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AERONAUTICAL NAVIGATION. . .

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Aeronautical Navigation.

THE advance of Aeronautics renders a knowledge of Aerial Navigation advantageous to all those who take an interest in aeronautics, as well as to the aeronaut himself. The same general methods and similar instruments will be employed as those which are now used for navigating the seas; and, as at sea, experience will be the greatest of all assets.

There is no royal road to safe navigation; it requires a capacity for taking trouble, and unremitting attention. The navigator observes every possible indication, and uses a few nautical instruments in order to know where he is, and to decide what course to steer, in order to arrive at his destination. The aeronautical navigator should proceed on the same lines, but he is under certain disadvantages, inasmuch as while he is under weigh, he will not have his hands free to rule courses on charts or adjust instruments, and therefore his course must be marked out on his chart before starting, his instruments adjusted, and as much information gathered and committed to memory as possible.

When once started, his eyes and brain must suffice to enable him to calculate just how to steer in order to make his passage successfully.

This is very similar to the manner in which small craft, such as torpedo boats, are navigated in dirty weather, when it is impossible (or at least unwise) to bring a chart on deck, and all information such as tides, shoals, dangers, leading marks and courses are carried in one's head, and one's eyes alone are used to verify and utilize these guides.

In consequence of the conditions prevailing, aeronautical instruments should, for the present at any rate, be very simple in construction, and require no manipulation during a flight.

I would therefore recommend the aeronaut to use only the chart, log and compass, and even to substitute for this latter a "shadow-plate" until a satisfactory aeronautical compass has been used and proved successful.

Charts.

The aeronautical chart should be constructed from the latest Ordnance Survey Map, and it should show about ten miles on either side of the route it is proposed to travel; it should be long enough for the whole of the journey, and, preferably, should be mounted on a pair of rollers and table, so as to allow of any desired portion of the chart being exposed to view, while the remainder is protected.

Railway lines, and whether of double or quadruple track—churches, factory chimneys, and all conspicuous features should be marked. Rivers should be more clearly shown than is usual on ordinary maps.

The course should be drawn upon the chart clearly by ruling a pencil line, and it should be marked off in ten-mile distances from the starting point.

The Log.

The log is very important, and is quite a necessity in order to enable the aeronaut to navigate with confidence.

The speed and distance shown by the log are necessarily the speed and distance **through the air**, not over the ground; but they will be proportional to them, so that if, for example, it is observed that one has proceeded twenty miles on one's way, while the log indicates thirty miles, one may fairly deduce that another twenty have been passed when the log shows sixty.

The proportion will, of course, alter with a change in strength or direction of the wind.

The Elliott Log for aeronautical work consists of a light anemometer, which can be fixed in an exposed position, preferably on the upper plane of an aeroplane, and the distance travelled through the air in miles is recorded on a set of dials fixed underneath, so as to be readily observed by the aeronaut.

The Compass.

Every aeroplane will eventually carry a compass, and this will be considered as much an essential part of it as its engines.

It must be pointed out that the difficulties of steering by compass are considerable, and these can only be overcome by practice added to a good fundamental knowledge.

These difficulties have been much enlarged upon by people who have had no practical experience of the use of compasses, notably the difficulty of allowing for "wind drift"; but by the method I will show in the succeeding pages, one's course can very easily be corrected for drift, and with experience the aeronaut will find that he can accurately allow for drift. This, by the way, will be caused by many other influences besides the wind, *i.e.*, the horizontal torque set up by the propellers, slight distortion of the "planes" from their symmetrical shape, and the centre of air resistance and centre of gravity not being in the same vertical fore and aft plane.

As regards the practical use of a compass, inasmuch as the directive force of the earth's magnetism is due to the electro-dynamical effect of the earth revolving inside an atmosphere containing particles of water vapour positively charged, this force on a compass needle will not be materially diminished when only about a thousand feet up from the earth's surface, which is the height recently recommended by practical aeroplanists.

The aeronautical compass, in order to be successful, must embody most of the principles found in Lord Kelvin's compass, which is the most perfect compass in existence, but which is debarred from use in its present form by aeronauts, on account of its considerable weight and dimensions.

The aeronautical compass must have ample correctors for "deviation," since the motor engine is mostly constructed of steel, and the propeller shafts, and the stay wires themselves will all have a very considerable effect on it.

Permanent, semi-circular and quadrantal deviation will be met with, but "heeling error" is not likely to give much trouble, and I expect the most important deviations will be the A, C and D co-efficients.

The quadrantal correctors should be hollow-spheres, and the whole instrument should be made light, and unaffected, as far as possible, by vibration or shock.

On starting out for a flight the aeronaut should take his course from the chart, correct it for variation and deviation, and also for drift (as will be shown further on), and, when these have been correctly deduced, he can steer by compass with comparative accuracy, since an error of 1° will only put him out of his course one mile in every fifty-eight.

When steadied on his course, he will find it convenient to steer on some distant object right ahead, steadying his course by compass from time to time, and observing some more distant object on which to steer later.

He must be careful only to steer on objects while they are distant, for more than one reason.

Not many years ago, at sea, a certain officer of the watch steadied the ship carefully on her course, and noticed that she was then heading for a distant lighthouse. He told the quarter-master to steer for the lighthouse, and then went and studied the chart, in which he became engrossed. The quartermaster continued to steer for the lighthouse, and eventually hit it.

For convenience in steering on an object when there is drift, marks should be painted on the forward elevating rudders (or some suitable fitting on the aeroplane) marking off, in degree spaces, the bearing from "right ahead," as seen from the position of the aeronaut, and instead of keeping the fore and aft mark on an object, he should, when there is drift to be allowed for, keep the mark indicating the amount of drift in line with that part of the landscape which it cuts at the moment when the course is steadied.

Many months of work and experiment will assuredly be necessary before a reliable aeronautical compass is produced, therefore, until a compass is available, and while aeroplanes remain in their primitive state I recommend the use of a shadow plate to steer by, and even when a compass is carried I think the overhead "shadow plate" should be retained, since it occupies no space that is otherwise required, also its weight and wind resistance are negligible, whereas it is a ready check for the compass, and is always absolutely accurate.

The Shadow Plate.

The aeronautical shadow plate, as made by Messrs. Elliott Brothers, consists of a circular celluloid plate 10 in. diameter, with a small pin 10 in. high and ⅛ in. diameter, mounted vertically on its centre. The plate is mounted in the forward part of the upper "plane" and close to the aeronaut in such a position that he can easily see it, the material of the "plane" immediately under the shadow plate being removed.

The outer edge of the plate is graduated in degrees, and a "Lubber point" is marked on the ring exactly in the fore part of the hole in which the shadow plate is mounted. A slotted frame is fitted on the plane close to it to take a list of the bearings of the sun's shadow for the day, and another slot should be fitted to hold a watch.

Method of Use.

1. The true course you wish to steer is taken from the chart —in the case of a flight from London to Manchester the course is N. 34° W.

2. The shadow plate is turned round until the graduation for this course is in line with the lubber point.

3. A list of the true bearings of the sun's shadow during the time that the journey will be made is copied out from the accompanying table A, and fixed under the upper plane close to the shadow plate. A watch is also secured close to it.

4. When started and clear of surrounding obstacles, the time by watch is observed and the bearing of the sun's shadow for this time is read from the list before mentioned. The aeroplane is then steered round until the shadow of the central pin cuts this bearing on the shadow plate.

5. The aeroplane is now heading in the true direction in which it is required to proceed, and should be kept roughly in this direction until the amount of "drift" has been estimated; this is done as follows;—

Estimation of Drift.

6. If there is any drift one will be set to one side of one's course, and therefore when first steadied one should observe some object the aeroplane is directly heading for: Suppose there is a village right ahead and about seven miles off, and that on correcting one's course by shadow plate, every few seconds it is noticed that one will pass to the **right** of the village, and eventually one **does** pass about half-a-mile to the right of it.

7. One estimates therefore that in seven miles one has been drifted half-a-mile to the right, *i.e.*, that the drift is 1 in 14 to the right—this requires (by table B which should also be in a conspicuous position) that the course be altered 4° to the left.

8. Instead therefore of keeping the shadow on the bearings given in table A (as one would do if there were **no** drift) which are say N. 10° E. at 12.45 p.m. and N. 11° E. at 12.50 p.m., it should be brought 4° to the right of these bearings, that is N. 14° E. at 12.45 and N. 15° E. at 12.50 and if steering on an object the 4° Drift mark should be kept in line with the object it cuts at the moment when steadied.

9. The aeronaut should check this drift two or three times, estimating as nearly as he can the distance of some definite object directly ahead in his fore and aft line, and the distance he is to one side of it when he passes it abeam, until he has judged his drift accurately, and corrected his course so well that he finds himself running over the track he has previously arranged and recognises the succeeding features of the landscape as they are marked on the chart.

Table A.

True bearing of Sun's shadow for Latitude 52 deg. (*See Note.*)

Apparent Time. a.m.	p.m.	Mar. 20 to Mar. 24 / Sept. 18 to Sept. 22	Mar. 25 to Mar. 30 / Sept. 12 to Sept. 17	Mar. 31 to April 5 / Sept. 7 to Sept. 11	April 6 to April 10 / Sept. 2 to Sept. 6	April 11 to April 15 / Aug. 27 to Sept. 1	April 16 to April 20 / Aug. 21 to Aug. 26	April 21 to April 26 / Aug. 15 to Aug. 20	April 27 to May 3 / Aug. 9 to Aug. 14	May 4 to May 10 / Aug. 1 to Aug.	May 11 to May 19 / July 23 to July 31	May 20 to May 31 / July 12 to July 22	All June / July 1 to July 11
4.0	8.0	The shadows are all to the WEST in the forenoon and to the EAST in the afternoon; for example, between March 20 and 24, or September 18 and 22 at 7.0 a.m. the true bearing of the Sun's shadow would be N.79 West and at 5 p.m. it would be N.79 East.											S. 53°
4.15	7.45										S. 58°	S. 57°	56
4.30	7.30									S. 62°	61	60	58
4.45	7.15								S. 66°	65	64	63	61
5.0	7.0							S. 70°	69	68	67	65	64
5.15	6.45						S. 74°	73	72	70	69	68	67
5.30	6.30				S. 80°	S. 79°	77	76	75	73	72	71	70
5.45	6.15			S. 84°	83	81	80	79	78	76	75	74	73
6.0	6.0	E. & W.	S. 88°	87	86	84	83	82	81	79	78	77	75
6.15	5.45	N. 87°	N. 89	E. & W.	89	87	86	85	83	82	81	79	78
6.30	5.30	84	86	N. 87	N. 88	E. & W.	89	88	86	85	84	82	81
6.45	5.15	81	83	84	85	N. 87	N. 88	N. 89	89	88	87	85	84
7.0	5.0	79	80	81	82	84	85	86	N. 88	N. 89	E. & W.	88	87
7.15	4.45	76	77	78	79	81	82	83	85	86	N. 87	N. 89	E. & W.
7.30	4.30	73	74	75	76	78	79	80	82	83	84	86	N. 87
7.45	4.15	70	71	72	73	75	76	77	79	80	81	83	84
8.0	4 0	66	67	69	70	71	72	74	75	77	78	80	81
8.15	3.45	63	64	65	67	68	69	71	72	74	75	77	78
8.30	3.30	59	61	62	63	64	66	67	68	70	71	73	75
8.45	3.15	56	57	58	60	61	62	64	65	66	68	69	71
9.0	3.0	52	53	54	56	57	58	60	61	62	64	65	67
9.15	2.45	48	49	50	52	53	54	56	57	58	60	61	63
9.30	2.30	44	45	46	48	49	50	52	53	54	56	57	59
9.45	2.15	40	41	42	44	45	46	48	49	50	52	53	55
10.0	2.0	36	37	38	40	41	42	43	44	45	47	48	50
10.15	1.45	32	33	34	35	36	37	38	39	40	42	43	44
10.30	1.30	28	29	30	30	31	32	33	34	35	37	38	39
10.45	1.15	24	25	25	26	26	28	28	29	30	31	33	33
11.0	1.0	19	20	20	21	21	23	23	23	24	25	26	27
11.15	12.45	14	15	15	16	16	17	17	17	18	19	20	20
11.30	12.30	10	10	10	11	11	12	12	12	12	13	14	14
11.45	12.15	5	5	5	6	6	6	6	6	6	7	7	7
12.0	12.0	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.

Table A.

True bearing of Sun's shadow for Latitude 52 deg. (*See Note.*)

Apparent Time. a.m.	p.m.	Sept. 23 to Sept. 27 / Mar. 16 to Mar. 20	Sept 28 to Oct. 2 / Mar 11 to Mar. 15	Oct. 3 to Oct. 7 / Mar. 5 to Mar. 10	Oct. 8 to Oct. 13 / Feb. 28 to Mar. 4	Oct. 14 to Oct. 18 / Feb. 23 to Feb. 27	Oct. 19 to Oct. 24 / Feb. 17 to Feb. 22	Oct. 25 to Oct. 30 / Feb. 11 to Feb. 16	Oct. 31 to Nov. 5 / Feb. 5 to Feb. 10	Nov. 6 to Nov. 12 / Jan. 29 to Feb. 4	Nov. 13 to Nov. 20 / Jan. 21 to Jan. 28	Nov. 21 to Dec. 1 / Jan. 10 to Jan. 20	Dec. 2 to Jan. 9 / Dec. 2 to Jan. 9
6.0		E. & W.											
6.15	5.45	N. 86°	N. 85°										
6.30	5.30	83	82	N. 81°									
6,45	5.15	80	79	78	N 77°								
7.0	5 0	77	76	75	74	N. 73°	N. 72°						
7.15	4.45	74	73	72	71	70	68	N. 67°					
7.30	4.30	71	70	69	68	67	66	64	N. 63°				
7.45	4.15	68	67	66	65	64	63	61	60	N. 59°			
8.0	4.0	65	64	63	62	60	59	58	57	56	N. 55°	N. 54°	
8.15	3.45	61	60	59	58	57	56	55	54	53	52	51	N. 50°
8.30	3.30	58	57	56	55	54	53	52	51	50	49	48	47
8.45	3.15	55	54	53	52	51	50	49	48	47	46	45	44
9.0	3.0	52	51	50	49	48	47	46	45	44	43	42	41
9.15	2.45	48	47	46	45	44	43	42	41	40	39	38	37
9 30	2.30	44	43	42	41	41	40	39	38	37	36	35	34
9 45	2.15	40	39	38	37	37	36	35	34	34	33	32	31
10.0	2.0	36	35	34	33	33	32	31	31	30	29	29	28
10.15	1 45	32	31	30	29	29	28	27	27	26	25	25	24
10.30	1.30	27	27	26	25	25	24	24	23	23	22	22	21
10.45	1.45	23	23	22	21	21	20	20	20	19	19	18	18
11.0	1.0	19	18	18	17	17	16	16	16	16	15	15	14
11.15	12.45	14	13	13	13	13	12	12	12	12	11	11	10
11.30	12 30	9	9	9	9	9	8	8	8	8	8	7	7
11.45	12 15	5	5	5	5	5	4	4	4	4	4	4	4
12.0	12.0	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.	N.

NOTE.—Though this table is only *absolutely* correct for latitude 52 deg., it is sufficiently accurate for practical purposes when used anywhere over England.

Table B.

Correction for Drift.

For a drift of	1 mile in every	58 miles of one's journey the course should be corrected	deg. 1
,,	1 ,,	30 ,, ,,	2
,,	1 ,,	20 ,, ,,	3
,,	1 ,,	14 ,, ,,	4
,,	1 ,,	12 ,, ,,	5
,,	1 ,,	10 ,, ,,	6
,,	1 ,,	8 ,, ,,	7
,,	1 ,,	7 ,, ,,	8
,,	1 ,,	6 ,, ,,	9
,,	1 ,,	5 ,, ,,	11
,,	1 ,,	4 ,, ,,	14
,,	1 ,,	3 ,, ,,	18
,,	1 ,,	2 ,, ,,	27
,,	1 ,,	1 ,, ,,	45

Table C. Wind.

There exists considerable misconception concerning the speed and force of the wind so I add the following information :—

Description of wind.	Speed in miles per hour.	Pressure in lbs. per square ft.
Calm	0	·000
Hardly perceptible	1	·005
Light air	2	·020
	3	·044
Gentle breeze	4	·079
	5	·123
Fresh to strong breeze	10	·492
	15	1·107
Moderate gale	20	1·970
	25	3·067
Strong gale	30	4·429
	35	6·029
Whole gale	40	7·870
	45	9·900
Storm	50	12·304
Great storm	60	17·733
	70	24·153
Hurricane	80	31·490
	100	49·200

The total number of hours that winds of various forces were experienced at Kew during the year 1908 is as follows :—

Speed in miles per hour.	Hours.	Speed in miles per hour.	Hours.
0	44	13 to 18	1147
1 to 3	2018	19 to 24	191
4 to 7	3099	25 to 31	40
8 to 12	2245	Over 31	0

At Shoeburyness during the whole of the year 1908, a whole gale wind of over 39 miles per hour was experienced for nine hours only.

The average force throughout the year at Kew was 8 miles per hour, and the average wind experienced at 2 p.m. was 4 miles per hour greater than at 2 a.m.

Table D.

To correct the watch to "apparent time."

The watch should be kept fast or slow on Greenwich mean time by the amounts given in this table—commonly called *"The Equation of Time."*

From	To	Correction in minutes	From	To	Correction in minutes.
Mar. 20	Mar. 23	7 slow	Aug. 19	Aug. 22	3 slow
,, 24	,, 26	6 ,,	,, 23	,, 26	2 ,,
,, 27	,, 29	5 ,,	,, 27	,, 29	1 ,,
,, 30	April 1	4 ,,	,, 30	Sept. 1	0
April 2	,, 5	3 ,,	Sept. 2	,, 4	1 fast
,, 6	,, 8	2 ,,	,, 5	,, 7	2 ,,
,, 9	,, 12	1 ,,	,, 8	,, 10	3 ,,
,, 13	,, 16	0	,, 11	,, 13	4 ,,
,, 17	,, 21	1 fast	,, 14	,, 16	5 ,,
,, 22	,, 26	2 ,,	,, 17	,, 19	6 ,,
,, 27	May 5	3 ,,	,, 20	,, 22	7 ,,
May 6	,, 22	4 ,,	,, 23	,, 25	8 ,,
,, 23	,, 31	3 ,,	,, 26	,, 28	9 ,,
June 1	June 6	2 ,,	,, 29	Oct. 1	10 ,,
,, 7	,, 11	1 ,,	Oct. 2	,, 4	11 ,,
,, 12	,, 16	0	,, 5	,, 7	12 ,,
,, 17	,, 20	1 slow	,, 8	,, 11	13 ,,
,, 21	,, 25	2 ,,	,, 12	,, 16	14 ,,
,, 26	,, 30	3 ,,	,, 17	,, 22	15 ,,
July 1	July 5	4 ,,	,, 23	Nov. 13	16 ,,
,, 6	,, 12	5 ,,	Nov. 14	,, 18	15 ,,
,, 13	Aug. 7	6 ,,	,, 19	,, 22	14 ,,
Aug. 8	,, 13	5 ,,	,, 23	,, 25	13 ,,
,, 14	,, 18	4 ,,	,, 26	,, 28	12 ,,

Table D.—*continued.*

From	To	Correction in minutes.	From	To	Correction in minutes.
Nov. 29	Dec. 1	11 fast	Jan. 3	Jan. 4	5 slow
Dec. 2	,, 3	10 ,,	,, 5	,, 6	6 ,,
,, 4	,, 6	9 ,,	,, 7	,, 9	7 ,,
,, 7	,, 8	8 ,,	,, 10	,, 11	8 ,,
,, 9	,, 10	7 ,,	,, 12	,, 14	9 ,,
,, 11	,, 12	6 ,,	,, 15	,, 17	10 ,,
,, 13	,, 14	5 ,,	,, 18	,, 20	11 ,,
,, 15	,, 16	4 ,,	,, 21	,, 24	12 ,,
,, 17	,, 18	3 ,,	,, 25	,, 29	13 ,,
,, 19	,, 20	2 ,,	,, 30	Feb. 23	14 ,,
,, 21	,, 22	1 ,,	Feb. 24	,, 28	13 ,,
,, 23	,, 24	0	Mar. 1	Mar. 5	12 ,,
,, 25	,, 26	1 slow	,, 6	,, 9	11 ,,
,, 27	,, 29	2 ,,	,, 10	,, 13	10 ,,
,, 30	,, 31	3 ,,	,, 14	,, 16	9 ,,
Jan. 1	Jan. 2	4 ,,	,, 17	,, 20	8 ,,

The watch should also be corrected for longitude, 4 minutes per degree of longitude being added if east of Greenwich, subtracted if to west of Greenwich.

The longitude can of course be obtained from the chart.

Example:—Noon at Greenwich corresponds with 12 hours 4 minutes at 1° East, say at Canterbury, and 11 hours 56 minutes at 1° West, say at Reading.