THE DECCA SYSTEM
FOR SHIP ACCEPTANCE TRIALS

by J. Th. VERSTELLE
Hydrographic Office, Royal Netherlands Navy, March 1958

Reproduced from *Nieuwsbrief Hydrografie* No. 28

SUMMARY

This newsletter describes the Decca procedure used nowadays in the Netherlands for conducting ship acceptance trials, such as speed, turning circle, etc...

Results of some of the trials are given and a worked-out example is added as an appendix. For speed trials carried out during daylight, the accuracy (standard error) is of the order of 0.1 to 0.2 % of the hourly speed. A few night trials resulted in an accuracy of 0.4 %, but the possibility of a slightly larger inaccuracy during night trials cannot be excluded.

A graph of the relation between speed, depth of water and ship's draft is given in section 2.

In section 12 the results are given of *simultaneous* determinations of speed on the measured mile and by means of Decca; the difference in speed from the two methods is 0.25 % only.

Section 14 summarizes the advantages of the Decca method.

For speed trials on the measured mile, reference is made to newsletter no. 28, 1958 (*).

1. INTRODUCTION.

Netherlands Hydrographic Newsletter no. 18 (March 1953) deals with different methods of conducting ship acceptance trials and makes various suggestions as to the way in which the existing Decca Navigation chains could be used for this purpose (**).

Since 1954 Decca has actually been used for conducting trials on board Netherlands ships. In the course of the succeeding years practical experience has resulted in a different procedure from the one proposed in Newsletter no. 18.

(*) See *International Hydrographic Review* of November 1958, page 85.
(**) First mention of Decca trials was made in 1952 by Fennessy.

The present newsletter fully describes the Decca procedure as it is used nowadays in the Netherlands and no. 18 may therefore — as far as regards Decca — be considered obsolete.

The principles on which the Decca Navigator System is based are assumed to be known.

2. DEPTH OF WATER.

A general requirement — independent of the method used (conventional or electronic) — is a sufficient depth of water. The problem is complicated and, in case of insufficient depth, accurate prediction of the amount of deceleration is very difficult. It is therefore highly preferable that the trials be carried out in an area having a depth such that no increased resistance will be encountered.

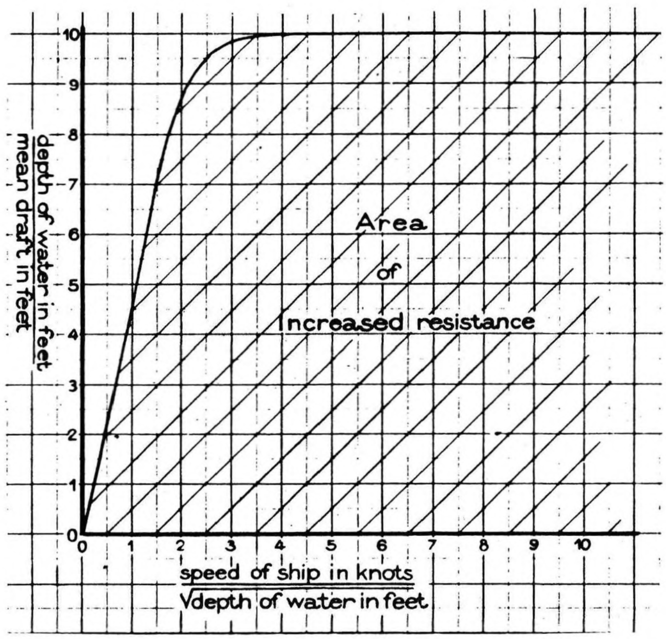


FIGURE 1

Dr. Günther KEMTE's (ship trial tank Hamburg) curve of fig. 1 gives the required information.

Example : Speed 18′, depth of water 164 ft, mean draft 23 ½ ft.

$$\text{hor. axis : } \frac{18}{\sqrt{164}} = \frac{18}{12.8} = 1.4$$

$$\text{vert. axis : } \frac{164}{23\frac{1}{2}} = \quad = 7.0$$

intersection outside of area of increased resistance

Remark : Many of the existing measured miles do not fulfill the requirement of sufficient depth.

3. THE DECCA METHOD.

Position-fixing is continuously available — in or out of sight of land — with any desired interval of time. From the differences between successive Decca fixes all the data required for the determination of :

a) ship's speed
b) turning circle
c) steering capacity
d) acceleration and « crash » stop,

can be derived.

All movements are determined with respect to the ground and — as in conventional speed trials on the measured mile (fig. 2) — the effect of drift (wind and current) has to be eliminated.

The accuracy of position-fixing by means of normal navigation receivers is very satisfactory for normal navigational use but wholly insufficient for the purpose of ship trials. This difficulty is however completely overcome when measures in section 5 are taken.

Decca trials can be carried out in daylight as well as during the night; as daytime accuracy however is considerably higher, the trials should preferably be conducted during daylight hours (*).

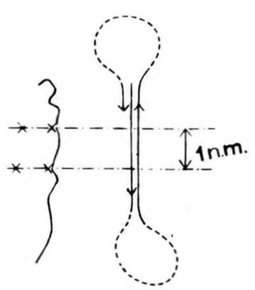


FIG 2

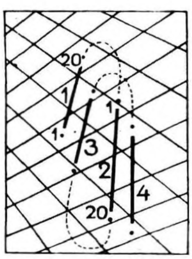


FIG. 3

a) Speed.

Fig. 3 shows a Decca trial area (usually $\pm$ 6 $\times$ 8 M). The ship starts run no. 1 on an *arbitrary true* course; usually, however, this course is taken roughly in the direction of the prevalent current. The observations start at the moment when the ship is considered to be at full speed. In this course and with intervals of 30 seconds 20 successive readings of 2 decometers are observed, giving 20 fixes or 19 intervals. Consequently each run takes 9 $\frac{1}{2}$ minutes.

As a result of small errors in steering and in Decca itself, and of small changes in direction and strength of wind and current, there will be a small spread in the fixes with respect to the mean straight line drawn through them, as indicated in fig. 4; this spread of course is a measure of the accuracy.

(*) Sun's altitude $>$ 10° — to 15°.

After conclusion of run no. 1 the ship is turned round (rudder ± 5° in order not to reduce speed too much) to starboard or port until she is exactly on opposite true course. Practice has shown that it takes 5 to 10 minutes before the ship is again at full speed and can start a second run of 20 observations.

As a result of drift due to wind and current the 2 runs — notwithstanding the fact that they are on exactly opposite course — will not be parallel, nor will they be of equal length.

After finishing run no. 2, the ship again goes on opposite course for run 3 and once again for run 4.

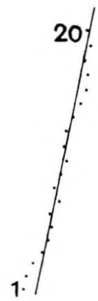


FIG. 4

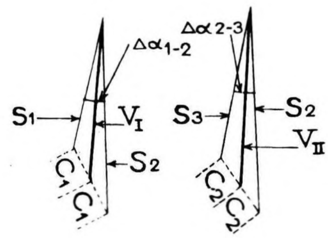


FIG. 5

A complete speed determination always consists of (at least) 2 runs in each direction.

Using a method to be described in section 8, the mean value of the intervals in each run is determined and converted into hourly speeds (over the ground) S_1 to S_4 for the 4 runs.

Drift is eliminated as illustrated in fig. 5. The combination of S_1 & S_2 gives V_I; from S_2 & S_3 V_{II} is obtained and V_{III} finally follows from S_3 & S_4.

By this method of 3 combinations, variable drift effects are more likely to be eliminated than by just combining S_1 & S_2 and S_3 & S_4.

Finally the desired speed V through the water is obtained by computing the so-called means of means of V_I, V_{II} and V_{III} (see also example in appendix).

Fig. 5 also shows how the drift vector can be determined.

b) Turning circle.

Observations every 15 seconds; just as in speed trials, the observations are timed in such a way that the lane identification kicks on the decometers are avoided.

The procedure is illustrated in fig. 6 and by an example in the appendix.

c) Steering capacity.

Interval between observations 15 seconds. The line of fixes is of the type in fig. 4. After plotting on a sufficiently large scale the deviations from a straight mean line can be read off.

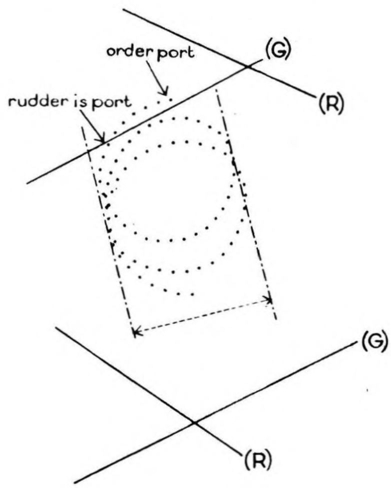


Fig. 6

d) Acceleration and stopway.

Observations and plotting as under *b*) and *c*). Drift can be eliminated from runs back and forth.

4. ACCURACY.

Accuracy is dependent on the following factors :

1. The stability of the Decca patterns, radiated by the transmitters. It is with respect to these invisible hyperbolic position lines that the Decca receiver measures phase differences, the result of these measurements being displayed on the decometers.
2. The accuracy of phase measurement of receiver decometers.
3. The degree of accuracy to which 2 decometers can be read off simultaneously.
4. The accuracy of computation and printing of the Decca chart patterns (they are the graphical representation of the radiated patterns).
5. The angle of intersection of the hyperbolae.
6. The plotting accuracy in the Decca chart.

Note : It will be clear from the above description that only *differences* between Decca fixes are used. Fixed pattern corrections — as published in the Decca Data Sheets — therefore are not applied, because their value will not change within the small area used for the trials.

With respect to the 6 points mentioned above, the following is remarked :

1. Day.

Pattern stability of a navigation chain is high and during the period of a run very high indeed, being of the order of 0.01 lane or sometimes even better.

2. *Night.*
Considerably less, but still acceptable over short periods when high accuracy is not required.

3. Small systematic errors occur in navigation receivers and decometers. In normal navigation they are simply neglected, because their magnitude will be between 0 and + or — 0.03 lane.

4. At high speed and in « narrow » Decca patterns, the decometers move fairly fast and it is quite difficult to read 2 decometers simultaneously to the required accuracy of 0.01 lane (even with 2 observers).

5a. The computation and printing procedure for navigational Decca charts does not guarantee accuracies of 0.01 lane; such a high accuracy moreover would be meaningless for the scales at which nautical charts are published.
Distortion of chart paper has a quite serious effect when ultimate accuracy is aimed at.

5b. *Absolute* distances in a Decca pattern are a function of the speed of propagation of the radio waves. On that account systematic errors in a distance between two Decca fixes certainly will be smaller than 1 part in 10 000 of the distance; consequently this source of error is of no importance whatsoever for the applications envisaged here.

6. Just as with compass bearings, a reasonable angle of cut is a requisite for accurate position-fixing.

7. The main factor determining plotting accuracy is the scale of the chart, which will seldom allow plotting to the nearest 0.01 lane.

5. MEASURES TO IMPROVE ACCURACY.

The Decca method of speed trials in the first place makes use of the favourable properties mentioned in section 4.*1*. and 4.*5b*. For the rest it will be clear from section 4 that the required accuracy of 0.01 lane cannot be achieved when the normal navigational procedure is applied, using navigation receivers and nautical Decca charts.

To overcome these difficulties, in the trials as carried out by personnel of the Netherlands' Decca agents : I.N.A. Rotterdam, use is made of a receiver, calibrated for the systematic errors, mentioned in section 4.*3*. This guarantees a decometer accuracy of 0.01 lane and therefore is in accordance with the (daytime) pattern stability. In addition a special modification reduces the decometer kicks from lane identification and Mk 10 (*) transmissions.

A further step is to carry out these trials in areas not too far from the transmitters (that is, not too wide lanes and a good angle of cut of the hyperbolae). Moreover the trial areas are so chosen, that depth of water is as great as possible and as far as possible outside through shipping lanes.

For a number of areas fulfilling these conditions and favourably located with respect to harbours in the Netherlands, special and very

(*) Mk 10 is a specialized Decca receiver for use in aircraft.

accurate Decca charts were computed and plotted on dimensionally stable drawing material (*astralon*) on a scale 1/20 000 (*).

On these special charts all the observations for the purposes mentioned in section 3 under *a*) to *d*) can be accurately plotted. The general accepted drawing accuracy is of the order 0.2 millimetre (0.01 inch), corresponding on scale 1/20 000 to 4 metres (4 yards) on the terrain. As 0.01 of a lane corresponds to 5 metres or more, the scale of 1/20 000 therefore under all circumstances guarantees a plotting accuracy equivalent to or better than 0.01 of a lane.

Special Decca charts have been prepared for the following areas :

a) Galloper light vessel, depth ~ 50 m. (27 fm.).
b) West entrance English Channel; depth ~ 100 m. (55 fm.).
c) Two areas in the Irish Sea; depth up to ~ 130 m. (72 fm.).
These 2 special charts have been *cancelled*, because in 1957 one of the Decca transmitters was moved to another location.

In addition I.N.A. has prepared tables, substituting and very much simplifying and speeding up the use of special Decca charts. These tables are available for the following areas :

a) Galloper area mentioned above.
d) Newbiggin (Newcastle) area : depth varying between 35 and 50 m. (20 & 27 fm.).
e) Farn Deeps [10 miles N.E. of *d*)] : depth between 95 and 110 m. (53 & 61 fm.).

The tables and their use will be discussed in sections 8, 9 and 10.

Finally the difficulty of accurately taking simultaneous readings of 2 decometers (section 4.4) is overcome by taking a photograph every 30 seconds; any reasonable camera will do and 35 mm is a suitable size of film. A *moving* stopwatch hung on the dashboard of the decometers provides the time of exposure, or — more important — the exact interval between exposures. The advantage not only is the absolute synchronization of time and both decometer readings, but also that all essential data can be checked at a later time, without risk of uncontrollable personal errors.

It is the combination of these measures and precautions that makes it possible to use a Decca *Navigation* chain for this type of accurate work.

6. DETERMINATION OF *s*, S AND V.

When using the special large-scale Decca charts, the 20 observations in each run are plotted.

The information required from those 20 fixes is the distance S run in $9\frac{1}{2}$ minutes = 570 seconds (or whatever it may be from the photographed stopwatch), thereby making use of *all* 20 observations; after multiplication by $\frac{3\,600}{570}$ the hourly speed S (over the ground) is obtained.

There are several methods of making equivalent use of supernumerary (**) observations. The one used in the Netherlands' trials is to scale off

(*) Photographic enlargement of a section of an existing nautical Decca chart would be no solution, because errors in the chart would be enlarged by the same factor.

(**) Mathematically *s* can be determined from 2 fixes (as in conventional speed trials); in this case there are 18 supernumerary observations.

the 20 positions in rectangular cordinates and to compute s according to the method of least squares. This is a mathematically rigorous method from which at the same time the true course α (over the ground) and the standard errors in s, S and α can be computed.

The method is complicated and laborious and will not be described here, mainly because the whole procedure of using special Decca charts is — in the Netherlands — superseded by the use of the tables to be described in the following sections.

The next step is to compute V_I (fig. 5) and its standard error from S_1, S_2 and $\Delta\alpha_{1\text{-}2}$.

Finally V (hourly speed through the water) and its standard error are computed from V_I, V_{II} and V_{III} according to the method of the means of means; see also example in appendix.

7. SOME RESULTS OF DECCA SPEED TRIALS.

Method : special Decca charts and rigorous least square adjustment.

Decca day :

Ship 1	V = 15'.902 ± 0'.017 = 0.11 % of V	(standard error)
Ship 2	V = 19'.17 ± 0'.02 = 0.10 % of V	»

Decca night :

Ship 3	V = 17'.056 ± 0'.067 = 0.39 % of V	(standard error)
Ship 4	V = 21'.97 ± 0'.07 = 0.32 % of V	»

Note : The possibility of *night* errors exceeding 0.4 % cannot be excluded.

8. TABLES REPLACING CHARTS.

Facilities on board ship usually do not permit accurate (0.01 lane) plotting of the numerous fixes on the special Decca chart (in 4 runs there are 4 × 20 = 80 fixes). Moreover the plotting and consecutive scaling off of rectangular coordinates X, Y is very time-consuming (*).

In order to overcome these objections, special tables have been prepared by I.N.A. They are based on the following considerations and theory :

A trial area is always of small dimensions and — with the exception of the area in the West Entrance of the English Channel — it can be shown that the hyperbolae are very nearly straight lines within such an area (**).

The intersection S of two straight Decca lines (fig. 7) is determined by the following 2 equations :

$Y_S = Y_G + X_S \cot \alpha_G$.(in fig. 7 α_R is between 90° and 180°; hence cot α in negative).

$Y_S = Y_G + X_S \cot \alpha_G$.

(*) Solving V entirely by construction in a special Decca chart would not result in sufficient accuracy and it would be impossible to implicate all observations in an equivalent way.

(**) For the areas under consideration *the effect on S of neglecting* curvature never exceeds 10 metres per hour, which can be completely neglected.

The values of Y_R, Y_G, cot α_R and cot α_G have been computed and tabulated for intervals of 0.01 lane.

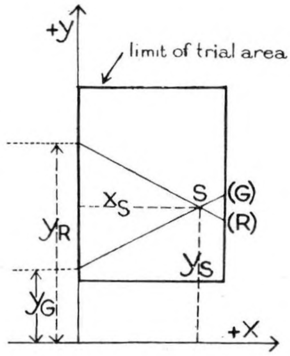


FIG. 7

From the above 2 equations the 2 unknown quantities X_S and Y_S can be solved for each of the Decca fixes. In geodesy this problem is known as (forward) intersection and the fastest way to solve X_S and Y_S *simultaneously* is to compute by means of a so-called double Brunsviga computing machine (fig. 8). In the Netherlands' speed trials carried out by I.N.A. nowadays all the computations are carried out by means of this machine.

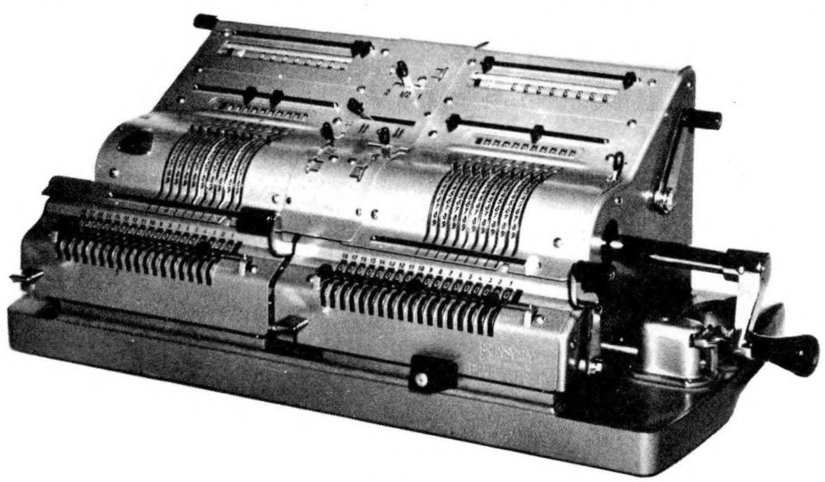


FIG. 8

The simultaneous solution of X_S and Y_S takes less than 1 minute for each fix, which is a very considerable saving in time compared with the earlier method of accurate plotting and scaling off of coordinates.

Tabulated quantities and computational procedure warrant an accuracy in X_S and Y_S of 1 metre, which is far in excess of the inherent accuracy of the Decca position-fixing itself; as less accuracy, however, would not speed up the computation, there are no objections against this high degree of computational accuracy.

9. COMPUTATION OF *s*, S AND V.

For the procedure of computation reference is made to the example given in the appendix.

In form 1 the 20 values of X and Y for the 20 fixes of run no. 2 (as computed by means of the double Brunsviga machine) are tabulated and grouped together for the combinations fix 1 with 11, 2 with 12, etc., thus giving 10 differences ΔX and ΔY, each for an interval of time $\Delta t = 300$ seconds. From their mean values $\frac{[\Delta X]^{(*)}}{n}$ and $\frac{[\Delta Y]}{n}$ now tan α and s (= speed over the ground in the interval Δt) are computed, while S (= hourly speed over the ground(follows from multiplication by $\frac{3\,600}{\Delta t}$ being in thise case $\frac{3\,600}{300}$.

The next step is to compute the standard error m in the mean values of ΔX and ΔY from the differences with the 10 individual values (top right hand side of form 1) and finally the standard errors in s and in S are computed by the formulae given on this form.

The angle $\Delta\alpha$ and therefore also α is not very critical in the final computation of V, as may be seen from form 2, where the cosine of a very small angle $\Delta\alpha$ enters into the computation. For this reason there is no need to compute the standard error in α.

Four runs — 2 one way and 2 the other — result in 4 hourly speeds S_1, S_2, S_3 and S_4, to be computed on form 1. The way they are combined is shown on form 2 (see also fig. 5). The speed *through water* V finally is computed by the method of the means of means; see form 2.

This method of computation can be regarded as an approximation of the much lengthier rigorous least square solution; it can be shown, however, that its accuracy is more than sufficient, that is to say far within the limits of the standard errors in the computed quantities.

10. TURNING CIRCLE, STEERING CAPACITY AND STOPWAY.

This type of trial is always confined to a small area, usually covering less than the width of one Decca lane.

The required data are obtained by scaling off from a plot on a scale 1/10 000 on graph paper with millimetre division; a sample of a turning circle is given in fig. 9.

First the nearest intersections of « full » or « half » Decca lane numbers are computed in X, Y by means of the double Brunsviga. These intersections are plotted on the graph paper and straight lines representing the hyperbolae are drawn through them. Within this grid all individual decometer readings (as photographed every 15 seconds) are plotted by interpolation.

Steering capacity and stopway are determined by scaling off from a similar construction.

(*) [ΔX] stands for sum ΔX.

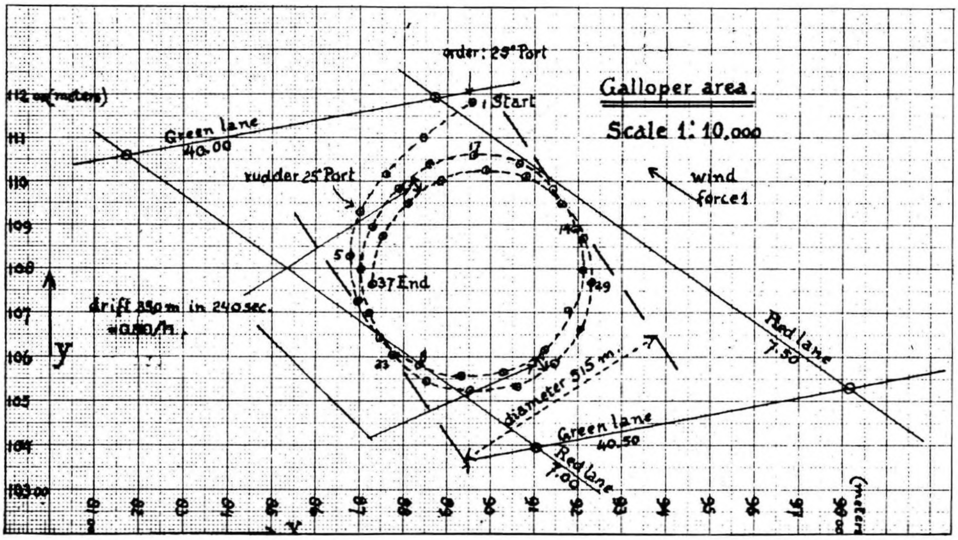


Fig. 9

11. COMPUTATION OF DRIFT.

Usually drift is not computed. If desired, however, form no. 3 (appendix) is self-explanatory for the method of computation.

In this particular case there was very little wind and consequently the drift vector represents the current.

The computation shows that the *direction* of the current in this case

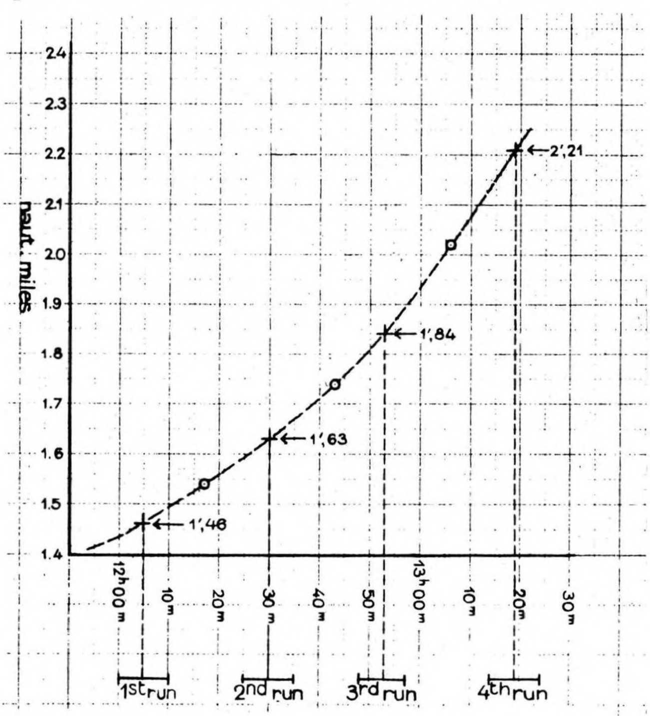


Fig. 10

is practically constant during the whole period of the 4 runs and makes an angle of about 12° with the ship's course.

The current strengths for the 3 speeds V_I, V_{II} and V_{III} have been plotted in figure 10 and from the smooth curve through them the current strengths for the 4 runs can be read off.

These strengths, *multiplied by the cosine of 12°* result in the 4 current components in the direction of the course.

Applied to the 4 values of S, they should of course be equal to V; the mean of the 4 V's thus obtained proves to be in very good agreement with V as computed from the adjustment :

$S_1 = 20'.52 \quad c = +\,1'.43 \rightarrow V = 21'.95$
$S_2 = 23'.53 \quad c = -\,1'.59 \rightarrow V = 21'.94$
$S_3 = 20'.09 \quad c = +\,1'.80 \rightarrow V = 21'.89$
$S_4 = 24'.07 \quad c = -\,2'.16 \rightarrow V = 21'.91$

mean $V = 21'.922$
from adjustment $V = 21'.929 \quad \pm\, 0'038$ st.e.

12. COMPARISON BETWEEN DECCA AND MEASURED MILE.

In February 1958 the Netherlands Decca agents in the Netherlands (I.N.A., Rotterdam) conducted speed trials *simultaneously* on Decca and on the (Newbiggin) measured mile.

Measured mile . . .	4 runs	18'.01		119 revolutions :
Decca	4 runs	18'.032	± 0'.038 st.e.	
Measured mile . . .	4 runs	17'.58		115 revolutions :
Decca	4 runs	17'.53	± 0'.06 st.e.	
Measured mile . . .	4 runs	16'.76		110 revolutions :
Decca	4 runs	16'.66	± 0'.07 st.e.	

Standard errors in measured mile speeds have not been computed; a fair estimate in this case however is ± 0.04 miles (*). The two methods therefore agree within the limits of the errors in the determinations. The mean difference between the two methods amounts to

$$+\frac{0.022 - 0.050 - 0.100}{3} = 0'.043 \text{ or about } 0.25\ \% \text{ of V.}$$

As far as known this is the first time that a direct comparison of the two methods could be carried out under exactly the same conditions. It should be remarked that the conditions for Decca speed trials are not ideal in February, because of the possibility of small sky-wave effects during daytime; nevertheless, the accuracy and agreement are very good.

13. PROVISIONAL SPEED (DECCA).

Speed when determined on the measured mile is available a few minutes after the conclusion of the trials. When using Decca, it takes time

(*) Newsletter no. 28, 1958 should be consulted for more details.

to develop and read the photographs and to compute the results, which therefore are not available at short notice.

To overcome this serious inconvenience — during speed trials everyone is always very anxious about the results — it has become the practice to take *visual* decometer readings of the first and last fix of each run. These readings are converted into X, Y coordinates by means of the double Brunsviga machine and then are used for a preliminary computation of *s* and S (left lower corner of form 1 in appendix), which does not take more than 3 or 4 minutes and can be carried out while the ship is turning round to opposite course.

The means of means of the 4 runs — like on the measured mile — is adopted as the provisional speed.

Usually the difference between provisional and definite speed is less than 1 % of V. This would be accurate enough for all practical needs. However, the possibility of reading or other errors in the two readings cannot be excluded and it is considered absolutely necessary to compute the definite speed from all available information as described in the foregoing sections.

Moreover for theoretical studies the shipbuilder will be interested in the accurate speed and its standard error; he will not object to the delay of the few days it takes to make the computation and to evaluate the wealth of further information that can be extracted.

14. ADVANTAGES OF THE DECCA METHOD.

The following measurements are possible with Decca but not on the measured mile :

a) Speed determination in any desired course: for example wind or current or waves in a self-chosen direction with respect to ship's course.

b) The effect of rolling and pitching on the speed can be studied from a comparison of the results on different courses (*).

c) Variations in speed during a run can be determined. From the 20 fixes in each run it can be ascertained whether or not the ship is at full speed at the start of a run (*); if not, the first few fixes can be left out, the remaining ones being used for the computation. (On the measured mile — only 2 observations — this can never be *shown*).

d) Turning circles.

e) Steering trials.

f) Stopways.

Decca offers the following advantages over the measured mile :

aa) Independent of visibility.

bb) In many cases :

1. Considerable saving in time and cost because of shorter distance to shipyard; Hook of Holland to Galloper for instance is 80 M only, while the nearest measured mile with the same depth of water is 300 miles away.

(*) Trials at night are not accurate enough for this purpose.

2. Greater depth than on most of the measured miles.

cc) Practice has shown that 6 Decca runs take the same time as 4 runs on the measured mile, the explanation being that in the Decca method less time is lost in turning round as may be seen from comparing figs. 2 and 3.

One of the great advantages of a shorter total time is a better chance that changing effects of wind and current are more completely eliminated.

dd) It can be determined with certainty whether the ship is at full speed or not (*).

ee) The 20 observations in each run enable computation of reliable standard errors.

ff) All the information required for acceptance trials can be determined by one single system and in the same area.

Note : The opinion has been expressed that — contrary to the usual procedure of fig. 3, where successive runs are some small distance apart — it might be better to make all runs as near the same location as possible, like in speed trials on the measured mile (fig. 2). The argument then is that this would give a better chance for unchanging current conditions.

As the suggested procedure would require full turning circles and a longer approach run, it would take about the same amount of time as speed trials on the measured mile and the advantage mentioned under *cc*) would be lost. The argument will hold for the measured mile, of necessity always being near the shore; the Decca trial areas, however, are farther out at sea (advantage : greater depth), where current conditions are much more unlikely to change over the short lateral distances between runs in opposite directions.

Personally I am therefore of the opinion that the procedure of fig. 3 is to be preferred, because advantage is taken of the fact that the current is more unlikely to change over the shorter interval of time between two successive runs and consequently will be eliminated with greater accuracy. The drift computation described in section 11 (fig. 10) seems to prove my opinion.

15. GENERAL REMARKS.

Independent of method used, it is always doubtful whether the effect of increased resistance from *strong* winds, and *high* seas can be eliminated. Under those circumstances it is always preferable to conduct trials in a sheltered area. The Galloper area gives little shelter; the Newbiggin area, however, offers reasonable shelter for the prevailing westerly winds at distance of 2 to 3 M from the shore with depths from 18 to 23 fathoms (measured mile as well as Decca) or between 3 and 9 miles and depths of 23 to 36 fathoms (Decca trial area).

The Farn Deeps Decca trial area with depths of 53 to 61 fathoms is too far from shore to offer shelter in bad weather.

Few measured miles are sheltered and at the same time have sufficient depth.

(*) Trials at night are not accurate enough for this purpose.

16. CONSULTED LITERATURE.

N = in Netherlands language
E = in English
F = in French

N. *Schip en Werf*
no. 26, 1950, p. 566; no. 3, 1951, p. 56; no. 5, 1951, p. 100; no. 11, 1951, p. 224; no. 21, 1954, p. 538.

E. *Decca Navigator News*
July 1952, p. 12; March 1954, p. 10.

F. *Navigation* VIII no. 9, Janvier 1955, p. 376.

N. « *de Zee* » no. 2, 1958, p. 62.

E. *Hydr. News Letter* no. 28, 1958.

DECCA SPEED TRIAL.

s.s./m.s Form 1 SAMPLE COMPUTATION

date: .... G.M.T. ± 12h 30m

terrain: GALLOPER — RUN n° 2

computed by: Verstelle

obs. n°	stopwatch min	stopwatch sec.	decometers R	decometers G
1	03	16	10.25	38.80
2		46	10.60	38.65
3	04	16	10.93	38.51
4		46	11.27	38.36
5	05	16	11.61	38.22
6		46	11.98	38.08
7	06	16	12.33	37.93
8		46	12.68	37.78
9	07	16	13.04	37.65
10		46	13.38	37.52
11	08	16	13.73	37.37
12		46	14.08	37.22
13	09	16	14.42	37.10
14		46	14.77	36.95
15	10	16	15.13	36.82
16		46	15.46	36.68
17	11	16	15.81	36.55
18		46	16.15	36.41
19	12	16	16.48	36.26
20		46	16.83	36.13

visual decom. readings.

PRELIMINARY COMPUTATION

$(X)_{20}$	13787	(Y)	18947
$(X)_1$	9738	(Y)	13428
(ΔX)	+ 4049	(ΔY)	+ 5519

$tg(\alpha_2) = \frac{(\Delta X)}{(\Delta Y)} = +0.73365$

$(\alpha_2) = 36°\ 16'$ (Δt): 570 sec.

$(s_2) = \sqrt{(\Delta X)^2 + (\Delta Y)^2} = 6845.0$ m.

$(S_2) = \frac{3600}{(\Delta t)} \cdot (s_2) = 43232$ m/h

$= 23.34$ n.m./h.

X	ΔX	$v_{\Delta X}$	Y	ΔY	$v_{\Delta Y}$
X_{20}	13781		Y_{20}	18963	
X_{10}	11658		Y_{10}	16032	
ΔX_1	+ 2123	− 33	ΔY_1	+ 2931	+ 9
X_{19}	13544		Y_{19}	18677	
X_9	11435		Y_9	15756	
ΔX_2	+ 2109	− 47	ΔY_2	+ 2921	− 1
X_{18}	13377		Y_{18}	18373	
X_8	11180		Y_8	15474	
ΔX_3	+ 2197	+ 41	ΔY_3	+ 2899	− 23
X_{17}	13176		Y_{17}	18078	
X_7	10982		Y_7	15170	
ΔX_4	+ 2194	+ 38	ΔY_4	+ 2908	− 14
X_{16}	12937		Y_{16}	17793	
X_6	10782		Y_6	14868	
ΔX_5	+ 2155	− 1	ΔY_5	+ 2925	+ 3
X_{15}	12751		Y_{15}	17503	
X_5	10533		Y_5	14573	
ΔX_6	+ 2218	+ 62	ΔY_6	+ 2930	+ 8
X_{14}	12500		Y_{14}	17216	
X_4	10327		Y_4	14289	
ΔX_7	+ 2173	+ 19	ΔY_7	+ 2927	+ 5
X_{13}	12301		Y_{13}	16908	
X_3	10140		Y_3	13991	
ΔX_8	+ 2161	+ 7	ΔY_8	+ 2917	− 5
X_{12}	12057		Y_{12}	16644	
X_2	9945		Y_2	13711	
ΔX_9	+ 2112	− 42	ΔY_9	+ 2933	+ 11
X_{11}	11859		Y_{11}	16338	
X_1	9743		Y_1	13411	
ΔX_{10}	+ 2116	− 38	ΔY_{10}	+ 2927	+ 5
$[\Delta X]$	= + 21558	(Σ = +6)	$[\Delta Y]$	= + 29218	(Σ = −2)

n = 10 Δt = 300 sec.

$mean = \frac{[\Delta X]}{n} = +2155.8$ m.

$tg.\alpha_2 = +0.73783$

$\alpha_2 = 36°\ 25'$

n = 10 Δt = 300 sec.

$mean = \frac{[\Delta Y]}{n} = +2921.8$ m.

$\{s_2\}^2 = \left\{\frac{\Delta X}{n}\right\}^2 + \left\{\frac{[\Delta Y]}{n}\right\}^2$

$s_2 = 3631.0$ m.

computation of standard error

$m^2_{\Delta X} = \frac{[v_{\Delta X} v_{\Delta X}]}{n(n-1)} = \frac{13886}{90} = 154$

$m^2_{\Delta Y} = \frac{[v_{\Delta Y} v_{\Delta Y}]}{n(n-1)} = \frac{1076}{90} = 12$

$m^2_{s_2} = \frac{\left\{\frac{[\Delta X]}{n}\right\}^2 \cdot m^2_{\Delta X} + \left\{\frac{[\Delta Y]}{n}\right\}^2 \cdot m^2_{\Delta Y}}{s_2^2} = \frac{715\,843\,744 + 102\,457\,008}{13\,184\,761} = 62.1$ m.

$m_{s_2} = 7.9$ m.

$m_{S_2} = \frac{3600 \cdot m_{s}}{\Delta t} = 95$ m/h.

$S_2 = \frac{3600 \cdot s_2}{\Delta t} = S_2 = 43572$ m/h

FORME 1

DECCA SPEED TRIAL s.s./m.s. .... date 19

ELIMINATION OF CURRENT AND DRIFT

Form 2
SAMPLE COMPUTATION

combination RUN 1 & 2 = I (metres/hour).

$S_1 = 38012 \quad \pm 83 \quad - 6889 \qquad \alpha_1 = 218° \ 06'$

$S_2 = 43572 \quad \pm 95 \quad - 9025 \qquad \alpha_2 = 36° \ 25'$

$m^2_{V_I} \approx 15914 \qquad \Delta\alpha_{1-2} = 181° \ 41' \rightarrow \cos = -0.99957$

$2 \cos = -1.99914$

$V_I = \frac{1}{2}\sqrt{S_1^2 + S_2^2 - 2S_1S_2 \cos\Delta\alpha_{1-2}} = \frac{1}{2}\sqrt{3343\,431\,328 + 3311\,093\,345} = \frac{81575.3}{2} = 40788$ m./h.

combination RUN 2 & 3 = II (metres/hour).

$S_2 = 43572 \quad \pm 95 \quad - 9025 \qquad \alpha_2 = 396° \ 25'$

$S_3 = 37210 \quad \pm 65 \quad - 4225 \qquad \alpha_3 = 217° \ 49'$

$m^2_{V_{II}} \approx 13250 \qquad \Delta\alpha_{2-3} = 178° \ 36' \qquad \cos = -0.99970$

$2 \cos = -1.99940$

$V_{II} = \frac{1}{2}\sqrt{S_2^2 + S_3^2 - 2S_2S_3 \cos\Delta\alpha_{2-3}} = \frac{1}{2}\sqrt{3283\,103\,284 + 3241\,655\,452} = \frac{80776.0}{2} = 40388$ m./h.

combination RUN 3 & 4 = III (metres/hour).

$S_3 = 37210 \quad \pm 65 \quad - 4225 \qquad \alpha_3 = 217° \ 49'$

$S_4 = 44573 \quad \pm 91 \quad - 8281 \qquad \alpha_4 = 35° \ 53'$

$m^2_{V_{III}} \approx 12506 \qquad \Delta\alpha_{3-4} = 181° \ 56' \rightarrow \cos = -0.99943$

$2 \cos = -1.99886$

$V_{III} = \frac{1}{2}\sqrt{S_3^2 + S_4^2 - 2S_3S_4 \cos\Delta\alpha_{3-4}} = \frac{1}{2}\sqrt{3371\,336\,429 + 3315\,231\,900} = \frac{81771.4}{2} = 40886$ m./h.

DETERMINATION OF MEANS OF MEANS AND STANDARD ERROR

I . 40788 . . .
. 40588 .
II . 40388 . . . . 40613 m./h. = $\frac{40613}{1852}$ = 21.929 n.m./h. = V
. 40637 .
III . 40886 . .

$m^2_V \approx \frac{1}{16} m^2_{V_I} + \frac{1}{4} m^2_{V_{II}} + \frac{1}{16} m^2_{V_{III}} = 995 + 3313 + 781 = 5089$

$m_V \approx 71$ m./h. = 0.17% of V

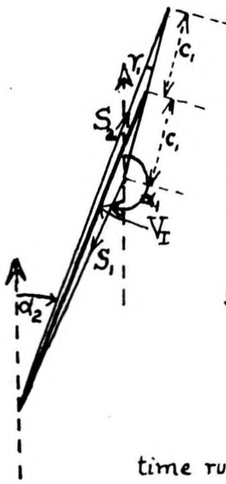
$m_V \approx 0.038$ n.m./h.

V = 21.929 naut. mi/hour (± 0.038 standard error). (0.17% of V)

FORME 2

Computation of current (drift).

Form 3
SAMPLE COMPUTATION



Combination runs 1 & 2

time run 1 $12^h00 - 12^h10$

time run 2 $12^h25 - 12^h35$ mean time 12^h17^m

$$c_1 = \frac{1}{2}\sqrt{S_1^2 + S_2^2 + 2S_1S_2\cos.\Delta\alpha} = \frac{1}{2}\sqrt{32\,337\,983} = \frac{5690}{2} = 2845 \text{ m./h.}$$

$c_1 = 1'.54/h.$

$\alpha_2 = 36°25'$

$\sin.\gamma_1 = \frac{S_1 \sin.\Delta\alpha}{2c_1} = 0.19631$ $\qquad \gamma_1 = 11°19'$

Direction of drift $= 25°06'$

Combination runs 2 & 3

time run 2 $12^h25 - 12^h35$

time run 3 $12^h48 - 12^h58$ mean time 12^h43^m

$c_2 = 1'.74/h.$ Direction of drift $= 24°18'$

Combination runs 3 & 4

time run 3 $12^h48 - 12^h58$

time run 4 $13^h14 - 13^h24$ mean time 13^h06^m

$c_3 = 2'.02/h.$ Direction of drift $= 26°14'$

FORME 3