MODERN NAVIGATION

by

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(Translated from the German.)

The subject "Modern Navigation" necessitates the formulation of a policy with regard to the following points:—

I. Simplification or standardization of the apparatus ;
II. Simplification of astronomical position finding at sea ;
III. Possibility of unifying navigational methods in the Navy and the Mercantile Marine ;
IV. Co-ordination of maritime and aerial navigation.

I. This point embraces, first of all, the adoption of the 360° compass rose and consequently navigation on this system, which is additive to the right. Is it, by chance, necessary to speak of this self-evident item ? Scarcely ! for in all sea-going ships it has long since been installed and therefore recognised as a really practical improvement. If the small coasting trade is still opposed to it, the reasoning of G. KUESTER (*Der Seewart,* 1938/3), is certainly in accord with the facts. Here indeed is a case where steps might be taken in the interests of the community and much achieved without great sacrifice, namely, to fix a date on which all compass roses must be divided into degrees. It is undoubtedly much easier and safer to lay the true course on a nearby meridian than to have to "work one's way" with a dubious parallel rule towards a magnetic rose more or less distant from the course. The objection that the laying of a course from true to compass, and conversely, entails a dangerous source of error for the small coasting trader, is without foundation, for there must be certain fundamental problems on the accurate solution of which actually depends the qualification to navigate a ship, even the smallest. One should see no hardship in such a useful requirement which is, rather, called for by safety and the preservation of life and property.

II. The problem of simplifying the working out of the astronomical fix at sea, that is, to accelerate the solution, is by no means new ; it has been emphatically taken up in aerial navigation and again brought to the forefront. What can be actually simplified here ? How can a further economy of time effectively be attained ? Let us consider in this respect the main parts of astronomical position finding, which are the following:—

1.— The observation ;
2.— The computation of the hour angle ;
3.— The spherical-trigonometrical calculation.

1.— In the observation itself and the correction of the height, I scarcely see a possibility of obtaining any noticeable economy of time. In this it is presupposed that the instruments (modern sextants) can be read clearly with accuracy and that comprehensive tables are available. The possibility of applying the height correction on a drum on the sextant — the attempt has already been made — in order to avoid the use of tables, scarcely brings about an economy of time, apart from the fact that the operation is technically restricted.

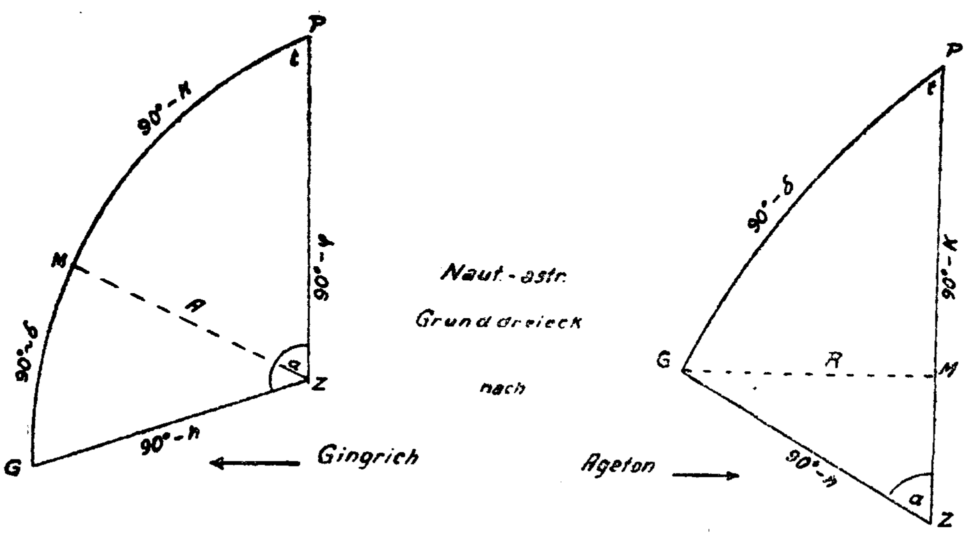
2.— The computation of the hour angle is a very laborious, time-consuming intermediate step in determining the astromonical fix, which cannot be much improved upon with the ordinary means. The use of the sidereal time equation ($m \ominus \alpha$ — $\star\, \alpha$) does not help very much ; two lines of computation are economised in this way, as Dr. FREIESLEBEN shows in his article. But, on the other hand, the nautical almanac becomes very bulky. More interpolation also results because the sidereal time equation changes just as quickly as the $m \ominus \alpha$ (R.A.M.S.). I doubt whether the end here justifies the means. Shortly before his death my unforgettable chief, W. NIEMANN, experimented with an hour-angle chronometer. In explanation I would like to quote literally what NIEMANN said on the subject in his lecture at the *Wissenschaftliche Gesellschaft für Luftfahrt* in Berlin (see also *Hansa* 1935/26-28):—

"In addition to reading off G. M. T. in hours, minutes and seconds, as is the present practice, I have made it possible to read off directly from the same dial the desired hour angle of the fix. The dial is made up of fixed and rotatable rings. The system of fixed rings gives the G. M. T., the system of rotatable rings, the position or the hour angle. Through this system of movable rings the actual longitude of the fix and the hour angle equation corresponding to G. M. T. are mechanically laid off. For observations of the sun this method is intelligible without further explanation. For observations of the moon, planets and fixed stars we arrive at a new concept, that of Schrader's sidereal time equation. This concept is composed of the two quantities:— right ascension of the mean sun and right ascension of the star. The difference between the last values gives the magnitude of the sidereal time equation, which is then laid down or applied to the chronometer setting in combination with the longitude of the fix, exactly as described above, in connection with the mean solar time, the solar time equation and the longitude of the fix."

NIEMANN's hour-angle chronometer has naturally its short-comings and inconveniences. He neither wanted to, nor could, make any pretence of something complete and ripe for introduction in practice with this his first, and unfortunately last, attempt. At any rate he has opened the door to a new method which, especially with the sun, seems interesting and worth following up.

3.— (a) *Nautical Tables :* A great many nautical tables exist for the computation of the altitude and azimuth of a heavenly body ; incidentally they may also be used to solve other nautical problems. I must point out from the outset that none of the tables can provide a fully satisfactory solution, that in practice it is actually impossible to arrive at this ideal with tables, i.e. to find the altitude and azimuth of a heavenly body by one single reference to the tables. This is due, not to the arrangement of the tables, but to the nature of the problem itself.

For those seamen lacking time and opportunity to get sufficient information about the newest tables, the following summary may be of use:— the existing tables may be divided into two groups: the perpendicular is dropped in the celestial triangle GPZ either from the zenith on the declination circle of the heavenly body ; or from the centre of the heavenly body itself on the celestial meridian. (See figures). The first method is adopted by PIERCE, OGURA, DREITSONSTOCK and GINGRICH ; the other by AQUINO, AGETON and the DEUTSCHE SEEWARTE. In both cases the perpendicular and the distances from its foot to the



pole, the equator and the heavenly body are auxiliary quantities, which must first be derived from the time triangle, in order to calculate with them, in the altitude triangle, the altitude h' and the azimuth. In this connection it is unavoidable that certain rules be memorized — a fact which may be a thorn in the flesh of those who believe in the possibility of a fully mechanized or even automatic navigation.

The AGETON and DEUTSCHE SEEWARTE Tables, as logarithmic tables, can be calculated based on the D. R. position. This is unquestionably an advantage compared with other tables with which the introduction of an assumed latitude and longitude facilitates only relatively the ease of calculation and, for instance with a fix of several altitudes implies the assumption of an equal number of longitudes in order to round off the hour angle τ correspondingly. Greater altitude differences may hereby occur which, especially with a small zenith distance, falsify the ship's position.

Two tables seem to be worthy of mention : those of GINGRICH and those of AGETON. Let us briefly explain their manipulation by an example :—

(a) *Gingrich*. Given : φ 38°09'N, λ 50°38,5'W, τ 8 h. 44 m. 10 s., δ 10°5,1' S, h.23°37',

A 9478	K 49°58,8'N	X-0,679
B 30191	δ 10° 5,1' S	Y-0.234
A+B 39669	K $\backsim$ δ 60° 3,9'	Z-0,913
h' 23°39'		az. 125,7°

h-h'= -2', to be laid off from 38°00' N and 50°41' W.

(b) *Ageton*. Given : φ 42°10,5'S, λ 68°38'W, τ 118°26', δ 23° 7' S, h.35°57'.

R	K	h	a
A 5583			
B 3635	A 40604		
A 9218	B 23052	B 23052	
(R 53°58,5')	A 17522	B 0,6	A 9218
	(K 41°52,5')	A 23052,6	B 9218
	K $\backsim$ δ 0°18'	h' 36°1,5'	A 0,0
			Az. 90°

h - h' = - 4,5', to be laid off from the compound fix.

(γ) *Comparison of various methods :*

A comparison of the ease of calculation for the determination of altitude and azimuth with the different methods gives the following record :

	GINGRICH	AGETON	sem *t* Formula
Recourse to the tables	4	7	8
Entries	7	10	10
Mathematical steps	3	6	4

It follows that GINGRICH's tables, as regards economy of time, have the lead. With a convenient arrangement, they comprise 63 pages. Those who do not care to calculate from an assumed position at sea may resort to AGETON's tables, the synoptic arrangement and lesser bulk of which are to be particularly stressed. AGETON has transformed the formulae in such a way that only two functions, *sec* and *cosec*, repeat themselves. As he himself indicates, he did not want to work out a "new short method" but, rightfully acknowledging that "the advantages of D. R. position are the disadvantages of assumed position", to go a step further in the logarithmic calculation method. This goal he has attained thanks to the simplicity of his solution, avoidance of interpolations and economy of space.

To sum up, GINGRICH's and AGETON's tables are to be judged in the sense that they constitute a certain advance, and that they are to be recommended in maritime navigation to all those to whom the slightest simplification and economy in time are welcome.

3.— (b) *Combined Altitude and Azimuth Tables* (*Alt-Azimuth Tables*) : In order to find the altitude and azimuth of the sun, I hold the following procedure to be practicable :— such a combined Altitude and Azimuth Table as NIEMANN once caused to be calculated. The altitude and azimuth were given for every complete hour-angle degree and declination degree for 60 degrees of latitude. (See also *Hansa* 1935, Nos 42, 43, 45, 49). The interpolation work was thus insignificant. The printed book comprised about 2000 pages — a disadvantage easily surmounted by breaking it up into different latitude regions. This proposal would be incomplete if it were not also extended to the most frequently observed fixed stars. While not underestimating the difficulties presented with fixed stars — difficulties which stand in the way of the introduction of such a table because with about 40 stars it would already become rather bulky and because the declination of these stars does not remain absolutely unchanged — I venture to say that, with a corresponding regard to the usually navigated latitudes (60° N — 50° S) and neglecting the star altitudes under 10°, the bulk of such a table (for 40 stars about 3000-3500 pages) is still acceptable for maritime navigation. For many steamship lanes, of course, a part of these tables would suffice. The calculation and introduction of such a book should be well considered, for a combined altitude and azimuth table represents the last resort of such auxiliary tables for the rapid determination of the astronomical position. (Cf. the work published in dictionary size : "The Sumner Line of Position" H.O. 203 ; 870 pages).

3.— (c) *Astronomical Calculating Machines*. The question "Nautical Tables" being exhausted, there remains only to say a few words about the most up-to-date means for taking astronomical fixes, *viz.* the Astronomical Calculating Machine. The expression "Machine" has something alluring about it. It would be the ideal if this calculating machine, due to the high degree of accuracy required, were not so complicated, hence delicate, and therefore short-lived. In addition, the comparatively high purchase price leaves but little hope for the introduction of such aids on a wide scale. Nevertheless, the solution of the problem seems to lie on the technical side, and it can only be expected that progress will provide us, here also, with a technical wonder : the complete automaton.

Meanwhile, trials should be made with the ordinary calculating machine, by computing the altitudes with the natural values according to the formula

$$\sin h = \sin \varphi \sin \delta + \cos \varphi \cos \delta \cos t.$$

Whatever the ensuing economy of time, it is, at least, worth knowing, but has not yet been ascertained in practice.

If we cast a retrospective glance on the chapter "Simplification of astronomical position finding at sea", we must conclude that, in respect of the altitude itself and, above all in respect of the computation of the hour angle, any simplification is hardly to be expected, and that the lever may be applied with more chance of success in the domain of spherical-trigonometrical calculation.

III. In the third chapter of my exposition I wish to deal with the possibility of unification of navigational methods in the Navy and the Mercantile Marine. Let us pass on to astronomical position finding at sea. It is much easier to introduce standardized apparatus than to dictate standardized methods which, after all, have cropped up exclusively as a result of the requirements of their domain of utilization — and yet, no, even within their different domains of utilization they cannot be sharply normalized because the experienced navigator has generally adapted a method "of his own", which seems to him to be the quickest if not always the most convenient. On this point the American Commander LOGAN expresses himself as follows in the *United States Naval Institute Proceedings* (1931, p. 223) :— "The selection of a method of solution will always be a matter of personal preference with the individual navigator and will depend frequently upon what he has 'been brought up on' and finds himself most accustomed to". I consider that in astronomical position finding at sea, the position line should uniformly be used, and for the sake of a quick check I deem it very useful. The introduction of a printed form, as recommended by K. PFENNIG, would surely be beneficial. This concept does not tend to do violence to the fact that the old method of position finding from latitude and resultant longitude leads quickest to the goal. Less important in dealing with this problem is the question of which method one opts for than the realization that in future both must continue to be learned (Captain W. GLAHN rightfully designates this as least requirement (1)

(1) W. GLAHN limits his least requirement to the position line method and requires the altitude formula, the meridian latitude and the exmeridian latitude (*Der Seewart*, 1938, Heft 2). Editorial Department.

and the fact that one has a clear idea of their respective limits of usefulness. A necessary assumption for the unification of the navigational methods of the Navy and the Mercantile Marine is the introduction of the same text-books and nautical tables, as well as a rigid standardization of all the technical expressions of the profession. As regards our nautical tables, the time has certainly come to see about overhauling them and, by re-arranging this or that part of the contents, to make them more suitable. I am inclined to think, by the way, that the five-place logarithms might be dropped in favour of the four-place, as the latter are amply sufficient for the degree of accuracy required in navigation at sea. I cannot, however, agree with Dr. CONRAD, who considers 4 - 6 minutes a sufficient degree of accuracy for an altitude, because, when making a landfall, i.e. in cases where accuracy is needed and erroneous latitudes mean going dangerously astray, astronomical position finding at sea presents at least the same importance as when navigating on the "big pond" where, in cases of emergency, a carefully estimated position may suffice. An astronomical fix with the above-mentioned errors is as a rule ,i.e. under normal daily conditions of observation, in no respect better than the accurate position worked out by D. R., and by no means susceptible of inspiring or strengthening confidence in the observer ; especially not when the astronomically observed position begins to swing perceptibly from one side of the course to the other and shows sets which the ship has never experienced. I also am of opinion that in sea navigation, under normal observational conditions, one will have to get accustomed to a *single* reliable observation ; for the possibility of serial observations is not always given, apart from the fact that thereby one may very easily become the victim of self-delusion. If Dr. CONRAD sets as basis a 4 to 6-minute degree of accuracy for observations over the artificial horizon which, with trained observers, may for the present certainly be considered as the practical limit, there nevertheless remains in sea navigation the fact that absolute accuracy is decisive, that is to say, an apparatus which does not attain such degree has little chance of being introduced in practice. In this connection I might at once take up K. PFENNIG's point of view that astronomical navigation has, generally speaking, lost in value through the introduction of the radiogoniometer, so that we are no longer dependent on astronomical observations in the same measure as before. No method of navigation can put in a claim for real perfection. There follows at once the conclusion that no method of navigation is liable to dislodge another, but that they must complement one another. Indeed it is thus that, under "navigation", there is virtually understood a capability of mastering methods with a "living spirit", to apply, in each given case, that individual one which is most promising and will yield most.

IV. How far should maritime navigation merge with aerial navigation ? A vital question ! To answer it requires first an investigation into the goal they each aim at, the apparatus and aids at their disposal and the degree of accuracy these endeavour to obtain. The goal is clear: to determine the position quickly and reliably, using for this purpose the old, long-sanctioned methods, supplemented by the modern up-to-date technical appliances. In practice, this is always possible in sea navigation. Aerial navigation has taken from it what it could use, has adapted it to its conditions, its higher speeds, and provided itself with all sorts of aids. It has built up its methods on course, time and speed, i.e. on traverse flying, without which any attempt at orientation, even in sight of land, means navigating with uncertainty, guessing one's way. Despite the confidence which may be placed in radio-navigation, one learns to appreciate the value of exact traverse flying only on flights without land sight. Time and experience have, at all events, sufficiently taught me that. When it has been clearly realized that, without a check no method of navigation is reliable, every possibility of check will be fully utilized ; and the latter consists precisely in the above-mentioned conditions of flight, merely in a careful traverse, which may sometimes be rather difficult on account of the unknown wind. Thus in the fruitful co-ordination of traverse flying and radio position finding may be seen the present-day basis of air navigation. The difficulties in astronomical position finding lie, not in the methodical but in the instrumental domain. The question as to how quickly the observed altitudes can be utilized is, for the moment, secondary. The outstanding requirement for aerial navigation is a reliable horizon sextant. Should we not concur fully with Dr. CONRAD when he particularly emphasizes the value of such an instrument for maritime navigation also ? Should not maritime navigation also welcome the invention of a compass with a comparatively long period of oscillation, such as is required with the present-day airplane speeds ? Does not a common interest exist in the perfecting of the position-finding instruments and the cartographic material for the utilisation of long-range bearings ? It is perhaps by no means a dream of the future that maritime navigation will finally make use of a system of ultra-short wave beacons in thick weather and for navigation in restricted waters, such as present-day aerial navigation already successfully uses for bad weather or blind landings. I believe these few hints will suffice to refute the somewhat over-hasty theory that maritime and aerial navigation must follow separate routes. As concerns the degree of accuracy, the ideal would certainly be to attain the same, even if the air-craft can "catch up" quicker. I see only one essential difference : the very different speeds require a correspondingly quicker evaluation of the observations. In actual fact it is far from being yet demonstrated whether the mechanisation attempted here and there — not to speak at all of automatisation — will prove a success. It is a very dangerous error to believe that, in navigation, thought and initiative can be eliminated, thus robbing it of the "living spirit" as K. SCHWARZ (Kiel) opportunely says. There are no lack of advocates for an entire mechanisation of air navigation because one sees in this a restriction and a shortening of the training period, whereas, as a matter of fact, exactly the contrary is true ; for when one can do something "in one's sleep", then one is master of it. What one is not master of, however, must be taken into account.