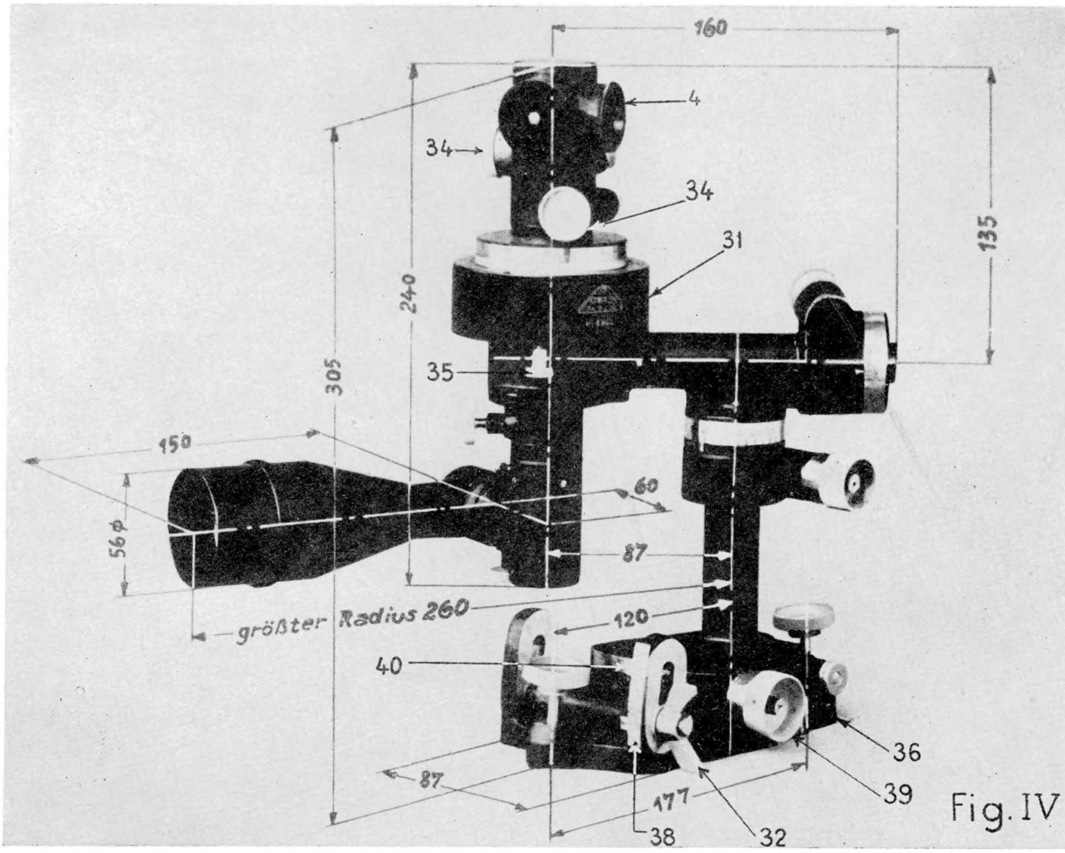
160
4
34
34
31
135
240
305
35
150
56 φ
60
87
größter Radius 260
120
40
36
39
87
177
38
32

Fig. IV

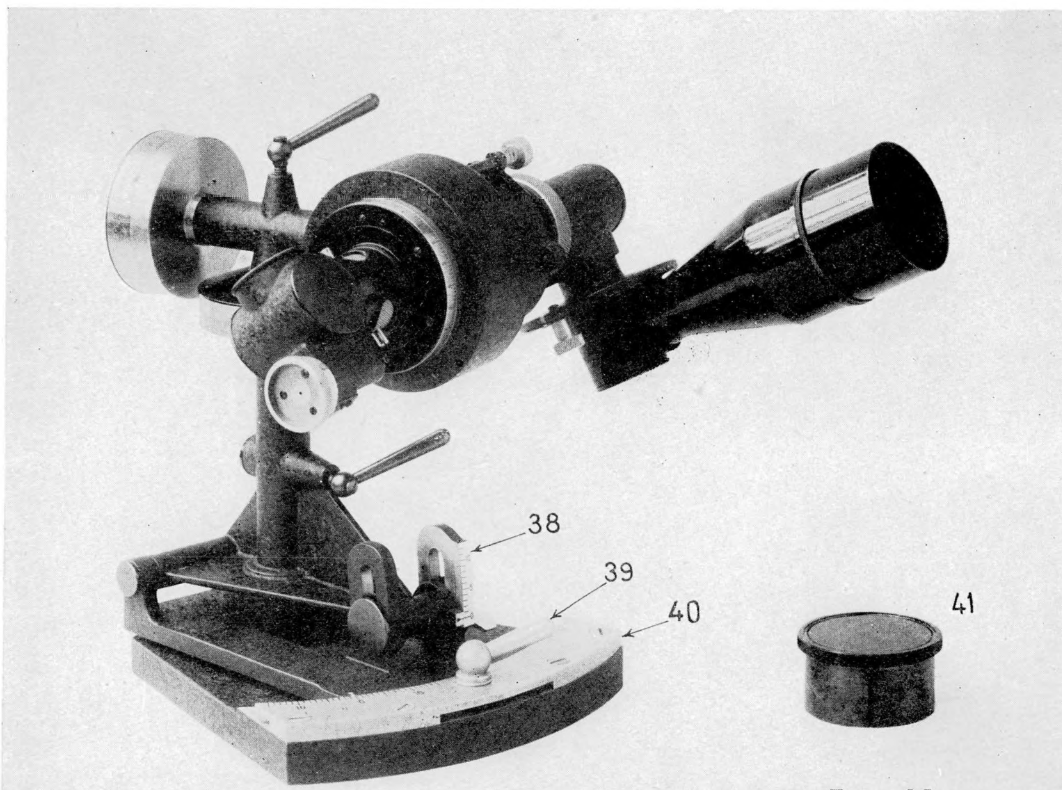
38
39
40
41

Fig. V

GOERZ SOLAR COMPASS WITH SPECIAL FITTING FOR LATITUDE AND AZIMUTH (*)

The solar compass as constructed by the *Optische Anstalt C.P. Goerz Aktiengesellschaft*, Berlin, for the polar flight of AMUNDSEN in the summer of 1925, was a panoramic telescope (fig. II) having a directive circle (1) fitted with a screw (2) and a clockwork mechanism (3), so that the objective prism (4) might follow the apparent rotation of the sun around the polar axis (5-6) (fig. I) of the Earth. By setting the axis of rotation of the directive circle parallel to the axis of the path of the sun, *i. e.* nearly vertical during a polar flight, and consequently in the direction of the earth's axis, the image of the sun, when the clockwork is in motion, is permanently maintained in the panoramic field of the telescope eye-piece, whatever the time of day. If a telescope of this kind is mounted on an air-plane with the objective prism directed towards the sun, the apparatus may be used as a compass. The device is a Galilean telescope with a prism for rectifying the image and assures the certainty that when using this instrument in a swaying air-plane, the movements of the sun's image in the eye-piece will always correspond exactly

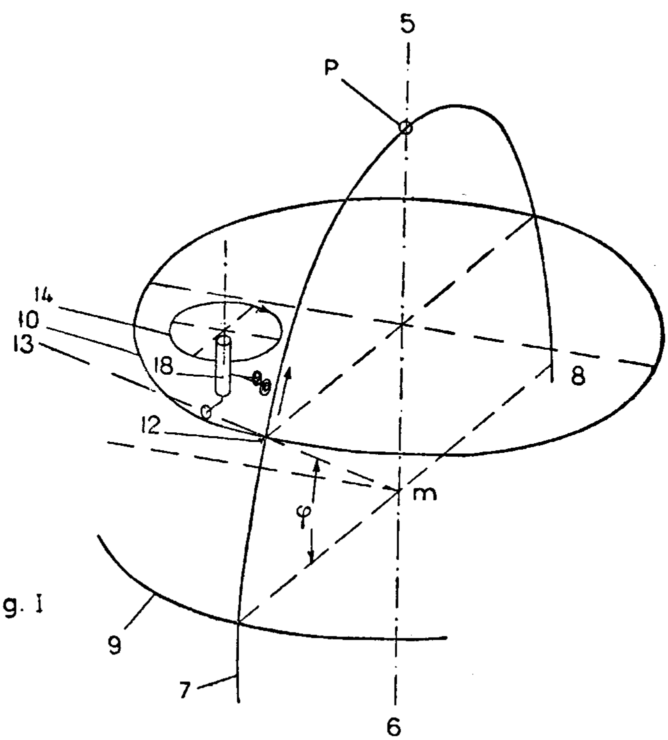

Fig. I

(*) The two articles given hereafter relating to the solar compass have been kindly communicated to the International Hydrographic Bureau by the Head of the *Nautische Abteilung der Marineleitung* - Berlin.

to the motion of the air-plane both in the vertical or horizontal planes. In order that the pilot may not be constantly obliged to look into the ocular of the telescope (which might otherwise be arranged by inserting optical devices capable of absorbing the light and the heat), the lenses of the eye-piece have been replaced by a ground-glass screen, on which the image of the sun appears as a small luminous circle. Markings engraved on the ground glass are used as a lubberline of the solar compass.

On the flight of AMUNDSEN in the polar regions the axis of the path of the sun was nearly perpendicular to the plane of the hozizon; for this reason the vertical axis of the telescope could also be placed in a nearly vertical position, the same also applied to the axis of the directive circle (1).

This simplified device no longer functions correctly when the *solar compass has to be used for aerial flights outside the polar regions in any latitude or in* ANY *direction whatever* with respect to the meridians or parallels. In this case the compass must be arranged in a special way to take into account the relative position of the path of the sun with respect to the geographical position, and the direction of the flight. The local conditions and the conditions relative to the direction of the flight which are to be taken into account and the corresponding arrangement of the instrument are shown diagrammatically in the sketches appended.

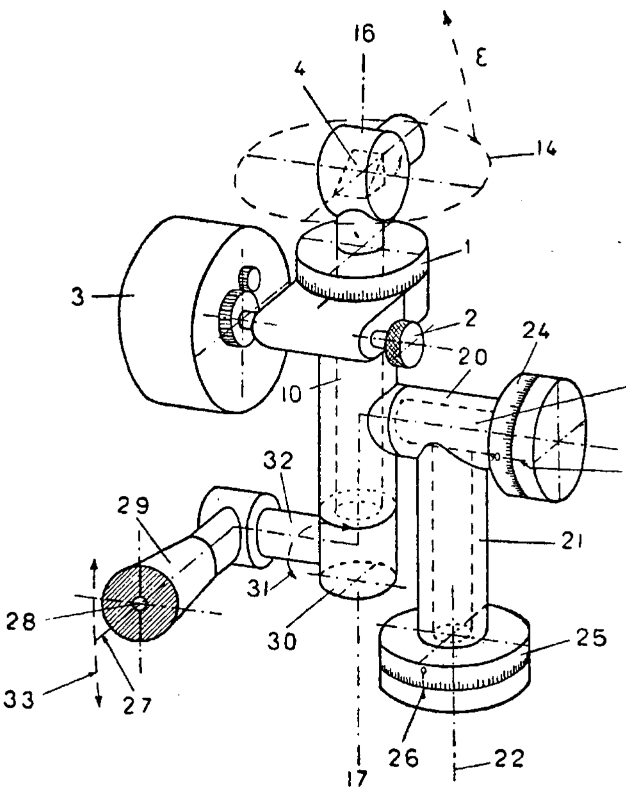

Fig. II

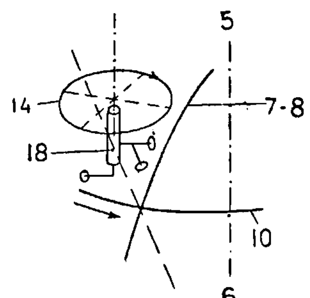

Fig. III

In Figure I, (5-6) is the polar axis of the Earth, (7-8) is the Earth's meridian, (9) is the Equator, and (10) a parallel of latitude; (*m*) is the fictitious centre of the Earth, (m-10-13) is a fictitious line connecting the locus of the air-plane (12) with the centre of the Earth; (14) is the apparent diurnal path of the sun which, to a first approximation, we shall suppose to be parallel to the parallels of latitude by neglecting the angle of the declination, (P) is the terrestrial pole, (φ) is the angle of geographical latitude. When, from any point on the Earth, a flight has to be made in any direction the axis of rotation (16-17) of the reflecting prism (4) which follows the sun must also be perpendicular to the path of the sun, *i. e.* according to our hypothesis, to the Equator. To make this adjustment the body of the telescope (18) is fitted with a supplementary axis (19) which may be rotated in the casing (20). The casing (20) carries a prolongation at right angles (21) which rotates around another axis (22) and which may be orientated parallel to the vertical (m-13). For this purpose the axis (19) is fitted with a pointer (23) so that its displacement may be read on the graduated scale (24), representing the latitude. This graduated scale is divided into 90 parts to each quadrant. If in the polar regions flights radial with respect to the path of the sun, *i. e.* heading towards the pole (P) or receding from the pole, are considered to be the normal case, the graduated scale (24) must coincide with 90° when the axis of the telescope (16-17) is parallel to the axis (22) or, what is the same thing, to the polar axis of the Earth (5-6). For a flight in the direction of a meridian (7-8) the axis (19) will be perpendicular to the axis of the air-plane, *i. e.* orientated according to the tangent to the parallel of latitude (10), and the graduated scale (25) fitted to the casing (21) will coincide with the 0. Relative to the Earth and the path of the sun the solar compass is in the position shown diagrammatically in figure I. If the flight is to be made in the direction of the parallel of latitude the axis (19) is placed parallel to the axis of the plane, and the instrument has the position shown diagrammatically in figure N° III relative to the Earth. The graduation (25) is set at 90°. If the flight is to be made in any other course the drum has to be set at the graduation of the scale (25) corresponding to this course. For this purpose the scale is graduated from 0 to 360°.

According to the above the orientation of the axis (19) is not permanently fixed relative to the axis of the plane; it may assume any azimuth angles comprised between 0 and 360°. For a flight following the Equator the axis (16-17) of the instrument will be placed horizontally.

For a flight from any point on the Earth at any angle to the meridian the graduated scale (24) has to be set to indicate the altitude of the pole (latitude) and the graduated scale (25) to the angle between the line of flight and the meridian (course).

Until now, and for simplicity, the path of the sun (14) has been assumed to be on the equator. Such is not generally the case, and for this reason the objective prism (4) of the telescope is mounted on a ball and socket joint in order that it may be inclined according to the declination as far as the maximum angle (E) (inclination of the ecliptic). Also it has been assumed that the direction of the flight is always parallel to the axis of the air-plane, but it is known that such is not the case when there is a *lateral wind*. In such cases there is a drift of the air-plane and the axis of the plane itself is inclined relative to track. This inclination relative to the axis of the plane may be compensated by a correction on the index (26). As the horizontal tilt of the air-plane in the air does not correspond to the same tilt when it rests on the earth, and besides, this tilt varies with the various weights on board, speed, *etc.* it is also recommended that the axis (22) be mounted on the air-plane in such a manner that it may be inclined at an angle. A graduated scale may be devised for reading this angle of tilt in order that the axis may be set for a certain "angle of trim" corresponding to a given weight and velocity of the type of air-plane used.

Since, according to the above description, the axes (16-17) and (19) of the solar compass may take every conceivable position in relation to the air-plane, it might happen that with the axis of the eye-piece (27) rigidly fixed to the body (18) of the telescope it may take a position relative to the air-plane or to the pilot which does not permit the small image of the sun (28) to be observed. It was found necessary therefore to fit the eye-piece supports (29) with a mounting capable of rotation to counter-act the movements of rotation of the instrument around the axes (19) and (22). For this purpose the eye-piece (29) is mounted on an additional jointed socket (30), movable about the axis (16-17), relative to the body of the telescope (18), in the direction of the arrows (31), while the ocular is also capable of rotation about this socket (32) by a movement of the jointed socket (30) at right angles to the other movement and in the direction of the arrows (33). Consequently the solar compass itself may be placed in every position required by the geographical and astronomical conditions, and the eye-piece of the instrument may be turned *towards the pilot of the air-plane at all times.*

Figures IV and V are photographs of the solar compass of the most recent type. It is similiar in its essential parts to the description given above, except that the clockwork (3) of the diagram N° II has been placed in the casing (31) of Fig. IV, under the directive circle (1), because the projecting casing of the clockwork in fig. II has been found to be unhandy. In the new type the gear connecting the clockwork with the axial cylinder of the prism box is no longer a tangent screw but it operates directly through cog-wheels. Consequently, care must be taken not to forcibly rotate the prism box (4) because it may give rise to inadmissable pressure on the gears of the clockwork. When the prism-box (4) (fig. IV) is to be rotated and directed towards the sun it is first necessary to hold the box firmly (4) in one hand, loosen the milled screw (34) by turning it in the direction of the arrow; then the prism-box (4) is rotated until the image of the sun appears in the middle of the ground glass (28). The milled screw (34) is then tightened again by turning it in the direction opposed to the arrows. The clockwork is wound up by turning the head (35). The motion of the prism-box (4) which follows the apparent track of the sun may be read on the directive circle (1), which is graduated in 24 hourly graduations. The graduated scales for the latitude (24) and for the course (25) are identical to those of the graduated drums corresponding to fig. II. The casing (21) rests on the bridge (36) whose angle of inclination (corresponding to the angle of trim of the air-plane) may be varied when the nut (37) is released. The angle of inclination may be read off on the graduated scale (38). When the milled screw (39) is released the angle of drift may be set on the graduated scale (40). If the image of the sun on the ground glass is to bright, a smoked glass screen may be fitted on the cylinder of the eye-piece.

Figure IV shows the setting of the solar compass for a flight in the polar regions. Figure V on the contrary shows a setting of the same in equatorial regions. It is to be noted that the solar compass loses its properties as a directive instrument when the sun is exactly in the zenith ; a case which may occur in the tropics at noon. As in the polar regions, and principally in the region of the magnetic pole, where the magnetic compass loses its directive force, so also the solar compass in the equatorial regions (aside from the night period) loses its usefulness, but it is only near noon. The solar compass serves its purpose best in the polar regions where it is the sole directive instrument for continuous use, when, on the contrary, the magnetic compass fails. The solar compass is able to render valuable service during the day at every hour in the temperate zone. In tropical regions its serviceablilty is subject to the above-mentioned restrictions.