NAVIGATION IN THE ANTARCTIC

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Interest in and speculation concerning the antarctic increased considerably last year when several nations announced their intentions of sending expeditions to the frozen continent surrounding the south pole. Largest of these was the U. S. Navy's Operation Highjump, which made polar explorers of some 4000 persons.

Although the navigators of this expedition were hindered by the lack of charts of the accustomed accuracy, the surprising fact is not the paucity of information available but the abundance of it, when the position of the region is considered. The antarctic is separated from the world's civilization and trade routes by the world's stormiest seas. Some 90 per cent of the population of the earth lives in the northern hemisphere. The only great circle routes of potential commercial interest crossing the antarctic continent are those from eastern South American cities such as Buenos Aires and Rio de Janeiro to Australia—certainly not the world's most traveled routes.

Yet H. O. 138, the Sailing Directions for Antarctica, contains 312 large pages of condensed information which Operation Highjump found to be reliable. Two and a half pages are devoted to a bibliography.

HISTORY OF ANTARCTICA

There are many reports of landfalls by early mariners who were driven south by violent storms, but most of these were of islands in the sub-antarctic. These date back at least to the year 1599 when the ship *Good News* was driven off its course while doubling Cape Horn and found high snow-covered mountainous land between 61° and 64° S. It is uncertain whether the land sighted was insular or continental. Captain Cook of the Royal Navy visited the area in 1772 and 1773.

American sealers operated for many years prior to the nineteenth century in the vicinity of the various islands fringing the Palmer Peninsula, but they were reticent regarding their discoveries because they did not seek competition in their thriving sealing industry. These seamen are reported to have sailed within 20° of the south pole in a few instances. That their fears of competition were justified may be seen from the fact that activity became so great between 1820 and 1828 that the fur bearing seals were entirely exterminated.

A crisis in arctic whaling led to the organization in 1904 of the first company for antarctic whaling. The industry grew rapidly and by 1931 almost 98 per cent of the world's whale oil came from antarctic waters.

Antarctica has been visited frequently during the last century and a half. The extent of the interest in this continent, twice the size of the United States, is revealed by a single look at a modern chart of the area, which shows many names in many languages. The United States has supplied its share. The Navy's interest did not begin with Operation Highjump. More than 100 years ago it sent an exploring expedition south under Lieutenant (later Rear Admiral) Charles Wilkes. This expedition is credited with establishing the continental dimensions of the land surrounding the south pole, two of its ships having followed the coast line for 1400 miles.

The first visit to the south pole is credited to Amundsen, who reached it by sledge and skis from the Bay of Whales on December 14, 1911.

There is a marked contrast between the physiographical and hydrological conditions of the north polar regions and those of the antarctic. The pack ice of the north polar basin moves across or around a comparatively open sea, which is shorebound except for several straits which bottleneck the ice. The arctic pack may therefore be safely traveled upon and the abundant life found in that region enables a traveler to sustain himself for long periods. In the antarctic conditions are quite different. Antarctica is the world's highest continent, having an average elevation of about 6,000 feet. In most places the shore is composed of high ice cliffs which rise abruptly from the sea. The polar plateau, a vast expanse of snow and ice, is about 10,000 feet high. Extensive mountain ranges having peaks over 13.000 feet high are situated in various parts of the continent. There are few good harbors or safe anchorages. The physical character of antarctic icebergs and pack ice and the elements influencing their movement is different from those of the north. The dimensions of antarctic icebergs is frequently measured in miles and icebergs more than 100 miles in both length and width have been reported. The drift of the pack ice is around and outward from a central land mass surrounded by notoriously stormy seas.

Pre-Highjump antarctic navigation was characteristically conventional. It is true that aids to navigation were lacking and charts were inaccurate or unavailable, this placing greater importance on dead reckoning and celestial observations, when available. However, the conventional tools used in moderate latitudes served also in Antarctica. When Admiral Byrd first visited Antarctica, he went prepared with special Hydrographic Office Mercator plotting sheets extending to latitude 89°45' S.

OPERATION " HIGHJUMP "

Operation Highjump is worthy of more detailed consideration, not only because of its magnitude, but also because it has been the only large operation there since modern equipment has been available.

The force consisted of four groups :-

1. *The Central Group,* consisting of the *Mount Olympus,* flagship; the icebreakers *Burton Island* and *Northwind,* the latter a Coast Guard vessel; the submarine *Sennet,* and two auxiliary ships. The aircraft included several types for local flights and 6 R4-D transports for long range flights. The R4-D's and three smaller planes were land based at Little America.

2. *The Western Group,* consisting of a seaplane tender, a destroyer, and an oiler. The aircraft included 3 PBM-5's for relatively long photographic and mapping runs.

3. *The Eastern Group,* similar to the western group.

4. *The Supporting Group,* consisting of the *Philippine Sea,* an aircraft carrier, which transported the R4-D aircraft to their Antarctic bases.

Let us consider first the air navigation.

AIR NAVIGATION

The central group operated from a shore base at Little America southward across the Ross Shelf Ice, and the polar plateau as far as the south pole. Hence, their navigation was essentially polar. The eastern and western groups operated from seaplane tenders, their flights being confined principally to coastal regions. The south magnetic pole is in the operating area of the western group. The maximum latitude reached by the side groups coincided approximately with the minimum latitude of the central group. Since the side groups made most of their flights between 65° and 75° south latitude, their navigation might be considered sub-polar, rather than polar in the strict sense. This should be kept in mind as we contrast the methods used.

Navigation consisted principally of dead reckoning, because of the inaccuracy and lack of detail of charts, the absence of conventional aids to navigation, weather limitations, and the press of other duties. It was generally a full-time job for the navigator to keep the DR plot and check the drift. He was usually assisted by the co-pilot, who operated the astro-compass.

The principal problem involved in maintaining an accurate DR was the difficulty in determining drift, due to lack of targets, except along the coast, and frequent and radical wind shifts. Inland the snow covering effectively obscured irregularities of the terrain that might have served as targets. This effect was accentuated at greater absolute altitudes. Shadows were-sometimes available as the only indications of unevenness of the terrain.

Direction was maintained by means of an electric directional gyro, which gave excellent results. In the two side groups the maximum precession was only 3° per hour. In the central group it was but little greater. The gyro was checked at frequent intervals by means of an astro-compass. The eastern group found it convenient to install a special astro-compass bracket on the instrument panel. This consisted of a slotted arm permitting the astro-compass to be moved in or out or to be slewed to either side. This location saved the co-pilot a trip back to the astrodome for each observation. It could not be used when the celestial body was abaft the beam. The eastern group, operating a considerable distance from the magnetic pole, used the fluxgate and magnetic compasses as additional checks. These instruments operated reasonably well, but could not be used as primary methods of maintaining direction because of uncertainty of magnetic variation. However, the isogonic lines on the charts proved to be generally correct to within 1 to 2 degrees.

Because of lack of information and inaccuracies of charted land masses, charts were used more as plotting sheets than charts. In fact when the eastern group made one flight beyond the longitude limits of the available navigational charts, the meridians of one of their charts were renumbered, isogonic lines were sketched in from a chart of a different projection and scale which were not considered suitable for navigation, and the flight was made without difficulty.

The selection of charts represented a curious difference of opinion. The eastern group preferred the Hydrographic Office V 30 charts on the Mercator projection. The AAF long range Lambert conformal charts were used for checking the location of reference points, but not for navigation.

The western group preferred the Lambert conformal projection for the same reason that the eastern group liked the Mercator projection : plotting was easier ! The Army long range charts were used, but did not prove entirely satisfactory, principally because the scale was too small, being approximately 45 miles to an inch. Also, the ink had a tendency to rub off and the graduations of the latitude and longitude scales were not entirely satisfactory.

The central group, which operated within 12° of the pole, used the Hydrographic Office south polar charts on the inverse Mercator projection. The reason ? Plotting was easier ! These charts are constructed on the Mercator principle, but the surface of the earth in conceived as being developed on a cylinder tangent to the 90° E.-90° W. meridians. From this fictitious equator a system of fictitious meridians and parallels are shown as a green overprint. A straight line on this chart is a fictitious rhumb line closely approximating a great circle, as an actual rhumb line does near the earth's equator. For grid navigation direction and distance are measured as on an ordinary Mercator chart.

Grid navigation in the south polar regions is essentially the same as in the north, except that when interconverting grid and true directions, all signs are reversed. Both the central and western groups used grid navigation. The western group practiced it, but did not use it for their routine flights.

Celestial observations were solved by H. O. 214 and H. O. 218. Beyond latitude 80° S. the pole was used as the assumed position. The lines of position derived in this manner were adjusted by means of the correction table given in the 70°-90° north latitude volume of Weems' Star Altitude Curves. Although these corrections were computed for the polar stereographic projection, their use with an inverse Mercator projection did not introduce a significant error.

Shore based electronic aids such as loran, racons, radio beacons, etc., were not available. Airborne radar was of little use because of the lack of targets which could be identified. Even the coastline was hard to distinguish because of the sameness of the return from snow covered ice on both land and water. Airborne radar was not even of much value in returning to the ship, because numerous nearby icebergs often presented the same appearance on the scope as did the ship, except at very short ranges. Shipborne radar was very useful in checking the accuracy of the dead reckoning during the early part of the flight and in assisting the planes in their return. Planes could be identified on the scope for a maximum distance of 30 to 90 miles, depending principally on their altitude. Radio direction finders were also very effective for homing at distances as far as 120 miles. GCA equipment was installed at Little America and although 27 practice approaches were made, no actual bad weather runs were needed because of good weather during flights. Fine, powdery snow penetrated the tightly closed trailer when a blizzard came up during dismantling of the equipment, thus indicating that better weather sealing will be necessary to prevent such equipment being rendered inoperative when it might be most needed.

MARINE NAVIGATION

On the water, as in the air, dead reckoning was the principal method of navigation used, but equally difficult to maintain. Pit logs were not used advantageously in ice because of slow speeds and long periods of lying to, and in some cases they became inoperative due to freezing or mechanical damage by ice, making it necessary to determine speed by some other method. In clear water engine room revolutions proved effective, but this was of little value in the pack ice. The best method of determining speed here was developed by the icebreaker *Burton Island* after it was determined that estimates were consistently low. The method consisted of tracking a large iceberg by radar and determining the speed by plotting. Speed through the water was thus quite accurately determined, and icebergs were usually available when needed !

Speed over the ground was more difficult to determine because of the meager information available on currents. The *Cacapon,* an oiler, at one time was allowed to drift for three days in an attempt to determine the set and drift of the surface current. Although the ship moved about 60 miles in that time, it was impossible to separate the effect of the current from that of a rather strong wind, and the procedure was not repeated. The *Pine Island,* a seaplane tender, attempted a similar project and ended up with a table for drift before the wind which proved to be quite accurate for ships of her class.

Direction was maintained principally by gyro-compass. These instruments operated satisfactorily to latitude 78°28' S., the maximum latitude reached, but beyond 65-70 degrees the errors were larger and somewhat more erratic than in lower latitudes. Magnetic compasses were normal to 60-67 degrees south. Beyond this, the deviation changed somewhat erratically on different headings. In the Ross Sea the magnetic compasses in steel pilot houses were useless. It must be remembered that the area in which the magnetic compass proved unreliable was in close proximity to the south magnetic pole. The aircraft carrier *Philippine Sea* had an aircraft type fluxgate compass, which behaved better than the regular magnetic compass.

The marine charts were little more accurate than those used for air navigation. A check on the coast line of the Antarctic continent was not obtained, but several discrepancies in charted position of islands were noted. Two ships passed through the reported position of the legendary Nimrod Islands and spent an entire day investigating their supposed location, but nothing was sighted, although visibility was good. The reported position of Swain's Island was similarly passed and not as much as an abnormal sounding was found !

The Bay of Whales was found in its charted position, but had shrunk to about a fourth of its former size. This serves to emphasize the difficulty of charting the coast line of an ice barrier, which is continually changing.

Actual plotting was done by all ships on Mercator plotting sheets. Although considerable distortion is present in these sheets this difficulty was considered to be more than offset by the additional ease of plotting on this type or projection.

The principal difficulty of celestial navigation was the lack of observations. Since there was continuous daylight during most of the period spent in antarctic waters, the sun was the chief body available for observation, although the moon and Venus were occasionally observed. The weather constituted the principal obstacle to more frequent observation. It was found desirable to keep a navigator on duty 24 hours a day to obtain sun sights when available, for the cloud cover and fog cleared with remarkable rapidity, but often for a very brief interval, sometimes measured in seconds. When neither clouds nor surface fog were present to prevent observation, false horizons were sometimes encountered. In the ice pack the hummocky ice made it difficult to estimate the correct position of the true horizon. One ship used a bubble sextant with good results, since there is very little ship motion in the ice pack. The navigator of one of the destroyers made exhaustive tests of a ball recording sextant, with disappointing results. Observations were solved by H. O. 214.

Radar proved to be invaluable. Reliable ranges of initial contact of icebergs were 15 to 30 miles, with one contact reported at 84,000 yards (about 37 miles). Pack ice was picked up at 10,000 yards. Growlers were the chief concern. These were large enough to damage a ship, but small enough to be lost in the sea return. Sonar proved to be a valuable adjunct to radar. Average ranges of first contact by sonar ranged from 1,000 to 2,500 yards for growlers to 3,000 to 4,500 yards for icebergs, with maximum ranges of 7,000 yards or greater. Pieces of ice as small as three feet in diameter were sometimes picked up by sonar ! The submarine *Sennet* found that it could make about 5 knots through ice fields by using sonar to continuously search a sector 15° on each side of the bow and track all contacts. It was even possible to run submerged by extending the sector to 40° on each side of the bow. The fact that sonar proved more effective on ice than radar at short ranges is not surprising when it is remembered that a relatively small part of ice floats above the surface.

Radar was, of course, very useful in fixing position when in the vicinity of an established landmark.

For making rendezvous during periods of low visibility the radio direction finder proved itself essential. The first instance of its use for this purpose occurred when the icebreaker *Northwind* rendezvoused with the *Mount Olympus, Yancey* and *Merrick* after having towed the *Sennet* north, clear of ice pack. The *Northwind* had not been able to verify her position for several days. It was imperative that she return to the three ships as soon as possible, as they were in danger of being crushed by the ice. In order to set a course for their position RDF bearings were used. These proved accurate and invaluable. The rendezvous was made during a blinding snow storm and the *Northwind* was able to tow the ships to safety.

On another occasion two ships, neither of which had been able to fix its position for 3 or 4 days, attempted to rendezvous, but found nothing but empty water at what was believed the rendezvous position. Since neither ship had RDF equipment, one of them improvised an instrument by winding about 25 turns of small wire lengthwise around a cardboard box. This was mounted on a small boom, connected to a galvanometer, and trained manually while signals were sent by the other ship. Meanwhile the other ship had evolved a similar rig. By this means the rendezvous was made.

It may be asked, " Why was radar not used " ? The answer is simple. At the beginning of the rendezvous runs the ships were usually out of radar range of each other. As the range decreased, it was difficult, by the use of radar alone, to determine whether rendezvous was being made with a ship or an iceberg, without tracking every contact. This situation could be corrected by the use of IFF.

CONCLUSION

And so another chapter has been written in the history of Antarctica. The experience of Operation Highjump confirms the fact that the principal problems to be solved before navigation in the antarctic will be simple and reliable revolve around (1) the problem of maintaining direction, (2) the difficulty of determining position, and (3) the need for accurate charts.