METHODS NOW IN USE BY THE INGENIEURS HYDROGRAPHES OF THE FRENCH NAVY

by

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The methods employed by French Ingénieurs Hydrographes for surveying and the construction of charts have not changed, as far as their fundamental principles are concerned, since the year 1808; when BEAUTEMPS-BEAUPRÉ enounced them in the "*Appendice au Voyage du Contre-Amiral* BRUNY D'ENTRECASTEAUX."

This enouncement alone would not have sufficed to create the traditions which have been retained in the Corps of Ingénieurs Hydrographes since then; it was necessary, in addition, that, for nearly forty years, the great hydrographer himself should survey and give, by his example, instruction to those Ingénieurs who were his contemporaries and who, in turn, handed on their knowledge to their successors.

In the "*Exposé des travaux relatifs à la Reconnaissance Hydrographique des Côtes Occidentales de France*" which appeared in 1829, BEAUTEMPS-BEAUPRÉ set out his methods, which did not differ from those of 1808 except in certain details, of which the advantages had been shown by the experience gained in the course of particularly difficult operations.

The "*Traité de Géodésie à l'usage des Marins*", by Ingénieur Hydrographe BÉGAT appeared in 1829. This gave not only the methods of triangulation, as the title seems to indicate, but also those used in making soundings, doing topography, *etc.*

In 1882, Ingenieur Hydrographe GERMAIN published a "*Traité d'Hydrographie*" which gives the methods used at this time; they do not greatly differ from those described by his predecessor.

A few years later, the same officer published the "*Notions d'Hydrographie Expéditive*" which was intended to provide Naval Officers with the necessary information, in the form of a manual, for making surveys of small areas.

From this time onwards Ingénieurs Hydrographes published, in their Reports on Hydrographic Surveys of which they had been in charge, more or less detailed reports on the methods which they had employed, and thus continuously contributed to perfect the methods of BEAUTEMPS-BEAUPRÉ, making use of the progress of science and maritime technique.

Considerable modifications were thus introduced, but the works which have just been mentioned are far from giving a complete and accurate idea of present-day methods. To give them in detail it would not be a book but a veritable encyclopedia which would be necessary. This encyclopedia now exists, but in manuscript form. It consists of the lectures given by the Ingénieurs every year at the Hydrographic Office in Paris, to those students of the Polytechnic School who are joining the Corps of Ingénieurs Hydrographes; to Naval Officers detailed for hydrographic service, and to foreign officers who wish to be initiated into French methods.

It is much to be desired that these courses be collected into book form and published. But, in the meantine, it appears that it might be useful to set out briefly the methods and processes employed, giving their origin and authors, referring the reader for details to Memoires and Articles, most of which have appeared in the "*Annales Hydrographiques*" published by the French Hydrographic Office, a volume of which appears about every year.

TRIANGULATION.

1. As triangulation is the fundamental basis for every operation, the advantages offered by *making it before the sounding and topographic work is begun* have been recognized for many years.

Triangulation actually necessitates frequent moves and living on shore, sometimes far from the coast, and means of transport on shore being often imperfect, it is the surveying ship which has to transport the surveyors and their material; inconvenience is caused thereby and this hinders other work, which delays can be avoided if the operators work independently. If, on the other hand, the triangulation is comple-

ted and the positions of the points determined, at any rate provisionally, at the moment of beginning the survey proper, the chart can be constructed on the spot, thus making certain that no gaps are left, or if they should exist, that they are filled up.

Such organisation has only been feasible in recent surveys, and even then not in every case ; greater endeavours in this direction are being made however.

2. For *measuring bases* French hydrographic surveyors now use exclusively the *Jæderin Wire,* made of "Invar". This wire is provided by the firm of CARPENTIER, PARIS, as well as the accessories necessary for its use ; it is checked before and after each operation by the INTERNATIONAL BUREAU OF WEIGHTS AND MEASURES.

For using this method in the field, surveyors have been led to adopt certain arrangements which will be found described in the *A. H.*(*) of 1911 (Mission FICHOT, Tonkin 1906), of 1908-9-10 (Mission COURTIER, Madagascar, 1907) and of 1913 (Mission ROUSSILHE, Madagascar 1909).

3. In the surveys of banks extending out of sight of land, or again when it is impossible, owing to the nature of the coast, to place triangulation beacons so as to allow sea stations to be well fixed, floating beacons are used instead.

The construction of these beacons, which are moored off shore in convenient positions, has been gradually perfected since 1886, when they were used for the first time in the survey of the Kerkennah Bank, off the coast of Tunis. An apparatus has been evolved with which all hydrographic expeditions are now supplied ; it is neither heavy nor cumbersome, and it is but slightly moved out of its station even by had weather.

Devised to have great buoyancy, these beacons consist mainly of a cylindrical sheet steel barrel 1.6 meters (5¼ ft.) high, and 0.75 meters (2½ ft.) in diameter. This barrel surrounds the upper part of a tube which at its lower end has a flange to hold perforated cast iron discs, which act as counterweights, and it is provided with four rings to which are shackled steel wire cables, attached to mooring grapnels ; a wooden mast, secured by wooden wedges, is fixed in the tube. At the top of the mast is fixed a top-mark made of planks painted black.

These beacons are placed and weighed by the ship — a very delicate operation — which ingénieurs have studied and described in detail in their reports.

(*) Hereafter the "*Annales Hydrographiques*" will be referred to as *A. H.*

The beacons are visible from the bridge of a ship at a distance of from five to six miles. There are two types, which draw 6.5 meters (21¼ ft.) and 9 meters (29½ ft.) of water respectively.

The widest use which has been made of these was in Madagascar, for the survey of the Pracel Bank, which extends 25 miles from land. This survey necessitated the mooring of 40 beacons at an average distance apart of 11 miles.

For further details as to the use of these buoys the *A. H.* of 1903 (Mission FICHOT, Madagascar, 1900), of 1906 (Mission DRIENCOURT, Madagascar, 1906) and of 1913 (Mission ROUSSILHE, Madagascar, 1909) may be consulted.

4. The positions of the angles of the triangles of the triangulation are recorded by *rectangular co-ordinates* which are the distances to the meridian of a point chosen as the origin of the sheet and to the perpendicular thereat. It is only for the construction of charts that the co-ordinates are expressed geographically; they are referred to those of the origin.

Not only are the primary triangulation points so calculated but also all secondary beacons, which are used for fixing the soundings and topographic stations. The triangle method, or that of fixing by stations is long and complicated and, in doutful cases, it is not evident which position should be adopted, but these calculations have been made very simple, rapid, and clear, thanks to the method invented by Ingénieur Hydrographe HATT, in 1903.

It consists of starting from an approximate position, which can always be determined by graphic construction, and of calculating at what distance each of the bearings or each of the segments containing the observed angles taken from known points, passes from it. The construction can then be made on a very large scale (1:100 or 1:10), and it is very easy to select, from this diagram, the position to adopt.

This procedure, which subsequently has had certain details added to it by other surveyors, was the starting point of a radical change in the methods of calculation; it has increased the accuracy of surveys by allowing the multiplication of determinations of precise positions in secondary triangulations.

Although it is very convenient for fixing the points on the plotting sheets and for calculations, this system of rectangular co-ordinates has the disadvantage of being badly defined from a geometrical point of view, and introducing errors which it is impossible to estimate exactly when at a great distance from the origin; this entails frequent change of origin and complicates the calculations.

The difficulty has been overcome by the use of *azimuthal co-ordinates* also invented by Mons. HATT, in 1886. The process of calculation by approximate position can be applied to these co-ordinates also, and thus has led to its general use in all calculations of triangulations.

The processes and methods above have been described in a book by Mons. HATT, published by the Hydrographic Office under the title "*Des coordonnées rectangulaires et de leur emploi dans les calculs de triangulation* (*S. H.* 746)."

5. Geographic positions are now determined exclusively by means of the *prismatic astrolabe,* invented by Mons. CLAUDE and Ingénieur Hydrographe DRIENCOURT; it is universally known and used. The precision and rapidity with which this instrument allows positions to be fixed permits its use for the determination of bases measured by the difference of latitude between two points of a triangulation net of small extent. *A. H.* 1906 (Mission DRIENCOURT, Madagascar, 1904).

SOUNDINGS.

For soundings, surveyors generally continue to use the ordinary lead-line, a rope weighted with a lead armed with tallow; this may be called the classical method. However, the lead has been given a conical form to facilitate its passage through the water.

But for several years surveyors have experimented with a much more convenient sounding apparatus which makes it unnecessary to haul up the lead after each sounding. This apparatus, which is now perfected and is coming into general use, is composed of a lead, the shape of which has given it the name of "*fish-lead*", suspended by the finest possible steel wire. This arrangement, attached to the stern of the boat, follows it, the wire remaining practically vertical as long as the speed is not too high, though it may reach four knots. It is sufficient to lift the lead slightly and then let it fell again. Thus soundings may be obtained as closely as is desired, and no rise in the bottom will be overlooked.

This operation is made still easier by winding the wire on a drum which can be turned in either direction by a crank. Ingénieur Hydrographe MARTI has constructed an apparatus, attached to the drum, which continually registers the depth. By this means soundings can be obtained up to depths of thirty meters (16½ fathoms).

It is no exaggeration to say that this invention constitutes one of the most remarkable forward steps for the exploration of the bottom

since the time of BEAUTEMPS-BEAUPRÉ. It is particularly valuable for checking dredging operations. It is described in the *A. H.* of 1924. (3rd Series, volume of 1922, published in 1923).

For sounding from ships, Ingénieur Hydrographe FAVE invented a device for heaving the lead forward after it has been hauled up aft after the sounding; soundings can thus be obtained from a ship at a greater speed than if the lead had been hove by hand; the apparatus is now provided with electric winches placed aft. This apparatus is described, with all the improvements introduced by other ingénieurs, in the *A. H.* of 1890 (Mission FAVE, Madagascar, 1888); of 1897 (Mission DRIENCOURT, Madagascar, 1891); of 1913 (Mission RICARD, Indo-China, 1908 and Mission VANSSAY, 1910).

Today most of the French surveying ships are fitted with an *Echo Sounding Apparatus*, of either the detonating or ultra-sonic type, the latter being Prof. LANGEVIN's method, fitted with the recording apparatus devised by Ingénieur Hydrographe MARTI, who described the first of these types in the *A. H.* 1924.

The THOMSON or WARLUZZEL sounding machines are but very rarely used by surveyors. It seems to them that the uncertainty in the depths recorded is not compatible with the confidence which hydrographic surveys should inspire. When, however, they have been obliged to use them they have taken precautions to verify the soundings so as to obtain a certain degree of guarantee as to their accuracy. These methods are described in the *A H.* 1906 (Mission VANSSAY, Madagascar, 1901) and 1913 (Mission LESAGE, Madagascar, 1909).

As early as 1902, Ingénieur Hydrographe RENAUD described in the *A. H.* the methods which he employed in *Searching for Submerged Rocks*. He showed that the preliminary operation should consist of the survey of regular sectional profiles as near to one another as possible; then the plotting of the soundings obtained on a rough sheet on which are drawn the depth contours by which the form of the relief is disclosed; this can be explored afterwards when the sea is calm and at low water.

As this method does not disclose pinnacles, however, it is necessary to use a *floating sweep* which is allowed to drift with the current and which catches on rocks rising from the bottom. This system, which Mons. RENAUD used in Tonking since 1882, has been considerably developed by American hydrographic surveyors, and French surveyors now use several sweeps of the type which they have evolved.

A *Finnish sweep* is also used.

Finally, in special cases where it is essential to find the top of a very sharp rock, or to explore a channel in order to discover the

slightest unevenness, *divers* are employed. Mons. FICHOT, Ingénieur Hydrographe, who used this method for the first time in the West Channel at Cherbourg, described it in the *A. H.* of 1908; it is now often used, in similar cases, when the necessary personnel and material are available.

Ever since 1902 Mons. RENAUD had advocated also the use of *kite-balloons* for searching for submarine rocks which show up when the observer is sufficiently elevated. Today photographs taken from air-craft are used. A description of the methods employed and the results obtained will be found in the *A. H.* of 1919.

The Ingénieurs Hydrographes have been led to modify entirely the arrangement given by BEAUTEMPS-BEAUPRÉ to *lines of soundings*. He contented himself, owing to lack of time, to determining the general form of the sea bottom and to assigning limits to dangerous rocky shoals or to those places unfit for anchorage; dangers were pointed out to him by local seamen, and he ran lines of soundings from one to the other or "starred" round each of them.

When it was necessary to study much more closely the huge areas in which modern vessels can navigate, the Ingénieurs realised the necessity of making systematic parallel profile sections perpendicular to the direction of greatest slope of the bottom, and the steeper the slopes the closer the lines.

These profiles are always arranged geometrically; they are never run by compass because of the errors to which this method may lead. They are either straight lines, determined by a transit, or arcs of a circle of great radius, followed by keeping on an angle between two points; this last method is very convenient when it is desired to bring the sections nearer, or when there are only two points in sight; finally it allows as many lines to be inserted as may be desired.

The soundings are taken along the lines at points as near to one another as possible; they are taken *under way* and their positions are fixed by fixes made with the sounding sextant, the angles between at least three points being observed. A "fix" is not considered to be definite unless made with three circumscribling arcs of circles.

Fixes are taken at least at every seventh sounding, and are plotted at once onto a rough field sheet, which ensures that no *gaps* are left in the scheme of profile lines.

For such plotting, and for all plotting or fixing, Ingénieurs never use the *station pointer*; the serious inconvenience of this instrument, which only provides for the use of two angles, is that it is impossible to check the accuracy of the plotting because this accuracy depends

upon the angle at which the two circumscribing circles cross each other. On the other hand, by drawing each angle or circle separately, three arcs of circles are obtained which, in most cases, do not intersect exactly at the same point, but they allow the most probable position to be chosen.

The arcs of circumscribing circles are drawn either by means of a pair of dividers, and according to the well-known method (but when angles taken between the same two points are to be used frequently, the perpendicular erected at the centre of the line which joins these two points is divided; *i.e.* the centres of regularly spaced circumscribing circles are marked beforehand); or by means of the "*movable arm protractor.*"

This instrument is actually a two-armed station pointer which has only half a leg outside the circumscribing circle. Two points on this circle are then plotted, one on each side of the probable location of the fix; by joining these two points a short straight line is obtained which may be considered to be an arc of circumscribing circle. Very great accuracy is thus obtained.

The marks to be observed must evidently be contained within the plotting sheet; Mons. ROLLET DE L'ISLE, however, has described a method which allows this procedure to be carried out even when one or more beacons are outside the sheet (*A. H.* 1893. "A Solution of Several Special Cases").

The angles for fixing the stations are observed with a special "reflecting circle" called the "*hydrographic circle*" which is more simply divided (it reads to minutes) and better balanced than sextants or ordinary "reflecting circles"; the three angles necessary for fixing a position can thus be rapidly observed.

These circles can be read from zero to 160° only. Mons. ROLLET DE L'ISLE has caused a circle with four mirrors to be made, which reads from 0° to 180° without a break (*A. H.* 1893).

The plotting sheets are all of the same size, known as "grand-aigle", 1.10 m. × 0.75 m. (43 ins. × 29 ½ ins. approximately "double-elephant") and are linen-backed.

The sounding fixes are plotted on one of these sheets, called *sounding plotting sheets* and the lines of soundings are drawn by joining them; the lines of soundings and the fixes are then drawn in pencil on another sheet and the soundings, corrected for tide and for the errors of the lead line, are inserted on these lines. Those which were taken at fixes are written actually on the fixes and the others, taken between the fixes, are inserted at equal intervals on the line which joins the fixes;

usually seven soundings, or some other uneven number, are taken between two stations in order to facilitate this distribution. On this sheet, called the *Sounding Sheet*, the contours of equal depth are drawn in pencil, from meter to meter, so that all the unevennesses of the bottom are revealed, as stated above. By means of tracing paper the soundings which are to appear on the "Fair Sheet" are chosen.

Two special sheets are also kept, one for *plotting fixes which have been made at rocks, i.e.* fixes which have been made on rocks which do not uncover, and the other for *showing rocks*, giving the altitudes of these dangers; sometimes rocks which cover and uncover are drawn in blue, the heights of which and their contours are determined at full low water; the heights are written in red, as are all altitudes above chart datum.

The "Fair Sheet" is then drawn; this must contain as many perfectly legible soundings as possible, with the nature of the bottom and contours equal. It must be carefully checked because it constitutes a standard document which is used as the basis for the chart and which can be referred to in case of doubt. It shows also the topography, so far as it has been surveyed.

TOPOGRAPHY.

A very extended use of *aerial photography* is now made, and every endeavour is made to obtain photographs before commencing the field work. The surveyors can then take prints with them and on them mark the points where they make theodolite stations in order to determine their position. This does away with the necessity of making drawings of the detail of the coast, and also those of the rocks adjoining the shore, which cover and uncover, and of which the survey is sometimes very difficult.

These photographs give, besides, the topography of portions of the land near the coast, which it is necessary to indicate on the chart on a larger scale than that on which it is given on geographical maps, from which, consequently, it cannot be taken. Thus a great deal of work can be avoided to which the methods of moving from place to place, used by hydrographic surveyors, are badly adapted.

This photographic service is now organised in a satisfactory manner; the pilots, military and naval, have been trained to follow the line of the coast so as to photograph a strip including on each photograph both land and sea, and the surveying parties both in France and in the colonies have obtained documents which much facilitate their topographic

work. (A. H. 1922. Rapport sur l'emploi des photographies aériennes par l'ingénieur hydrographe COT. Description d'un viseur pour pilote d'hydravion par M. BONNAFOUS, agent technique).

TIDES.

Observation of tides is always made by means of a graduated plank which gives greater accuracy than self-registering gauges, the inaccuracy of which might seriously vitiate the results obtained from the sounding work.

The "FAVE *Marégraphe Plongeur*" is also used to determine the movements of the tidal wave off shore, or between two distant gauges, which is useful for interpolation between such gauges for the correction of sounding.