DEVELOPMENTS IN BRITISH HYDROGRAPHY SINCE THE DAYS OF CAPTAIN COOK

A Paper by

REAR-ADMIRAL G. S. RITCHIE, CB, DSC, FRICS

Hydrographer of the Navy,

read to the Commonwealth Section of the Society

on Tuesday 3rd February 1970,

with Sir Alfred Sims, KCB, OBE,

former Director-General Ships, Ministry of Defence, in the Chair

THE CHAIRMAN: Two hundred years ago at this time – and not long after this Society was formed – Captain James Cook was circumnavigating the islands of New Zealand during the first of his three great voyages. He was accomplished in many fields, and it is to the credit of our Commonwealth Section that he should be remembered to-day through his pioneering work in hydrography.

His efforts in this specialization have been largely continued in this country by the Hydrographers of the Royal Navy and their staffs. We are privileged to have the present holder of this appointment to talk to us to-day.

It was a surprise to me to find that Rear-Admiral Ritchie is only the nineteenth holder of the post during the one hundred and seventy-five years it has existed. Clearly his predecessors have a fine record of fortitude in high office, and we all hope he will be no exception to the rule!

Admiral Ritchie has been in the hydrographic service for thirty-three of his nearly forty years in the Royal Navy. During the Second World War he was attached to the Eighth Army and played a vital part in surveying damaged ports and harbours in North Africa and Italy – work which gained for him the Distinguished Service Cross. On D-day he sailed for Normandy and carried out survey work in readiness for Mulberry Harbours and in damaged ports and harbours of North West Europe. Since the War he has had a variety of important assignments – a world voyage in which the nature of the ocean floor was investigated by seismic methods, in New Zealand and Samoa when on secondment to the Royal New Zealand Navy, in the West Indies, in the approaches to the Straits of Gibraltar and in many other areas.

I hope I have said enough to make you all the more eager to hear his account of the developments in British hydrography since the days of Captain Cook.

The following paper, which was illustrated with lantern slides, was then read.

IT IS 200 years since Captain James Cook was making his first survey of the New Zealand coastline so that those who were to follow would have a chart to guide them. By April he was employed on a similar task on the east coast of New South Wales.

Cook was the father of British naval hydrography, of that there is no doubt. During his three great Pacific voyages he developed his technique of the running survey for laying down an uncharted coastline and taught it to his junior officers who later, in their turn, made their own great surveys. Vancouver was one of these, who was to chart the west coast of North America and pass on to his own juniors, such as Broughton and Puget, the methods and the dedication to the work displayed by Cook. Captain Bligh was another of Cook's pupils in *Resolution*, and he taught Flinders during the second successful breadfruit voyage in *Providence*. Flinders clearly states that he employed the methods of Captain Cook when making his great survey of Australia in *Investigator*, and passed the knowledge on to Franklin, from whom, if we wish, we can follow the line of hydrographical descent to the Royal Navy surveyors of the present day.

In 1758 Cook was serving as the Master of HMS *Pembroke*, employed on the North American coast during the war against the French. Both Simcoe, his Captain, and Cook himself were enthusiastic students of the art of navigation. On the day after the surrender of Louisberg an officer of the Royal American Regiment of Foot was surveying the harbour at Kensington Cove. He was a land surveyor of Dutch ancestry named Holland, and he was using a plane table for his work when Cook, who was on shore from his ship, came upon him and showed a keen interest in what he was doing. He invited Holland on board to meet his Captain, and this visit resulted during the long winter of 1758-9 in these three men working together in the great cabin of *Pembroke* using captured French documents to construct a chart of the Gulf and River of St. Lawrence. Cook was able to add significantly to this chart in the summer by his survey in boats of the area known as the Traverses through which the British fleet were subsequently to pass, to the great surprise of the French, up to Quebec.

After the fall of Quebec Cook was directed to survey in the St. Lawrence and then, for five seasons, in the small schooner *Grenville*, along the rocky and fog-bound coasts of Newfoundland. The fair sheets resulting from these surveys, drawn and hand-coloured by Cook himself, form one of the most valuable parts of our archives at the Hydrographic Department, Taunton. Search as we may, it is, however, difficult to see how he set down his triangulation of the larger scale surveys, but it seems clear that he was adopting the principle of extending triangulation from a measured baseline which Holland undoubtedly would have described to him.

Cook's greatest works are, however, his running surveys along the coasts of New Zealand and Australia and among the islands of Polynesia, and here it is clear that he was developing for seagoing use the technique of the plane table which Holland had demonstrated.

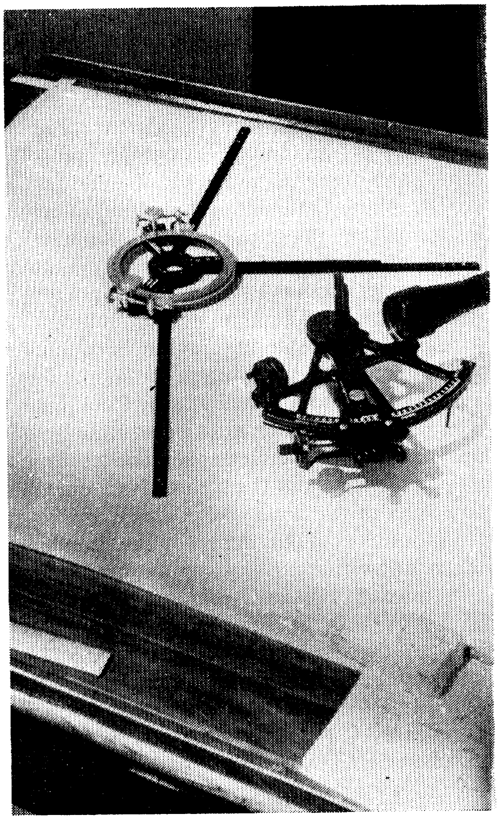
To employ the plane table to lay down topography on paper a number of selected stations are occupied by the surveyor, the relative distance between each such station being measured by pacing out, or some more exact means, and the direction observed by compass. At each station the alidade, a telescope mounted on a straight-edge, is directed upon easily recognizable peaks, trees or other land features and a pencil line drawn on the plane table along the straight-edge. As the survey progresses, and if the relative positions of the stations are correctly plotted, the intersecting rays will indicate the positions of the landmarks and detail of the topography may be sketched in between.

To develop this technique for laying down a coastline from a vessel at sea, Cook found it necessary to record most accurately by log the distance run between each course alteration necessitated by the trend of the coastline or a shift of the wind. At points where such alterations occurred, compass bearings were taken to prominent features on or near the coastline, or to distant peaks; on the accuracy of his log and course records depended the fixing of these features, between which detail was sketched in from the deck.

Darkness or foul weather would oblige him to leave the coast only to return at dawn, or when better weather prevailed, to take up the survey again off some recognizable point where it had been left off. Cook found it necessary to plot the legs of his offshore traverse and the bearings to the points onshore at the end of one day before commencing the following day's work. His great success lay in his detailed attention to recording every course and distance correctly, in his eye for detail and the importance he attached to completing the work while fresh in the mind, which often necessitated working far into the night.

Such dedication has survived to the present day amongst Britain's sea surveyors, despite the tremendous developments in technical equipment which have taken place and which we will now examine more closely.

Concurrently with Cook's great work overseas, but apparently little known to him or his fellow naval officers, a small body of civilian surveyors had been employed in home waters by the Admiralty since 1751, when Murdoch Mackenzie made a start on charts of the West Coast. Mackenzie was an enlightened man and in 1774 he published his *Treatise on Marine Surveying*, in which he lays the foundation of hydrographic surveying methods for a century to come. He realized that a carefully measured, long baseline ashore was the first essential for any



The sextant and station pointer – primary tools of the hydrographic surveyor's trade

harbour or coastal survey. Its direction must be obtained by compass needle, and then intersecting angles must be taken with a theodolite or Hadley, from either end of the base to what he termed stasimetric points, among them preferably being two on hilltops at the extremities of the survey from which he could intersect further points. Once a number of such points had been intersected, they were plotted on paper by protractor, two rays being used to plot them; he checked the third angle of the triangle by observing that angle in the field.

He then plotted the coastline by taking angles to prominent features by compass needle bearings from two or more of his stasimetric points; but when he came to important headlands he fixed them by resection with a Hadley. He set down geometrical and trigonometrical methods of finding such a position in three different cases when the three stasimetric points formed a straight line, or when the observer was either inside or outside the triangle formed by them. In this way he became aware of the danger of a 'circular fix' – when all three of the stasimetric points lie on or near the circumference of the same circle which also passes through the observer's position. To fix his soundings taken from a boat he took bearings to two of his stasimetric points with a hand compass.

In 1771 Murdoch Mackenzie was superseded as Admiralty Surveyor by his nephew of the same name, a lieutenant in the Royal Navy who had learnt his trade as a midshipman sailing round the world with Byron.

After retiring from active surveying Murdoch Mackenzie developed an instrument to solve the laborious problem of finding one's position from two horizontal angles observed between three stasimetric points. This was to become the station pointer, little different in construction from the invaluable instrument in use to-day. It consisted of a graduated circle of brass, six inches in diameter, to which three legs, the centre one fixed and the other two movable, were attached. By means of clamping-screws the two movable legs could be fixed so as to measure the same angles as observed with the Hadley. When the instrument was moved so that the three legs passed through the plotted positions of the three observed points, the surveyor's position at the centre of the instrument could be marked upon the plotting sheet. Within a few years the first commercial models of the station pointer were being made by Troughton, the instrument maker.

It is here convenient to glance at the history of the other two instruments, the theodolite and the Hadley which, together with the station pointer, had enabled the Mackenzies to bring hydrographic surveying to an advanced stage before the end of the century.

Hadley, a Vice-President of the Royal Society, worked for many years on optical instruments and in 1731 he showed his optical quadrant for observing the altitude of heavenly bodies to the Royal Society. This instrument took over at sea from the crude 'Davis pig yoke' for observing the sun's altitude, and the Mackenzies were using it in the 1770s for observing horizontally between stasimetric points. The logical successor, the sextant, is in use by surveyors similarly to-day.

The history of the theodolite is much older, there being a picture of this instrument in use on the cover of *The Surveyor* by Aaron Rathbone, published in London in

1616. It appears even then to have been capable of measuring both true horizontal and vertical angles on graduated circles, and since Cook's time to the present day this instrument, with many improvements, has been in use by the hydrographic surveyor for his preliminary triangulation work ashore.

Early forms of theodolite were greatly handicapped by the difficulty of graduating a circle, for it is not easy to accomplish without finding the final division either too large or too small, and Hadleys also suffered from poor division of the arc. In response to the offer of a reward by the Board of Longitude, Jesse Ramsden, a Yorkshireman, invented his dividing engine in 1775, for which he was paid £615 on condition that he explained its use to ten mathematical instrument makers. John Troughton was one of these, and he made a superior model of the machine, which not only enabled him to graduate Hadleys and theodolites, but also the station pointer which Mackenzie had set before him.

The greatest prize the Board of Longitude had to offer was, however, reserved for a timepiece which would operate successfully at sea so that longitude could be determined by carrying time faultlessly from Greenwich. The eventual winner of this prize, after many vicissitudes was, of course, John Harrison. When his No. 4 timepiece was eventually successful it was taken to pieces and its working explained to six nominated persons, three of whom were watchmakers. One of these was Larcum Kendall, and it was his No. 1 time-piece, modelled on Harrison's, that accompanied Cook on his second and third voyages and simplified the longitude problem immeasurably.

The eighteenth century had witnessed a great stride forward in the provision of the tools of the sea surveyors' trade. During the nineteenth century there was to be no similar advance in instrumentation; it is the way in which surveying officers of the Royal Navy developed the use of these tools in every ocean and sea of the world during the nineteenth century that makes the story remarkable.

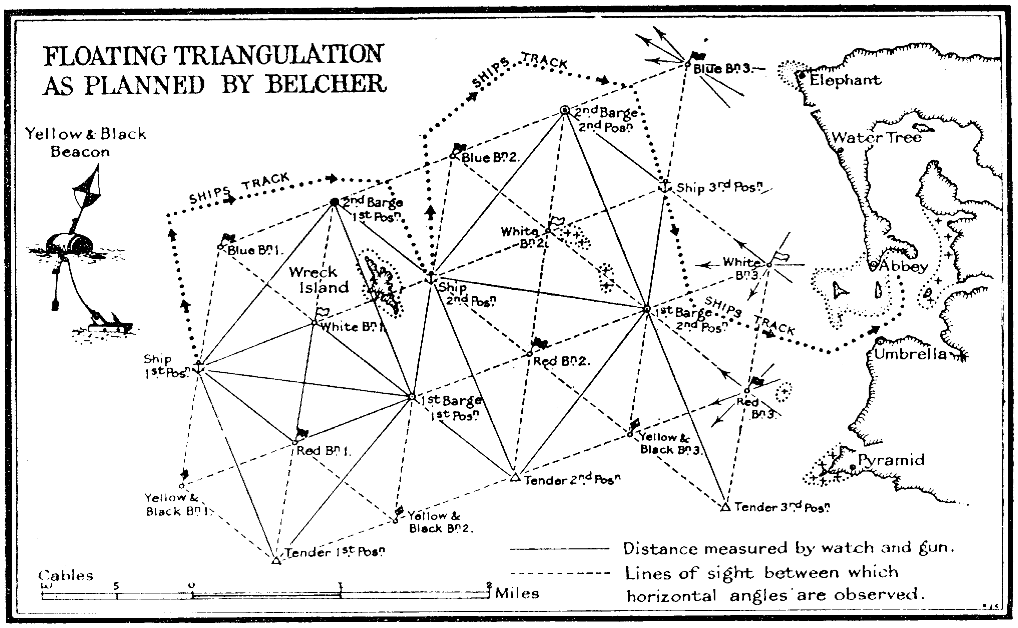
By the beginning of the nineteenth century more attention was being given by the naval surveyors to the charting of bays and natural harbours, whilst each succeeding visit to such well known places as Point Venus, Nootka Sound, Port Jackson and Queen Charlotte Sound enabled more celestial observations to be made, thus improving the accuracy of their positions.

We can look at Flinders's arrival in the south-west of Australia in 1801 to see the developing pattern. He first visited King George's Sound where Vancouver had observed for position ten years earlier; after more celestial observations, he took his departure for the running survey of the Great Bight, arriving 57 days later in Spencer Gulf to find a fine natural harbour which he named Port Lincoln, the great majority of his officers hailing from that county. The first thing to be done was to set up a shore observatory with tents, timekeepers, and the necessary astronomical instruments for rating them.

Then the survey of the harbour was taken in hand. No open beach or level stretch of clear ground being readily available for measuring a base, and the general alignment of the port being too far from the north/south direction to permit base measurement by difference of observed altitudes, Flinders fell back on the gun and pendulum method to measure an eight mile base from the ship at anchor to a station on Boston Island.

Such anchorages, laboriously surveyed and fixed, became part of a steadily increasing network of established natural harbours about the world to which the intervening coastal and oceanic surveys were adjusted and connected. It was necessary to expend every effort to establish the position. Of Port Lincoln Flinders wrote: 'The latitude of our tents at the head of Port Lincoln, from the mean of four meridian observations of the Sun taken from an artificial horizon was 34°–48′–25″ S. The longitude from thirty sets of distances of the Sun and stars from the Moon was 135°–44′–51″ E.'

Now came the work of fitting in the intervening coastline which had been delineated since leaving the previous established position at King George's Sound. The rates of acceleration or deceleration of the timekeepers had been carefully measured by daily observations of equal altitude over a period of six days at Port Lincoln. Flinders now compared these with the rates obtained fifty-seven days previously at King George Sound and employed a rate accelerating in arithmetical progression between these two to give the longitude of Port Lincoln. This differed by 7′ 25″ from the position fixed by the lunars, and so he then re-worked the longitude for all coastal features laid down between the two places by applying to each



FLOATING TRIANGULATION AS PLANNED BY BELCHER

a proportion of 7′ 25″ commensurate with the total elapsed time in days since quitting King George's Sound.

To complete the routine observations now common to every established geographical position ashore, the magnetic variation and dip of the needle were measured, the nature of the daily tides was noted with their range in height, whilst maximum and minimum daily temperatures were recorded.

Although the office of Hydrographer of the Navy was established in 1795 it was not until the Napoleonic wars were over that Captain Hurd, the second Hydrographer, began to organize a permanent naval surveying service at sea, manned with such officers as he could find who had sufficient mathematical knowledge for the work.

From 1829 to 1855 Rear-Admiral Sir Francis Beaufort held the office of Hydrographer, and during this period naval survey vessels were employed in every quarter of the globe. The resulting charts were made available freely for sale to encourage ships of all nations to carry overseas the growing number of products of the British industrial revolution.

One can find out something of the methods being employed in the mid-nineteenth century by reference to a work published in 1835 entitled *A Treatise on Nautical Surveying containing an outline of the Duties of the Naval Surveyor*. It was written by Captain Edward Belcher, who despite many quarrels with both his seniors and his juniors, remained at sea in command of surveying ships throughout the whole of Beaufort's long reign as Hydrographer.

A quote from Belcher's work is helpful in setting the scene:

> Only Masters still use the Azimuth compass. In a survey ship instantly the sextant is in request: even the pleasures of the table are forgotten. Astronomical pursuits, surveying, etc., have a peculiar attraction. Let but one moderate draught be taken fairly tested, a species of intoxication follows, scientific mania ensues. Example only is wanting, and if that happens to be the principal (Captain or Lieutenant) the contagion rapidly spreads – it becomes the fashion.

The sextant was used ashore in conjunction with the mercury artificial horizon for taking equal altitudes of the sun, a.m. and p.m., to rate the chronometers that they might be used as accurate recorders ot longitude. The sextant was similarly used with the artificial horizon to observe the sun's meridian altitude for latitude. At sea the sextant was used with the sea horizon to a lower standard of accuracy, and in the boats it was used horizontally with station pointers to fix whilst sounding.

Floating marks formed from spars and casks and moored with pig-iron ballast anchors were increasingly in use for controlling the survey. Onboard, the sextant and the ship's compass were used with the sun to obtain a true bearing between one floating mark and another; ashore the theodolite and a landing compass were used to obtain the true bearing with greater accuracy.

At sea bases were measured by the firing of a gun, ashore by the use of chains or rods.

Belcher describes with the use of the diagram a plan for carrying out a survey off the African coast using the survey ship, her tender and two five-ton boats carried in the ship, together with a number of floating beacons, to extend the triangulation towards the shore.

The smaller boats, using the various floating marks and with two leadsmen in the headsheets, sounded out the areas within each triangle, largely under sail, but under oars if need be.

The organization which was required each evening to prepare for the following day's activities as the triangulation moved shorewards, followed by the ship in surveyed water, was enormous. Any of the officers in the barges or boats could wreck the whole day's work by a failure to carry out their instructions to the letter. In planning and executing each day's work Belcher saw a similarity to chess.

The latitude and longitude was carried forward by plane trigonometry through the network of triangles from a position obtained when the ship first anchored. Once the vessel was safely anchored inshore a party was landed with the artificial horizon to obtain position ashore and develop a triangulation along the coast. From these stations the floating beacons, still in their final positions, were fixed by theodolite intersections, and the whole floating network re-adjusted for latitude, longitude, azimuth and scale. Belcher regarded the whole as a plane chart and the adjustment was effected by redrawing in ink the meridians and parallels which up to this stage had remained in pencil.

The second half of the nineteenth century saw an interest in the deep oceans beyond the comparatively shallow continental shelf areas where interest had so far been concentrated in the service of coastal navigation. The move towards the laying of trans-ocean cables fostered this interest in the ocean floor.

The first Atlantic cable was laid in 1858, but its insulation soon failed. Commander Dayman, in HM Surveying Ship *Cyclops*, had been employed in sounding along the proposed route using hemp line and a valve lead which retained a sample of the ocean-bed. The method was laborious and restricted the soundings to one every 50 miles, each needing about six hours to take in depths up to 2½ miles.

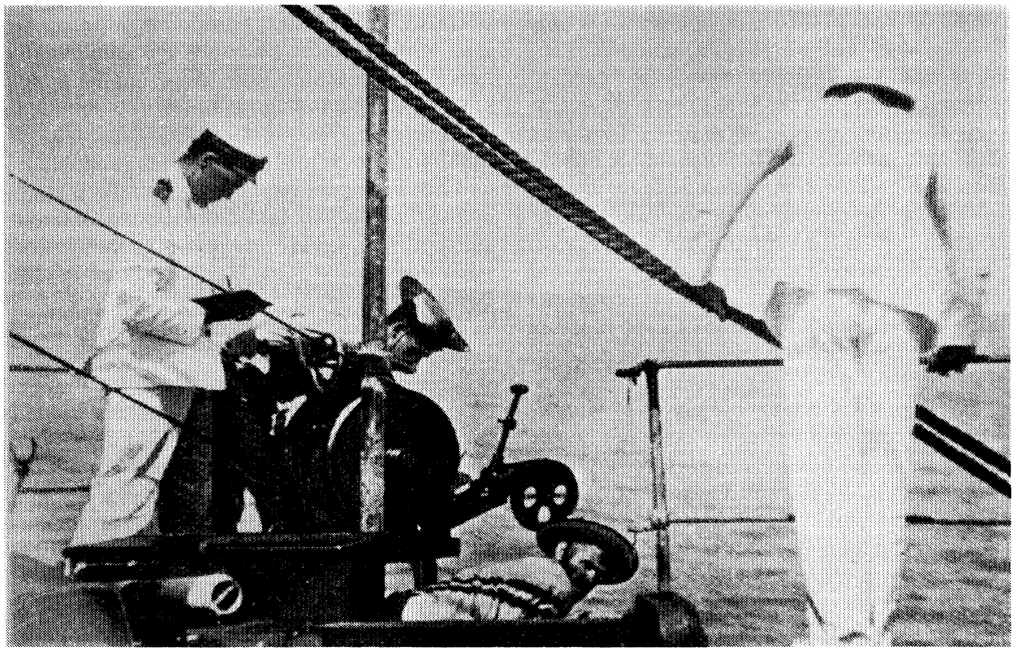
The first permanently successful transatlantic cable was laid from Brunel's *Great Eastern* in 1866, during Vice-Admiral Richards's period as Hydrographer of the Navy.

This success gave great impetus to cable laying in many parts of the world, and wherever these were, British naval surveying ships pioneered the way under Richards's direction, sounding the depths along the route and sampling the seafloor.

When Richards retired in 1874 he became Managing Director of the Telegraph Construction and Maintenance Company which, under his guidance, laid 76,000 miles of deep-sea cable during the next ten years. For this work a more rapid and precise type of sounding in deep water was required, and the Lucas sounding machine was developed by the Telegraph Construction and Maintenance Company. This used piano wire, and the arrival of the valve lead on the sea floor released sufficiently the weight on the arm carrying the sounding dial so that the wire was prevented from running out further and depth could be read from the dial. There were hand and steam-operated versions of this machine for shallow and deep water respectively.

By the mid 1880s this apparatus was fitted in a number of HM Surveying Ships and the first systematic charting of the deep oceans began, although the task was enormous and is far from complete to-day. Ocean-sounding cruises were made between then and the end of the century in HM Ships *Egeria*, *Rambler*, *Penguin* and others.

Surveyors gained a benefit from the advent of submarine cables whereby they were enabled to transfer longitude from one distant station to another by means of time signals passed along the cables. For years surveys in different areas of the world were connected in longitude by sea traverses, using large numbers of carefully rated chronometers, to the long-established observation stations referred to earlier. Such stations had been designated 'Secondary Meridians' and were listed in the publication *Instructions to Hydrographic Surveyors*. For example, the longitudes of charts of Southern Africa were related to the Secondary Meri-



Sounding with the Lucas Machine on board one of HM Surveying Ships at the end of the nineteenth century

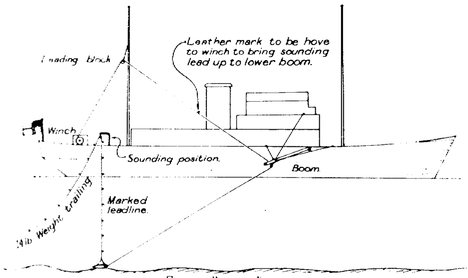
dian of the Cape Observatory. Modern telegraphy also enabled these 'Secondary Meridians' around the world to be connected to the 'Prime Meridian' at Greenwich.

In 1882 Captain Wharton published the first edition of his manual, *Hydrographical Surveying*, the up-to-date successor to Belcher's work, in which the various steps of marine surveying and the associated formulae were set down in a lucid manner. When Wharton became Hydrographer in 1884 he ensured that instructions in the manual were followed by his surveying officers. Wharton laid down how triangulation should be plotted by the 'long-side' method. The gnomonic projection was used, whereby the spherical shape of the earth is represented on a flat surface by means of a single imaginary point of contact. The measured baseline was used to commence a coastal survey, a mean of the true bearings from either end being used as the mercatorial bearing for plotting purposes. The true scale of the survey was eventually decided by careful astronomical observations at the two extreme limits of the survey.

Plotting, which could begin when a number of lengths of sides of the triangulation had been computed, entailed the scribing on linen-backed paper of one of the longest sides, from both ends of which the 'shots' to a third station were plotted by the angles which had been observed. The work was proved by plotting to a fourth station shots from the ends of the long side and the third station just mentioned. Other stations of the survey were then similarly plotted, always working inwards to reduce error.

The graduation of the sheet had to await the observing of the terminal geographical positions, when the related converging meridians and curved parallels were carefully scribed in.

Throughout the nineteenth century the traditional method of sounding by marked leadline had been used from the ship and her boats, the leadsmen becoming extremely skilful whilst under weigh; but over six fathoms in the boats, and double that depth from the chains onboard the ship, were beyond their capability. To use the Lucas machine in deeper water the ship had to stop. It was therefore a development of considerable importance when Captain Somerville invented his mechanical apparatus for casting the lead ahead with the ship under weigh. By means of a wire operated from a steam winch aft, through a leading block on the mainmast, to the lower boom below the bridge, the lead was repeatedly released well forward. The leadsman situated in the chains aft was able to 'feel' for the



Somerville sounding gear

depth with the marked leadline when it came vertical abreast of him, the leadline being kept taut by a trailing weight. This apparatus considerably speeded up the work of ship sounding in comparatively shallow water.

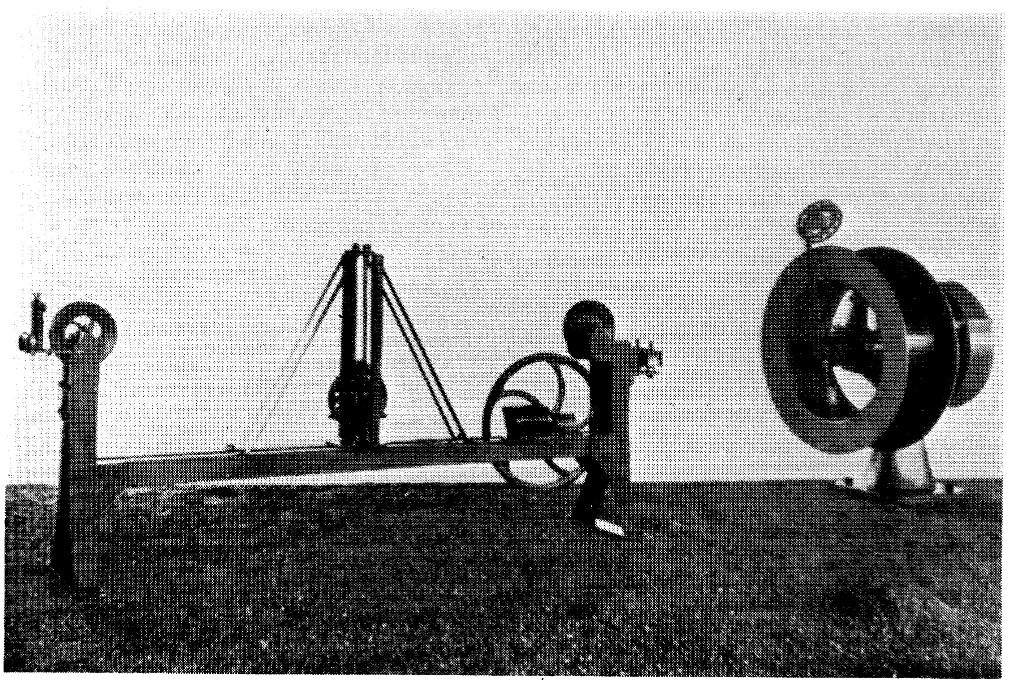
Surveying officers were constantly improving upon the design of the floating moored beacon for work at sea, which was capable of carrying a large flag 30 feet above the surface of the sea. Measuring the distance between two or more such marks to form a baseline far from land posed problems until after World War I, when the taut wire measuring gear became available to the surveyor, and only to-day is this tool being displaced by radar methods of measuring baselines at sea. The gear was first developed for minelaying in the war when, taking a departure from friendly shores, the minelayer needed something more accurate than a log distance to tell him when he had reached the laying position.

The apparatus consists of a large static drum carrying 140 miles of piano wire; this leaves the drum by means of a wheel set on a revolving flyer arm controlled by a hand-operated band brake. The wire then passes round a measuring wheel of 6·080 feet circumference and thence through a dynamometer and over the stern of the ship.

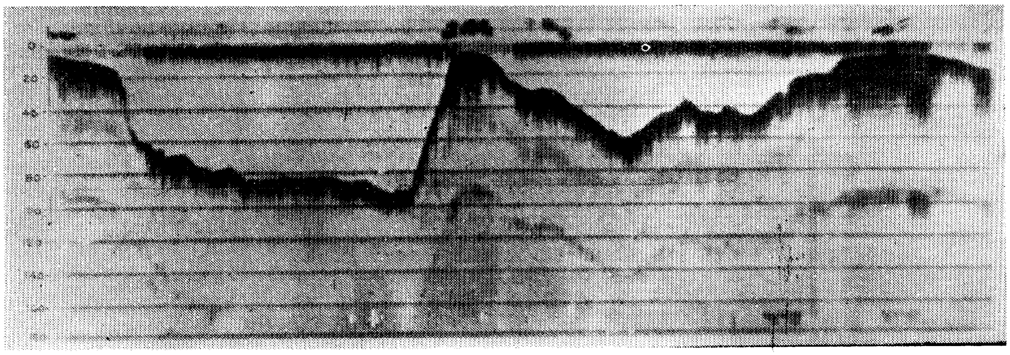
Anchoring the end of the wire with a sinker, the ship slowly increases speed, the band brake being operated to exert a given pressure on the wire. The apparatus soon begins to run steadily, every 1000 revolutions of the measuring wheel indicating the advance of one nautical mile. This equipment gives surprisingly accurate results, and when measurement is made in both directions an agreement of one part in a thousand can be expected.

Lines of beacons far out of sight of land could now be laid, the ship herself taking her departure from a good sextant and station pointer fix using triangulated landmarks and measuring the distance to succeeding beacons, laid in transit, by use of taut wire measuring apparatus.

By the 1930s, rectangular co-ordinates were being used for plotting a survey north



Taut wire measuring gear



The first records made with a magnetostriction echo depth recorder. Fitted in a surveying motor boat at Sheerness in 1930

and east from an imaginary origin. The rectangular co-ordinates of each station in the triangulation were computed mathematically from the field observations developed from the co-ordinates of the national land survey concerned. Most of these co-ordinates were on the Cassini projection in the 1930s, but after World War II increasing use has been made by almost all countries of the orthomorphic transverse mercator projection, and hydrographic surveyors have necessarily followed suit.

For 150 years since Cook's day it had been necessary to lower a lead to the seabed by one method or another to measure the depth, but by the 1920s knowledge of acoustics in sea water, gained by Admiralty scientists in World War I in their attempts to locate submarines, enabled a significant breakthrough in this direction to be made.

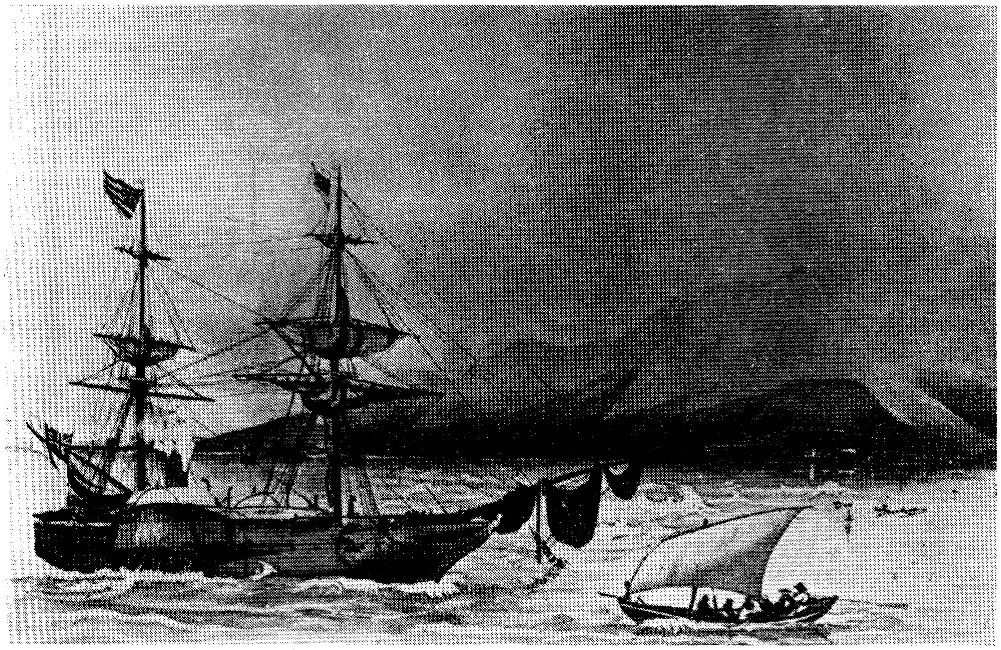
The new Admiralty Research Laboratory was completed in 1921 adjacent to the National Physical Laboratory at Teddington, and there scientists, previously employed at Shandon in Scotland, formed a new Acoustics Group. B. S. Smith of this group subsequently developed the first telephone audio-frequency system of echo-sounding to obtain depth. The sound source was a steel diaphragm which emitted a train of audio-frequency waves when struck at regular intervals (about three times a second) by blows from an electro-magnetically operated hammer. A small hydrophone received the returning echo from the seabed. Both the transmitter and the receiver were mounted in water-filled tanks on opposite sides of the ship, the hull forming a partial screen against the direct sound.

Wearing headphones the operator manipulated a calibrated dial until he could hear the returning echo. This action measured the interval of time since transmission, so that with a knowledge of the velocity of sound in seawater the dial could be read off in fathoms and feet of depth.

The first sea trials of the equipment were made in HM Surveying Ship *Kellett* in September 1923, and eventually this sounder was fitted in other naval surveying vessels and handed over to Henry Hughes and Sons for commercial manufacture.

Its depth range of 200 fathoms made the equipment suitable for work on the continental shelf, but attempts to fit it in survey motor boats failed because of the lack of screening by the hull between the transmitter and the receiver, so the group settled down to develop an echo sounder using high frequency sound impulses which could be made directional and thus eliminate the need for screening. A condenser discharge was developed for the transmission, together with a magnetostriction receiver, and successful trials were made from a surveying motor boat in the presence of the Hydrographer across the dredged channel into Sheerness in 1930. Successful shipboard trials in HM Survey Ship *Flinders* followed, in depths far beyond the continental shelf. The magnetostriction echo sounder was a complete success and was again handed over to Henry Hughes and Son (now Kelvin Hughes), who supply such equipment today, not only to survey vessels but to every other type of craft in the world. This is a fine example of an Admiralty research project contributing to commercial profit.

It is pleasing to conclude this phase by saying that the three scientists who developed this equipment at the Admiralty Research Station, A. B. Wood, F. D. Smith

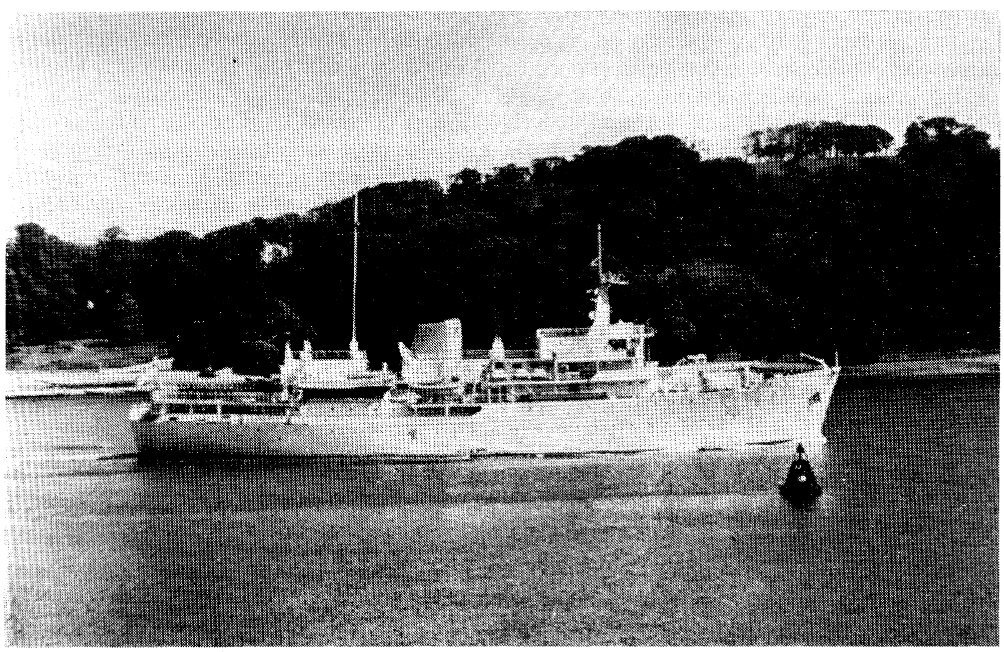


HM Surveying Ship Hecate *off Honolulu, circa 1860*

and J. A. McGeachy, were awarded the Thomas Gray Prize by this Society for their fine work.

The echo sounder had given the sea surveyor an electronic method of depth measurement, but he had to wait until after World War II before he got an electronic method of fixing his position to match it.

Before the war Mr. Harvey Schwarz, of the Decca Record Company, had submitted to the Admiralty the Decca Navigator System, but this was not developed until



HM Surveying Ship Hecate *entering Devonport, 1968*

1944, when it was made ready for guiding our vessels to the D-Day landings in Normandy.

In the early part of 1945 the equipment was transferred to the River Schelde, where Commander E. G. Irving, in HM Surveying Ship *Franklin*, carried out successful evaluation trials in an area in which he was surveying in connection with the Allied advance into Europe. This led to further and final trials in *Franklin* in the Bristol Channel in November 1945, and the establishment in 1946 of the first permanent English chain to be used by any ship carrying a Decca receiver.

The navigation system relies upon a master and three slave stations situated at fixed locations onshore. Triggered by the master station's transmissions the slaves transmit on CW, each at a different frequency; the onboard receiver compares the phase of each slave signal with that of the master. The wavelength differences between master and slaves are plotted on the chart as hyperbolic patterns, and the ship's position may be found by inspection of the appropriate intersections of the pattern.

However, navigational Decca is not accurate enough for hydrographic work, and surveyors wish to have their own fixing patterns appropriate to the area being surveyed. By developing a two-range system Decca provided for the surveyors' special needs in the mid 1950s. The master transmitter is carried in the survey ship, two transportable slave stations being set up at suitable fixed positions ashore. Direct range circles on the chart replace the navigational hyperbolae, enabling the surveyor to fix constantly by day or night out to 150-200 miles from shore.

By 1960 Decca had developed Hifix, a smaller and easily portable adaptation of the two range system, for use at shorter ranges and by smaller vessels.

Thus to-day we find the surveyor in the electronic age well catered for but still with a very great deal of work to be done. For instance, all areas surveyed prior to 1930 were made with lead and line only, and without the use of sonar, which is now used to locate wrecks and obstructions between the sounding lines. All this lead and line work must be done again with modern methods wherever it is required to meet in our shallow seas the increasingly exacting charting requirements of the ever-deepening draught merchant vessels.

How can developing technology once again come to the aid of the sea surveyor?

The sonars now used in surveying ships are those designed to find submarines or, in the case of some types, fish. A surveyor's own sonar is now required of a highly sophisticated type, capable not only of locating shoals and wrecks but of recording the depths over them although they are situated some distance on either side of the sounding vessel. This is probably not beyond present technological capability, although the development of such equipment could be very expensive. Undoubtedly the next step forward which the surveyor awaits is the ability to survey a wide swathe either side of his advancing vessel, rather than the single line of soundings beneath the vessel to which he is restricted at present.

I am confident that we shall see the development of this wide band surveying, although such a major development can no longer be tackled by the Admiralty Research Laboratory which so successfully put us into the electronic sounding age. The invention of the echo-sounding machine is probably the most significant advance throughout the whole of the 200 years under review, with the possible exception of the introduction of steam in ships, which is so significant that I have made no particular reference to it in this Paper.

DISCUSSION

LIEUT.-COMMANDER J. C. E. WHITE, OBE, FRICS (Hydrographic Officer, Port of London Authority): Can the lecturer say anything about how the measurement of tidal heights developed through the period?

THE LECTURER: It was very slow. The automatic tide gauge is something very much of the last twenty years. Before that it was all done by visual reading, and in order to get the constituents for making tidal predictions you had to have twenty-nine days' continuous readings in very many remote parts of the world. So it was really all done by Jolly Jack Tar – three sailors in camp watching in turns and recording the tide going up and down – for a matter of months. Sometimes it went wrong – the people would go to sleep on the job! I once got back to a tidal camp to find that one of the operators had got married to a native of the country and left for the jungles of the hinterland.

DR. H. BONGERS, DLIT (Holland): What was the precise task of the ship in which Darwin made his trip round the world?

THE LECTURER: The *Beagle* was one of six brigs provided for surveying in 1834. She was working in the Magellan Strait and then came back and sailed right round the world with Fitzroy in command. Darwin was taken as a young scientist, to help, but of course the voyage really became his in the end. The *Beagle* subsequently did a great deal of work in Northern Australia. She was employed in surveying for twenty-eight years – a very successful vessel.

MR. S. G. LEWIS (Hydrographic Surveyor, Port of London Authority): Could Admiral Ritchie tell us what use a surveyor to-day makes of a satellite fix?

THE LECTURER: Satellite navigators at sea are a fairly new thing. They rely on four American navigation satellites in polar orbit going round like the sections of an orange. You only get a fix about every hour – between fifty-five and seventy-five minutes – depending on your whereabouts, so it is not an entirely satisfactory system for surveying. It gives you your position out of sight of land, but you have got to have some subsidiary method, such as an inertial navigation system, to carry you along the survey lines between those two rather distant fixes. The two survey ships fitted with the sets are working satisfactorily, and I think the RRS *Discovery* also uses one for research work.

CAPTAIN J. A. N. BEZANT: What does the modern surveyor think of the accuracy of Cook's surveys?

THE LECTURER: One has to consider what equipment he had. He only spent six months on his first voyage round New Zealand and of course his chart is surprisingly accurate in the short time involved. He had no really good method of finding longitude, he had no timepiece on the first voyage. If you put a modern chart of New Zealand over the old chart, however, there are very few differences and the longitude is the chief one. He made various errors when driven offshore in a foul gale and unable to re-establish his former position precisely – Stewart Island is an example, for Cook thought it was a peninsula. But what work he did is extremely accurate with the instruments he had.

But one is often asked a similar question – are we still using Captain Cook's charts at the present day? Now this is an interesting one. We are not, of course, but there is an element of Cook, there is an element of many surveyors who have contributed over the years. Last September there was a very interesting exhibition out in New Zealand at the Cook Bicentenary celebrations, where they showed something like twenty-five editions of the Admiralty chart of New Zealand, from Cook's day to the present time, each an improvement on the one before, but still you could never say there was nothing of Cook left in it. His perception was astounding – he missed so very little in the short time available.

MR. E. STEANE (Ministry of Defence (Navy)): To what extent do we co-ordinate our surveying work with that of other nations, like the United States?

THE LECTURER: Fairly closely. In 1919 after the First World War a meeting was held here in London to set up an International Hydrographic Bureau. In 1921 it was established with twenty-one member nations and we were invited by Prince Rainier's grandfather, Prince Albert, to set up in Monaco because he himself was an oceanographer in his own right and he wanted us there. We are still there at the present day. We now have forty-three member nations in the organization.

Chiefly what has been done in the past is the co-ordination of symbolization so that each nation's chart begins to look more like another. The Bureau encourages the free exchange of hydrographic data. We maintain a world series of Admiralty charts, but we don't go and survey off the coast of Brazil, for instance – we get the latest Brazilian charts or surveys direct from Brazil, and such co-operation is encouraged by the International Hydrographic Bureau.

Since this country decided to go into the metric system and since we have decided to go metric on charts other countries have followed our lead. The United States Oceanographic Office and Canada, and Australia and New Zealand, are going metric, India had already gone metric. Thus very shortly an international chart will become possible. We have been actively pursuing this, and about a year from now we shall see the first international charts. Two such chart schemes have been agreed; the first for a scale of one over ten million, which is a very small chart – twenty-five covering the world – and another for a scale of one over seven million – about one hundred and twenty-five charts covering the world. Now in future instead of six countries making a chart of the Western Mediterranean, one country, possibly Italy, will make it and all the other countries will be able to buy the reproduction material and print that international chart on their own presses, include it in their own series, provided they keep the international number. All symbolization and the language differences have been ironed out, so I think that although collaboration has been good it is now reaching an even more encouraging stage.

SIR SELWYN SELWYN-CLARKE, KBE, CMG, MC, MD, FRCP: I wonder if Admiral Ritchie could tell us how often it is necessary to change Admiralty charts as the result of submarine explosions? I remember being visited on one occasion by Carl Petersen, Director of the Swedish Oceanographic Expedition that had started in the Philippine depths, where the sea, I believe, is about seven miles deep. He told me that as they came from Ceylon to the islands in the middle of the Indian Ocean, where I was at that particular time, they passed over a plateau of volcanic rock which he believed to be due to a fairly recent volcanic eruption. I asked how recently, having in mind perhaps the eruptions at Pompei and Herculaneum of AD 79, or Krakatoa about seventy years ago, and he replied 'Well we thought it was about thirteen million years ago'!

THE LECTURER: In modern limited volcanic eruptions, like the great one in Chile some years ago, no major alterations have occurred on the sea floor which would affect navigation, and that luckily has very much been the pattern of all modern eruptions anywhere near coastal towns, ports and so on. The moving of sand and so on by ordinary natural causes is far more effective in changing the charts, such as the changes we experience in the Thames Estuary.

MR. NICHOLAS KENOLTY (Institute of Geological Sciences): Why don't the hydrographers contour their charts as the Ordnance Survey does with its maps?

THE LECTURER: We do contour them, of course, but not like the Ordnance Survey; we have fathom lines, and up until recently that meant pecked and dotted lines. Recently we have modernized the chart so that everything on it is capable of being carried out by automation. On the new charts coming out – you can tell them by the yellow land colour rather than the grey – we use contours because a solid contour is much easier to draw by automation than a pecked line.

SIR ARTHUR SMITH: The people who benefit from a large part of this work are the merchant shipping companies. Will Admiral Ritchie tell us if the Navy leads and they follow, or is there co-operation between the Navy and the Merchant Shipping Companies?

THE LECTURER: In 1823 we first started selling charts, and we were allowed to sell them to anyone. To-day merchant fleets all over the world buy our charts; we have agents in most countries. We have not got any close association with foreign mariners, but our own mariners, the Marine Superintendents of forty or fifty British companies that sail round the world, are on what we call a Chart Users' Advisory Panel. We know which line is interested in certain parts of the world and we get in touch with them over all sorts of points about the charts, and I would say that collaboration with our own shipping people is extremely close. With the oil companies, of course, this is particularly close because most of the big tankers have only got a few feet between the keel and the seabed in some parts of their voyages, and they come and find out from us where the deep water is.

CAPTAIN J. L. C. MILNE (Board of Trade): There was a report in *The Times*, I believe a week or so ago, about the Russians altering the latitudes and longitudes of different places. Does this affect the publication of charts by the different countries at all?

THE LECTURER: The Soviet Hydrographer has never belonged to the International Hydrographic Bureau, but he sends advisers to Monaco and we exchange charts with him. If they change their latitudes on their charts we will be in a bit of a fix. But I can't believe it is true, because it sounds a rather fatuous idea and not typical of the Soviet Hydrographer.

CAPTAIN MILNE: I have not got the report with me and I could not quite understand whether this was intentional or whether they were just correcting the latitudes and longitudes.

MR. T. J. SANDELL: There was some talk about changing the meridian of longitude from Greenwich to an alternative internationally selected.

THE LECTURER: No, I don't think so. It has never been seriously suggested and I hope I shall be gone before it is. There is no move away from Greenwich so far as I am aware, and there would be no advantage in changing the Prime Meridian.

MR. SANDELL: I thought there were some quite serious suggestions internationally in this connection.

MR. NIGEL C. KELLAND (Hunting Geological Survey): Is the price of the charts a fair reflection of their cost or are they subsidized?

THE LECTURER: The price represents what it cost actually to make the chart. It does not include the cost of the compilation or the survey work done at sea by the very expensive vessels. The Navy bears that burden. On the other hand, of course, the Navy gets all the charts it wants free and it gets priority with surveys.

THE CHAIRMAN: It has been pointed out to me that Captain Cook has been watching our lecturer carefully this afternoon. In James Barry's picture above the exit door, entitled *Commerce, or the Triumph of the Thames*, you will see Cook underneath the cockleshell. Nearby are Drake and Raleigh. Captain Cook looks very satisfied with what he has heard this afternoon!

Admiral Ritchie, I think you will agree, has given us freely of his subject both in his lecture and in answering the diverse questions put to him. He has taken us through two centuries of hydrography, from primitive position fixing to radar, from lead lines to echo sounding, from sail to steam, and from many other simple devices into this exciting technological age.

As he told you, we are moving from fathoms and cables to metres, something which doesn't please all who manage to get their letters accepted in *The Times*! Perhaps this will be less an affront to our traditions than if the Admiralty chart had changed its name. Luckily that still survives with its original title.

He has also moved from Captain Cook to Admiral Ritchie! Our speaker has paid rich tribute to the former, and I am sure you will agree that rich tribute should also be paid to successive hydrographers who have carried on the great Cook tradition. In particular, we pay our tribute to Admiral Ritchie and thank him very much indeed for rendering this Society a great service.

The vote of thanks to the Lecturer was carried with acclamation and, another having been accorded to the Chairman upon the proposal of Sir Gilbert Rennie, the meeting ended.