# HYDROGRAPHIC SURVEY OF MELVILLE BAY
## (WEST GREENLAND)
## IN 1959 USING TWO RANGE RAYDIST

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*IHB Note.* — The author composed this article from a summary and excerpts from his thesis which was presented at the Ohio State University.

### 1. — Historical review

During the past fifteen years the strategic importance of the Arctic Region has necessitated the building of various types of installations. Logistically to support some of these facilities, additional sea-lanes required either hydrographic expansion or exploration.

The primary mission of the U.S.S. *Edisto* was to conduct a precise hydrographic survey in Melville Bay, West Greenland in order to obtain accurate nautical data to ensure safe navigation in the Northabout route.

### 2. — Preparation of the survey

#### 2.1. — Geodetic control

All primary, secondary, horizontal and vertical control had been established by previous Danish triangulation personnel. In general, large cairns erected over metal tablets made recovery and identification easy.

#### 2.2. — Selection of projection and scale

Since Melville Bay, West Greenland is in the polar region, the Universal Transverse Mercator (UTM) is particularly suitable to a large band of latitude as well as extending to a relatively short distance on each side of the tangential meridian.

The area to be charted extended from Red Head to Cape Melville, a latitude difference of approximately 1°. Scale specifications of 1/100 000 necessitated the computation and lay-out of two separate smooth sheets.

An overlap area was chosen with the intention of positioning the red relay station and the main calibration buoy common to both sheets. In addition, it was necessary to include a great central portion of the survey area, in the event that only one green relay station installation was possible (fig. 1).

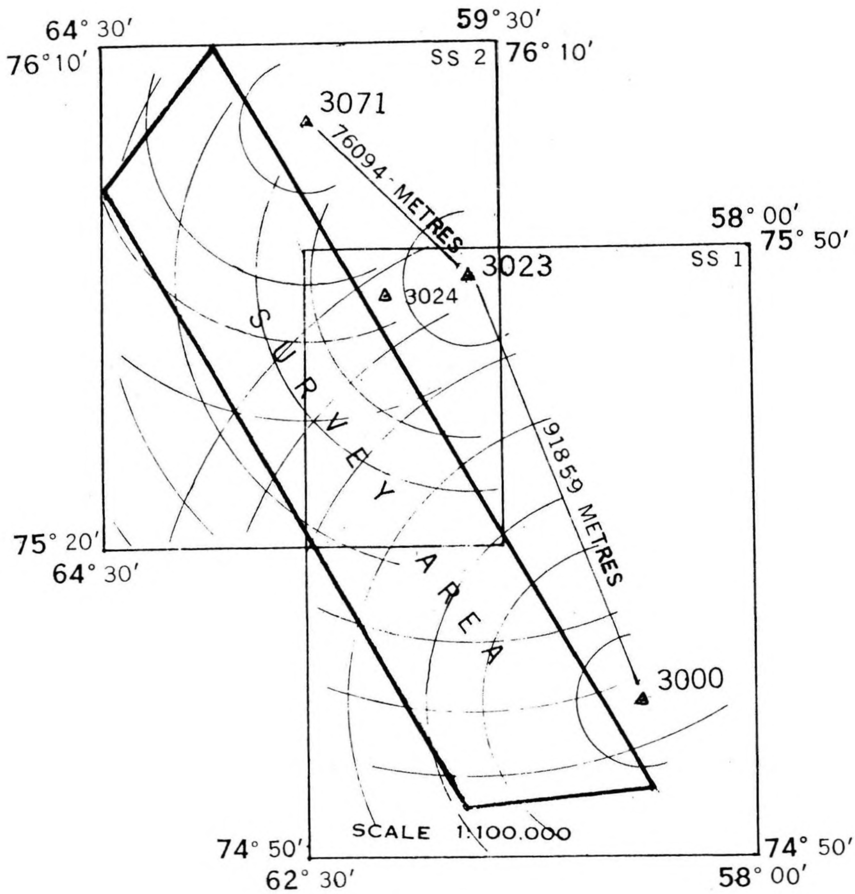


FIGURE 1

## 2.3. — Raydist

All Raydist systems are based on the fundamental principle of determining distances or differences in distances in terms of the relative phase of an audio heterodyne.

The two range 100 watt DM Raydist system employed the method of phase comparison at an audio frequency of continuous wave signals. The unmodulated transmitters operated on frequencies being properly related. The frequency $f$ and the audio frequency plus a multiplier $n$ of the frequency developed a heterodyne $a$ in the audio modulated receivers at each of the three units (the ship, the red relay station (3023) and the green relay station (3000, 3071).

After an amplitude modulation receiver detected the heterodyne at each shore station, a data transmitter returned the resultant tones to a phase sensitive circuitry in the Navigator station. Since the heterodyne was derived from a fixed transmitter and a mobile transmitter, the range data of the ship was contained within the relative phase relationship of these three tones. The instantaneous dual range data was continuously displayed on two Veeder-Root type counters in digital form of increments (lanes) of one half wave lengths at the fundamental frequency. A permanent record of both range versus time was produced on an inking type strip chart recorder.

### 2.4. — Computation of the lane width and baseline equivalent

A radio wave propagation speed of 299 690 kilometres per second was suggested by the U.S. Naval Oceanographic Office. Raydist assignment frequencies of 1 614 kc, 1 653.5 kc, 2 398 kc, and 3 307.4 kc were also requested by the Commander, Military Sea Transportation Service and granted by the Chief of Naval Operations for the survey.

In computing the lane width, Raydist Corporation advised using the frequency (3 307.4 kc) of the transmitter which was to be adjacent to the position indicators.

The method of computation was :

$$\text{Lane width} = \frac{\text{Velocity of propagation } (v)}{2\ (nf + a)}$$

$$1 \text{ lane} = \frac{299\,690}{2 \times 3\,307.4} = 45.30598 \text{ metres} = 4530.598 \text{ centimetres}$$

At a scale of 1/100 000, 1 lane equals 0.045 centimetres.

Baseline Red Head — Marie (91 859.177 metres) equals 2 027.528 lanes.

Baseline Marie — Skenes (76 094.826 metres) equals 1 679.575 lanes.

### 2.5. — Raydist arrangement and equipment

The two-dimensional 100 watt system utilized two shore stations and one mobile station. The red relay station, which was common to both baselines, was situated at Marie, and the green relay station was located at Red Head for ship positioning in the southern portion of the survey area and station Skenes for the northwestern portion of the survey.

### 2.6. — The installation of the mobile station aboard the U.S.S. *Edisto*

The Raydist installation aboard the *Edisto* was performed by the ship's personnel with the assistance of the Raydist engineers. The equipment was mounted on shock preventive racks in the upper radar space immediately aft of the bridge. An electrical event marker for the precise synchronization was linked between the Raydist position recorder and the fathometer (ocean depth recorder). On the radar antenna platform, two steel angle yard arms were welded to support securely a thirty-five foot tubular aluminium antenna. A second antenna, which was collapsed to its minimum length of six feet, was to be used as a spare in the event of failure in the original antenna due to windage, icing or shock from ice operations (the spare was never needed). Two RG-8U coaxial cables, connected to the Raydist Navigator, were run up to the loading box located at the pedestal of the radar platform and adjacent to the base of the antenna.

The elevation of the antenna permitted approximately twenty feet of it to extend above the top of the ship's radar sweep, thus permitting a three hundred and sixty degree unobstructed radiation pattern of the Raydist signals.

### 3. — In Melville Bay, West Greenland survey area

Due to the brevity of the survey season in the Arctic and the possible lack of drafting facilities aboard ship, expediency demanded going further in the preplanning development than was customary (i.e., drawing on to the projection the concentric Raydist circles). From previous experience in Greenland, the author anticipated reliable Danish triangulation methods and results (i.e., erection of large cairns over metal tablets), and after studying the existing aerial photography of the area, felt justified in his assumptions. However, in the event of the preplanning failing to have value, enough material and data were available to handle all emergencies.

The U.S.S. *Edisto* departed from Boston, Massachusetts on 9 July 1959 and after one port of call arrived at Melville Bay, West Greenland on 22 July. Reconnaissance by the helicopter of the existing ice conditions and the recovery of the geodetic control commenced immediately.

#### 3.1. — Red and green relay station selection

Considerations in the selection of relay stations were based on : geodetic control; obtaining the best geometric Raydist pattern in the survey area (90° circular intersections); uniformity in the velocity of propagation of the radio waves along all paths between stations (totally over water) to eliminate range variations and avoid shadow zones; a baseline check; suitable elevations in order to make helicopter support feasible and to prevent icing of antennae, and a large flat ground area to land helicopters and for installation of living quarters for the personnel attending the station. For convenience it was hoped a favourable tide gauge location could be found close to the camp. It may be mentioned that all the relay stations chosen fulfilled the above considerations.

The Raydist relay stations, as preplanned, were located at the first order triangulation stations. The red range was at station Marie (3023), elevation 195 metres and the green station at Red Head (3000), elevation 263 metres, which was moved later to Skenes (3071), elevation 140 metres.

At station Marie, the station marker for the red range measurement was located between the receiver antenna and the continuous-wave transmitter, with the transmitter antenna for the sum measurement placed directly over the marker itself. At station Red Head and Skenes for the green range stations, the receiver antennae were situated directly over the metal tablets.

### 3.2. — Installation of the shore relay stations and the time required

At the red relay station Marie (3023), a single eighty foot aluminium triangular antenna, guyed from five levels to pipe pins at 120° intervals and extending outward approximately 35 feet, was assembled and erected by five men using a block and fall and a twenty foot gin pole. To have the antenna operational, a ground radial system consisting of thirty-two units, one hundred feet in length of No. 10 solid copper wire joined at the centre of the antenna base. Adjacent to the base insulation, a loading box was mounted and three RG-8U coaxial cables connected from it to the electronic equipment located in the housing tent. After proper tuning, the station was ready for full utilization.

While the camp installation was essentially the same at the three relay sites, the antenna systems were different. The green relay stations at Red Head (3000) and Skenes (3071) each required two antennae which were erected one hundred to one hundred and fifty feet apart and having a ground radial system about each base. The receiving antennae were positioned directly over the Danish geodetic markers.

The time taken for installation and evacuation at the three sites was as follows :

| Station | Installation | | Evacuation | |
|---|---|---|---|---|
| | Date | Hours required | Date | Hours required |
| Marie (3023) .... | 23 July | 14 | 9 September | 4 |
| Red Head (3000). | 25 July | 12 | 24 August | 4 |
| Skenes (3071) ... | 25 August | 9 | 9 September | 4 |

Having continuous arctic daylight, and weather permitting, it was possible to begin operations at any time, and the excellent seamanship of the Commanding Officer in navigating the *Edisto* close to the stations saved considerable time and effort. The stated periods of time were from the first helicopter lift of the working personnel to the time that the station was fully operational (with camping facilities and provisions for three men at each site).

The average work party consisted of ten men plus one Raydist engineer, and required approximately 100 man hours to erect and forty man hours to evacuate each site. This approximate installation time was used as follows : transfer of personnel and housing tent, 60 %; electronic equipment, 3 %; antennae, 30 %; generators and shelter tent, 7 %. The 16 × 16 foot wood floored, insulated housing tent was levelled with rocks at two sites and with a 2 × 4 inch lumber framework at Skenes Island. The generator tent was pitched fifty to one hundred feet from the housing tent. In order to assure continuous power, two diesel generators were operated simultaneously with a switch for disconnecting either (i.e., maintenance) without disabling the other; they were fed from a common 55-gallon oil drum.

### 3.3. — Auxiliary equipment

Each shore relay station was equipped with two diesel generators, 5 kilowatt, 110 volt, 60 cycle, weighing approximately nine hundred pounds each. Since the maximum power requirement at each site was one kilowatt, the generators were never fully loaded. The initial line voltage from each of the units was 135 to 140 volts and a governor connected to the generators was adjusted to reduce the excessively high line voltage before the equipment suffered any damage. A switch assemblage for the rapid transfer of generators to avoid survey stoppages during the operation was furnished for each site by the electrical division of the ship. Although the generators were larger than necessary they operated satisfactorily.

A pneumatic gasoline Cobra rock drill reduced considerably the time spent on site installation (i.e., setting pins for guying antenna wires).

Several 25 watt battery powered Sonofone portable transceivers were provided for voice communications between the ship and the shore sites. They proved satisfactory up to a range of from twenty to thirty miles. Beyond this range essential traffic was handled by code from the Raydist equipment, without interrupting the survey operation.

### 3.4. — Calibration of the Raydist ship positioning

After the relay stations at Marie and Red Head were in operation, the initial calibration was determined at Thoms Island (3024) because the island was situated in the overlap area of the two boat sheets and could also serve as a calibration point for the second green relay station at Skenes (3071). Thus, considerable time was saved by only requiring one calibration point to complete the entire survey.

The calibration point was located geodetically by positioning a buoy over a unique bottom feature whose depth was 100 feet. The buoy was close to grounded icebergs and positioned from two shore stations (having known positions and azimuth reference). Simultaneously, by radio synchronized observations from two T-2 Wild theodolites located at the known positions, six sets of readings were taken to the buoy. After the angles and intersections were computed, checked and field plotted on to the boat sheet, a green and red lane value for the buoy was obtained. When the ship was brought alongside the buoy and next to the Raydist antenna, the red and green relay station ranges were set into the phasemeters. Before leaving the buoy, angles were observed to prominent points on the islands to insure quick recovery of the bottom feature in the event of the buoy being lost or moved by the ice (as occurred during the operation).

Additional buoys to facilitate calibration checks were placed at convenient places (i.e., Sabine Island and an isolated rock near Red Head) and were tied back to the initial calibration point at Thoms. When dropping a buoy, the ship's heading, direction and distance of the Raydist antenna from the buoy, the current direction and the maximum radius of swing (due to slack or scope of the wire attached to the buoy) were noted. The buoys consisted of oil drums painted international orange, with a large black numeral designator, and a wire slug attachment (concrete set in a large paint can).

Calibration was checked approximately every seventy-two hours of continuous hydrographic surveying. The ship's radio Raydist station log was used to record all incidents concerning the electronic and mechanical malfunctions. Communications between the ship and shore stations were maintained by sonofone units on the beach and TCS units aboard ship. In addition, the recorder tapes and sounding journals were annotated to indicate each event or incident such as lane loss, lane check, generator shift, power failure, etc.

During a signal loss, the ship was maintained at a steady course and speed, crossing lanes at even intervals, and as a result after the signal came back on the air it was possible to correct the lanes gained or lost by using dividers and continuing the even spacing across the section of the tape run while the signal was off the air. This occurred on the average of once every forty-eight hours. After rechecking calibration at the buoy all adjustments were confirmed to be accurate. Corrections were made immediately upon detection of error.

### 3.5. — **Depth recording in the survey area**

The ship's speed during 95 % of the operation was ten knots and reduced to five knots only during poor visibility, proximity to shoal areas, and dangerous and heavy ice conditions. With few interruptions (i.e., going to the assistance of a ship in distress), the *Edisto* surveyed twenty-four hours daily. Thus, it required scheduling personnel to maintain six hydrographic watches of four hours each. A watch consisted of three men performing the following duties : a ship's position plotter for the boat sheet, a journal recorder who also observed and marked the Raydist strip chart, and a fathometer annotator.

The time intervals between Raydist positions and fathometer soundings were recorded and plotted every five minutes or less, on to the boat sheet. The scaled depths obtained later from the fathometer roll were entered for each minute into the sounding journal. However, the depths were shown between the five minute fixes at two minute spacings in order to avoid crowding of numbers on the boat sheet. In general, courses of 140° and 320° on the southern sheet and 120° and 300° on the northern sheet were maintained. Each sheet was developed at a scale of 1/100 000 and divided into two priorities. The line spacing in priority 1 was 2 000 feet or four lines to the inch, up to a 7/10 ice and iceberg coverage, and 4 000 feet or two lines to the inch in priority 2. The volume of icebergs sometimes prevented the ship from steering and maintaining steady courses which are essential in order that the plotter may enter straight lines between fixes on the boat sheet.

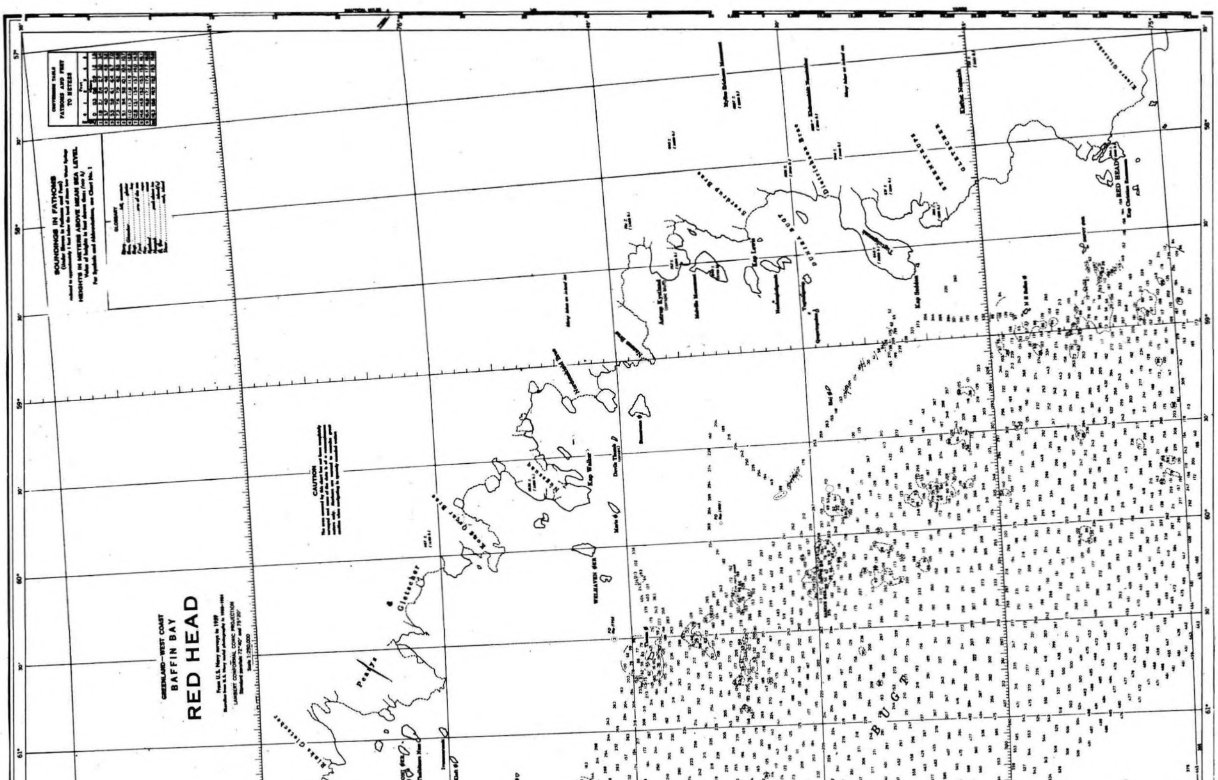
GREENLAND—WEST COAST
BAFFIN BAY
RED HEAD
SOUNDINGS IN FATHOMS
CAUTION

FIGURE 2

Soundings were obtained by an AN/UQN-IC Edo depth sounder (0-6 000 fathoms) that was electrically synchronized to the Raydist position recorder. Fathometer roll, raydist roll and sounding journal were all coordinated by time and fix number. Corrections for predicted tide, transducer depth, zero settings and frequency check (twice daily) were entered into all sounding journals.

Except for rechecking calibration, resupply and minor repairs and maintenance of the relay stations, the total sounding time required to complete survey operations was thirty-six days (the ship sounded for nineteen and seventeen consecutive days). Approximately seven thousand five hundred linear miles were hydrographically sounded in the two priorities.

In addition, a Canadian hydrographic small boat (called *Pogo*) was used to chart the offshore islands, out to 100 fathom bottom contour at Thoms Island, Sabine Island, a rock awash and an island with no name. The positions were obtained by the Radar Range method. It may be noted that whenever the *Edisto* investigated dangerous and doubtful areas *Pogo* was hoisted overside to record the depth directly ahead of the ship.

The entire area sounded was contoured and it was noted that between Thoms Island and Depot Island, out to a 400 fathom depth, the bottom had a highly irregular and unusual characteristic (fig. 2). There was a definite south-westerly submerged peninsula continuation trend from the highly complex mountain topography on shore and an unpredictable steep bottom change of great magnitude in elevation on small bottom features which had no apparent gradient warning. In addition, there was a relatively slow current, containing units or clusters of icebergs which made identification of grounded icebergs extremely difficult. Therefore shipping was advised to use extreme caution when navigating in this area.

### 3.6. — Tidal predictions and observations

While en route to the survey area, the tidal predictions for the entire anticipated survey time were obtained by a tie-in between the secondary tidal station at North Star Bay and Melville Bay, West Greenland. As a result of the longitude similarities, the predicted tidal Melville Bay graphical plot required no adjustment for time differences between stations. A daily graph was plotted and smooth curves drawn through the highs and lows. The hourly tidal variations were tabulated and later entered into the sounding journals.

In order to have precise tidal data during the survey and for future analysis, a portable tidal gauge was installed. The ideal portable tidal gauge survey location was Marie Island and it was found to be undesirable for installation because of precipitous cliffs, and the heavy concentration of ice encircling the island.

After reconnaissance around the Red Head peninsula, a portable tide gauge with a reference tidal staff was erected. The site selection had free communication for the tide, sufficient depth of water even at extreme low tide, shelter from storm waves (shelter proved erroneous after a bergy bit dismantled the gauge), freedom from freshets (seasonal variation in the volume of drainage waters) and accessibility for the personnel from the red relay station.

After recording eleven days of successful tidal variations, it was decided that it would be impractical and unsafe to continue tide gauge operations.

### 3.7. — Photogrammetry

Photo coverage of the area to be surveyed was made available with the exception of a critical flight strip between Sabine Island and a non-existent Ajakos Island. After a search was made for the photos at the home office, it became apparent that the flights were never extended out from the shoreline as far as that. Identification of the physical features and photo annotations were limited because of the emphasis placed upon the importance of getting the area sounded. However, questionable islands and shoals were investigated.

The author became curiously concerned as to why so many islands that did not exist were reported by previous mariners, and similarly why previous chart editions compiled by photogrammetric techniques of the offshore islands also showed no islands where islands do exist. Apart from the personal element of error, it became apparent during the survey that dirty icebergs, existing at the time of the flight filming, could easily be mistaken from aerial photographs for small islands, and small islands could easily be hidden by icebergs. The ice since gone offers each succeeding year an entirely different appearance. In addition to the same mistakes made by the photogrammetric compilers at the office, the mariners reported hollow arched icebergs for non-existent islands. The refraction and diffusion of light balanced proportionately, the hollow arch is miraged as a dark island.

Another possible explanation may be the changing coastline. Large ice movements and prominent iceberg creation in this area has undoubtedly altered the isostatic equilibrium.

### 3.8. — General

The entire season's weather information, sea and ice conditions, were observed, logged and reported to Washington, D.C. by the Aerology Department aboard the *Edisto*.

Aids, dangers to navigation, and sailing directions were a continuous process of observing, recording, and reporting. It was suggested to the Captain that the Navigation Department submit copies of all navigational information directly to the Sailing Direction Section of the U.S. Naval Oceanographic Office.

## 4. — Conclusion

### 4.1. — The results required from the field

The technical specifications of the U.S. Naval Oceanographic Office were followed as rigidly as practical. Development of the hydrographic survey area was shortened to a 7/10 ice and iceberg coverage rather than the fast ice limit.

### 4.2. — The degree of positional accuracy

Due to long periods of bad visibility and poor communications between triangulation stations, it became impractical during the initial calibration to attempt to position the ship (dropping a buoy at the same time) simultaneously from the three first order triangulation stations. Having first order geodetic control to expedite the survey, a surrender of a degree of accuracy by using the subtense baseline reference method was felt justified in order to start the survey and later was proved wise by the results obtained. A baseline was measured from a first order station by observing six subtense bar sets of observations at each end.

Two independent Raydist baseline crossing measurements were within one metre of the length of the baseline as computed by an inverse computation of the two first order Danish geodetic positions. The length of the baseline from Marie to Red Head was 91 855.17 metres or approximately forty-seven miles. It also confirmed the accuracy of the initial calibration and the velocity of propagation of the radio waves.

### 4.3. — A summary of the Raydist performance and evaluation

1. The equipment proved to be capable of sustained operation because there were no failures in the electronic components during the forty-five day operating period (two periods of seventeen and twenty-eight consecutive days). Seven thousand five hundred linear miles were positioned in thirty-six sounding operational days.

2. During continuous round the clock routine operational procedure neither magnetic disturbance nor sky-wave effect (so called night effect) were encountered. (Sky-wave effect may cause phase displacement which is dependent upon time, place and the height of the E layer (ionozation density zone in the ionosphere)).

3. No directional effects were encountered during turns or manœuvres permitting unrestricted navigation about icebergs and shoals. The Raydist Navigator's excellent sensitivity was capable of identifying slight changes in wave propagation speed when the ship was behind an iceberg and in line with one of the relay transmitting signals. Probably, by analyzing the strip chart one could compute the iceberg's dimensions. However, the Raydist system at no time lost lane count because of the ship's movements.

4. From all indications the Raydist positional accuracy was well within specification requirements.

5. Overlap of sounding depths between boat sheets and cross check lines showed good consistent matching. It proved the reliability of the baseline after the transfer of the green relay station (no baseline check between Skenes and Marie), and the excellence of the Danish triangulation.

6. Although only seventy-five miles' range was required to accomplish the survey, during the emergency (ship in distress) the equipment successfully tracked to a range of two hundred and ten miles.

7. Calibration and recalibrations were readily accomplished. Of the five recalibrations which were necessary one was caused by a three minute total blackout of all radio reception aboard ship. This occurred during a severe storm, accompanied by limited visibility which forced the ship to a complete stop. The remaining four incidents were due to power failure and were therefore not a result of malfunctioning of the Raydist system.

8. Visual and audible monitoring facilities permitted immediate detection of any malfunctioning of the Raydist equipment (reeds for cyclic variation and tones for heterodyne variations).

9. Correction of lane count after short breaks in operation due to power failure, etc., were simple and precise, as shown by the frequent calibration checks.

10. Sensitivity of range indication permitted the reliable detection of an error of fifty feet in position or a course change of one degree (even when plotting on a 1/100 000 scale boat sheet).

11. Good repeatability was proved by returning to predetermined points such as buoys, shoals and specific bottom features. These return trips were made after periods of several days and under all climatic conditions.

12. The Raydist Navigator was not adversely affected by normal generator shifts in the ship's electrical system.

13. No interference problems were encountered between the Raydist and routine ship's communication.

14. The Raydist equipment was used for auxiliary emergency communications between the ship and the relay sites without interruption in the survey operation.

15. The green relay station was manned very successfully by an all Navy shore party with no prior Raydist training.

It is the author's opinion that the Raydist electronic navigational DM system can be evaluated as a very accurate and reliable hydrographic survey tool.

### 4.4. — **The field results and recommendations**

The Melville Bay hydrographic effort by all personnel involved resulted in a precise survey being accomplished in a limited operational season. The area sounded gave all the intended information necessary for maritime safety in Melville Bay, West Greenland. Unless the office compilation and evaluation found that the survey had not fulfilled survey specifications, it was recommended that no future field work was necessary in this area.

### 4.5. — **Appreciation**

On behalf of his colleagues the author thanked the Navy and the Commanding Officer of the *Edisto* for the opportunity to have been of technical service to the nation. For the author, he was proud to have taken part in the superb team-work which was carried out during the entire Melville Bay survey.