# CHRONOMETER AND NAUTICAL ALMANAC

by

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*(Translated from the German).*

## I. *THE CHRONOMETER.*

It is well known that the first serviceable marine clocks date from about the middle of the XVIIIth century, and it is rather remarkable that with the invention of the chronometer escapement by Earnshaw in the year 1790, the internal and external appearance of the chronometer as it is to-day became more or less fixed. Aside from the chronometer escapement still in use to-day, there were the cylindrical springs, the bimetallic balance, the fuse and train, the detent, the winding-telltale, cardan suspension, etc. that is, all the essential appurtenances of the modern chronometer were already extant. In the course of the next century and a half, little change was made either in their construction or their external appearance. The numerous experiments conducted during the XIXth century with compensating balances to eliminate the so-called secondary error, were surpassed by the invention of the nickel-steel balance by the Swiss C.E. GUILLAUME in 1898, as a result of which the old steel-brass balances in the German chronometers were entirely discarded. The chronometer rates then attained fully sufficed for maritime requirements — particularly after the introduction of radio time-signals — and it seemed that no further improvement was possible. After the War, the opinion was frequently expressed in nautical circles that in future, in view of the increasing number of radio-stations broadcasting time signals and the resultant accuracy attainable, the pocket watch should suffice. But the ship's safety requires that a more reliable time-keeper than the pocket watch should be available on board, since one must reckon from time to time on the impossibility of obtaining time signals. Therefore, in collaboration with the Seeberufs-Genossenschaft (Seafarers Association) the *Seewarte* several years ago drew up the following specifications for chronometers :— the precalculated error of the chronometer after an absence of all time signals for ten days shall not show a discrepancy of more than $\pm$ 2 seconds. This is better than the performance of any pocket — or observation-watch. This concept of the indispensability of the chronometer has been fully subscribed to by the navy and merchant marine of to-day. Also the conviction that there should be at least two chronometers on board, either for purposes of comparison or for possible replacement, is again coming to the fore.

However, in view of the changed conditions and requirements, the external appearance and the internal construction of the chronometers to-day stand in need of re-examination. At the time of the industrial crisis, the tendency was toward the possibility of meeting these requirements through simplifying the construction and a reduction in manufacturing costs based on modern industrial processes. For several years tests on pocket watches at the *Seewarte* had demonstrated the fact that the old anchor escapement, invented in the year 1765 by the Englishman Thomas MUDGE and used in the finest pocket watches, was definitely superior to the chronometer escapement. It appeared, therefore, that experiments might be conducted to determine whether the results obtained with watches could be realized on the scale of the box chronometer. At the same time the advantages of greater reliability of the escapement and the lack of sensitivity to careless handling, particularly when transported, should not be overlooked. A cheapening could be accomplished by discarding the fuse and train, by the simultaneous transformation from a 56 hour (2-day) running period to a 36 hour (1-day) period, and also the suppression of the winding indicator. A questionnaire sent out by Professor STEPPES of Hamburg in the Spring of 1933 to the maritime associations regarding the chronometer appliances (in particular the winding indicator and running time) brought interesting results and general approbation. In the same year these considerations instigated an order for a new style of chronometer to fulfil the following requirements :— Anchor movement of the same size and construction as the previously employed balance and spirals; with a 36-hour running period instead of 56 hours, with the fuse and train eliminated, and further with a hand-setting device on the side so that the glass cover need not be unscrewed to set the hands. However, an effort was to be

made to find a simple substitute for the winding indicator, (tell-tale) which would be satisfactory. Further, in this experimental model, provision was made to eliminate the cardan suspension and simply provide a gimbal ring with one axis for winding (passing through XII and VI). The experimental instrument which was completed in the summer of 1934 (A. LANGE & SÖHNE N° 692) was first tested in the autumn and then entered in the 58th competition for nautical chronometers (1934-35). This new chronometer model beat all other chronometers entered and stood at the head of the list with regard to performance. In particular, the variation of mean rate, that most sensitive criterium for the excellence of a watch, was smaller (0.04s) than any figure which had previously been observed except very exceptionally and possibly accidentally. In the 59th competition, the firm of LANGE & SÖHNE delivered another anchor escapement chronometer (N° 691, manufactured at the same time as N° 692, later sold to the firm of F.N. TIETZ, Kiel, with the instrumental designation F.N. TIETZ N° 2029). This sister instrument also showed a variation of rate of 0.04s which was the smallest determined in the 59th competition. Temperature errors and long period changes of rate are therefore independent of the new construction since the dimensions of the balances and spirals and the other works have not been altered. On the other hand the curve of isochronism deserves particular attention. The fuse and train serve the purpose of keeping the force exerted on the escapement as nearly constant as possible; in the absence of these parts therefore a large error in isochronism was not impossible. This fear proved to be groundless in that the tests on the Lange chronometer N° 692 of the rates within the first 30 hours showed variations of not more than 1/10th second from the mean rate. The anchor escapement therefore showed up better than the chronometer escapement. The same was true of the tests with chronometer inclined, in which the performance was not inferior to that of the chronometer escapement.

Even though we must assume that the excellent performance of the first two anchor chronometers might be due in part to the special care exercised in their manufacture, it must still be granted that the course pursued was the right one and that the new types are in no wise inferior in respect to their rates. As a decisive point with regard to their success it must be remembered that the balance and spiral have remained unaltered in so far as their dimensions are concerned, and experience shows that smaller dimensions of the escapement give smaller errors in rate.

With regard to their insensitivity to vibrations, jars, etc., the anchor chronometer is far superior to the previous type, as tests have shown. In spite of severe disturbances the rates of the new chronometers were not affected, while the older chronometers were quickly brought to a stop.

With regard to the necessity for the cardan suspension, tests have been conducted to determine the influence on the rate of periodic inclinations. For the artificially produced inclinations, values have been chosen which far exceed those likely to be encountered at sea. The numerical data obtained from these tests indicate that no great changes in the rates are to be expected. Therefore on all of the larger vessels it will suffice to have one gimbal with axis through the XII to VI direction instead of the cardan suspension, and this axis should be placed in the fore and aft direction as far as practicable. The chronometer is then free of the rolling motion and is subjected solely to the less detrimental pitching movements and also the plunging motion of the ship, (which cannot be avoided in any case) and which acts to increase the rate. These, together with the irregular vibrations and jolts, act to increase the variation in rate over and above the small variation shown when delivered on board. Chronometers to be used ashore should always be fitted with one gimbal only (See Fig. 1).

Experiments have also been conducted along other lines with a view to making the chronometer free from magnetic influences. To-day more and more consideration must be given to the presence of magnetic fields — especially aboard men-of-war. Much may perhaps be gained by making the parts of the chronometer which are readily magnetized, such as the balance, the main-springs, the driving mechanism, screws, etc. out of non-magnetic material. This procedure was some time ago initiated for pocket watches. For the main-springs, a material which was discovered by the German-Swiss Reinhold STRAUMANN and is now manufactured by the Vacuumschmelze Heräus, Hanau, under the trade-name *Nivarox* has been used in innumerable watches as it is not affected by moisture as well as being non-magnetic. For chronometers also, suitable materials are available and are being tested. Similar materials are under consideration for the balances, draw-springs, shafts and gears. Steel screws may be replaced by brass.

The most important constructive problems have already been solved or are approaching a definite solution. It is to be hoped that these improvements will meet with a favourable reception in the merchant marine; they are not so much improvements as simplifications which lead to reducing the costs. It has been found already that the new anchor chronometers are some 200 RM. (75.00 dollars; £ 15 sterling) cheaper than the older type. The manufacturers are: A. LANGE & SÖHNE, Glashütte and the *Chronometerwerke,* GmbH, of Hamburg.

Up to now we have not touched upon the question of the change in the form of dial for the transition from readings in hours to degrees. The *Journal suisse d'Horlogerie* in November 1932 described some watches manufactured for aviators at the suggestion of WEEMS and LINDBERGH. The faces of these wrist-watches, which were fitted with the ordinary hands, had dials graduated in degrees and minutes of arc in addition to the usual graduations in hours, minutes and seconds. The *Seewarte* first received a request for this type of chronometer with dials graduated in this manner in January 1935 when the Ephemerides and Altitude-Azimuth Tables were being prepared for aviation and it was desired to simplify the calculation by employing solely degrees as a basis of measurement. The numerous foreign, and particularly the American Nautical Tables in which the tabulation and calculation are based on the use of time-keepers graduated in degrees, are generally well known.

In considering the proposals for the clocks graduated in degrees, the author started with the fundamental assumption that to insure easy reading the old form of graduation of the dial into 60 divisions should be retained. This necessitated the employment of a small indicating pointer to count the revolutions of the large pointer marking degrees, the dial of which could either be graduated to show 180° (12h) or 360° (24h). The arc-minute hand was centrally arranged (Fig. 1, 2, 3), and for experimental purposes it was also excentrically placed as in Fig. 4. Thus there were developed the different types of chronometers and B-chronometers shown in the table, which were given a practical test by the author during a cruise to the West Indies in April and May 1936. The type shown in Fig. 1 proved better than that shown in Fig. 3, since the slowly moving large arc-minute hand is more easily and accurately read on the large dial than on the small, and also better comparisons were obtained with the B-chronometers. Further, on the large dial it is possible to estimate to quarter and even to tenths of a second, which is impossible with the small excentric dial. Also, all chronometers destined for navigational purposes are fitted with the usual time-second hand dial in order to facilitate time comparisons. Since a chronometer showing hours accurately cannot be dispensed with on board and as the 180° chronometer was already fitted with both hour and second hands, further efforts were confined to the perfection of a dial to indicate simultaneously and fully both measures. By adding a time-minute pointer there was developed the arrangement shown in Fig. 4 as the first model of this type. Fig. 5; see also *Seewart* 5, 1936, p. 379 which was the basis for this type. This not very clearly readable dial gave the incentive to find a better solution and the modifications shown in Fig. 6 were next experimentally tried out.

In this the degree and hour readings are entirely separated; the first is indicated by the blue hands in the middle and the latter by the two gold hands on the two excentric dials. The upper dial face, corresponding to that of an ordinary clock, displaces the winding indicator, which in future must be relegated to some less important position. For the rest, every good ship's clock keeps sufficiently accurate time for nautical purposes, particularly if it is compared daily with the chronometers.

The practical and serviceable models of time-pieces graduated in degrees are thus unequivocally determined : either three pointers concentric in the centre, such as the Torpedo-watches in Fig. 2 and 3, or with the addition of a small excentric dial for indicating the seconds in time, (See Fig. 1) to aid time comparisons or, in addition, an upper excentric dial for the hour-minute hands, which means that both types of time indicators are completely separated from each other (Fig. 6 and 7). The 180° graduation then corresponds to the former 12-hour graduations of the chronometer. Some will prefer the 360° graduations (Fig. 3 and 7) : to the advantage of carrying the day's computations right through is opposed the disadvantage of dealing with larger figures. The combined type can also be carried out with the 360° graduations and the excentric 12-hour dial (See Fig. 7).

It should be mentioned also that it has been proposed to the *Seewarte* to develop a clock with dial similar to the usual type of chronometer and with a small oblong opening near the location of the present winding indicator to show directly the corresponding degrees and minutes in clearly legible figures, thus $\boxed{326°57'}$. The arc minute figure must then jump

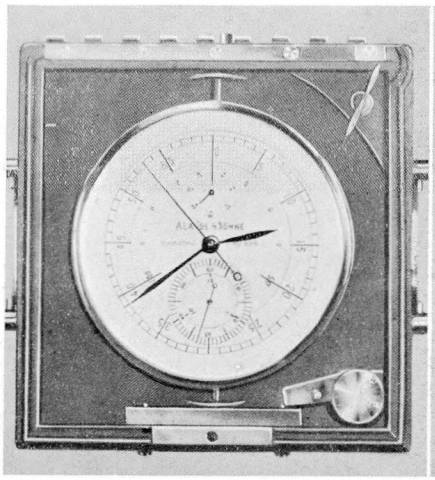


FIG. 1.

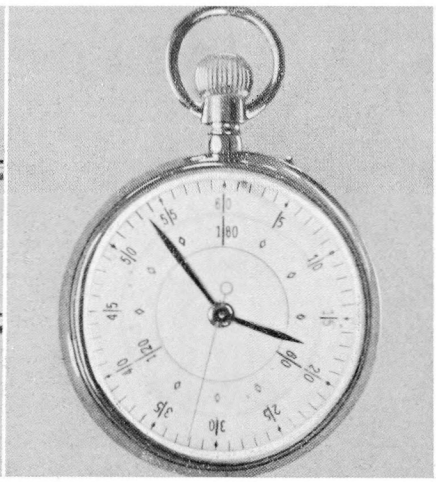


FIG. 2.

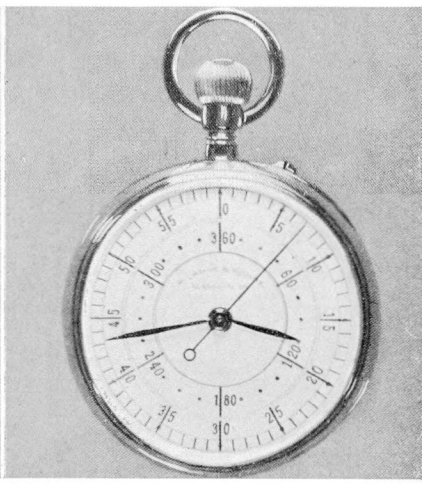


FIG. 3.

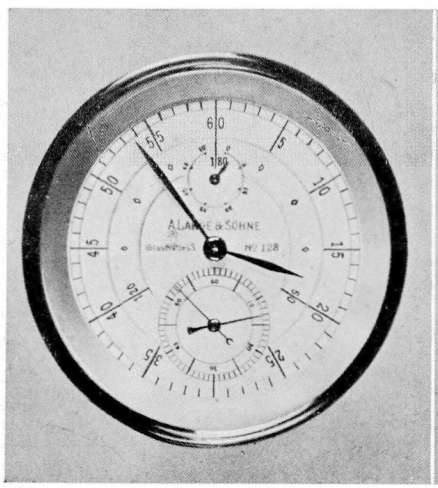


FIG. 4.

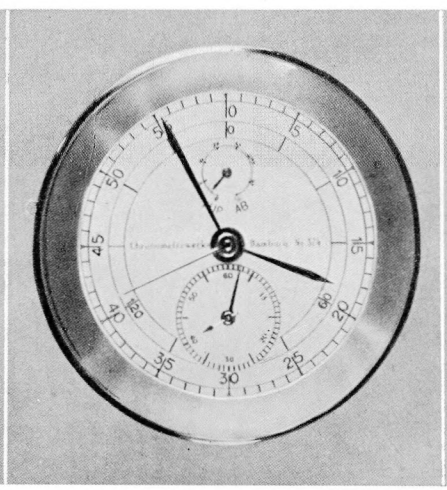


FIG. 5.

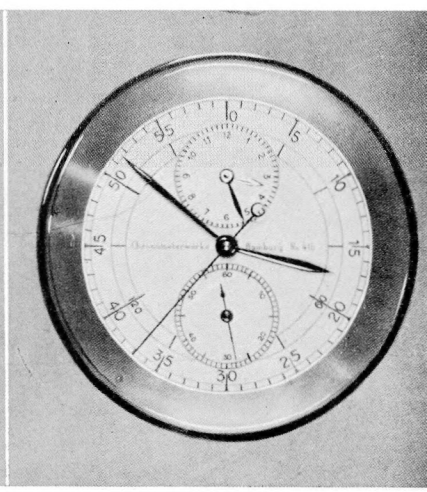


FIG. 6.

ahead one unit every four seconds of time. This undoubtedly very ingenious and beautiful solution cannot be carried out practicallly, however, with the present technical means available in the chronometer, since the work required to shift the figures — in particular where several tens are to be moved simultaneously — is beyond the capacity of the clock-mechanism.

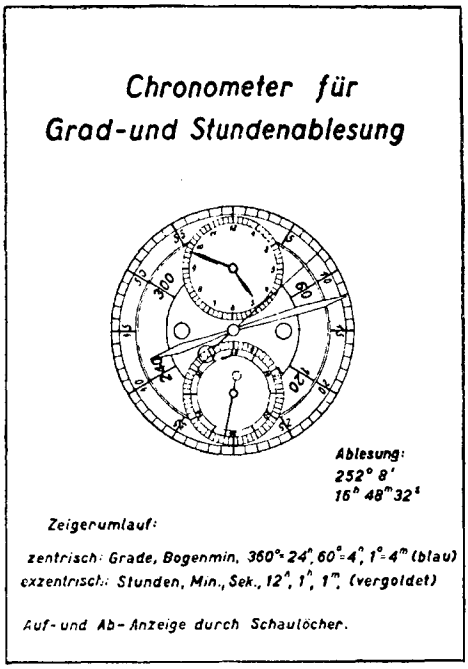



Abb. 7.

FIG. 7.

I have become convinced by frequent tests that the arc graduations into 60 minutes and seconds as proposed above can be easily read by everyone and is at least as safe and certain as the hour minute and second dial readings on the ordinary clock.

The above described technical alterations in the chronometer, in particular the escapement, as well as the new arrangements of the hands, necessitate a completely new construction of the inner works undertaken from some standard view point.

## II. *THE NAUTICAL ALMANAC.*

Inseparable from the development of the chronometer reading in degrees is the question of the preparation of the Nautical Almanac and in particular the transition from the older to the new type of nautical almanacs and chronometers. The standardization of the measures of longitude and latitude necessitates the arrangement of the arguments and functions in degrees, i.e. headings, right-ascensions, equations of time and mean sun must in future be given in degrees. If changes in the Nautical Almanac are to be made these must be restricted to basic and long advanced calculations, owing to the fact that the preparation of the manuscript and the printing must be completed several years in advance. It is therefore essential to make a systematic investigation of the most suitable form for the Almanac.

Above all consideration must be given the fact that, with the introduction of the new Almanac, the greater part of the chronometers in present use in navigation will not, owing to the expense, be replaced by the new chronometers graduated in degrees, or even remodelled, as was done for experimental purposes with several chronometers for the *Seewarte*. One can simply count on the fact that the new "degree" chronometers will come into use only when orders are placed for new instruments, and it is certain that for a decade to come there will be very many chronometers in use having the dial graduated in hours. Therefore

in the new Nautical Almanac which it is proposed to introduce, the arrangement must be such that it can also be serviceable with the old-type chronometer and — if it is to make friends — it must also provide greater facilities in practice.

No difficulties would be encountered even to-day by a Nautical Almanac in degrees, since the calculations involved for the conversion of longitude differences into time intervals has to be done first and therefore, we should instead first have to convert the chronometer time into degrees. It would appear more desirable, however, to provide the Ephemerides with double entry (both degrees and hours). Thus we obtain a new form differing from the previous types of Nautical Almanac. As an example I have reproduced here a section from the Sun Ephemerides for May 1, 1937 (See table below) :

| M.G.Z. G.M.T. | | Abweichung (*Declination*) | Zeitgleichung (*Eq. of Time*) | Mittl. Sonne Ger. Aufst. (*R.A.M.S.*) |
|---|---|---|---|---|
| h | ° | | | |
| 0 | 0 | N. 14° 52.9' | + 43.3' | 38° 30.2' |
| 2 | 30 | 14° 54.4 | 43.5 | 38° 35.1 |
| 4 | 60 | 14 56.0 | 43.6 | 38 40.1 |
| 6 | 90 | 14 57.5 | 43.8 | 38 45.0 |
| 8 | 120 | N. 14° 59.0' | + 43.9' | 38° 49' 9' |

As a result of this form we obtain a standardized method for the calculation of the latitude and longitude, without creating difficulties for the practical calculator. A further improvement in the Nautical Almanac — without altering its basic form — can be made by shortening the calculation of the hour-angle (in that for the moon and planets, instead of the right ascension, the so-called "Schrader" sidereal time equation (m ☉ $\alpha$ — ☺ $\alpha$) is given) and by tabulating the values of 360° — $\alpha$ instead of $\alpha$, as well as the inverse of the sun's Equation of Time (as given in the English and American Ephemerides). In this manner subtraction will be eliminated for all heavenly bodies.

Further, it will also be useful, with the change in the Almanac, to alter the Nautical Tables by eliminating all the arguments in hours, i.e. replacing them by degrees. Thus in *Fulsts* Tables 4 and 7 the double entries would be omitted. The hour-minute-second lacks clearness and gives rise to greater possibilities of error than the degrees and minutes (of arc) tabulation which is repeated on both sides of the page.

When we investigate the possibilities available for the Almanacs, we must distinguish between the contents and the arrangement. These are frequently opposed so that the most favourable method of presentation does not always agree with the best means for giving the contents. With regard to contents three fundamentally different forms may be distinguished.

1. The existing Nautical Almanac, which contains the Equation of Time for the Sun, the Right Ascension of the Mean Sun for the fixed stars and heavenly bodies;
2. The form of the sidereal time equation proposed by C. SCHRADER which combines into one magnitude the values of m ☉ $\alpha$ and ☺ $\alpha$ for the stars; and
3. The form first proposed and carried out in America of tabulating directly the Greenwich hour angle, which involves a combination of the G. M. T. with the Eq. of Time (in its widest sense).

The arrangement of the Ephemerides can be carried out in different ways : in particular by publishing them separately in one volume for the individual stars (American Ephemerides and Nautical Almanac), or combined into a monthly group (Nautisches Jahrbuch), or on the daily pages (everything necessary for one day to be on one page or one sheet) giving rise to the so-called "calendar" form, which is in use for aeronautics as well as being useful for navigation at sea (Aeronautisches Jahrbuch).

For practical purposes the different tabulations can be arranged alongside each other in one and the same almanac. In the following paragraphs we have analysed some of the advantages and disadvantages of the three forms mentioned above :

*Re* 1: The most obvious possibilities of improvement of the nautical almanac (conversion to degrees, Eq. T. for moon and planets also) have been analysed above. The calendar form is possible here also. All data for the sun, moon and planets and the R.A.M.S. come on one page, while the Right Ascensions of the fixed stars are given as at present at the back of the book. If the daily Ephemerides are arranged in this manner, then the Nautical Almanac will be increased from the present size of 184 pages to 365 plus 6 (fixed stars) plus 7 (pole stars) = 378 pages, or in other words about twice the present size. Even if we arranged the fixed stars in some suitable order on the back of the individual pages, the total publication cost would not be appreciably increased, since only the cost of paper would increase, and not the labour of composition. Thus we could provide separate editions for navigation at sea and in the air.

*Re* 2: The SCHRADER proposal to tabulate the element m $\odot\,\alpha$ — $\circledcirc\,\alpha$ for the fixed stars standardizes the calculation of the hour angle of the sun and the stars. The practical benefit is not, however, very great. On the other hand the increase in size of the volume is quite appreciable, if we consider the older form of nautical almanac and keep approximately the same number of fixed stars. SCHRADER provided for tabulating for the fixed stars a daily value of the sidereal Eq. T. (at Greenwich Mean Midnight); in one page of his almanac he hoped to list seven stars alongside each other. With 70 (instead of 80) stars this would mean ten additional pages for each month or a total of 120 pages extra for the year, in place of the four at present. Thus with Schrader's proposal to reduce the number by ten stars the book would still contain about 116 pages extra, or a total of 300 pages in place of the present 184 pages. In all this it should not be forgotten that there will be a considerable amount of interpolation necessary, which can only be shortened to an extent comparable with that involved in the case of the mean sun when the Eq. T. is tabulated for every two hours, i. e. if the size of the ephemerides for the planets and the fixed stars is not to be increased twelve-fold — which is manifestly impossible.

The matter appears somewhat more favourable with the employment of the calendar form, since this in itself necessitates an increase in the scope. But in this case one must either be content with one daily value for the Eq. T. for an adequate number of stars and thus put up with the extra work of interpolation, which again annuls the saving otherwise gained through shortening of the calculations, or else only a few stars can be listed on one page. As alluring as this proposal might seem at first glance, in practice it does not prove to be very advantageous, since it is hardly feasible to double or even quadruple the size and costs of the Nautical Almanac for the sole purpose of simplifying the calculations to a slight extent.

*Re* 3: The direct tabulation of the Greenwich hour angle, if carried out for all stars in a similar manner, as was done in the Air Almanac brought out by the Naval Observatory of Washington, D.C., leads to even greater difficulties than form 2 with regard to the space and the work of interpolation. Either one must publish a number of excessively large volumes or else one must take into account the necessity for interpolation, which again defeats the very purpose of the publication (simplification of hour angle determination) by complicating the calculations. Here also there appears to be no absolute necessity for the employment of the chronometer graduated in degrees in order to obtain a standardization of the measure of latitude and longitude. As IMMLER has shown in the Annalen der Hydrogr. 63, 1935, p. 245, it is only by the employment of degree entries, i. e. using a chronometer graduated in degrees, that it is possible to reduce the interpolations to a point where they are convenient and easily performed. By the employment of a further artificial concept, an extension of the above method in which, instead of tabulating the hour angle of each star, we use only the first point of ARIES (Gr $\gamma\,\tau$ = m $\odot\,\alpha$ + G.M.T.), and further, at the end of the book tabulate the values of 360° — $\alpha$ for each of the fixed stars, IMMLER arrives at the form of the Aeronautical Almanac published for 1937. (This differs from the form given under 1 only by the addition of the G.M.T. to the functional values). From the standpoint of the calculations this is only an apparent retrogression as compared to form 2 and in addition it requires only half the space of the Aeronautical Almanacs for the years 1935 and 1936 despite the fact that the latter only give the data for 14 fixed stars. After careful tests it was found that form 3 is not inferior to form 2, with regard to the labour involved in calculation, and is equal at least to form 1.

One advantage lies in the fact that the chronometer time is not combined, and therefore the employment of the older type of chronometer is admissible without alteration, and further, in the case of the sun, moon and planets, the interpolation prevents the 360° limit of the hour angle from being exceeded. The altered form 1 has the advantage over form 3 that it can be included in the present Nautical Almanac.

Taking into consideration the requirement that the Nautical Almanacs should not have too great a volume, three different proposed forms are tabulated herewith in accordance with contents, which indicate the sequence of the calculations.

| | | *Sun, Moon, Planets.* | *Fixed stars.* |
|---|---|---|---|
| 1 | Altered Nautical Almanac | G. M. T.<br>+ Eq. T.<br>Gr. H. A. | G. M. T.<br>+ m $\odot\alpha$<br>+ (360 — $\alpha$)<br>Gr. H. A. |
| 2 | Schraders Proposal<br>Aeron. Almanac 1935 & 1936 | G. M. T.<br>+ Eq. T.<br>Gr. H. A. | G. M. T.<br>+ Eq. T.<br>Gr. H. A. |
| 3 | American Form<br>Aero N. A. 1937 | G. M. T.<br>Gr. H. A. | G. M. T.<br>Gr $\gamma\tau$<br>+ (360 — $\alpha$)<br>Gr. H. A. |

In cases 1 and 2 for the moon and planets the Eq. T. (m $\odot\alpha$ — $\odot\alpha$) is tabulated : parentheses indicate the addition. In case 1 three values have to be added for the fixed stars. In case 3 the G.M.T., although written down is not added in, but there is a further interpolation which is added in.

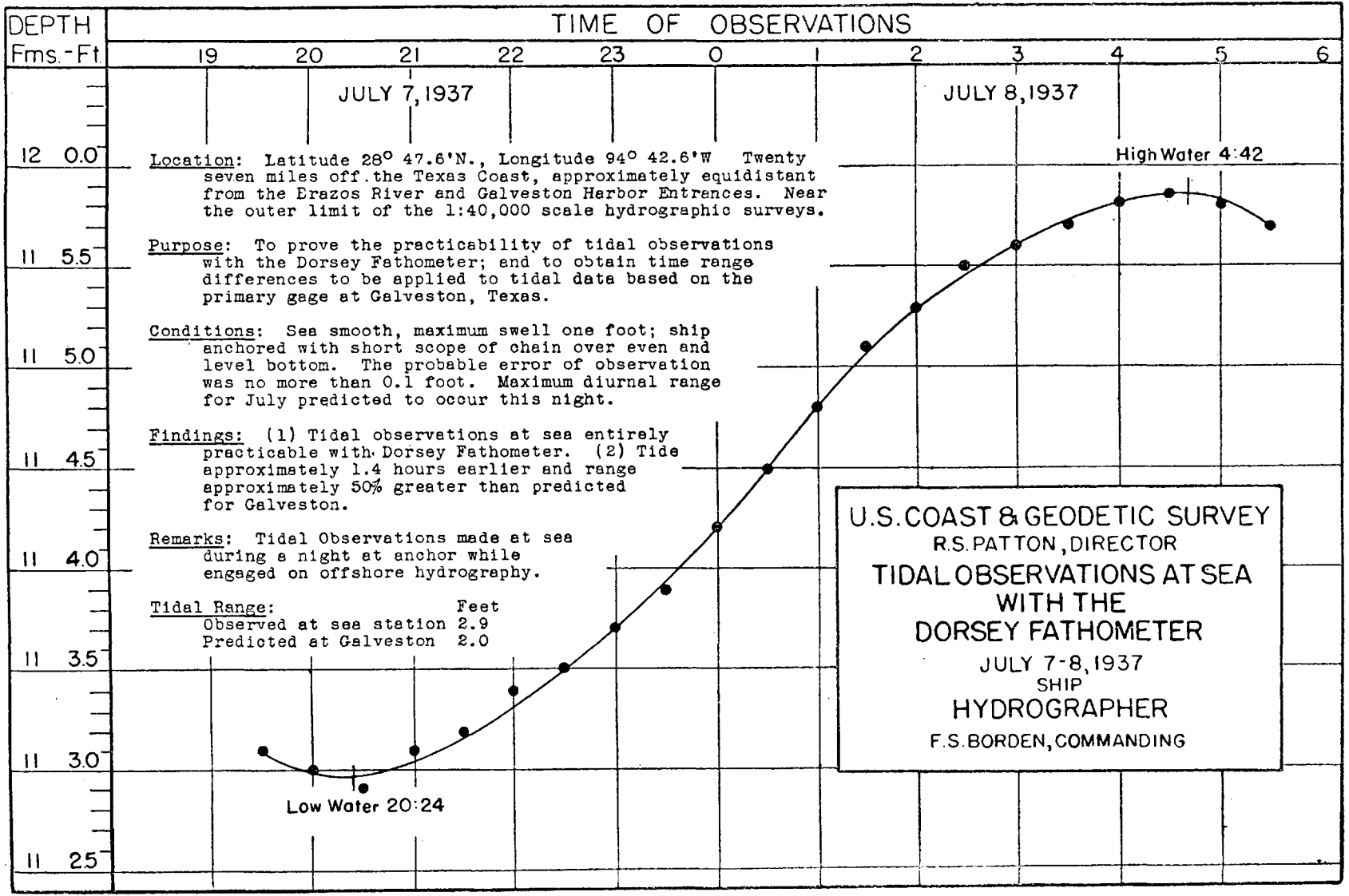
By arranging the projected Almanac in calendar form, an attempt has been made to standardize the form of the Nautical and Aeronautical Almanacs, and this aim may possibly be achieved. Taking into account the old style of chronometer, it is advisable to maintain the double entry of degrees and hours. There are also details to be worked out with regard to the arrangement of the Almanac, such as the most convenient form for the interpolations, which cannot be further discussed here.

A careful examination of the possible forms for the nautical almanacs reveals that there is scarcely any possibility for a further simplification in the calculation of the hour angle — unless it is the Niemann proposal:— pre-setting on the chronometer face the Equation of Time, the Longitude Difference and the error on movable rings on the chronometer. Although the revolutions of the degree pointer on the chronometer involve the addition of only slight mechanical alterations and additions to the chronometer, the Niemann adjustable rings require a very high degree of precision in workmanship and give grounds for the fear that technical difficulties in reading may give rise to errors. Therefore in the introduction of the degree readings on the chronometer, I foresee the practical technical limit in the development of the chronometer.

## *CONCLUSION.*

It now becomes a matter of practical test and demonstration at sea to determine which of the three proposals will be most serviceable and practical. It is to be expected that the standpoint will frequently be taken that the old form has proven serviceable and is not in need of improvement. There is no question but that a standardization of the measures for latitude and longitude will represent considerable progress. For this it will be necessary to be able to read the time intervals in degrees and minutes of arc unless, during the transition period, as outlined above, the conversion is done first. Reading off the time in

degrees presents no difficulties. Time and hour angles are identical concepts; the division of the day into hours is purely arbitrary and, for the purposes of astronomical navigation, a division of the day into degrees is equally feasible. The very important question of the transition from one chronometer to the other, from one form of calculation to the other and from one style of Almanac to another may be considered as solved. We can even go further : even though we retain the old style of chronometer with hourly graduations in combination with a new style of nautical almanac based entirely on degrees, this in itself results in a standardization of the measures and in a considerable simplification and ease in calculation. It can then be left to the shipping concerns, if and when they will adopt the chronometer with graduations in degrees. The question of the introduction of the chronometer graduated in degrees pre-supposes the previous introduction of the Nautical Almanac in which the entries are given in degrees and minutes of arc. With this achieved, the chronometer graduated in degrees will bring about the standardization of the calculations of latitude and longitude.


DEPTH
Fms.-Ft
TIME OF OBSERVATIONS
19
20
21
22
23
0
1
2
3
4
5
6
JULY 7, 1937
JULY 8, 1937
12 0.0
11 5.5
11 5.0
11 4.5
11 4.0
11 3.5
11 3.0
11 25
Location: Latitude 28° 47.6'N., Longitude 94° 42.6'W Twenty seven miles off the Texas Coast, approximately equidistant from the Brazos River and Galveston Harbor Entrances. Near the outer limit of the 1:40,000 scale hydrographic surveys.
Purpose: To prove the practicability of tidal observations with the Dorsey Fathometer; and to obtain time range differences to be applied to tidal data based on the primary gage at Galveston, Texas.
Conditions: Sea smooth, maximum swell one foot; ship anchored with short scope of chain over even and level bottom. The probable error of observation was no more than 0.1 foot. Maximum diurnal range for July predicted to occur this night.
Findings: (1) Tidal observations at sea entirely practicable with Dorsey Fathometer. (2) Tide approximately 1.4 hours earlier and range approximately 50% greater than predicted for Galveston.
Remarks: Tidal Observations made at sea during a night at anchor while engaged on offshore hydrography.
Tidal Range: Feet
Observed at sea station 2.9
Predicted at Galveston 2.0
High Water 4:42
Low Water 20:24
U.S. COAST & GEODETIC SURVEY
R.S. PATTON, DIRECTOR
TIDAL OBSERVATIONS AT SEA WITH THE DORSEY FATHOMETER
JULY 7-8, 1937
SHIP
HYDROGRAPHER
F.S. BORDEN, COMMANDING