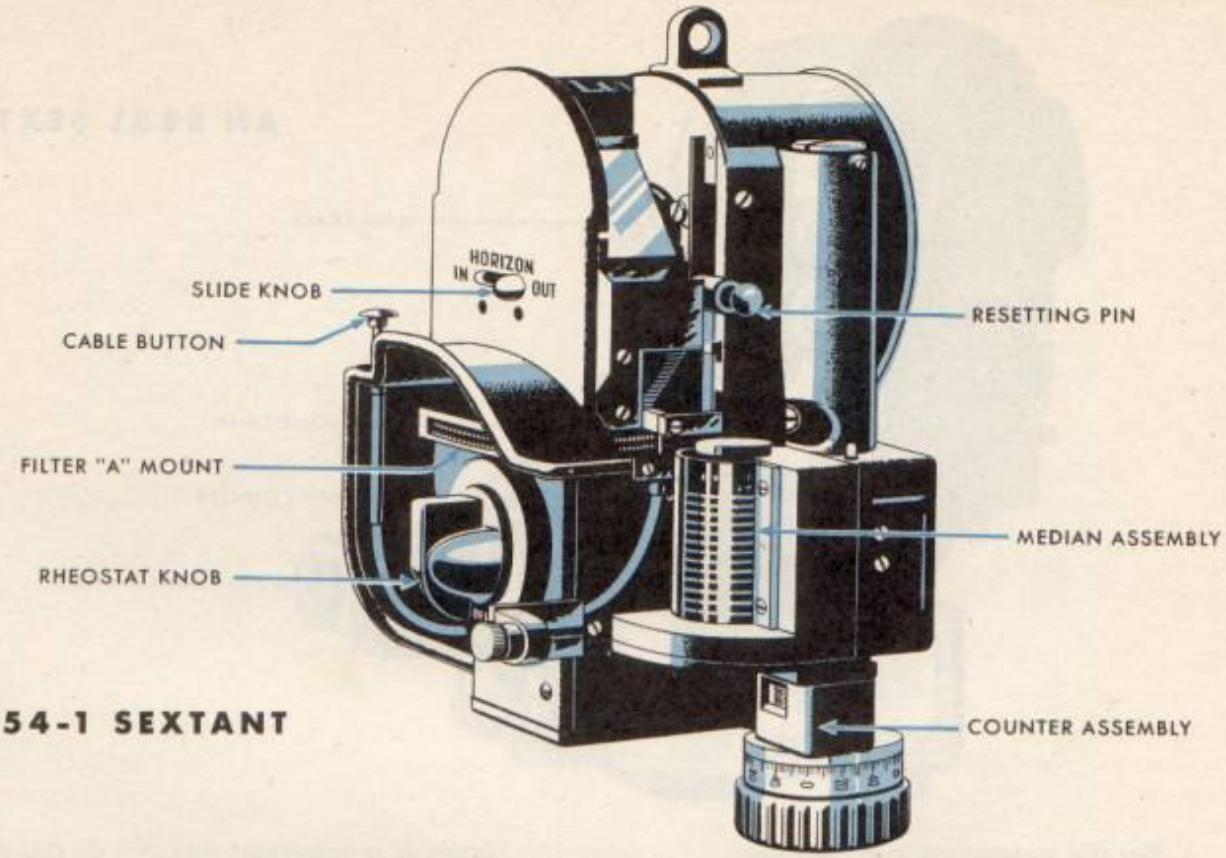
AN 5851 SEXTANT

Use the AN5851 sextant with the appropriate support arm. Like the A-10 and A-10A it is designed for horizontal vision. This sextant incorporates a chronometric, automatic averaging device which, at the end of a two-minute period, gives the average altitude on a counter.

The averaging mechanism picks off the setting of the instrument at two-second intervals and accumulates these values through a 60/1 gear reduction on the counter. Since a gear system does the averaging you must enter a full complement of 60 sights. You must, therefore, maintain collimation for a full two minutes. The reading on the counter is worthless if you stop observing before the two minutes have fully expired.

Operation

1. Set the counter to 0 by turning the counter knob. It is important that you do this accurately.
2. Wind the averaging device until you reach a solid stop.
3. Push lever 2 and rotate the scale drum to a stop. This operation engages the sextant with the averaging device and the stop indicates that the averager has been brought down to the base line.
4. Push lever 1 to engage lever 2. This operation disengages the averaging device from the sextant.
5. Take a preliminary sight. Push lever 2.
6. Again rotate the drum down to a stop, and if this amount of rotation is more than 2°, rotate the drum up to the sighted angle and collimate the star and the body.
7. If the amount of rotation is less than 2°, disengage the averaging device by pushing lever 1, rotate the drum down approximately one turn, push lever 2, and continue rotating the drum down to a stop. Then proceed with the sight. There is always a 15° spread between stops, which allows at least 2° on either side of the altitude of the body. This gives the drum room in which to rotate while the bubble is moving.
8. Push lever 3 to start the averaging device.
9. To obtain the average time, add 1 minute to starting time or subtract 1 minute from the time you finish your observation.
10. Maintain coincidence between the bubble and the celestial body. At the end of two minutes a



AN 5854-1 SEXTANT

shutter automatically moves into the field of view and obscures your vision.

11. To obtain the final avérage altitude, combine the counter reading with the main scale reading. (Do not read the scale drum; this indicates only the final altitude setting.) For example, if the counter reads 6° 35′ and the main scale pointer is between 4 and 5, the final reading is 46° 35′. Remember, the final main scale reading is within 2° of the average reading.

Bubble

In this type of sextant the star image and the bubble image are superimposed directly in the optical system and not by reflection, as in the A-10 series. You cannot see the star through the bubble, so use the cylindrical lens to astigmatize the star image, i.e., draw it out to a line instead of a point.

Optics

The real field of the instrument is 12°. Two-power magnification is built in.

Note that a rotatable polarizing filter in the eyepiece is designed to reduce horizontal (water) reflections of the sun at low altitude.

For general use, and always at night, remove this filter by pulling it straight out of the eyepiece. There is a finger ring attached to it for this purpose.

A horizon prism allows you to use the natural horizon.

See T.O. 05-35-22.

AN 5854-1 SEXTANT

Operation

Use the AN5854-1 sextant with the appropriate support arm. Hold the instrument by the handle, which is part of the sideplate, and by the graduated drum at the lower left side of the instrument. Operate the median averaging device with the index finger of your right hand. Press the cable button at each reading. Readings are recorded by the median assembly and are continued until the shutter automatically cuts off the field of view. Then, rotate the graduated drum until the median index is under the index line of the median assembly window, and read the angular altitude from the sextant scales.

To prevent any of the indexes from disappearing behind the median drum when you are determining the setting, the median drum is geared to turn half as fast as the graduated tangent screw controlling the sextant prism. This gear reduction also reverses

the direction of motion of the median drum from that of the tangent screw.

Spread the series of observations over the particular oscillation cycle of your airplane. In normal flying conditions, space a series of 15 readings at intervals of approximately six seconds between readings. In extremely rough air, two series of 15 readings are recommended with an interval of approximately six seconds between series. Average the two medians to obtain an average of the 30 readings. The average celestial time for the series of 30 readings is the average time from the start to the finish of the observations.

Another method of using the averaging device is to rotate the series of indexes until they seem to be distributed evenly on both sides of the fiducial line. This reading is a good average.

Clear the median assembly and load the shutter for another series of readings by pressing the resetting pin and rotating the indexes back to the index fiducial line in the center of the window.

For use with the sun and bubble horizon, the instrument is equipped with five combinations of filters for various sun intensities or field brightness. With the real horizon reflector IN, you can use the astigmatizer lens to astigmatize the sun across the bubble.

You can view celestial bodies at night either through the clear openings or the astigmatizer lens in the filter mount.

Radium paint provides such adequate dark field illumination of the artificial horizon bubble at night that you rarely need electric light. However, variable electric light intensity is available to boost the level of illumination.

Optics

The shutter is a thin sheet of metal that automatically cuts off the telescope field at the end of the observation. The shutter drops on the sixteenth reading and not at the end of the fifteenth. The shutter is mounted directly above the objective lens and the filter mount assembly.

The real field of the sextant is 12°. Two-power magnification is built in. You sometimes have difficulty in locating the desired star, as is the case when you use any horizontal-viewing sextant. See procedure outlined under Optics, A-10A sextant.

All scales are illuminated. A red bubble filter is supplied to provide a red bubble for contrast against the sky. This is particularly suitable for use against a moonlit cloudy sky.

See T.O. 05-35-27.

WATCHES

In accordance with Technical Order 00-30-61-2 you are entitled to three watches: the A-11 hack watch, the A-8 groundspeed timer, and the AN5740 master watch. These watches are the best products the American watch industry can make in the quantity the Air Forces demand. The life of your watches and the performance they give you are largely a matter of the care you give them. You should take the following simple precautions:

1. Carry your master watch in the metal case provided. This protects the watch from shock and from large magnetic fields. Always try to carry the watch in a horizontal, face-up position.

2. Wind your master watch regularly and determine its rate so that you may gain confidence in its performance. This watch is one of the finest timepieces made today. It is adjusted for position and for temperature.

If you anticipate flying in extreme cold (below −20° C) it is advisable to carry the watch on a piece of string inside your flying clothing. The slight inconvenience which this causes in reading the watch is greatly outweighed by the improved rate of the watch.

3. See that the screw-back and bezel of the watch are tightened securely at all times.

4. **Important: Your wrist watch is not waterproof,** so do not expose it to excessive moisture. The latest hack watches are supplied with a three-piece, dust-tight case. This simplifies maintenance and the rate of the watch is more constant. Take particular care to prevent water from running down your wrists after washing your hands; it collects around the stem of the watch.

5. Inspect your watch strap and strap pins occasionally to eliminate any chance of losing the watch.

Do not attempt to repair sextants or watches. They are delicate instruments and require expert adjustments.