ADMIRALTY RESEARCH LABORATORY, TEDDINGTON, MIDDLE5EX._

Examination of German Gyro-Sextant
SKS – 3D.

SUMMARY.

The gyro sextant described is a modification of the standard German (Plath) Bubble sextant, in which a gravity controlled gyro has replaced the bubble. There is nothing novel in the sextant construction or in the averaging mechanism, but it has been fully described in this report for record purposes. The gyro is stable and induced precession dies away rapidly.

The sextant is heavy and somewhat awkward to use and its accuracy under stable conditions is not as good as that of a bubble sextant.

1. **Sextant.**

The attached photographs show the general appearance of the Gyro-Sextant and schematic drawings, also attached, show (1) the optical system, (2) the clockwork mechanism, and (3) the averaging mechanism, (4) the gyro.

The actual sextant portion of the instrument is a modified form of the German Bubble Sextant (Plath), the modification consisting in the removal of the bubble chamber and its replacement by the gyro housing with the consequent alterations to the optical system. The limitations imposed by the adaptation of an instrument in this manner have led to inefficiency which necessitates frequent overhaul. The German bubble sextant is itself almost a direct copy of the R.A.F. Mark VIII. sextant (now obsolete) and has been fully reported in a Royal Aircraft Establishment report No. E.A.M. 58 dated October 1941

The dimensions of the Gyro sextant are as follows: -

Length	14 inches.
Width	6 inches.
Height	10 inches.
Weight	6 Ibs. 12 ozs.

2. Gyro - /

2. **Gyro-Operation and accuracy**.

The purpose of the gyro is to provide a stable artificial horizon for the sextant,as it only stabilises a beam of light, and has no mechanical output, it is possible to reduce it to a simple bottom-heavy rotor, running on a point in a bearing cup. The rotor is air-driven, and is run up to about 1200 r.p.m., either with a pump (hand or foot) or with compressed air. Observations are taken on the sextant while the gyro is running down, probably over the speed range 800 - 300 r.p.m. This allows about 12 mins. (See graph, page 5). The appended translation of the working instructions gives a good idea of the method of operation.

If the gyro is processing during the observation, and if its period of precession is a sub-multiple of the period of observation, the error due to precession tends to average out. Tests (see graph, page 5) showed that, as was to be expected, the period of precession is roughly proportional to the r.pm.of the rotor, and therefore continually varying. If appreciable precession does occur, it is therefore probable that it will introduce a serious error into the observation.

During the tests on precession, the gyro was forcibly tilted to a considerable angle, but the precession died away rapidly, being usually negligible after a couple of cycles. As there is not much frictional damping, it is thought that the curvature of the cup may cause damping, by compelling the rotor spindle point to climb up the slope when precession occurs, as the rotor axis must always be nearly normal to the curve. It is proposed to examine this point mathematically.

Attempts to cause the rotor to precess by jerking the sextant sideways, as might happen in practice, had no appreciable effect. It is possible that lateral acceleration might cause noticeable precession if continued long enough. Alternatively, periodic lateral acceleration, such as that due to the roll or pitch of a ship, might produce periodic oscillation of the rotor axis in a vertical plane at right angles to the plane of roll (or pitch). There are no facilities at .A.G.E. at the moment for testing these points; but if the sextant is taken to sea for trials, it would be a simple matter to make the required tests.

3. Construction Details.

(a) **<u>Optical.</u>** Drawing No.1 shows the general layout of the instrument. Light from the lamp is concentrated on the graticule situated on the rotor and rendered parallel by the lens on the rotor. It is then focussed on the field lens and again rendered parallel by the main collimating lens, after passing through the index mirror it is viewed by a small detachable galilean telescope. The view obtained is shown inset; the two wide lines being so spaced that the image of the sun fits between them and two narrow lines are provided for observations of stars. The index mirror is semi-silvered and shades are provided for observations of the sun or moon. The angle of the index mirror is controlled by an arm bearing on a spiral cam inside the right hand drum.

(b) **Clockwork**. Drawing No.2 shows the clockwork train which drives the averaging mechanism. An interesting feature of the clockwork is the method of changing the rate by allowing the pallet to engage 5, 10 or 15 teeth of the escapement wheel 30 that the whole run of the averaging device may be one, two or three minutes.

(c) **Averaging Mechanism**. Drawing No.3 shows the averaging mechanism. A cylinder carrying scales is driven in an axial direction by the clockwork mechanism. Bearing on this cylinder is a freely rotating caster the axis of which is normally perpendicular to the axis of the cylinder. When a pin on the rider is made to engage a hole in the drum any rotation of the drum causes the axis of the caster to be inclined and the cylinder is caused to rotate at an angular velocity proportional to the tangent of the angle of tilt. The mechanism for rotating the axis of the caster is such that an angular movement of the main drum is proportional to the tangent of the angle of tilt and hence to the angular velocity of the cylinder. Hence during the time occupied by the observation the cylinder rotates an angular amount proportional to the angle at which the drum is held and by correct adjustment can be made to indicate the angular movement of the main drum. Under certain conditions the integrated rotation of the cylinder therefore represents the average angle at which the main drum is held and can be taken as the actual angle at the mid point of the interval of time occupied by the observation.

(d) GYRO (See Drawing 4)

Rotor. The body (1) of this is an aluminum alloy die casting, with the brass rim (2) pressed onto it, and the aluminum alloy tube (3) pressed into it. The brass spindle (4) is screwed into the body and locked with a nut at its upper end. Into its lower end is spun a ball, 1 mm dia. of hardened steel, which bears on the cup (5) The graticule (6) and lens (7) are fixed in the tube (3). 35 buckets, roughly semi-circular, are milled into the circumference of the brass rim. The rotor is bottom heavy.

Casing and Bearing.

All the details of this, except the bearing cup (which is of artificial agate), springs and screws (of steel) are apparently of aluminum alloy. The casing itself is in 3 pieces. The cap (8) is attached to the centre casing (9) by 6 screws (not shown), and the bottom (10) is screwed into it. The 6 holes (11) appear to be meant for a tommy bar or pin wrench, though they must also serve as the main exhaust passages for the air. The ring (12) pressed onto the 2 flanges on the centre casing, forms an inlet manifold for the air supply. A hose nozzle (not shown), screwed onto the lower flange, provides the connection to the pump, which, to judge from the working instructions, is either hand or foot operated) or to the compressed air supply. 6 holes (13) 1 mm. dia., are drilled through the casing from the manifold at an angle of about 40° to the tangent, and through them the air impinges on the rotor, spinning it clockwise as seen from above.

The/

The arrangements for supporting and locking the rotor are rather elaborate. In its running position (as shown), the steel point of the rotor spindle rests in the cup (5), which is spun into the plug (14) screwed into the end of the sleeve (15) This sleeve is a somewhat tight sliding fit in the tube (16), and is supported by a spring (17) which bears on the hollow plug (18). This plug is apparently screwed into the tube (16) just so far as to bring the optical system into line, and then secured with the locking ring (19). The tube (16) is screwed into the bottom of the casing, and locked by the ring (20).

LOCKING THE ROTOR

When the sleeve (21) is raised sufficiently, it picks the rotor off the bearing cup and presses it against the casing cap (8). This locking action is brought about by turning the knurled ring (22),which is a sliding fit on the bottom of the casing, slightly clockwise (as seen from above), pressing it up as far as it will go, and then turning it anti-clockwise to secure. The 3 screws (23), which are screwed into the knurled ring (22), pass through U shaped slots in the casing and through shorter vertical slots in the sleeve (21), and register in a circumferential groove in the inner sleeve (24), When the knurled ring (22) is turned and pressed up, it lifts the inner sleeve (21) and this, through the spring (25), raises sleeve (21). The ring (29), spun into the lower end of sleeve (21), secures the inner sleeve (24).

CASING SUPPORTS

The casing is supported by the bracket (26) and by an L-shaped bracket screwed onto the top of the lamp housing (27), both these brackets being fastened onto the sextant casing. (26) and (27) are attached to the upper flange of the centre casing (9), each by 2 screws, (28) is a glass window, presumably meant to keep the air away from the sextant. The bulb (3 volt, 0.25 amp.) is fed by a "stick accumulator" (alkaline, non-spill, about 1 ¼ ampere-hour capacity) housed in the rear of the sextant. In addition to the ordinary switch, there is a second switch operated by a relay, which cuts off the current when the sextant is not in use. There is also a dimming resistance. A charging arrangement is provided, which can be plugged into any 110 volt D.C. socket.

<u>Gyro - Numerical Data,</u>

Weight of Complete Gyro = 437 g. = 0.96 lb. (without lamp housing (27) or supporting bracket (26)).

Weight of Rotor = 180 g. = 0.40 lb.

Centre of Gravity of Rotor it, 0.14" below Spindle point.

Moment of Inertia " " about spin Axis = 0.43 lb square inch

" " " " Horizontal axis through Spindle Point = 0.42 lb sq. inch

Radius of Curvature of Spindle Point = 0.005"

“ " " " Bearing Cup = 0.146"

No. of Nozzles = 6

Diameter of Nozzles = 1 mm. = 0.039"

Inclination of Nozzles to Tangent = 40° approx.

Buckets in rotor rim appear to have been cut by a milling cutter 11 mm. dia., inclined at approx. 16° to the radius (in horizontal plane).
No. of buckets = 35.

4. OPERATION

To use the gyro sextant a supply of compressed air is required, or the gyro may be run up by using a motor car type foot pump. After running up, the instrument must be allowed five minutes to settle and great care is necessary in handling to keep the instrument level and to avoid jerky movement. The sun or star is then observed in much the same manner as with a normal sextant, the lines in the field of view obtained from the rotating gyro being used as horizon. Rough direct reading of the altitude is possible and the averaging mechanism is intended to give the average altitude over a period of one, two or three minutes, the time of the observations being taken in the mid point of the interval. It is possible to make six or eight observations before the gyro runs down to such an extent as to cause noticeable flicker and erratic behavior.

The reading of the scales is not self-evident and some practice is required before the instrument can be used with confidence. The averaging mechanism indicates 3 degrees when set but the graduations are such that 2½ degrees appears to be set. The figures indicated by the averaging mechanism are added to the indication on the drum and on the main index which reads tens of degrees. In this respect the Hughes Bubble sextant is very much superior in that the reading is direct and self evident.

5. Results.

A large number of observations have been made (a), with the sextant firmly supported, (b) hand held and a similar series has been made with a Hughes marine bubble sextant.

In order to obtain numerical results, fifty observations of the altitude of the sun were made in each case, the time of observation being noted. The actual altitude of the sun from data supplied in the N.A. was calculated for the same instants of time. The difference between the observed and calculated altitudes was tabulated and histograms drawn showing the distribution of errors. The following quantities were also calculated and are tabulated below.

(a) Mean error - algebraic sum of errors divided by number of readings.

(b) Consistency or mean deviation = Sum of difference between actual error and mean error divided by number of readings.

(c) Standard Deviation = the square root of the sum of the squares of the difference between actual error and mean error divided by number of readings.

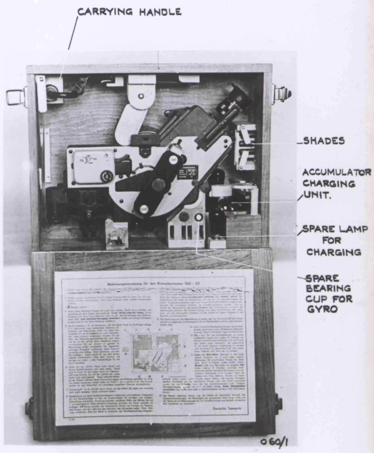
	Mean Error.	Consistency or mean deviation.	Standard Deviation.
Gyro Sextant Fixed	+ 3.25	4.3	5.5
Bubble Sextant Fixed	- 6	3.0	3.3
Gyro hand held	+ 10.9	7.86	8.86
Bubble hand held	- 4.7	3.64	5.76

The figures shown under Mean Error include instrumental errors which no attempt was made to correct and therefore have no significance.

The Histograms attached (page 5) show clearly the superiority of the bubble sextant over the gyro sextant under the steady conditions of trial. Owing to pressure of work and the difficulty of obtaining a clear sight of the sun from the rolling table it has not been possible to carry out any tests under accelerations.

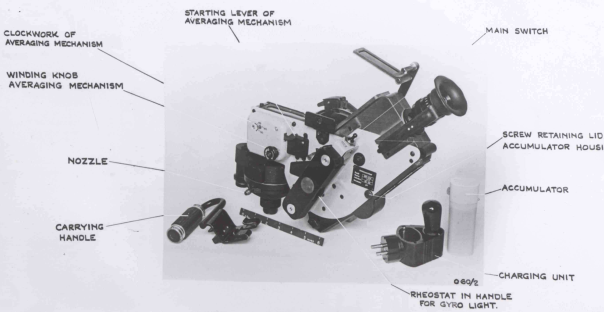
6, Conclusions.

The gyro sextant in the form described is not considered satisfactory. Extreme care in handling is necessary and since the gyro line of sight is maintained in the horizontal by the resultant direction of gravity it is improbable that accurate results will be obtained on a rolling ship. The bubble sextant is more convenient and gives results of equal or better accuracy. Either type of Sextant should be capable of giving a fix at sea, under calm conditions, within one to three miles, and provided a large number of observations are made similar accuracy may be obtainable in a moderate sea.



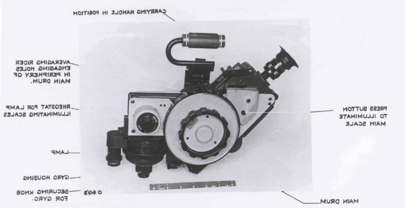
GERMAN GYRO SEXTANT IN CARRYING CASE.

OFFICE REF. A.R.L/N3/68·05/0 AUG.
A.R.L. TEDDINGTON 1945



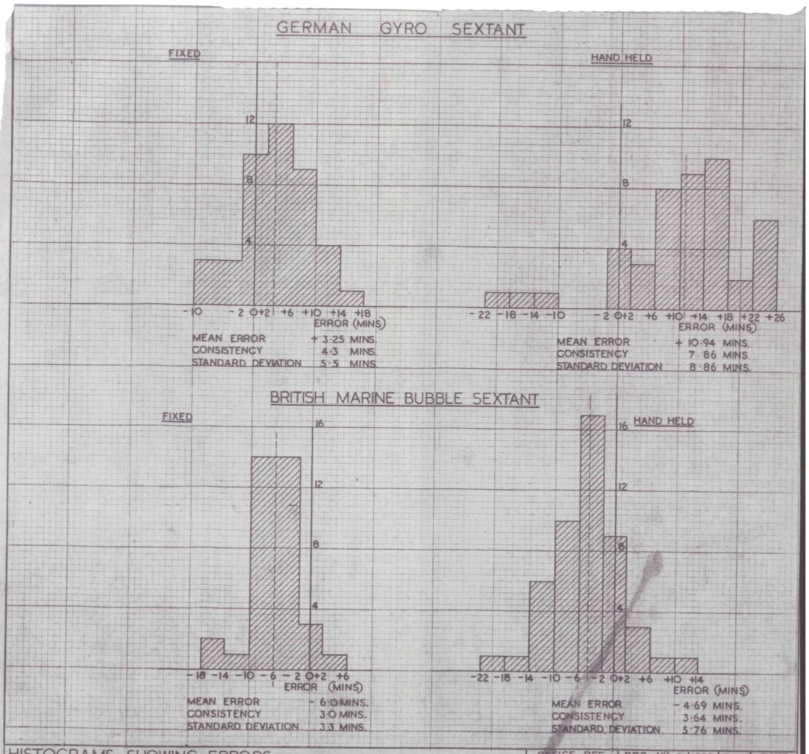
GERMAN GYRO SEXTANT - LEFT SIDE.

OFFICE REF. A.R.L/N3/68·05/0 AUG.
A.R.L. TEDDINGTON 1945



GERMAN GYRO SEXTANT - RIGHT SIDE

OFFICE REF. A.R.L/N3/68·05/0 AUG.
A.R.L. TEDDINGTON 1945



German Gyro Sextant, Fixed:

MEAN ERROR + 3·25 MINS.
CONSISTENCY 4·3 MINS.
STANDARD DEVIATION 5·5 MINS.

German Gyro Sextant, Hand Held:

MEAN ERROR + 10·94 MINS.
CONSISTENCY 7·86 MINS.
STANDARD DEVIATION 8·86 MINS.

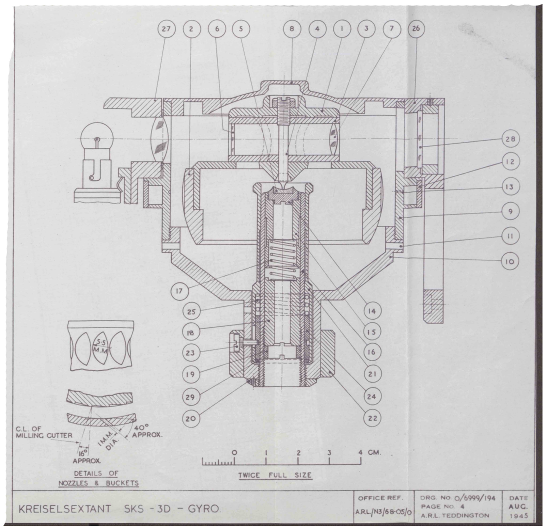
British Marine Bubble Sextant, Fixed:

MEAN ERROR - 6·0 MINS.
CONSISTENCY 3·0 MINS.
STANDARD DEVIATION 3·3 MINS.

British Marine Bubble Sextant, Hand Held:

MEAN ERROR - 4·69 MINS.
CONSISTENCY 3·64 MINS.
STANDARD DEVIATION 5·76 MINS.

HISTOGRAMS SHOWING ERRORS GERMAN GYRO SEXTANT & BRITISH BUBBLE SEXTANT	OFFICE REF. A.R.L./N3/68·05/0	DRG. No. 0/6999/194 PAGE No. 6 A. R. L. TEDDINGTON.	DATE AUG. 1945



DETAILS OF NOZZLES & BUCKETS

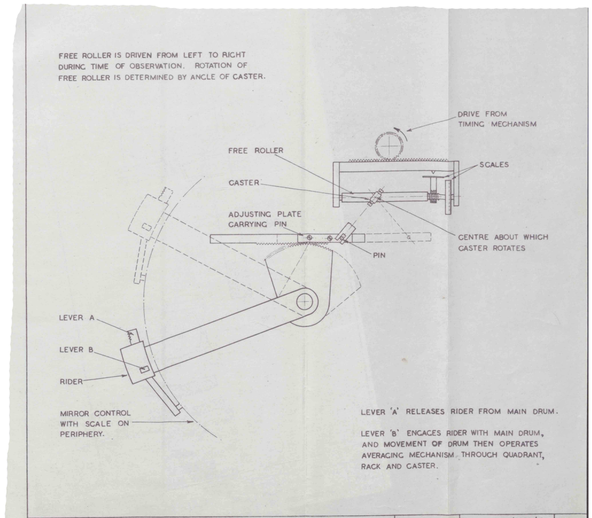
TWICE FULL SIZE

KREISELSEXTANT SKS - 3D - GYRO

OFFICE REF. A.R.L./N3/68-05/0

DRG. NO. 0/6999/194
PAGE NO. 4
A.R.L. TEDDINGTON

DATE AUG. 1945



FREE ROLLER IS DRIVEN FROM LEFT TO RIGHT DURING TIME OF OBSERVATION. ROTATION OF FREE ROLLER IS DETERMINED BY ANGLE OF CASTER.

LEVER 'A' RELEASES RIDER FROM MAIN DRUM.

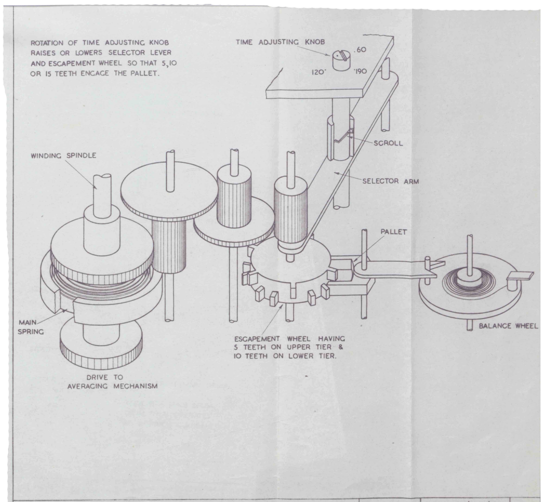
LEVER 'B' ENGAGES RIDER WITH MAIN DRUM, AND MOVEMENT OF DRUM THEN OPERATES AVERAGING MECHANISM THROUGH QUADRANT, RACK AND CASTER.

SCHEMATIC DRAWINGS OF GERMAN GYRO SEXTANT:
AVERAGING MECHANISM

OFFICE REF. A.R.L./N3/68-05/0

DRG. NO. 0/6999/194
PAGE NO. 3
A.R.L. TEDDINGTON

DATE AUG. 1945



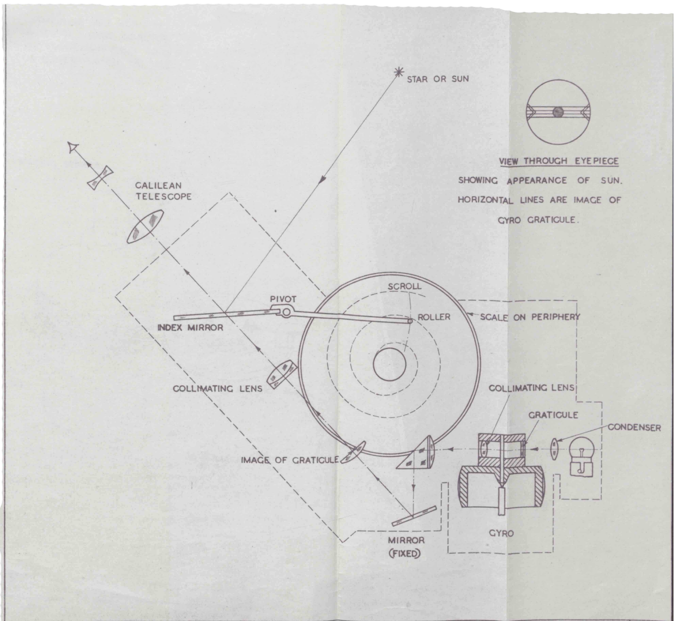
ROTATION OF TIME ADJUSTING KNOB RAISES OR LOWERS SELECTOR LEVER AND ESCAPEMENT WHEEL SO THAT 5, 10 OR 15 TEETH ENGAGE THE PALLET.

SCHEMATIC DRAWINGS OF GERMAN GYRO SEXTANT
TIMING MECHANISM

OFFICE REF. A.R.L./N3/68-05/0

DRG. NO. 0/6999/194
PAGE NO. 2
A.R.L. TEDDINGTON

DATE AUG. 1945



VIEW THROUGH EYEPIECE
SHOWING APPEARANCE OF SUN.
HORIZONTAL LINES ARE IMAGE OF
GYRO GRATICULE.

SCHEMATIC DRAWINGS OF GERMAN GYRO SEXTANT
OPTICAL LAYOUT

OFFICE REF. A.R.L./N3/68-05/0

DRG. NO. 0/6999/194
PAGE NO. 1.
A.R.L. TEDDINGTON

DATE AUG. 1945