International Aviation Cup Defender Design*

Computation of the Principal Features

By E. R. Armstrong

In the design of an aeroplane, five different quantities must be considered, the speed through the air, total weight in order of flight, power required, surface of support and head resistance including skin friction. To arrive at the correct relationship of these elements that the design must have in order to produce an aeroplane capable of the highest speed, is the problem under consideration.

The speed attained in the last Gordon-Bennett race was about 80 miles per hour. Recently the world's record was broken when the speed attained was more than 93 miles per hour, with a 70 horse-power motor.[1] There is no reason to doubt the assumption that the winner of the next race must be able to exceed a speed of 100 miles per hour. As a starting point in the design, it is necessary to assume that the proposed machine shall have a speed of at least 110 miles per hour.

The efficiency curves as given by Eiffel for the different wing areas and sections of the Blériot, Nieuport, Tatin, Breguet and R. E. P., show but a small variation, hardly more than 15 per cent difference between the least efficient and the best. That is to say, when these different wing sections are compared, they will lift about the same with equal head resistance, although they may be traveling at different speeds and have different angles of incidence. Generally speaking, the higher the speed the less the camber of the wing and angle of incidence necessary for support, so that the higher the speed the less power required for support. This is clearly shown in Fig. 3 on the design chart by curve No. 1, where the resistance of the planes becomes less and less as the speed is increased. The great difference in speed of the different machines, in relation to horse-power, is generally the difference in the head resistance.

Fig. 2 shows the lift and drift of the section adopted as the most suitable for the present design, the results being given in pounds per square foot at a speed of one mile per hour.

From existing machines it is estimated that at a maximum, the total weight of the machine, with pilot and fuel necessary for a flight of 1½ hours, will not exceed 1,100 pounds. The maximum loading per square foot is assumed to be 10 pounds which gives as the total area of the main planes 110 square feet.

Fig. 2 shows that the maximum angle of incidence possible with the type of wing section adopted is 15 degrees, at which angle the lift is 0.0024 pounds per square foot. It is now necessary to know what is the minimum speed that will give a support of 10 pounds per square foot. When 0.0024 is multiplied by such a multiplier of Fig. 1 that the result is equal to 10, then the

Speed in miles per hour.	Multiplier.	Speed in miles per hour.	Multiplier.	Speed in miles per hour.	Multiplier.	Speed in miles per hour.	Multiplier.
1	1	26	676	51	2,601	76	5,776
2	4	27	729	52	2,704	77	5,929
3	9	28	784	53	2,809	78	6,084
4	16	29	841	54	2,916	79	6,241
5	25	30	900	55	3,025	80	6,400
6	36	31	961	56	3,136	81	6,561
7	49	32	1,024	57	3,249	82	6,724
8	64	33	1,089	58	3,364	83	6,889
9	81	34	1,156	59	3,481	84	7,056
10	100	35	1,225	60	3,600	85	7,225
11	121	36	1,296	61	3,721	86	7,396
12	144	37	1,369	62	3,844	87	7,569
13	169	38	1,444	63	3,969	88	7,744
14	196	39	1,521	64	4,096	89	7,921
15	225	40	1,600	65	4,225	90	8,100
16	256	41	1,681	66	4,356	91	8,281
17	289	42	1,764	67	4,489	92	8,464
18	324	43	1,849	68	4,624	93	8,649
19	361	44	1,936	69	4.761	94	8,836
20	400	45	2,025	70	4,900	95	9,025
21	441	46	2,116	71	5,041	96	9,216
22	484	47	2,209	72	5,184	97	9,409
23	529	48	2,304	73	5,329	98	9,604
24	576	49	2.401	74	5,476	99	9,801
25	625	50	2,500	75	5,625	100	10,000

Fig. 1.—Table of Multipliers to be Applied to Lift and Drift at a Speed of One Mile Per Hour, to Obtain the Lift and Drift at Any Other Stated Speed.

speed opposite such multiplier is the slowest speed possible for the proposed monoplane. In the case under consideration the speed is found to be about 65 miles per hour.

It is now necessary to lay out the design chart illustrated in Fig. 3, to show the different resistance and power curves in such a way as to keep clearly in mind the various factors and their bearing on the whole design. The first curve to draw on the chart is the curve showing the plane resistance (curve No. 1) showing as it does the head resistance of the main planes at different angles of incidence and such speed in miles per hour that will give a support of 10 pounds per square foot for a total area of 110 square feet.

At 15 degrees the drift is 0.00057 pounds per square foot which, when multiplied by 4,225, the multiplier of 65 miles, gives the resistance of 2.408 pounds; this multi-

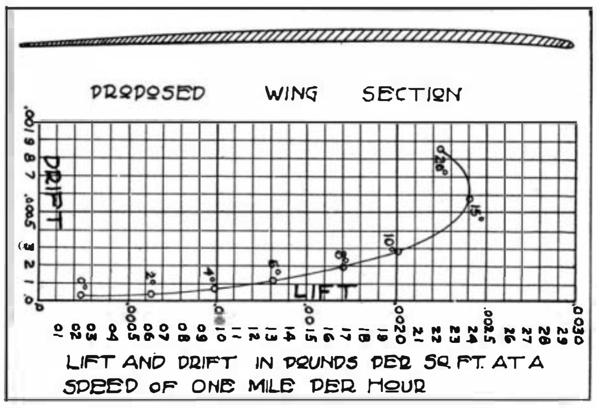

Fig. 2.

plied by 110, the number of square feet in the planes, gives as the total resistance of the planes at the speed of 65 miles per hour, 265 pounds. The lift at ten degrees is 0.00202 pounds with a drift of 0.00028 pounds. Ten divided by 0.00202 equals 4,950, multiplier of about 70 miles; 4,950 multiplied by 0.00028 and the result multiplied by 110 gives 151, the resistance of the planes at 70 miles per hour at an angle of 10 degrees, at which speed the support will be 1,100 pounds. Proceed in this manner and calculate the resistance for the different speeds up to 120 miles, as shown in the aeroplane chart, Fig. 3.

It has now been determined that, for a speed of 110 miles per hour, 110 square feet of surface is necessary to support 1,100 pounds at an angle of incidence of about 3½ degrees. To support this weight, at that speed, will require about 30 horse-power, if an efficiency of 70 per cent of the propeller is assumed. If the horse-power required for flight were only necessary to support the weight, speeds of 200 miles per hour would appear feasable, as the actual power necessary for support decreases with the increase of speed. Increase in speed is only a matter of decreasing the head resistance of the body and other essential parts of the machine. In the past the body design has been made to conform to the shape of the motor, and in almost every case is much larger than that necessary to contain the aviator and all controls. In the present design the cross section of the body is that necessary to contain the aviator, the motor and all accessories being so located in the same body as not to set up any additional head resistance. Such a cross section of the body will be the least possible for any aeroplane, as the dimensions adopted are based solely on the size of the pilot.

Fig. 3 shows the plan, elevation, and side view of the design. No attempt is made to show the structural features, as the present article has to do only with the size and arrangements of the different elements of the aeroplane. It is now necessary to estimate the head resistance of the different parts of the design as shown in Fig. 3. This is done by taking each exposed surface separately, correcting for shape and length to breadth ratio, and adding them all together to represent the total head resistance of a single surface, placed normally to the line of flight. The resistance, on calculation is found to be equivalent to less than four square feet of normal surface.

Using this amount as the area of head resistance, the resistance at the different speeds is calculated. The results are shown on the design chart by curve No. 2, Fig. 3. This curve shows the total head resistance of the machine, other than the plane resistance. The plane resistance is added to the body resistance, giving the total resistance as shown in curve No. 3. The chart also illustrates the speed of flight in feet per minute. If the resistance in pounds, at a given speed in miles per hour, is multiplied by the equivalent speed in feet per minute and the result divided by 33,000, it will give the necessary horse-power required at that speed. This has been done for the different speeds and resistances and is shown in curve No. 4, as the horse-power required. From this curve it is seen that about 65 effective horse-power is required to maintain a speed of 110 miles per hour. If an efficiency of 70 per cent is assumed for the propeller, at least 93 horse-power will be necessary for horizontal flight. In order to have a reserve of power and provide for climbing, a motor of at least 120 horse-power should be used. Assuming that the motor selected will give that power at 1.200 revolutions per minute and that its power is proportional to the speed, the horse-power available is next plotted by taking the power at a given number of revolutions. Correcting for the assumed slip of the propeller at that speed, will give the speed of advance at the number of revolutions considered, the power being corrected for the efficiency of the propeller. For instance, at a speed of 1,000 revolutions per minute, the power of the motor will be 100 horse-power, which, at 70 per cent efficiency, will be 70 effective horse-power. The propeller is 8 feet 6 inches diameter with a pitch of 11 feet 6 inches, of which the assumed slip is 28 per cent, so that the speed of advance will be 11,500 feet, less 28 per cent, which gives 8,280 feet as the speed of advance, or 94 miles per hour. At this speed the motor and propeller will be giving 70 effective horse-power. Proceeding in this manner, the effective horse-power curve is drawn for different engine speeds up to and including 1,300 revolutions per minute. This curve is shown as No. 6 in Fig. 3.

Curve No. 5, showing the gliding angle, is next plotted. This curve shows the gliding angle in degrees and as a ratio of the distance descended to the distance traveled in a horizontal direction. It is obtained by dividing the total weight by the total resistance at the different speeds, and shows the best possible gliding angle for the different speeds. The curve shows the best gliding angle to be about 9½ degrees, at a speed of 85 miles per hour. The chart also shows that, at a speed of about 95 miles per hour, there is a reserve of about 25 horse-power, which will permit a climbing rate of about 700 feet per minute. The chart further shows that the proposed design should give the extreme speed of 120 miles per hour.

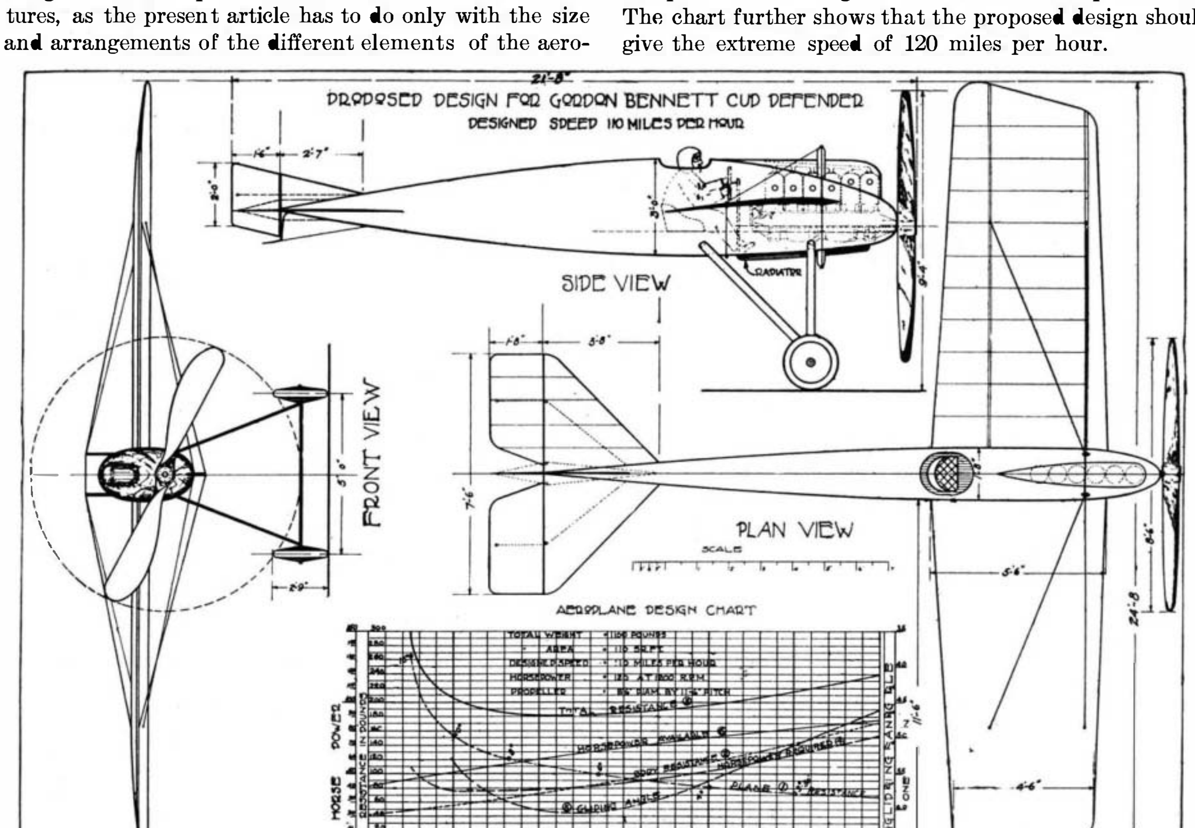

Fig. 3.

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[1] At Pau, on March 2nd, Jules Vedrines, on a 140 H. P. Gnome-engined Deperdussin monoplane, covered one circuit of a 10-kilometer (6.21-mile) course in 3 min. 34⅖ secs., equivalent to a speed of 104.33 miles an hour. This is the record at the present time. The Paulhan-Tatin torpedo monoplane, with propeller at the rear end of the body, is credited with a speed of 94 m. p. h. with a 50 H. P. Gnome motor.