GENERAL INFORMATION ON THE DECCA METHOD OF SHIPS ACCEPTANCE TRIALS

by J. Th. VERSTELLE
Senior Civilian Hydrographic Officer
Hydrographic Office Royal Netherlands Navy
May 1963

1. — General remarks

1.1. — Strictly speaking, acceptance trials of ships do not fall under the category of hydrographic surveying. However, as radio position fixing is used for these trials, they are — just as hydrographic surveying — a precision application of radio aids. Consequently this type of trial must be considered as of interest to hydrographic surveyors.

1.2. — In this paper, the scheme of the operational procedures and the principles of the computation methods will be described.

In another paper, entitled " Rigorous adjustment of Decca speed runs ", an example of computation as well as actual accuracy figures will be given.

1.3. — In acceptance trials, use is made of *differences* between successive (Decca) fixes. From a mathematical analysis of these trials, it is therefore possible to draw conclusions only as to relative accuracy of the radio fixes; no information as to absolute accuracy can be derived from such trials.

2. — Introduction

2.1. — It was for the first time in 1952 that Group Captain E. FENNESSY, a director of the Decca Co., drew attention to the capabilities of the Decca Navigator System as an aid for determining speed and manœuvrability of ships. In the beginning, the method — in its simplest form — was applied to only a few British ships.

2.2. — In the Netherlands, Decca speed determinations started in 1953 with a number of ships of the Holland America Line. The observational and computational methods were — together with the results — published in references (1), (2) and (3).

2.3. — In the course of years, the operational procedures were only slightly changed, but simpler and speedier methods were developed as described in references (5) and (6).

An ever increasing number of ships (mainly British, Dutch, Danish, Belgian, Norwegian and German) gradually changed over from the measured mile to the Decca method, especially when the whole of Western Europe became covered by the Decca system. It also gradually became standard practice to include turning circles and stopways in every acceptance trial program.

2.4. — For the advantages of the Decca procedure (and, in principle, of any other radio position fixing system) over the measured mile, reference is made to (1), (2) and (3).

3. — Purpose and required accuracy

3.1. — *Speed*

3.1.1. — Speed V through the water is required, but this speed cannot be measured directly with sufficient accuracy.

On the measured mile, as well as with radio position fixing systems, only ground speed S can be measured and the effect of current, tidal stream, wind and waves has to be eliminated from a proper combination of a number of runs on opposite courses.

After elimination, the speed V is used for calibration of the Sal — or other log.

3.1.2. — To the navigator, the speed through the water in relation to propeller revolutions is of direct practical importance.

For reasons of economy, the shipowner, the shipyard and the model testing basin are, however, interested in V in relation to Shaft Horse Power = S.H.P., Fuel Consumption = F. C., and rotations per minute = r.p.m.

All these parameters can be measured only within certain limits of accuracy.

3.1.3.— The general opinion is that S. H. P. and F. C. cannot be measured with an accuracy of better than 1 % (standard error = 68 % probability) and there are indications that unavoidable systematic errors in these measurements probably exceed 1 %, even with carefully calibrated equipment. Engine revolutions (r.p.m.), on the other hand, can be measured accurately within a fraction of a percent.

In properly planned and carried out speed trials, it will always be possible to eliminate the effect of current and tidal stream with an accuracy considerably better than 1 %. The accuracy with which the effect of wind and waves on the speed can be eliminated is dependent on circumstances and on the size of the ship, speed, course, etc., and no general figure can be given. Under very bad conditions, these effects cannot be eliminated with an accuracy of better than a few percent. Under reasonable conditions however, the errors in speed due to these effects can be kept within 0.2 % or less.

3.1.4. — Although there seems therefore to be little practical need to determine S with an accuracy of much better than 1 %, it will always be of advantage when one of the many parameters — S — can be determined with a higher accuracy.

Practical accuracy figures — assuming that a sufficient number of runs has been made to eliminate the disturbing effects — are 0.1 % to 0.3 % on the measured mile (see references (7) and (8)), 0.1 % to 0.3 % for Decca speeds during daylight and 0.2 % to 0.5 % during the night. (All these figures are standard errors under reasonable conditions of sea, swell and wind).

3.2. — ***Turning circles***

Knowledge of the radius of the turning circle to port and to starboard is of great practical importance to the navigator for purposes of manoeuvring, berthing and avoiding collisions. He should preferably know these radii under various conditions of loading, wind and state of the sea. This information cannot be obtained from trials on the measured mile.

It is sometimes claimed that the radius should preferably be determined with an accuracy of the order of, say, 10 metres or even a few metres.

I do not consider such high accuracy claims to be realistic. In actual practice, the only possibility for an accurate determination occurs during the acceptance trials and the radius deducted from a trial will therefore be valid only under the circumstances prevailing during that trial. In the practice of navigation the actual radius may — dependent on state of the sea, etc. — differ probably as much as 10 % or more from that determined during the acceptance trials. There seems therefore to be little practical need for aiming at extreme accuracies.

The effect of current and tidal stream on the radius can easily be eliminated from Decca turns (see section 4). The effect of wind and waves cannot be eliminated by any system, but certain properties of a particular ship (such as for instance a tendency of heading into the wind) can be shown from properly planned Decca turns (see section 4).

Under reasonable conditions of wind and sea, Dutch experience with Decca turns in daylight has an accuracy of radius of the order of 10 metres, which is considered to be more than accurate enough for the purpose. Decca pattern instability during the night is too large to permit measuring turning circles at night.

3.3. — ***Stopways***

For many ships of various nations it has become a standard procedure to determine stopways, usually crash-stops only.

It is general practice to determine the length of the stopway from Decca fixes at intervals of 10 or 15 seconds during the period of predicted slack water. These trials are usually carried out in-between the speed runs, from the preliminary results of which the actual time of slack water can be determined.

In principle it would of course be possible to eliminate current effect from stopways on opposite courses. This procedure would increase the accuracy, but would cost considerable time. It is felt that there is no real practical need to increase the accuracy of between 1 and 5 % that is obtainable from a single stop-run, carried out around the time of slack water.

Night-time instability of Decca patterns limits the determination of stopways to the daylight period.

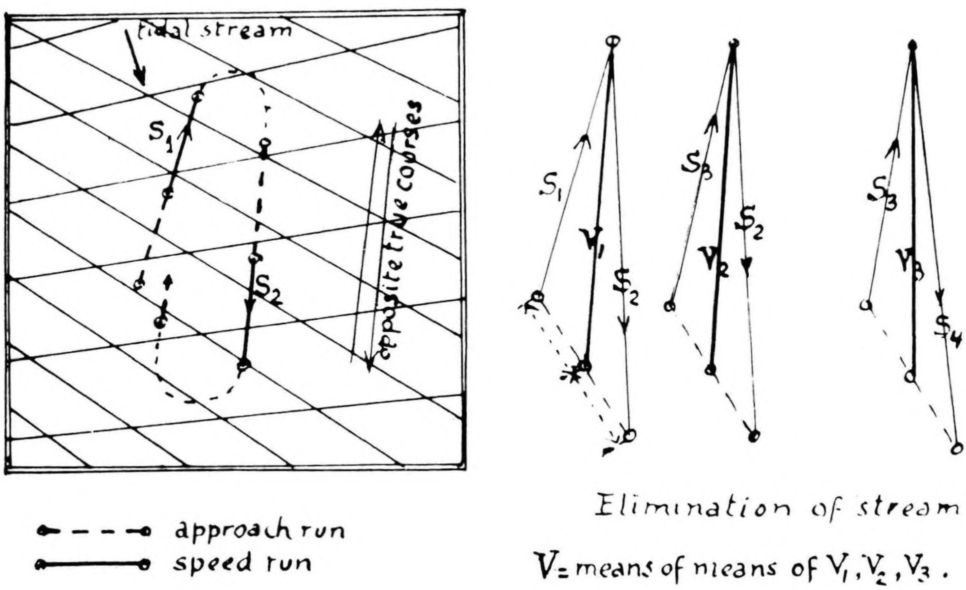

FIG. 1

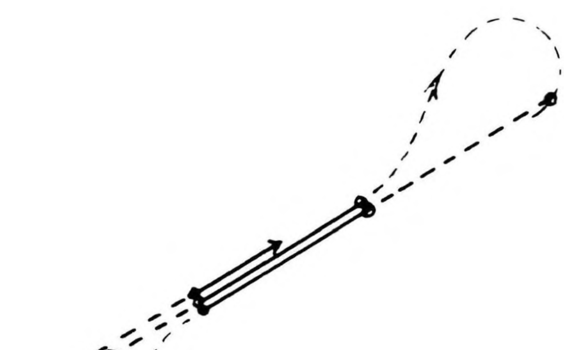

FIG. 1a

3.4. — ***General***

From the point of view of the hydrographic surveyor, the speed determinations are the most interesting because their accuracy is highest and can be mathematically proved.

4. — Programme of observations

4.1. — The programme in use since 1958 has been described in references (5) and (6). For those not disposing of this publication, a short summary will be given.

4.2. — The programme of speed determinations is illustrated in figure 1. A standard speed run takes 9 minutes = 540 seconds. At intervals of 30 seconds, 19 photographic recordings of the decometers and of a running stopwatch are taken (fig. 2). After a turn with rudder angle of 5° and a new approach run of 10 minutes, a similar run on opposite course is made. It is essential that the two runs are made at exactly opposite true courses; any error therein (for instance due to compass errors) will introduce cosine errors in the speed (consequently small errors are acceptable).

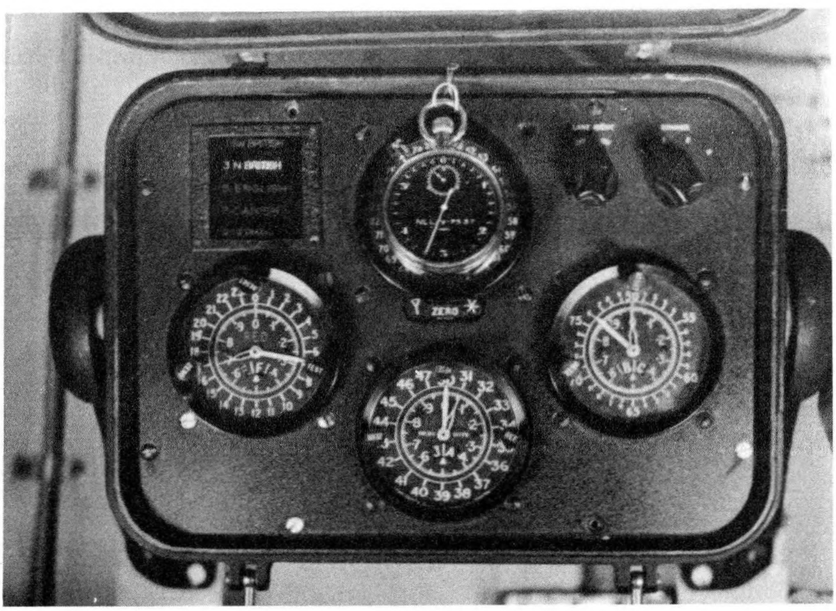

FIG. 2

As the strength (and, to some extent, also the direction) of the tidal stream is variable, these effects cannot be accurately eliminated from only 2 runs. At least a third run on opposite course is required and preferably a fourth one. It can be shown that the effect of (a not too abnormal) tidal stream can be eliminated to within 0.1 % of speed from 4 runs on opposite true courses, and with slightly less accuracy from 3 runs. It is essential that the runs be made as soon as possible one after another. The elimination of the tidal stream will of course become uncertain when the intervals are too long. In the Decca procedure, approach runs take 10 minutes, a speed run 9 1/2 minutes and a turning circle at 5° rudder angle 10 minutes. A complete set of 4 runs therefore occupies about 2 hours.

Some people are of the opinion that all runs should be made on the same spot, like on the measured mile, the argument being that this procedure would offer the best possible guarantee of equal tidal stream regime. This argument will hold definitely for trials on the measured mile, because near the coast the tidal stream may vary considerably with distance from shore. The procedure of coming back to the same place however requires more time for turning circles and approach runs (fig. 1a) and, because of the longer intervals between the successive runs, increases the risk of incomplete elimination of the tidal stream. Decca trials however are carried out in open sea, where the difference in stream will be small over comparatively large areas. Under these conditions it seems more advantageous to save time than to lose it by trying to get back to the same spot.

The photographed running stopwatch enables the application of corrections in case the interval occasionally differs from 30 seconds. With some experience, this will happen very seldom and I know of only one case of Dutch trials where a correction had to be applied.

The number of 19 fixes is not essential. We arrived at that number because — with some precaution — 38 pictures (2 runs) can be taken on a normal 36 exposure 35 mm film. Of these 19 fixes, 17 are redundant and thus enable an accurate determination of a mean value.

In principle one is free in the choice of the opposite courses. Using hyperbolic or circular radio position fixing systems, it is however advantageous to steer on courses roughly in the direction of the small axis of the error-ellipse of the system — because the effect of position fix errors on the speed will then be as small as possible (the effect of fix errors perpendicular to course has a secondary effect only on speed) ; see figure 3.

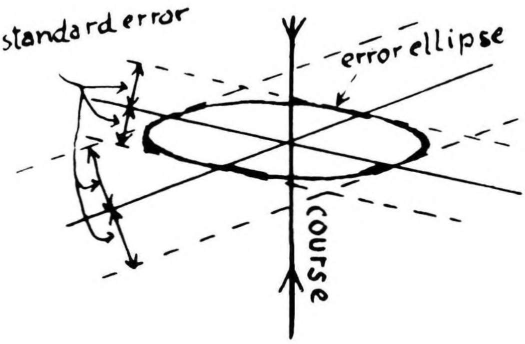

Fig. 3

4.3. — Figure 4 is an example of an actual Decca turning circle and illustrates the procedure of elimination of the tidal stream and/or current.

It gives a good idea of the accuracy normally attained under reasonable conditions of sea and wind.

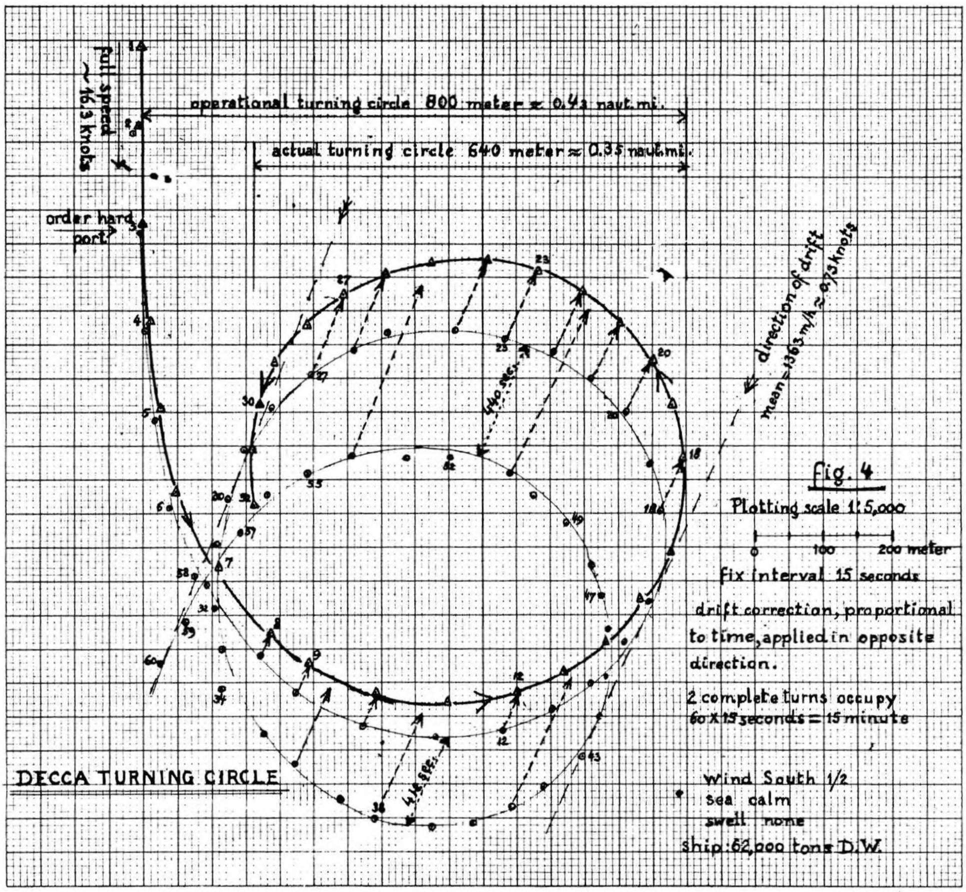

FIG. 4

Figure 5 (completed by figure 5a) is an example of a ship with a tendency of heading into the direction of a strong wind, resulting in a flattened turning " circle ".

4.4. — Figure 6 is an example of a crash-stop, taken in-between speed runs from which the time of slack water could be determined.

4.5. — It is absolutely essential that specially calibrated Decca receivers be used for the purpose of these trials.

Navigational receivers have small errors, that are perfectly acceptable for navigation, but unacceptably large for any sort of precision application. In addition, on navigational receivers, kicks of a few hundredths of a lane are produced by the MK 5 and still more by the MK 10 lane-identification transmissions and consequently the photographed decometers might be several hundredths of a lane out of their proper position.

The instrumental accuracy of these specially calibrated and kick-free receivers is 0.01 of a lane.

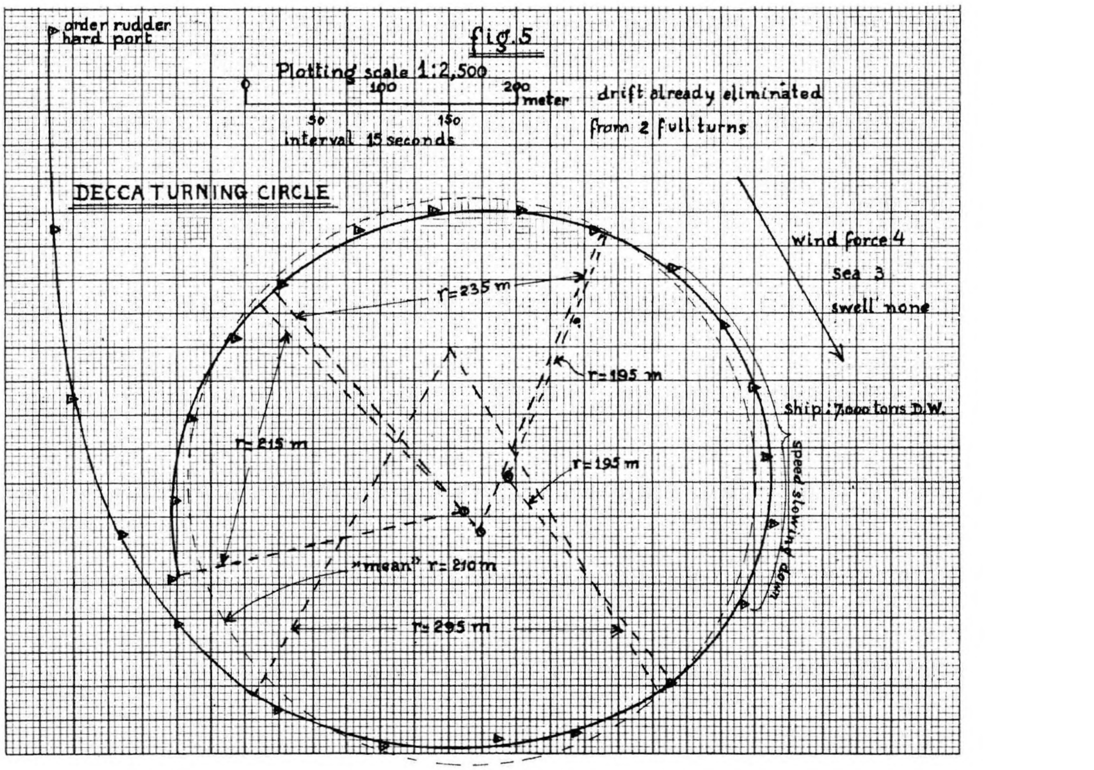

FIG. 5

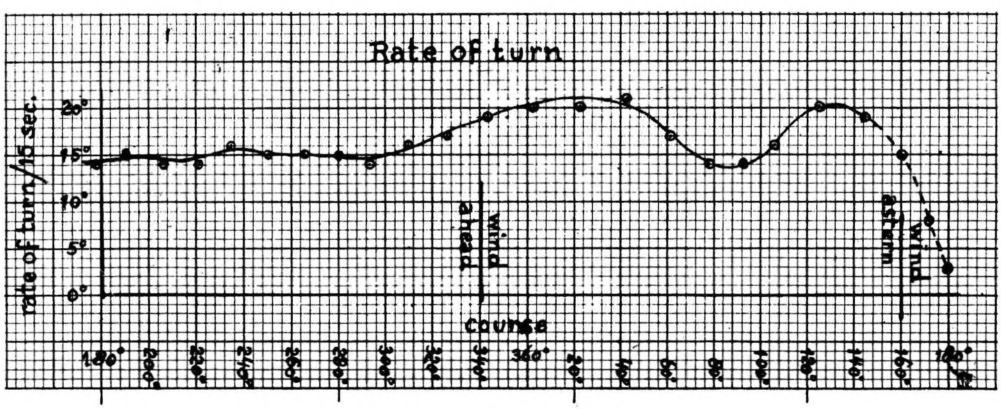

FIG. 5a

4.6. — Indirectly, the yard-stick of measuring the ship's speed is the propagation speed of the radio waves. This speed is known with an accuracy of the order of 1 part in 10 000 and in most cases considerably better. Any systematic errors in ship's speed because of uncertainties in propagation speed are therefore of completely negligible magnitude.

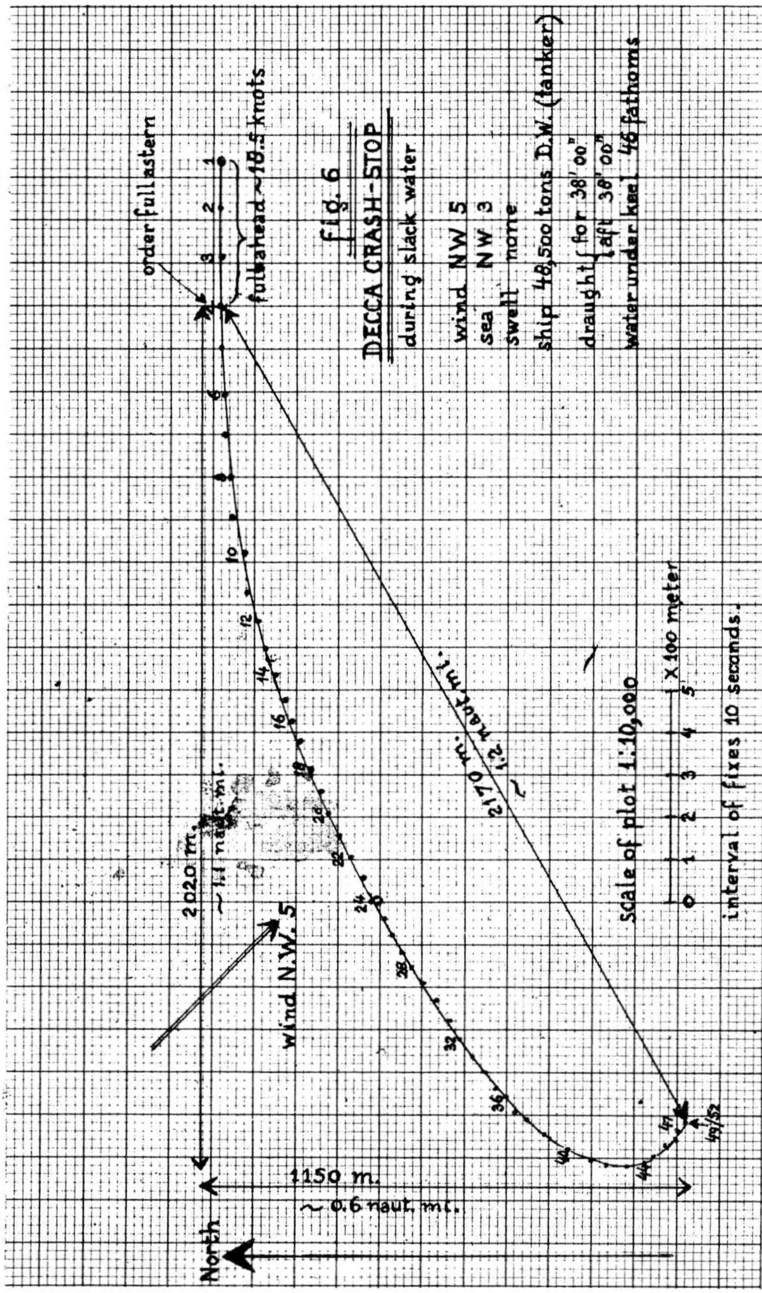
order full astern
full ahead ~ 18.5 knots
fig. 6
DECCA CRASH-STOP
during slack water
wind NW 5
sea NW 3
swell none
ship 48,500 tons D.W. (tanker)
draught for 38' 00" aft 38' 00"
water under keel 46 fathoms
2170 m. ~ 1,2 naut. mi.
2020 m. ~ 1.1 naut. mi.
wind N.W. 5
1150 m. ~ 0.6 naut. mi.
North
Scale of plot 1:10,000
X 100 meter
interval of fixes 10 seconds.

FIG. 6

4.7. — "Fixed errors" as applied for navigation (and given in the Decca Data Sheets) need not be applied for the purpose of acceptance trials, because only *differences* in position are used.

Strictly speaking, they should — because of the changing width of lanes — be applied, but the fixed corrections are small enough to permit the neglect of this effect in comparison with other uncertainties of larger magnitude.

4.8. — A programme of a large tanker is usually as follows.

a) 4 runs at full S. H. P.
b) 4 runs at 3/4 S. H. P.
c) 4 runs at 1/2 S. H. P.
} maximum draught

d)
e)
f)
} same programme, half-loaded

g)
h)
i)
} same programme, empty ship

Note. In order to save time, the number of runs for half-loaded and empty ship is sometimes reduced to 3 or even to 2, accepting the reduced accuracy.

j) 2 complete turning circles to port and to starboard
k) 2 crash-stop runs
l) 1 run for determining steering capacity

Including a few additional trials, the total number of runs of large tankers often amounts to as many as 50. The more important ones are taken during the day and for the others the reduced night-time accuracy (0.5 % of speed, or better) is accepted.

4.9. — Plots of speed against S.H.P., against F.C. and against r.p.m. give a good impression of over-all accuracy. In a number of cases it has been possible from these plots to detect systematic errors in either S.H.P. or F.C., for which errors the method of speed determination had originally been blamed. An example is given in figure 7.

4.10. — Apart from other limitations, many measured miles have become increasingly unsuitable for speed trials because of insufficient depth of water for the large draught of present-day big tankers.

The number of areas where Decca trials can be carried out is however also limited, in the first place to those covered by the Decca navigation chains. In addition, for the purpose of accurate acceptance trials, the areas should simultaneously fulfil the following conditions.

a) Depth of water in relation to draught of ship and speed should be large enough. In references (5) and (6) a diagram is given to determine the limitations; this diagram is annexed to this paper as figure 8.

b) The area fulfilling condition a) should have a "good" Decca coverage in the sense that the propagation conditions between transmitters and ship (especially for night trials) are reasonable, that the lanes are not

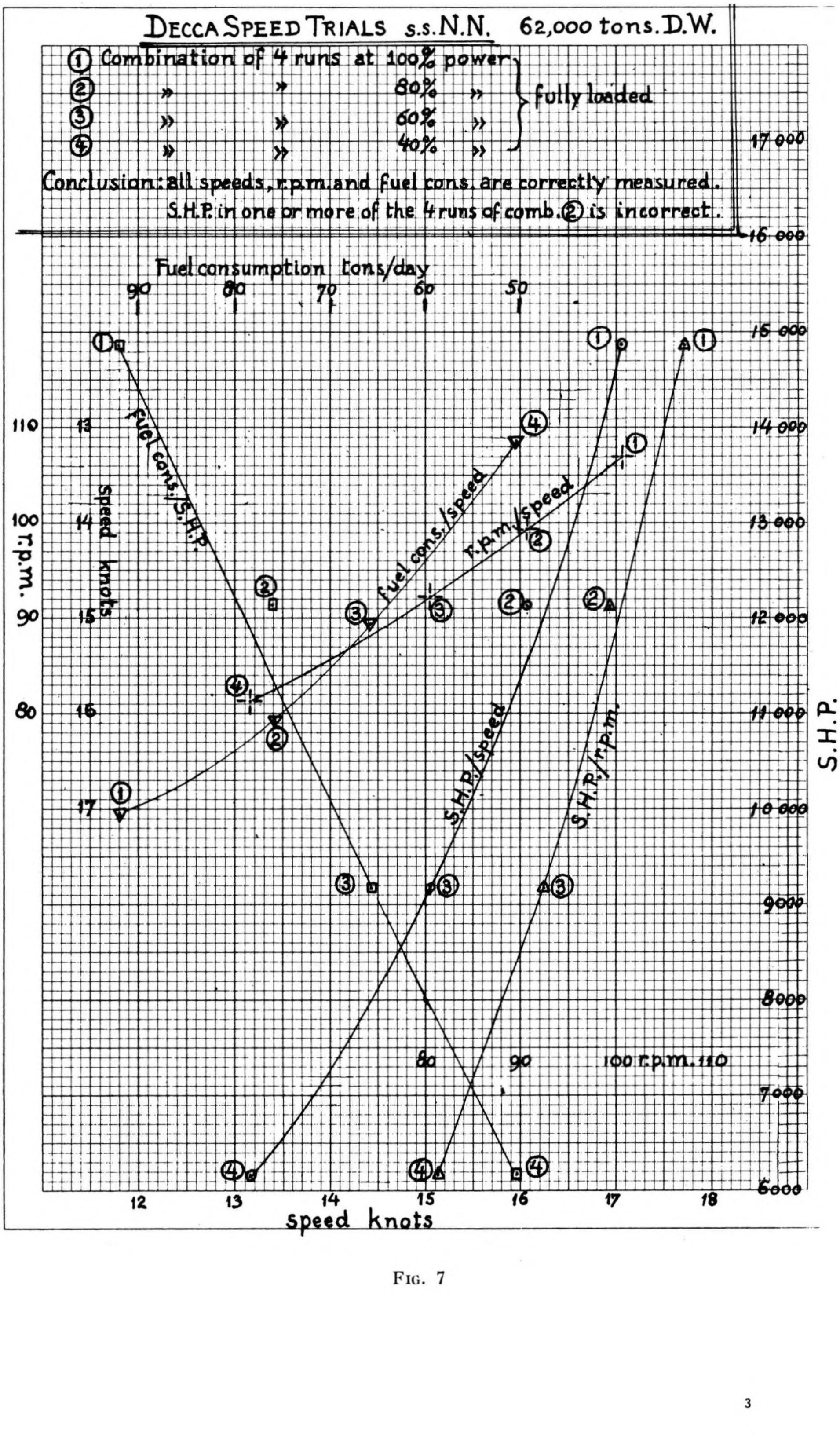
DECCA SPEED TRIALS s.s. N.N. 62,000 tons. D.W.
① Combination of 4 runs at 100% power
② » » 80% »
③ » » 60% »
④ » » 40% »
fully loaded
Conclusion: all speeds, r.p.m. and fuel cons. are correctly measured.
S.H.P. in one or more of the 4 runs of comb. ② is incorrect.
Fuel consumption tons/day
fuel cons./S.H.P.
fuel cons./speed
r.p.m./speed
S.H.P./speed
S.H.P./r.p.m.
r.p.m.
speed knots
S.H.P.
100 r.p.m. 110
speed knots

FIG. 7

excessively wide and the angle of cut of the hyperbolae does not fall below, say, 30°.

c) That the area is within reasonable distance from as many shipyards as possible.

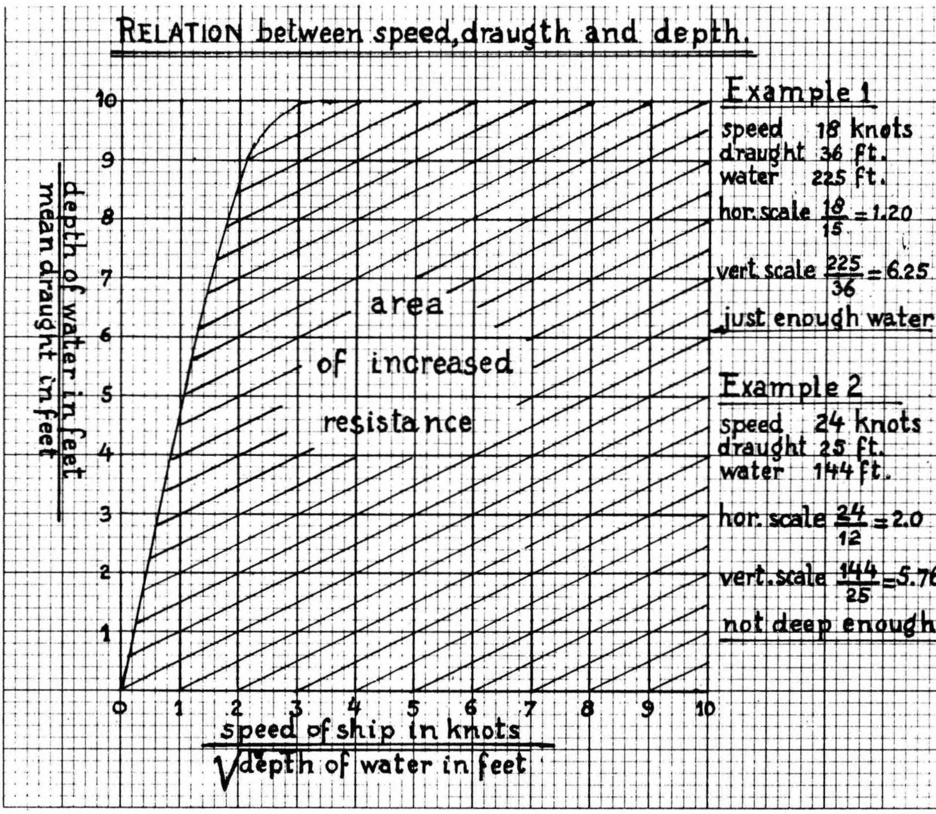

FIG. 8

The depth of water is the main limitation in N.W. Europe and still-existing minefields pose other limitations. Nevertheless, a sufficiently large number of areas fulfils all the conditions for the largest and fastest ships, and a much larger number of areas is suitable for smaller ships.

4.11. — It is sometimes claimed that the ultimately sought speed V through the water can be measured in a much more simple way by throwing a float overboard and measuring the time it requires to pass along a certain known distance on the deck of the ship. The method is indeed very simple, but in a separate paper, to be published later, it will be shown that the accuracy of this method can never be better than 5 % of speed and may easily be as much as 7 % in error.

4.12 — In principle, speed through the water can also be measured directly by using a floating buoy, equipped with a transponder beacon, to which the distance is continuously measured by the travelling ship by means of suitable radio distance measuring equipment. This method has been used in the United States; reference is made to it in (9).

For various reasons (among them that the variation in wind and current drift of ship and floating buoy will be variable under different conditions of wind, etc.), I do not believe very much in the absolute accuracy of speed determination by this method.

This method will be the subject of a separate paper, to be published later.

5. — Analysis of results

5.1. — In the very beginning, Decca fixes of acceptance trials were plotted on large scale nautical charts or photographic enlargements of them. The method soon proved to be far less accurate than the inherent accuracy of the position fixing system.

Plotting was from then on carried out on large scale charts, specially computed and plotted on dimensionally stable plastic material. In order to keep manageable dimensions of the charts of the trial areas, the scale was usually between 1 to 25 000 and to 20 000 and in some cases larger. In a few cases, this method is still in use.

Its inconvenience is that the accurate plotting of a large number of fixes is quite time-consuming and that the accuracy is limited. Perhaps a more serious limitation of the plotting method for the determination of *speed*, is that there are no graphical methods to determine its most probable value accurately from the 19 available fixes; in other words : there is no graphical method to make the most profitable use of the 17 redundant fixes in each run; any decision from a plot as to the final mean speed is no more than a reasonable guess, of which the accuracy remains unknown.

5.2. — It is for these reasons that the analysis of the first Netherlands trials (1953) was based on a least square adjustment of the 19 fixes in each run. Such a least square adjustment is in fact a mathematical model of the speed run, from which the most probable speed S as well as its standard error can be *computed*. A description and example of this method is given in a separate paper entitled "Rigorous least square adjustment of Decca speed runs".

At that time (1953) the least square adjustment had to be carried out on an electric desk computer and proved to be impractical as it took far too much time (1 1/2 hours for 1 run).

It was for this reason that a set of tables was computed by me for each of the trial areas which very much facilitated and speeded-up the conversion of the hyperbolic Decca coordinates into rectangular coordinates X, Y. With a hand-operated double Brunsviga computer this conversion could be carried out on board the trial ship; the conversion of each Decca fix into X, Y took less than a minute. The method has been described in detail in references (5) and (6). The computational accuracy was 1 metre and plotting sheets were no longer needed.

At the same time a much faster method of *approximate* least square adjustment was developed; see examples in references (5) and (6). The results of this approximate method were compared against a rigorous adjustment of 10 runs and proved to be very nearly the same.

Later it was discovered that the approximate method offered sufficient accuracy only for daytime runs (small spread of Decca fixes). For night runs the final *speed* proved to be still sufficiently accurate, but the standard errors, in a number of cases, proved to be too large.

At the time when this was discovered (1960), an ever increasing number of large tankers were making their acceptance trials on Decca and many of them wanted to make as many as 50 trial runs, usually half of them during the night. Even the approximate adjustment was beginning to take more time than seemed desirable, and in addition it now became desirable in any case to use a rigorous least square adjustment for the night runs; altogether, this would increase the total time required for the computations to an undesirably large number of days.

5.3. — The question was therefore raised whether it would be possible to change over completely to electronic computation. The main advantages would be :

a) Computing time would be reduced from many days to a few hours (assuming that an arrangement could be made for negligible computer waiting time).

b) Conversion of hyperbolic Decca readings into rectangular coordinates, a rigorous least square adjustment of *all* speed runs and the computation of standard errors could be carried out to any desired degree of computational accuracy.

c) Allowing for time required for typing out the results and the report, the final results of the acceptance trials could be made available to the ship, shipyard, shipowner, etc., within a few days.

d) The location of the trials would no longer be strictly limited to the relatively small areas for which either large scale charts or tables had been prepared.

e) The people charged with the task of computation on an electric desk calculator, could use the many days required for this work for more profitable tasks.

Formulae suitable for programming the electronic computation had to be developed. The derivation of these formulae and an example of a rigorous least square adjustment of a speed run (in a form suitable for computation on an electric desk calculator) are given in a separate paper : "Rigorous least square adjustment of Decca speed runs". The conversion of hyperbolic coordinates in a form suitable for electronic computation is discussed in another separate paper : "(Electronic) conversion of hyperbolic into rectangular coordinates".

The actual programming of the computer depends on the type, and is not given in these papers, being of little direct interest to the surveyor. For those who are interested, refer to (10) and (11).

5.4. — Since 1961, all Netherlands, and some foreign, Decca acceptance trials are electronically computed on the X 1 computer of the Ship Model Testing Basin at Wageningen, in the Netherlands. The typed-out computational results can always be made available in 1 day (computing time for each run, including standard error, is about 3 minutes).

6. — Closing remark

Provided proper procedures and receivers are used, the accuracy of the Decca method is very much higher than one might expect from a *navigational* aid. Actual figures will be given in the paper " (Electronic) rigorous least square adjustment of Decca speed runs".

Because of the accurate capabilities of the method, it is essential that accurate computational methods be used.

References

N = in Dutch
E = in English
F = in French

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