numbers, but Mr. Barker proposes to treat them as a series of hybrid varieties produced by much natural inter-crossing, in the first instance between the botanical species from which the ordinary cultivated apple has arisen, and, later, between the varieties resulting from the earlier hybridisation. The main problem is to determine the nature of the influence of the stock on the resulting fruit-tree, and, in particular, whether it is simply mechanical in nature and regulated by the morphology of the root system, or whether there is a definite physiological influence, the nature of which is determined by the character of the seedling. If the latter is a factor, the problem is, of course, extraordinarily complicated, but there are opened up possibilities of striking developments in the culture of fruit. Further work on this important subject will be awaited with interest.

A NEW GRAPHIC METHOD IN NAUTICAL ASTRONOMY.

A NEW departure of some little interest has been recently taken in America in the publication by the United States Hydrographic Department of a new chart, or diagram, for finding readily by a simple graphic process hour angle or azimuth at sea. So far as azimuth is concerned, a diagram of this nature, known as Weir's Azimuth Diagram, has been in use for many years, but in that case the hour angle is made use of as a datum, whereas in the new diagram the altitude takes the place of hour angle as argument; and, as an altitude can be observed at sea with much less trouble than hour angle can be deduced from chronometer time, some labour is saved by its substitution.

The construction of the diagram, which is due to the inventive genius of Mr. G. W. Littlehales, of the U.S. Hydrographic Department, is based upon a function of the angle very generally employed by navigators, but not much known outside nautical circles, called the haversine. A formula very generally employed in spherical trigonometry for finding an angle of a triangle from three sides given is

$$\sin^2\frac{A}{2}=\frac{\sin(s-b)\sin(s-c)}{\sin b\sin c}.$$

The practical application of this formula was very much simplified about a century ago by the introduction into the nautical text-books of a new table which gave the value of the logarithm of the square of the sine of one-half the angle, and was therefore called the "sine square" table. A little later, since

$$\sin^2\frac{A}{2}=\tfrac{1}{2}(1-\cos A)=\tfrac{1}{2}\text{ vers A},$$

the name of haversine, or half versine, suggested itself for the new function of the angle, and as such it is generally known to-day.

The particular formula on which the diagram is based was proposed about ten years since, and is as follows:

$$\text{hav}(a)=\text{hav}(b\sim c)+\{\text{hav}(b+c)-\text{hav}(b\sim c)\}\text{ hav A}.$$

If the sides b, c be regarded as constants, a, A being variables, this expression takes the form

$$y=mx+c$$

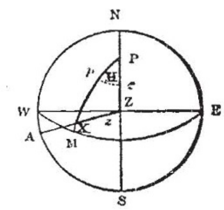
that is, of the equation to a straight line.

This formula suggested to the inventor the notion of a square chart, with sides graduated according to the values of a series of natural haversines, by means of which, having given the altitude and declination of a body and the latitude of place, hour angle and azimuth might be found by simple inspection. Upon such a chart, by drawing a straight line through two points readily determined, a connection would be established, in one case between the hour angle and zenith distance, in the other between azimuth and polar distance, so that, one of a pair being given, the value of the other could be taken approximately from the chart.

The Triangle of Position in Nautical Astronomy.

The diagram which follows exhibits on the plane of the horizon what is known as the "triangle of position," in which

PZ,	the co-latitude	$=90°-$lat. or c.
PX,	the polar distance	$=90°\pm$dec. or p.
ZX,	the zenith distance	$=90°-$alt. or z.
ZPX,	the hour angle	$=\mathrm{H}$.
PZX,	the azimuth	$=$Z.

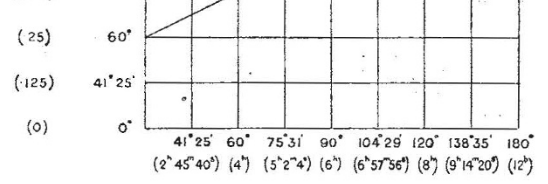


The general formula adapted to this triangle gives for hour angle

$$\text{hav } z-\text{hav }(p\sim c)=\{\text{hav }(p+c)-\text{hav }(p\sim c)\}\text{ hav }\mathrm{H},$$

the polar distance (p) and co-latitude (c) being considered as constants.

The small diagram given below will perhaps serve to explain the process adopted. The side is only 3 in. in length, compared with 2 ft. in that issued for practical use. In the actual chart, again, a system of "grillage," by means of lines drawn at short intervals parallel to the sides of the chart, enables the value of an angle to be read off to the fraction of a degree at sight, whereas in the small diagram the graduations of the sides are equal, and the points marked indicate the angles corresponding with successive values of the haversines at intervals of 0·125.



Hour Angle and Zenith Distance.

Example 1.—At a place in lat. 60°, when the sun is on the equator, find zenith distance at 4h. P.M., hour angle at setting, and at the end of twilight.

Rule.—On left-hand margin mark the point corresponding with ($p\sim c$), *i.e.* of meridian zenith distance at upper transit, and on right-hand margin the point for ($p+c$), or meridian zenith distance at lower transit. The line joining these points is the graph required, hour angle for any position being read off at foot of chart, and zenith distance on margin.

Here polar distance $(p)=90^\circ$, co-latitude $(c)=(90^\circ-60^\circ)=30^\circ$.

Therefore $(p-c)$ for left margin $=90^\circ-30^\circ=60^\circ$.
,, $(p+c)$,, right ,, $=90^\circ+30^\circ=120^\circ$.

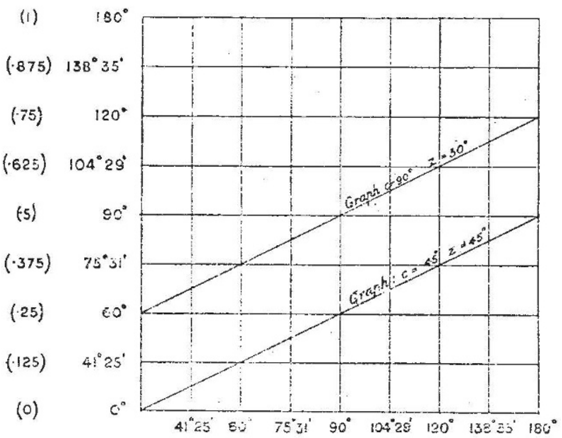
The graph being drawn accordingly, at 4h., or 60°, read off at foot of chart, we have zenith distance 73° 31′ on margin. When the sun is setting the zenith distance is 90°, and the hour angle is also 90°, or 6 hours. To find the hour angle at the end of twilight—that is, when the sun has a depression of 18°—we have to draw the parallel for 90°+18°, or 108°. The graph intersects this in the point (a), which would be found on measurement to correspond approximately with 8h. 33m. P.M.

Azimuth and Polar Distance.

Interchanging polar distance (p) and zenith distance (z), the procedure will be very much as before.

Example 2.—At a place on the equator find the azimuth of bodies of declination 14° 29′ N., 0°, 14° 29′ S., the altitude in each case being 60°.

Rule.—On left-hand margin mark $(z\sim c)$, and on right-hand margin $(z+c)$. Join these points, and azimuth for any position is read off on base, and polar distance on margin.



Here $(c-z)=90^\circ-30^\circ=60^\circ$, $(c+z)=90^\circ+30^\circ=120^\circ$. For declination 14° 29′ N., we have polar distance 75° 31′, and azimuth N. 60° W.; for declination 0°, polar distance is 90°, and azimuth N. 90° W.; for declination 14° 29′ S., polar distance is 104° 29′, and azimuth N. 120° W. or S. 60° W.

The following is an example of the converse case in which declination is obtained from azimuth:—In latitude 45° N. find the declination of a body which passes the prime vertical at an altitude equal to the latitude of place. For $(z-c)$ we have the value zero, so that the graph passes through the origin, while $(z+c)=90^\circ$. If the bearing is 90°, we have polar distance 60°, so that declination is 30° N. If the azimuth is 60°, it is also evident from the diagram that polar distance is 41° 25′, and declination 48° 35′ N.

The deduction of declination from observed altitude and approximate azimuth is of value at sea to identify an unknown star.

The most obvious use of the diagram is to supply an exceedingly simple graphic method for azimuth. In theory the diagram can be used with equal facility for hour angle. But in the latter problem much greater accuracy is required than in the other, and the diagram necessary would have to be upon too large a scale to be available for ordinary use at sea. It is quite possible, however, that another kind of navigation may become a matter of daily experience ere long, viz. the long-distance navigation of the air, and that in this form of navigation, which will undoubtedly possess many features peculiar to itself, the diagram may serve generally not only for azimuth purposes, but also for those of hour angle.

In the words of the inventor of the diagram:—"The feasibility thus disclosed of framing a nautical astronomy in which all requirements will be subserved by a single trigonometrical table, like the table of haversines, No. 45 in the *American Practical Navigator*, invested the subject with interest from the point of view of aerial navigation, because this formula, if successfully represented in graphical form, might provide the aerial navigator with the equivalent of a volume on nautical astronomy in a form simple enough to fulfil the instant needs of flight." H. B. G.

EXPERIMENTAL STUDIES OF THE MECHANICAL PROPERTIES OF MATERIALS.[1]

THE general purpose of experiment on materials is to distinguish between the fit and unfit, the suitable and unsuitable materials for the various requirements of the structural and mechanical work of the world. The special object of the engineer in testing materials is to obtain a rational basis for proportioning structures and machines so that they may sustain the straining actions to which they are subjected without fracture or prejudicial deformation, and at the same time without waste of material. Nor is there any finality in such testing, for new alloys, new heat treatments, new conditions of use are always making fresh investigation necessary. In the next place, the mechanical properties of materials desired and assumed in designing are embodied in specifications. Thence arises a second occasion for experiment. Tests of reception or inspection tests are necessary to determine whether material supplied reaches the required standard. With the widening of the sources of supply, an engineer can no longer depend merely on the reputation of the seller, but must make his own tests.

Early Researches.

There are two methods, said Roger Bacon in the thirteenth century, by which we acquire knowledge—argument and experiment; and he proved the fertility of the method of experiment in contrast with the barren dialectics of his time. But it was some centuries later before anything was done to ascertain by experiment the data required by the engineer in using materials of construction. Yet there is no subject of greater importance to engineers, or of more intellectual interest, than the study of the mechanical properties of materials which fit them for use in construction. Nor is there one which more deeply concerns the general public who depend on the product of machinery and travel on railways.

The earliest known experiments on the strength of materials were made by Galileo[2] in 1638, and not long after Muschenbroek,[3] of Leyden, made many tests on a small scale, some of which are quoted in Barlow's "Strength of Materials." Galileo knew nothing of elasticity, but he determined the tenacity of copper and started an inquiry into the strength of beams, giving a solution partly right, partly wrong.

[1] From the Thomas Hawksley Lecture delivered before the Institution of Mechanical Engineers on October 4 by Dr. W. Cawthorne Unwin, F.R.S.
[2] Fontenelle, "Histoire de l'Académie des Sciences," 1702.
[3] "Introductio ad cohærentiam corporum firmorum," 1729; Barlow, "Strength of Materials," 1867, p. 3.