APPLICATION OF DECCA NAVIGATOR TO MEASUREMENTS AT SEA

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ABSTRACT

The Decca Navigator, which is a navigational instrument, may also, when used under favourable conditions, supply sufficiently accurate indications for measurements at sea.

The following article gives illustration of measurements of turning radius, speed and deceleration carried out during ship trials.

Several original methods are proposed for measuring the speed of ships in service without appreciably interfering with schedules.

I. — INTRODUCTION.

Standard sea-trials, i.e. for speed, turning and stopping, include, among other measurements, determination of the successive positions of the ship.

The positions which appear in the final results are those related to the surface, whose horizontal displacement in relation to the bottom, i.e. the current, does not apply to the performance of the ship.

Two variants in conducting tests may therefore be considered:

— Direct determination of the ship's position in relation to one or more objects subjected to the same current;

— Separate determination of the current and ship's position in relation to the bottom in order to obtain the relative position by taking the difference.

In theory, the first variant is extremely attractive, but in practice one cannot be sure that the objects used as reference drift exactly as the ship; the second method is accordingly preferable if the position and current can both be accurately determined.

However, with the conventional methods of navigation that have prevailed until recent years, the ship's position along the bottom could only be determined with an acceptable amount of accuracy for measurement purposes by using measured distances delimited by leading marks and specially designed for speed trials.

The appearance of the Decca Navigator, which continuously indicates the ship's position over extensive areas, has altered the situation.

II. — INDICATIONS SUPPLIED BY DECCA NAVIGATOR.

The Decca Navigator is a hyperbolic radiolocation system, and has been previously described before the Association [1].

For our present purposes, we may define Decca as an instrument capable of continuously supplying the ship's position plotted against time. This definition is a precise one if the Decca Navigator is associated with its Track Plotter, a device which plots the course followed in special coordinates and also marks the times of identification signals, which constitute a highly accurate time-base.

Actually, experience has shown that accuracy of the Track Plotter, which contains mechanical parts of relatively high inertia, is appreciably lower than Decca Indicator accuracy, so that the Track Plotter is unsuited to measurements.

Under these conditions, the Decca Navigator supplies the coordinates of the ship's position, not on a continuous basis, but as often as it is materially possible to note them down with reference to the time. Owing to the inconvenience caused by identification signals to readings, the maximum rate of the readings is 15 seconds, which thus enables them to be taken down with ease. At this rate, the identification signals can be used as timing-signals (by taking the readings after each return of the needles to their stable position and reducing their number to three per minute: two 15 seconds apart and two 30 seconds apart), or the timing-signals can be given by means of a time-meter whose calibration can be checked by the identification signals.

The coordinates then enable the positions to be plotted every 15 seconds on a nautical chart overprinted with the Decca grid. The line joining such points is the track followed over the bottom, and distances and angles my be measured directly on this line. The average speed may be derived during any time-interval which is a multiple of 15 seconds, and the quasi-instantaneous speed over a 15-second interval; a drift angle may likewise be derived by comparing the plotted track with the course observed. In brief, the combined Decca records supply complete information with regard to the kinematics of the ship during the period in which they were taken, and they may be used to separate the speed of drift with the current, and the relative speed being sought. The methods which should be used differ according to the nature of the trials; we shall therefore successively examine each type of trial, beginning with turning, whose properties are applicable to speed trials.

III. — TURNING TEST.

This question has been amply treated in another article [2], and only the essential details will be taken up here.

On merchant ships, the turning diameter is often evaluated by visual comparison with the length of the ship; if measured by radar according to the track, the result is usually expressed in a round number of tenths of a mile, which corresponds to an approximation of the order of one hundred metres. The standard pole method, used on naval vessels, requires considerable facilities and laborious analysis; moreover, it is not certain that the pole will drift in the same way as the ship.

But in the absence of wind (there is no point in making a turning test if wind action is appreciable, as the ship no longer then describes a circle), a plot of the path defined by the Decca readings enables accurate determination of the ship's position itself, and the reconstitution, by correcting the drift points for a common initial time, not only of the relative circular path in a continuous turn, but of the relative paths upon entering and issuing from the turn. As soon as more than one circle has been described during continuous turning, homologous points are obtained, which are those for which headings are identical; or in case no headings are recorded, those for which the courses are parallel (assuming the current is constant, which is a likely assumption as between two instants separated by a few minutes): the vector joining two homologous points represents the drift of the ship during one rotation in magnitude and direction, whereas the amplitude of the path normal to this direction is equivalent to the turning diameter. In practice, it is useful to have two continuous-turn rotations in order to check the quality of the measurements through agreement of the figures derived from a certain amount of homologous points.

Figures 1, 2 and 3 illustrate the results obtained on an oil-tanker: rough Decca readings plotted against time (Fig. 1); path along the bottom (Fig. 2); path along the surface (Fig. 3). It was possible to use a compass in plotting the latter figure without appreciably deviating from the observed points; the possible error with regard to the turning diameter is of the order of 1 %.

As regards smaller and faster ships, results are less satisfactory owing to a systematic deformation of the apparent path, the reason for which is still being sought. We believe that the error may then reach 10 %, but there is no proof as to whether the other methods are more accurate in this case.

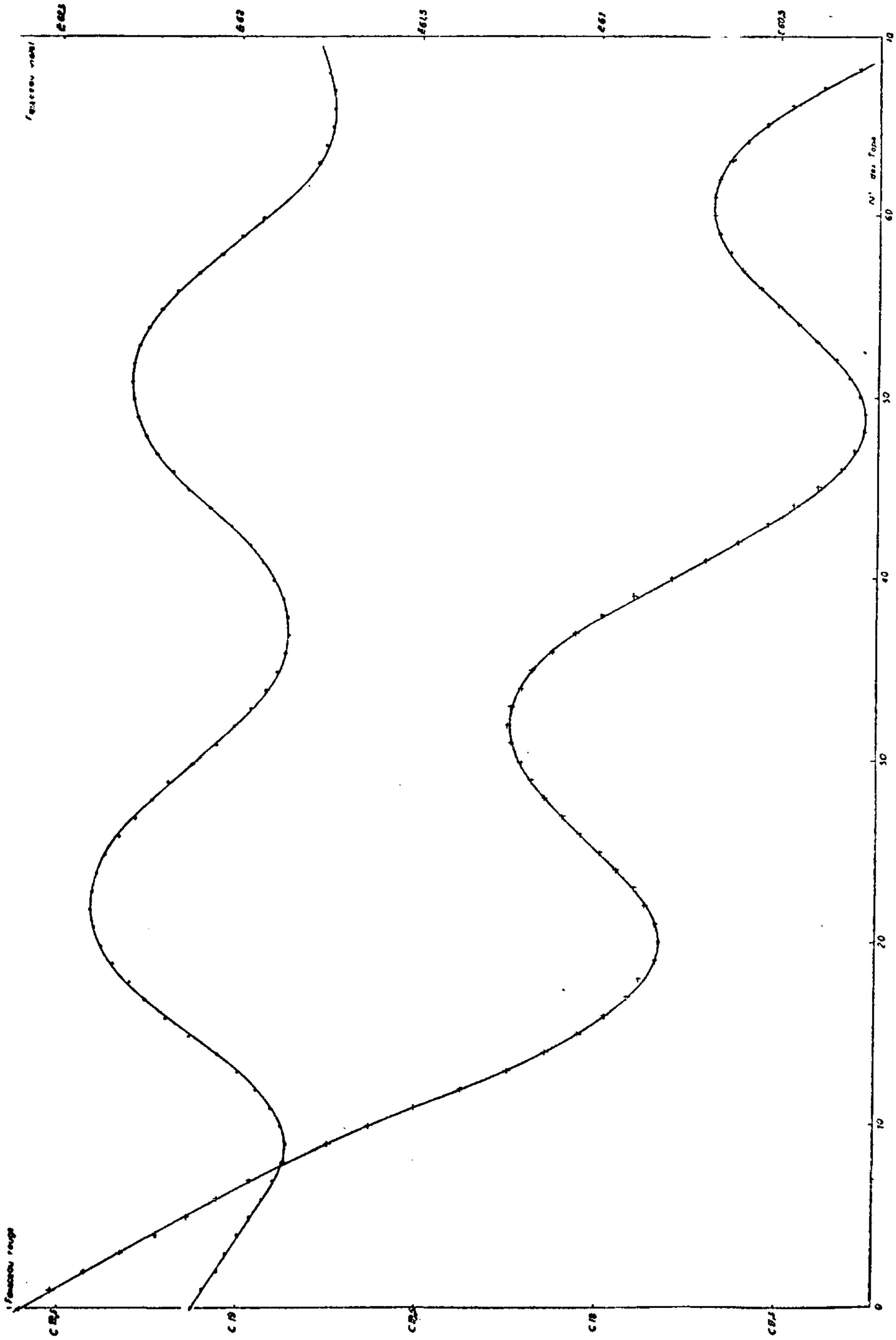
IV. — SPEED TEST.

This subject has been dealt with in detail elsewhere [3] and its theory will not be reexamined here.

In accordance with the considerations outlined in Section II, it is clear that Decca supplies the average speed along the bottom during the entire period of recording. It may be shown that if the length of such period is of the same order as that of a run over a measured distance, the accuracy of the two measurements is comparable. This result is partly due to the fact that, with Decca, the over-all readings can be used in determining the average speed.

(1) Standard Method.

The current may be eliminated, as on a standard measured distance, by making a series of runs in alternate directions with an identical mean point. When this condition is fulfilled, the use of Decca affords facilities that are unknown on measured distances. The testing location can be arbitrarily selected at sea, and the occasionally extremely long trip to the course thus avoided; handling of the ship between runs is not hindered by the proximity of the coast and its dangers; and a more regular current than the one prevailing at the courses may often be encountered. In addition to the choice of location, there is the choice of heading. There are two preferred headings, which no doubt enable a simpler and more accurate analysis of readings, but their adoption is not imperative, and headings related to the direction of wind and swell may be preferably adopted, especially in heavy weather. The length of the courses is arbitrary: they may be adapted to the speed to be measured and to the accuracy desired or the time available.

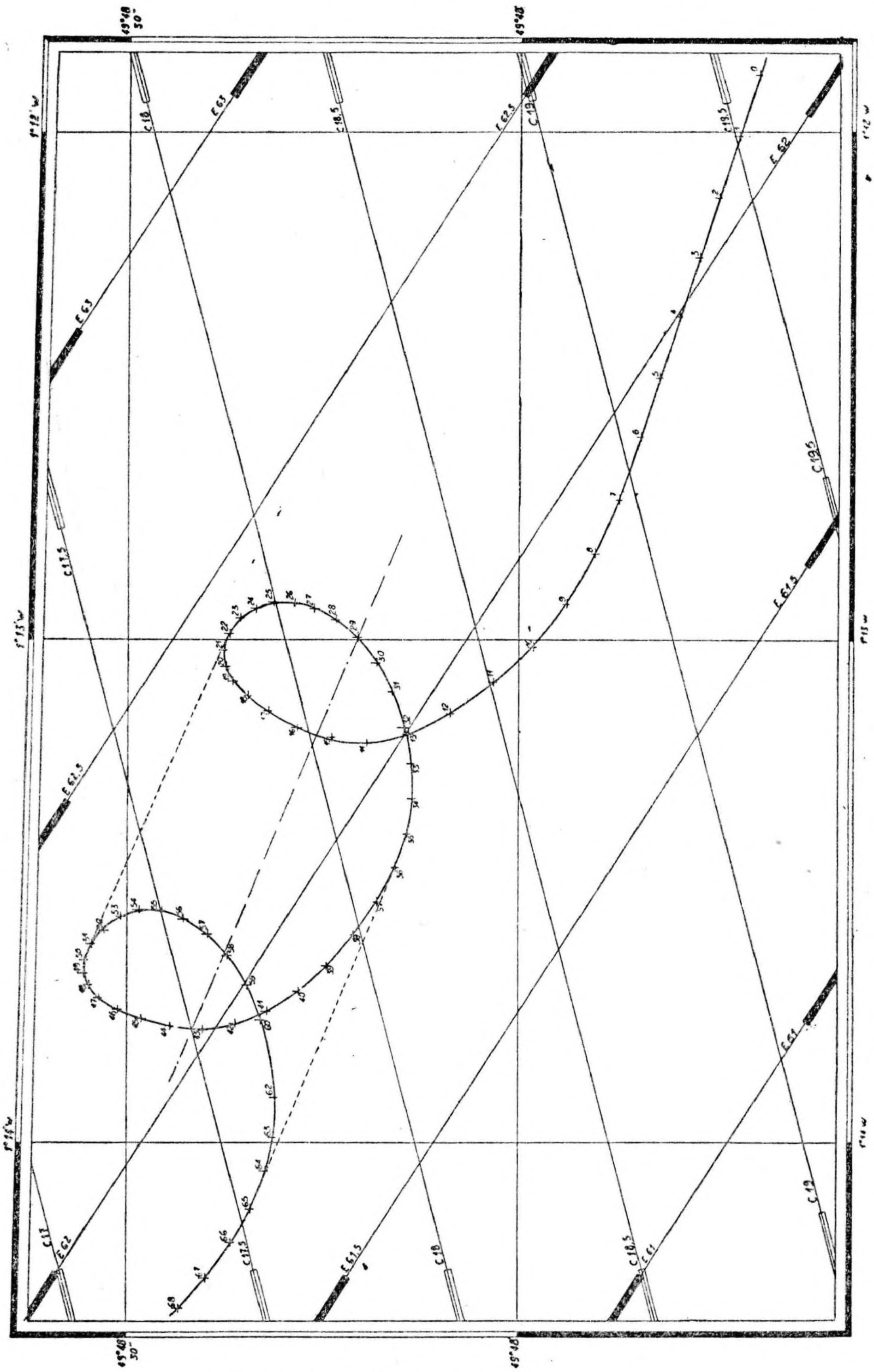


+—— Faisceau rouge. ●—— Faisceau violet.

FIG. 1. — Pétrolier. Balancement des relevés.

+—— : Red pattern. ●—— : Purple pattern.

Fig. 1.
Oil-tanker. Smooth readings.



Hyperboles violettes : E 61 à E 63.
Hyperboles rouges : C 17 à C 19,5.

FIG. 2. — Pétrolier. Trajectoire absolue.

Purple lanes : E 61 to E 63 — Red lanes : C 17 to C 19.5

Fig. 2.

Oil-tanker. Absolute track.

but this choice is not irrevocable, and if some mechanical or navigational difficulty should occur, the series is not lost as it would be in the case of a measured distance. Furthermore, the trials may be carried out when there is no visibility and preclude the necessity of giving advance notice for equipping the course; the ship

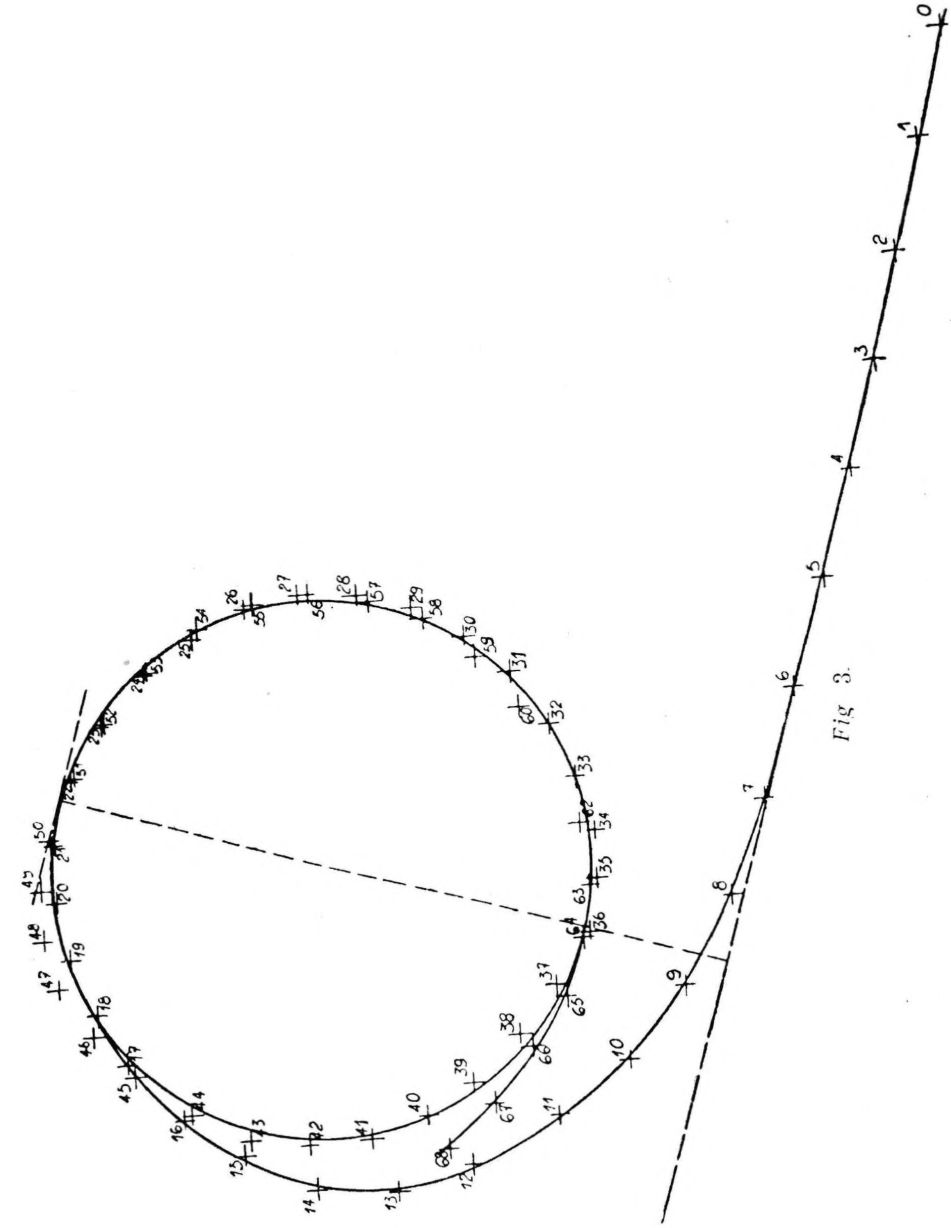


Fig. 3.

is completely self-sufficient and its schedule is independent of more or less uncertain communications with the shore; there is no chance of its untimely interruption in order to release the course for use by another ship.

As an illustration, Figure 4 shows the speed/number-of-turns relationship obtained on course by a trawler by means of four series of three course lines with Decca in heavy fog. The aspect of the curve is normal and its dispersion is insignificant; various checks lead us to believe that the errors do not exceed a few hundredths of a knot. In all the other cases where measurements were correctly carried out, the results were equally satisfactory.

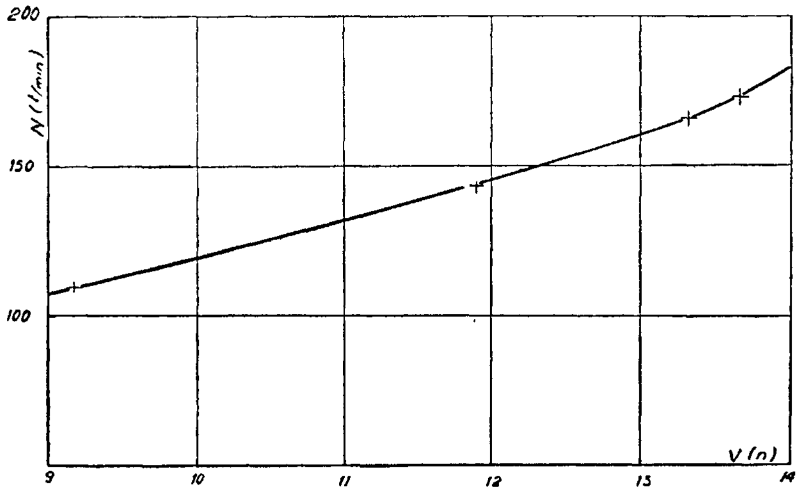


Fig. 4. — Chalutier Vitesse Nombre de tours.

Fig. 4.
Trawler. Speed. Number of revolutions.

(2) Short-Cut Methods.

The previous considerations are particularly applicable to ships undergoing trials. For those in service, the conditions governing the use of measured distances have seldom allowed speed measurements to be taken, and it is likely that an hour spent in travelling over three alternate-direction courses at some point during a passage is often considered on unacceptable procedure.

It is therefore believed that it may be of use to indicate the methods that can be used, with the assistance of Decca, to eliminate or at least considerably reduce the time lost in effecting the three courses.

(a) Estimation of Current.

Losses of time will be avoided entirely if Decca measurements of speed along the bottom are limited to points along the intended track where the currents are best known; various approximate values of the speed on the water will thus be obtained, and the scattering of such values will enable an evaluation of accuracy.

It is to be feared that accuracy is rather poor, since currents are subject to numerous influences that render their estimation hazardous. It is nevertheless considered appropriate to mention this method for two reasons: first, it is the only method which requires no maneuvering of the ship, and secondly, it is the only one which is applicable in heavy weather if it is desired not to undertake the three courses.

(b) Direct Measurement of Current.

The period of speed measurements along the bottom can be both preceded and followed by an equivalent period, or a total period of one-half hour, in which Decca observations of the drift of the stopped ship can be taken. It should be added, however, that this latter method is valid only if the drift due to wind action is negligible, which is probably a rare occurrence, as the stopped ship is extremely sensitive to wind action. The two following methods accordingly appear preferable.

(c) Current Measurement by Turning Test.

In turning tests, the current is merely a by-product that can be eliminated as noted in Section III, by measuring the amplitude of the path normally to drift. But as this test supplies an extremely accurate measurement of the current, it can also be used systematically to determine the correction for current to be made to the speed along the bottom, measured at the time of a speed test restricted to a single course. This process is simpler than the previous one, as it requires no management of the machinery; in addition, it is probably faster. The maneuvers are as follows: with the helm at a set angle, make two complete rotations, noting down the headings; bring the helm over to the speed-test heading and retain the latter for a sufficient period; reset the helm at an angle, on the same side or not, equivalent or not to the previous angle, and make two complete rotations noting down the headings; test completed. This operation is shown in diagrammatic form in Fig. 5, which shows the course along the bottom. During the entire test, the Decca readings should be taken when making the turns, every 15 seconds; but this rate may without inconvenience be increased to one minute during the speed test proper.

Unless the trial occurs at a time when there is a definite parabolic variation in the current, which may easily be avoided, it may be assumed that the mean current during the speed test is the mean of the currents measured before and after. For the turns, it is advisable to adopt a moderate helm angle, such as 10° or 15°; the duration of the turns is slightly increased, but the path is better defined, and as the slowing-down of the ship is less pronounced, the period required in resuming speed when coming out of the first turn is shorter.

It is believed that this method may be adopted without undue inconvenience by ships in service, and it also appears as if it might replace the three alternate-direction courses during trials, with an appreciable saving in time and the suppression of all operational difficulties.

It should be pointed out, however, that the method can only be used under negligible wind conditions. Should the effect of wind be considerable, it would generally be variable, and it might be difficult to define a valid rate of drift regardless of the pairing of the homologous points; even if one should succeed, the drift results from the combined action of the current and wind on the turning ship, and cannot justifiably be subtracted from the speed of the ship along a straight course. It may perhaps be well to add that the impossibility of obtaining the results of a test without wind from those of a test with wind is not due to use of Decca, but to the nature of wind effect: whereas the current subjects the ship to a definite drifting motion regardless of the motion proper, the wind supplies the ship with an additional resistance whose own value, and, to an even greater extent, whose effect on the speed, are dependent on the relative motion of the ship; it is not possible, therefore, to measure this effect by subjecting the ship to conditions other than those for which the correction must be made. Thus, in

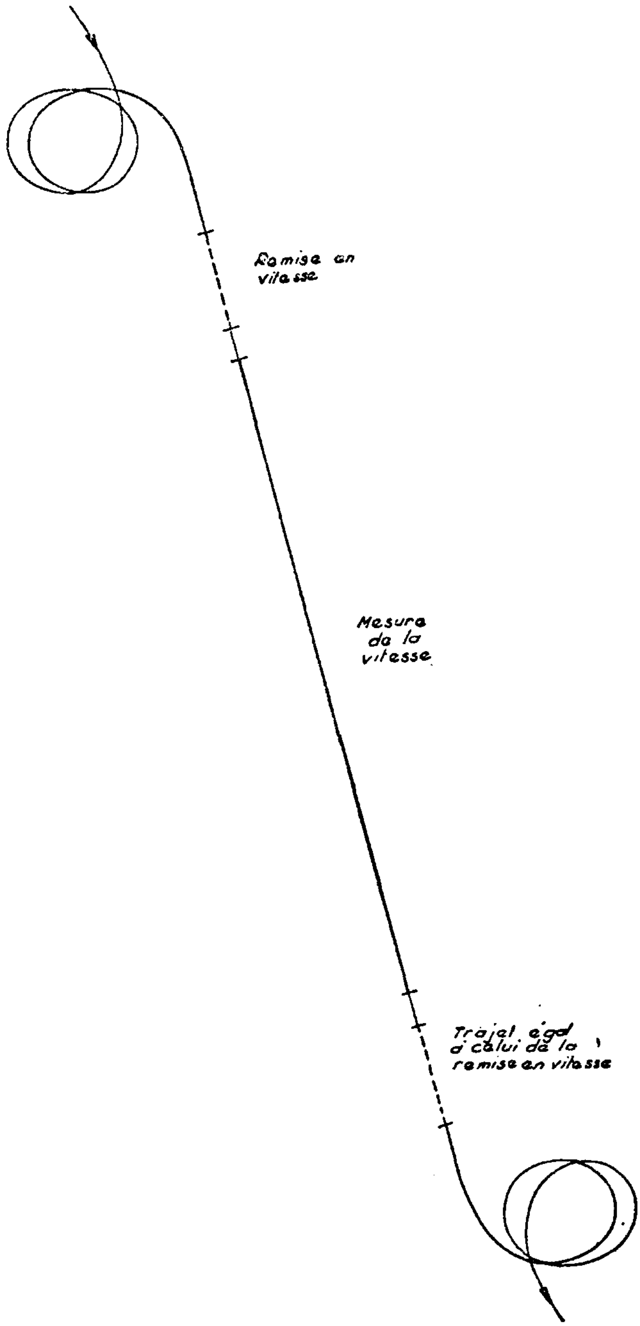


Fig. 5.

Resume-speed distance.
Measurement of speed.
Distance equal to resume-speed distance.

case of wind, the average speed obtained by the standard formula of measured distances is not the speed of the ship under dead calm conditions with the engines similarly set, but neither is the latter speed the difference between the actual speed and that of the stationary ship drifting solely under the influence of wind.

(d) Measuring Current by Changing Course.

This latter method is suggested by M. Sauvalle, who is an Engineer at the Naval Construction Research Institute. It consists in making two 90° course changes while proceeding along the single track, so as to obtain the path shown

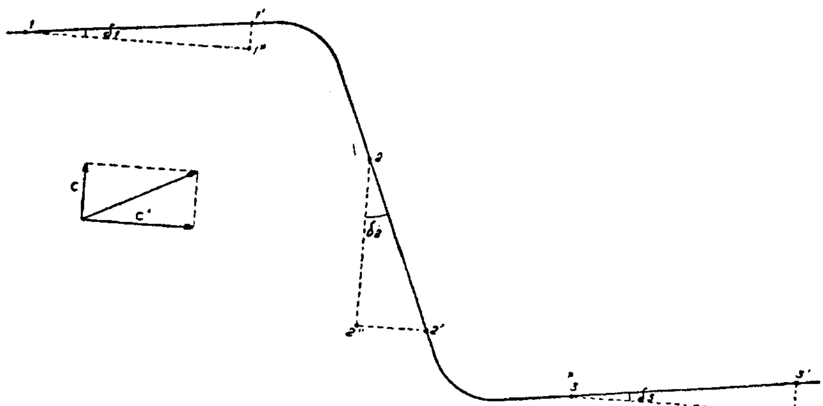


FIG. 6.

in Figure 6. For purposes of simplification, this has been drawn as for a constant current, but this hypothesis is not essential. Let C be the constituent of the current along the heading of course No. 2, and C' its constituent along the common heading of courses Nos. 1 and 3. The Decca readings enable the track over the bottom 11' 22' 33' to be plotted, and the drift data δ_1, δ_2, δ_3 to be recorded for the three courses; by projecting the track along the 1'', 2'' and 3'' headings, it is also possible to measure the apparent speeds V_1, V_2 and V_3 according to the heading.

We shall then have:

$$C_1 = V_1 \tan \delta_1$$
$$C_3 = V_3 \tan \delta_3$$

and if the current variation may be assumed to be linear in time:

$$C_2 = \frac{C_1 + C_3}{2} = \frac{V_1 \tan \delta_1 + V_3 \tan \delta_3}{2}$$

while the speed with respect to the second course is:

$$V'_2 = V_2 \pm C_2$$

the sign being plus in the case of the present figure.

Similarly, speeds V'_1 and V'_3, or at least their averages, may be obtained. For:

$$V'_1 = V_1 - C'_1$$
$$V'_3 = V_3 - C'_3$$

whence:

$$\frac{V'_1 + V'_3}{2} = \frac{V_1 + V_3}{2} - \frac{C'_1 + C'_3}{2}$$

But likewise assuming linearity of the current variation with time:

$$\frac{C'_1 + C'_3}{2} = C'_2$$

whereas:

$$C'_2 = V_2 \tan \delta_2$$

or finally:

$$\frac{V'_1 + V'_3}{2} = \frac{V_1 + V_3}{2} - V_2 \tan \delta_2$$

We thus have two determinations of the speed respectively corresponding to headings varying by 90°.

This method is just as simple and at least as rapid as the previous method. It invariably enables the evaluation of drift, but the results are valueless if the drift is solely due to the current, for the reasons described in connection with method *c*. It should also be pointed out that, with the exception of areas in close proximity to the transmitting stations where the basic parallelogram formed by the hyperbolae in the patterns involved is nearly square in shape, the accuracy of the two determinations of speed may be very different, the better one corresponding to the heading nearest the small diagonal of the basic parallelogram.

This remark is generally applicable, and whatever the method used, it may be worthwhile, in case a change of course is acceptable for measurement purposes, to adopt this heading, or rather, in order to simplify the analysis of the readings, to adopt a heading normal to one of the patterns sufficiently near the previous heading, thus combining accuracy with convenience.

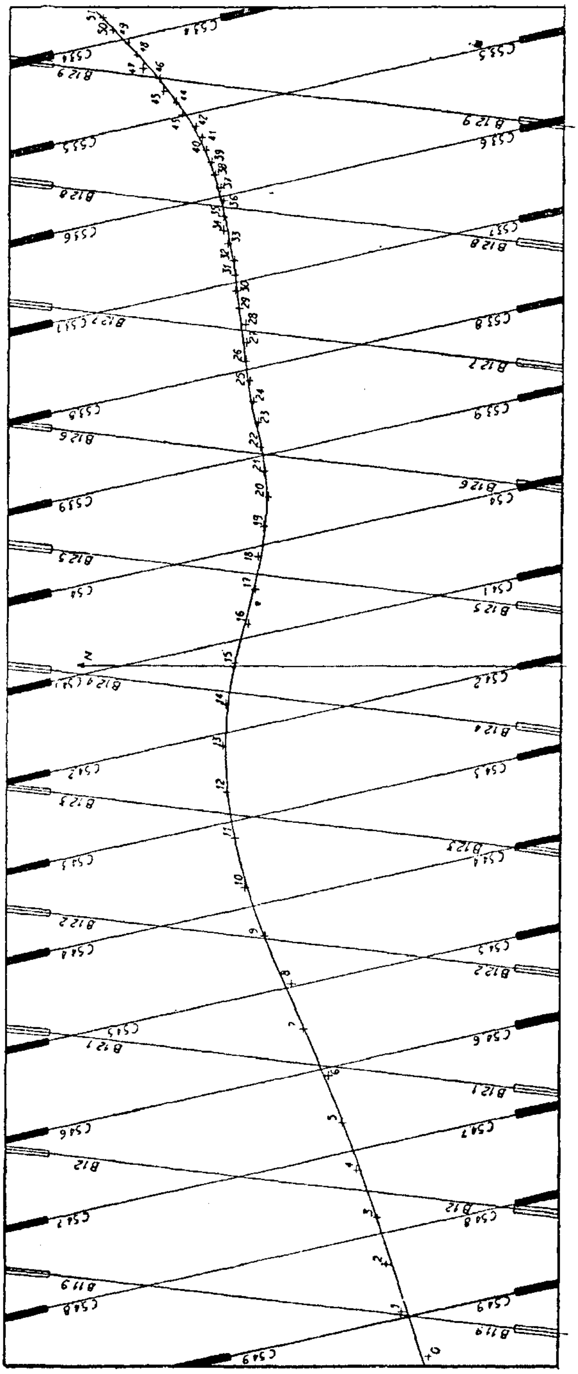
It may be added that, insofar as we are aware, neither method *b*, *c*, nor *d* have yet been used, and that our evaluation thereof is consequently not based on experience. It is hoped that acquisition of the latter will shortly enable selection of the method best adapted for the purpose.

V. — STOPPING TEST.

During stopping tests, the Decca coordinate readings enable the track to be reconstructed and a record to be obtained of the distance required to bring the ship to a stop, of speed development and acceleration, since the points are sufficiently reliable to allow of the twofold graphic derivation. An examination of the track likewise shows the extent to which the ship has stayed on course during the slowing-down period.

Figures 7, 8 and 9 illustrate the results obtained on a trawler while stopping without reversing the engines.

It is clear that the same procedure would enable a study to be made of the ship's acceleration under various interesting maneuvering conditions, and, more generally, of the ship's maneuverability.



Red pattern : lanes B 11.9 to B 12.9
Purple pattern : lanes C 53.4 to C 54.9

Fig. 7.
Trawler. Stopping test. Smooth readings.

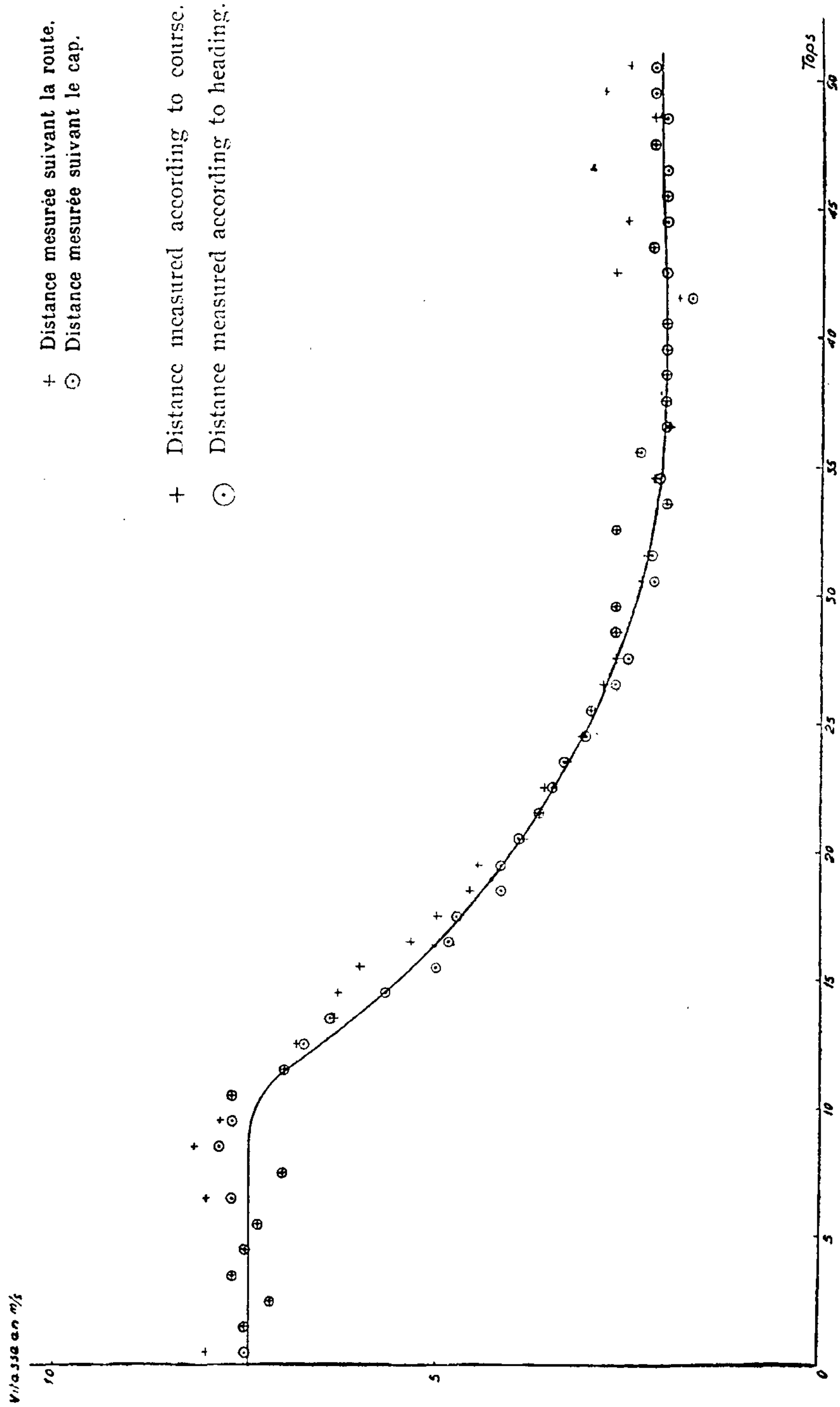


Fig. 8. — Chalutier. Essai d'arrêt. Vitesse moyenne entre tops.

Fig. 8.

Trawler. Stopping test. Average speed between timing-signals.

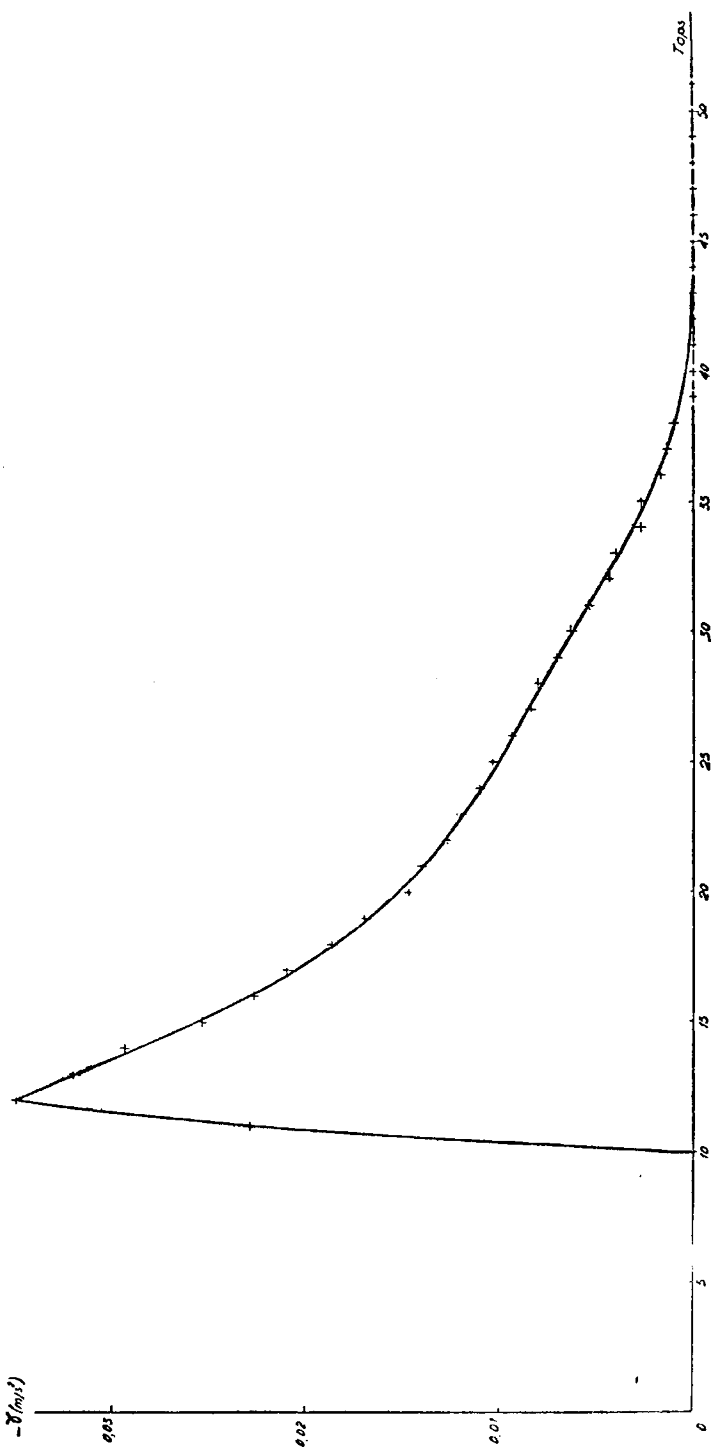


Fig. 9. — Chalutier. Essai d'arrêt. Accélération en fonction des tops.

Fig. 9.

Trawler. Stopping test. Acceleration plotted against timing-signals.

VI. — REQUIREMENTS FOR USE OF DECCA NAVIGATOR.

In the foregoing sections, the possibilities of Decca for measurement purposes were shown without reference to conditions that might limit such special application. Actually, certain rules must be complied with in order that satisfactory results may be obtained. These rules are discussed in reference [3], but in essence they may be sumarized as follows: do not operate too near the shore, or at night (1).

It is needless to add that operations can only be carried out in areas with Decca coverage, and that accuracy increases with proximity to the transmitting stations. The coasts of France have complete coverage (2), the most favourable being the North Sea and Channel coasts covered by the English and Southwest British Chains. It is expected that the Gulf of Lions covered by the Southern French Chain can later be used; there is adequate coverage on the Atlantic side for measurement purposes supplied by the Southwest British Chain in the north and by the French Chain in the south; and the Mediterranean coast is acceptably covered by the French Chain.

For such vessels as only occasionally navigate in waters with Decca coverage, and are not equipped with Decca, it may be mentioned that it can easily be installed on board for the voyage between any two ports; at the request of the Naval Construction Research Institute, moreover, the *Compagnie Radio-Maritime* has made three transportable units available — at Rouen, Saint-Nazaire and Marseille — which may be used temporarily by ships undergoing trials for the measurements described above. This service has been in operation since early 1955 and many vessels have already carried out measurements which have proved extremely satisfactory.

VII. — CONCLUSIONS.

The Decca Navigator is of definite assistance in carrying out measurements involving the accurate determination of the successive positions of a vessel.

For standard speed measurements, it may be substituted for the ordinary measured distances, while supplying the same order of accuracy though subjected to fewer restrictions. It is unequalled in the case of measurements with respect to non-rectilinear or variable-speed tracks.

It is moreover believed that its most useful application, although this at present is the least developed, would be for the measurement of speed under various conditions of ship operation, and by the methods described herein for the purpose.

Acknowledgment is hereby made with thanks to Professor of Hydrography Hugon and to Captain Fontaine, Inspector-General of the Compagnie Radio-Maritime, for their constant cooperation enabling the rapid perfecting of measurement technique, and to the numerous shipyards and shipbuilding concerns for their willingness in allowing it to be tried out on vessels undergoing tests, and for their efficient support; we are likewise indebted to the Navy, whose understanding help greatly facilitated the study of certain special points.

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(1) Such restrictions do not apply to the normal use of Decca for navigational purposes, where a lesser accuracy is acceptable than in measurement applications.

(2) A general chart showing Decca coverage is given in Fig. 2 of reference [4]. This chart does not, however, include the Southern French Chain, now operating experimentally, while it does include the Spanish and Italian Chains, which are not yet installed.

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