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AN ANALYSIS OF THE RATE OF ASCENT OF PILOT BALLOONS AT BUTLERS CROSS, SALISBURY PLAIN,

BY

R. P. BATTY, B.A.

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The home station is in Latitude 51° 15′ North, Longitude 1° 58′ West (approximately), and stands 498 feet above Mean Sea Level.

The two out-stations were 5,532 feet and 5,067 feet, respectively, from the home station. An excellent exposure is obtained at this station, the intervening country being mainly pasture land.

The period during which the ascents were made was from June 24th, 1919, to December 18th, 1919. Table I shows how the ascents were distributed throughout that period; double theodolite ascents being made on 84 days out of the 178 days in that period. Unfortunately for the results of this analysis, the ascents were not made at fixed hours of the day, but only when required by the School of Artillery.

As will be seen from the totals in Table I, more than 75 per cent. of the ascents were made between the hours of 9 and 13 G.M.T.

In **Table I** ascents occurring between 9h. and 9h. 59m. are grouped under the heading " 9 "; ascents occurring between 10h. and 10h. 59m. are grouped under the heading " 10," and so on.

The greater number of the ascents occur during the months of July, August and September, and at times of the day when convection currents of varying amounts would be expected. This fact should be borne in mind when considering the mean rates of ascent in the later tables.

Table II gives the average rates of ascent of pilot balloons for the first 13 minutes of the ascents. The analysis is not carried beyond 13 minutes, as practically no balloons were followed for longer than that time. (The School of Artillery only requires meteorological corrections up to a 40 seconds time of flight, *i.e.*, approximately to a trajectory height of 6,400 feet.)

As a matter of fact, out of the 225 ascents considered, complete 13 minutes readings were obtained from 20 ascents only.

From the 225 pilot balloon ascents 1,464 minute readings were obtained. Taking the grand total of all the rates of ascent worked out for each minute and dividing by 1,464, we find that the **mean rate of ascent of Pilot Balloons is 530 feet per minute.**

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ascent occur in the first and thirteenth minutes. The excess in the thirteenth minute average rate of ascent is probably due to the fewness of the observations, viz., 20 only.

The excess in the first minute average rate of ascent is a natural consequence of the effect of rising currents due to the heating of the surface of the earth This effect would be most pronounced in the lower layers of the atmosphere.

From the fourth to the twelfth minutes (*i.e.*, between 2,000 feet and 6,000 feet) the mean rate of ascent is 509 feet per minute.

In **Table III** the ascents have been grouped for **specified hours** of the day, viz., 8h. and 9h.; 10h.; 11h.; 12h.; and 13h. to 19h. The ascents have been grouped in this manner in order to obtain a more equal number of ascents in each group for the purpose of illustrating the diurnal variations in the rates of ascent of pilot balloons. Thus, for 8h. and 9h. we have 48 ascents, with a total of 292 minute readings; for 10h. we have 46 ascents, with a total of 261 minute readings; for 11h. we have 56 ascents, with a total of 357 minute readings; for 12h. we have 34 ascents, with a total of 250 minute readings; and for 13h. to 19h. we have 41 ascents, with a total of 304 minute readings. It should be pointed out that the majority of the ascents in this last group occurred between 13h. and 14h.

The mean rate of ascent for 8h. and 9h. is 517 feet per minute.
" " " 10h. " 515 " " "
" " " 11h. " 535 " " "
" " " 12h. " 560 " " "
" " " 13h. to 19h. " 527 " " "

Owing to the varying hours of the ascents, it is impossible to obtain an hourly curve showing the diurnal variations in the rates of ascent of pilot balloons. Table III is the best obtainable under the existing circumstances, taking into consideration all the ascents; but diurnal variations for certain days have been exemplified in Table VII.

It will be seen from Table III that the largest variations during the day in the rates of ascent are to be found in the lower layers of the atmosphere; generally speaking, up to 2,500 feet. Above this height there is usually little variation in the rates of ascent of pilot balloons throughout the day. (The somewhat large differences in the rates of ascent for the 12th and 13th minutes are probably due to the fewness of the observations for these minutes.)

Curves illustrating the diurnal variations in the rates of ascent, as demonstrated by Table III, are appended.

In **Table IV** the ascents have been classified according to the **amount of Cloud** in the sky, on the basis 0 (cloudless) to 10 (completely overcast). Three groups have been made, viz.: Cloud amount nil; Cloud amount 1 to 5; and Cloud amount 6 to 10.

For Cloud amount nil we have 35 ascents, giving 323 minute readings, with a mean rate of ascent of 515 feet per minute.

(28636—12) Wt. 5456—345 625 7/20 H. St. G. 3

For Cloud amount 1 to 5 we have 50 ascents, giving 390 minute readings, with a mean rate of ascent of 524 feet per minute.

For Cloud amount 6 to 10 we have 140 ascents, giving 751 minute readings, with a mean rate of ascent of 541 feet per minute.

From the above we see that increased cloud amounts in the sky give an increased rate of ascent for pilot balloons—a result to be expected, as the formation of clouds entails rising currents of air.

It will be seen from the graphs appended that the increased rates of ascent for increased cloud amounts are spread generally over the whole of the 13 minute readings of the ascents.

In **Table V** the ascents have been classified, according to specified **surface wind force,** into the following three groups :—

For surface wind 0 to 11 feet per second (light winds).
For surface wind 12 to 26 ,, ,, ,, (moderate winds).
For surface wind 27 to 45 ,, ,, ,, (strong winds).

For light winds we have 36 ascents, giving 312 minute readings, with a mean rate of ascent of 509 feet per minute. This result is quite a good one, as the assumed rate of ascent of 500 feet per minute is obtained in still air.

For moderate winds we have 138 ascents, giving 864 minute readings, with a mean rate of ascent of 537 feet per minute.

For strong winds we have 51 ascents, giving 288 minute readings, with a mean rate of ascent of 535 feet per minute.

It will be seen from Table V that very few ascents in the case of strong winds gave more than 10 minute readings. This probably accounts for the fact that the mean rate of ascent for strong winds is slightly less than that for moderate winds.

It should also be pointed out that the majority of cases of gusty surface winds occur in the group of strong winds.

In **Table VI** the ascents have been classified according to specified **Gradient Winds,** the direction of the wind at 2,000 feet being taken as the gradient wind.

Winds between 45° and 135° have been grouped as Easterly ; winds between 135° and 225° as Southerly ; winds between 225° and 315° as Westerly ; and winds between 315° and 45° as Northerly.

For Easterly winds we have 22 ascents, giving 135 minute readings, with a mean rate of ascent of 515 feet per minute.

For Southerly winds we have 41 ascents, giving 302 minute readings, with a mean rate of ascent of 521 feet per minute.

For Westerly winds we have 96 ascents, giving 608 minute readings, with a mean rate of ascent of 533 feet per minute.

For Northerly winds we have 66 ascents, giving 419 minute readings, with a mean rate of ascent of 538 feet per minute.

From these results it appears that the direction of the gradient wind affects the rate of ascent of pilot balloons. Among the con-

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From these results it appears that the direction of the gradient wind affects the rate of ascent of pilot balloons. Among the con-

tributory causes to the above effects the following should be noted :—

(1) The percentage of light surface winds in the ascents in each of the four quadrants is as follows :

	Per cent.
(*a*) Easterly winds	27
(*b*) Southerly winds	17
(*c*) Westerly winds	15
(*d*) Northerly winds	14

From Table V we see that this would increase the rate of ascent of pilot balloons in the order named above.

(2) The percentage of ascents in which the cloud amount in the sky was less than 5 in the various quadrants is as follows :

	Per cent.
(*a*) Easterly winds	41
(*b*) Southerly winds	49
(*c*) Westerly winds	38
(*d*) Northerly winds	36

From Table IV we see that this would increase the rate of ascent of pilot balloons in the order (*b*), (*a*), (*c*) and (*d*).

In **Table VII** one ascent in each of the months July, August and September has been considered, in order to illustrate the **diurnal variations** in the rate of ascent of pilot balloons. The prevailing conditions were as follows :—

(a) *July 11th*, 1919.

The atmosphere throughout the day was hazy ; cloud amount from 5 to 7, chiefly Ci. and Ci.St. ; the range of temperature from 65° at 9h. to a maximum of 75° at 12h. 40m. ; the barometer was falling steadily during the day.

At 9h. the mean rate of ascent was 475 feet per minute ; at 10h. 40m. the mean rate of ascent was 569 feet per minute ; at 11h. 40m. the mean rate of ascent was 546 feet per minute ; at 12h. 40m. the mean rate of ascent was 531 feet per minute ; at 14h. 30m. the mean rate of ascent was 495 feet per minute ; and at 16h. 15m. the mean rate of ascent was 408 feet per minute.

(b) *August 21st*, 1919.

The atmosphere throughout the day was clear ; cloud amount from 3 to 6, chiefly Cu. and Fr.Cu. ; the range of temperature from 60° at 9h. to a maximum of 65° at 14h. ; the barometer was rising steadily during the day.

At 9h. the mean rate of ascent was 434 feet per minute ; at 10h. 15m. the mean rate of ascent was 419 feet per minute ; at 11h. 15m. the mean rate of ascent was 672 feet per minute ; at 12h. 5m. the mean rate of ascent was 700 feet per minute ; at 14h. 10m. the mean rate of ascent was 733 feet per minute ; and at 15h. 15m. the mean rate of ascent was 677 feet per minute.

In this case the maximum rate of ascent occurred about the time of maximum surface temperature.

(c) *September 18th*, 1919.

The atmosphere throughout the day was hazy; cloud amount from 2 at 9h. 30m. to 7 at 15h. 15m., chiefly Ci. and St.Cu.; the range of temperature from 62° at 9h. 30m. to a maximum of 69° at 14h. 30m.; the barometer was falling steadily throughout the day.

At 9h. 30m. the mean rate of ascent was 442 feet per minute; at 10h. 45m. the mean rate of ascent was 574 feet per minute; at 12h. 15m. the mean rate of ascent was 712 feet per minute; at 14h. 15m. the mean rate of ascent was 563 feet per minute; and at 15h. 15m. the mean rate of ascent was 531 feet per minute.

Only 3 minute readings were obtained for the ascent at 12h. 15m.; this probably accounts for the somewhat high rate of ascent. In this example, the maximum rate of ascent occurred about two hours before the maximum surface temperature was attained (as in the first example considered).

Curves illustrating the above variations in rates of ascent are appended.

Other conclusions derived from this analysis are:—

(*a*) That immediately prior to entering cloud the rate of ascent of pilot balloons almost invariably increases appreciably; in most cases to 600-700 feet per minute.

(*b*) That in cases where the surface wind was changing considerably during an ascent there were large variations in the rates of ascent, especially between 1,000 and 2,000 feet.

(*c*) That in cases where the morning fog had cleared within half an hour of an ascent the rate of ascent was uniform, and very nearly 500 feet per minute.

(*d*) That gusty surface winds produce large variations in the rate of ascent of pilot balloons, especially in the first 1,500 feet.

(*e*) That rain has a very appreciable effect on the rate of ascent of pilot balloons, decreasing it by about 20 per cent.

(*f*) That drizzle does not appear to have very much effect on the rate of ascent of pilot balloons.

(*Note.*—Few examples have occurred of double theodolite ascents in rain and drizzle.)

Addenda.

(1) Tables III. and IV. are not given in detail as they are fully exemplified in Figures 1 to 4.

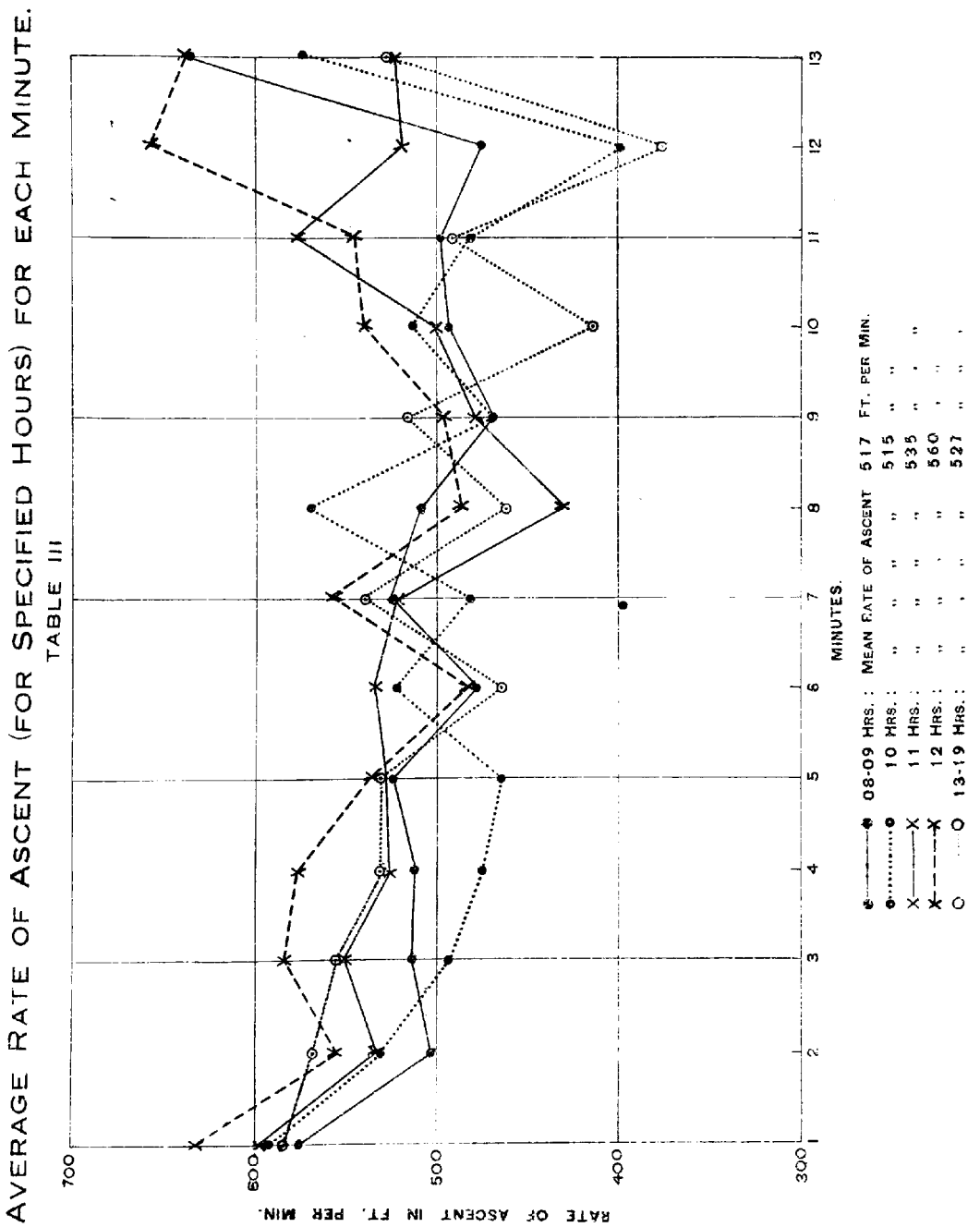
(2) The size of the pilot balloons used in the above ascents was 70 inches or 90 inches.

Their weight varied between 20 grammes and 30 grammes.

In the formula for the rate of ascent—

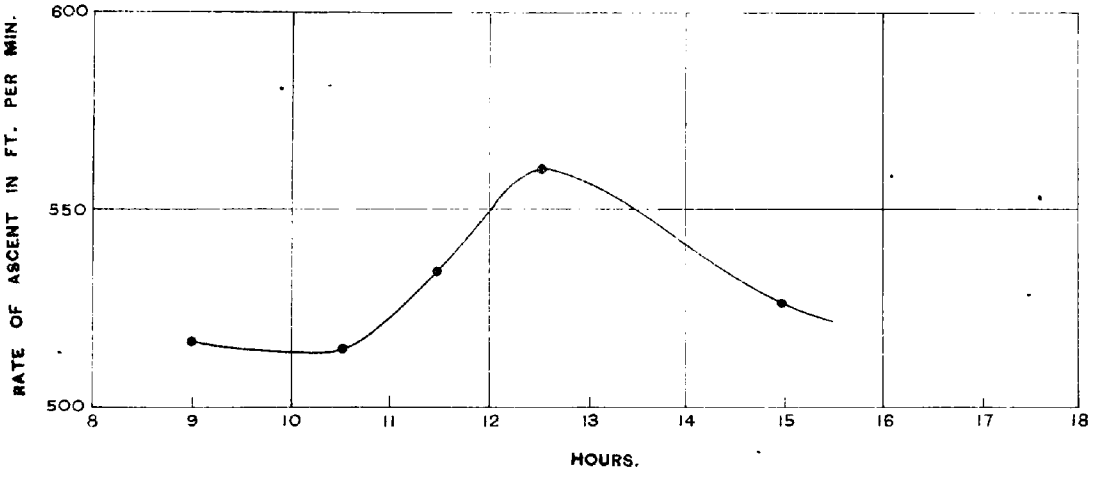
$$V = q \frac{L^{\frac{1}{3}}}{(W + L)^{\frac{1}{3}}}$$

q was taken as equal to 84; (276, using units in feet).


AVERAGE RATE OF ASCENT (FOR SPECIFIED HOURS) FOR EACH MINUTE.
TABLE III
RATE OF ASCENT IN FT. PER MIN.
700
600
500
400
300
1
2
3
4
5
6
7
8
9
10
11
12
13
MINUTES.
08-09 HRS. : MEAN RATE OF ASCENT 517 FT. PER MIN.
10 HRS. : " " " " 515 " "
11 HRS. : " " " " 535 " "
12 HRS. : " " " " 560 " "
13-19 HRS. : " " " " 521 " "

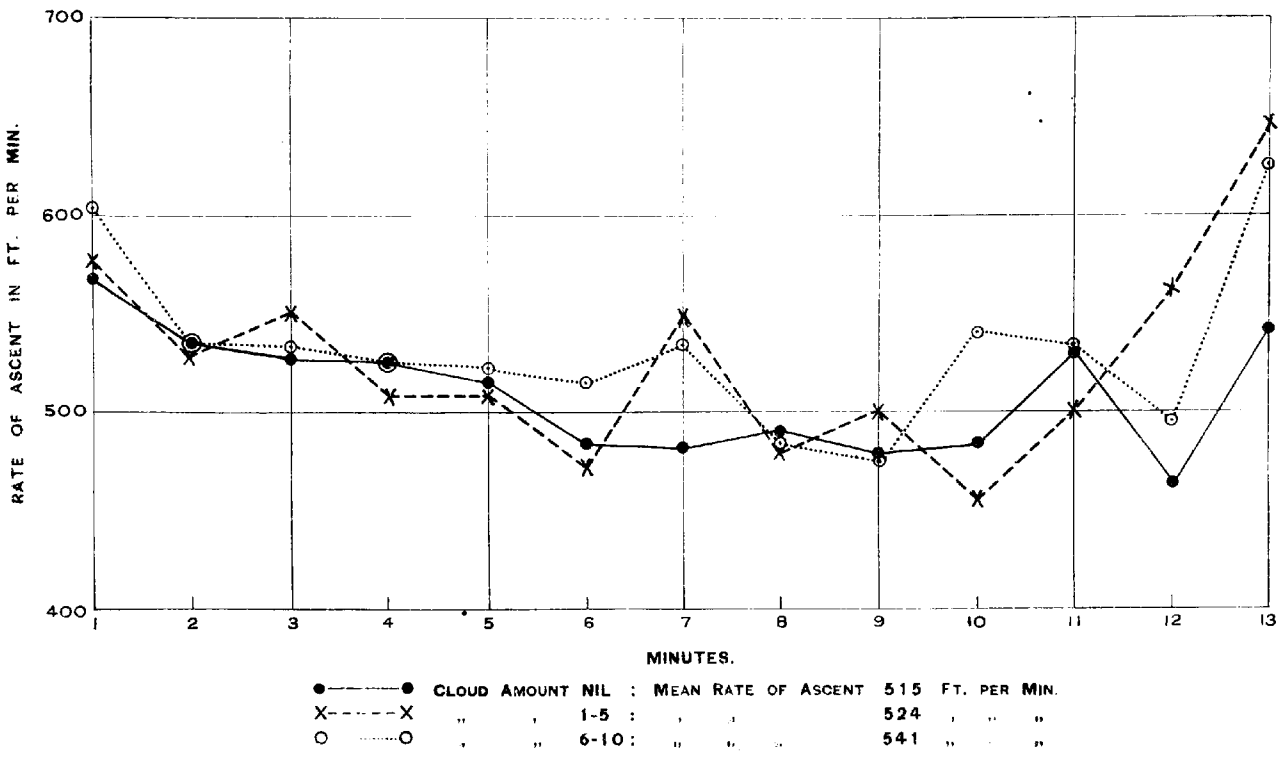
Diurnal Variations in Rates of Ascent of Pilot Balloons.

TABLE III.



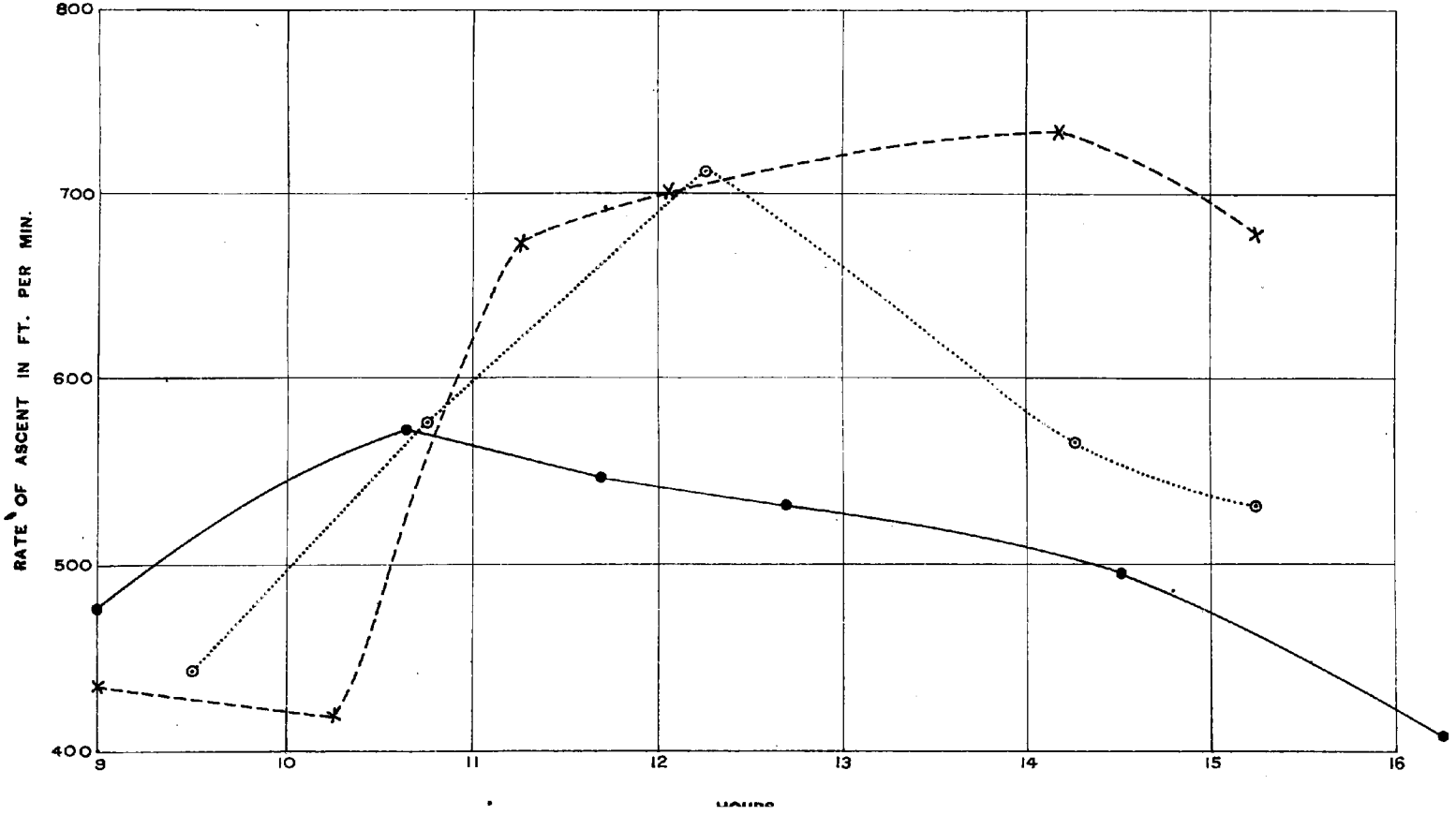
AVERAGE RATE OF ASCENT (FOR SPECIFIED CLOUD AMOUNTS) FOR EACH MINUTE.

TABLE IV.



Diurnal Variations in Rates of Ascent for Specified Days.

TABLE VII.



The free lifts used were as follows :—

W.	*L*.
20 grammes.	62 grammes.
21 „	63 „
22 „	64 „
30 „	72 „

(An increase of one gramme in *W* increasing *L* by one gramme.)

TABLE I.—NUMBER OF ASCENTS AT VARIOUS HOURS.

Month.	Hours.												Totals.
	8	9	10	11	12	13	14	15	16	17	18	19	
June ...	—	3	2	—	—	—	—	—	—	—	—	—	5
July ...	6	10	9	15	4	2	3	2	1	—	—	—	52
August ...	5	13	13	14	7	4	4	3	3	1	1	1	69
September	2	7	13	9	7	4	4	2	2	—	—	—	50
October ...	—	2	9	12	9	2	—	—	—	—	—	—	34
November	—	—	—	2	4	1	—	—	—	—	—	—	7
December	—	—	—	4	3	1	—	—	—	—	—	—	8
TOTALS ...	13	35	46	56	34	14	11	7	6	1	1	1	225

TABLE II.—AVERAGE RATE OF ASCENT IN FT. PER MIN. (FOR ALL HOURS) FOR EACH MINUTE.

	Minutes.												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Average rate of Ascent ...	593	534	537	521	516	497	525	515	486	493	523	503	587
Number of Readings ...	225	221	199	177	155	122	95	71	59	49	40	31	20

Mean Rate of Ascent for 1,464 Minute Readings. 530 Feet per Minute.

TABLE V.—AVERAGE RATE OF ASCENT (FOR SPECIFIED SURFACE WIND FORCE).

Surface Wind.	Mean Rate of Ascent.	No. of Minute Readings.	No. of Ascents giving more than 10 min. Readings.
0–11 ft./sec.	509 ft./min.	312	15
12–26 ft./sec.	537 ft./min.	864	21
27–45 ft./sec.	535 ft./min.	288	4

TABLE VI.—AVERAGE RATE OF ASCENT (FOR SPECIFIED GRADIENT WINDS).

Gradient Wind.	Mean Rate of Ascent.	No. of Minute Readings.	No. of Ascents Analysed.
Easterly	515 ft./min.	135	22
Southerly ...	521 ft./min.	302	41
Westerly... ...	533 ft./min.	608	96
Northerly ...	538 ft./min.	419	66

TABLE VII.—DIURNAL VARIATIONS IN RATES OF ASCENT FOR SPECIFIED DAYS.

	Minutes.													Mean rate of Ascent
	1	2	3	4	5	6	7	8	9	10	11	12	13	
July 11th, 1919.	Rate of Ascent in Feet per Minute.													
9h.	418	361	557	335	465	590	623	538	275	580	460	500	—	475
10h. 40m.	764	852	625	570	340	600	585	415	520	525	515	228	853	569
11h. 40m.	531	684	670	505	595	558	543	490	455	508	488	490	585	546
12h. 40m.	533	268	445	705	715	495	495	575	620	515	525	520	490	531
14h. 30m.	434	329	414	369	390	650	880	—	—	—	—	—	—	495
16h. 15m.	614	856	454	413	270	285	320	255	323	298	398	—	—	408
Aug. 21st, 1919.														
9h.	350	184	305	255	510	665	685	515	—	—	—	—	—	434
10h. 15m.	520	390	495	390	375	345	—	—	—	—	—	—	—	419
11h. 15m.	655	600	760	—	—	—	—	—	—	—	—	—	—	672
12h. 5m.	470	550	792	1,120	750	515	—	—	—	—	—	—	—	700
14h. 10m.	700	84	780	590	700	750	910	530	1,000	535	—	—	—	733
15h 15m.	650	660	540	750	785	—	—	—	—	—	—	—	—	677
Sept. 18th, 1919.														
9h. 30m.	545	480	490	420	485	360	430	325	440	—	—	—	—	442
10h. 45m.	613	520	598	695	445	—	—	—	—	—	—	—	—	574
12h. 15m.	660	725	750	—	—	—	—	—	—	—	—	—	—	712
14h. 15m.	790	465	300	765	440	625	555	—	—	—	—	—	—	563
15h. 15m.	593	548	602	575	495	375	—	—	—	—	—	—	—	531

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11h. 15m.	655	600	760	—	—	—	—	—	—	—	—	—	—	672
12h. 5m.	470	550	792	1,120	750	515	—	—	—	—	—	—	—	700
14h. 10m.	700	84	780	590	700	750	910	530	1,000	535	—	—	—	733
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