To obtain the highest degree of accuracy in pilot balloon work it is believed that a standard rate of ascent should be adopted for both one and two theodolite work. All balloons used should be as near the same weight and shape as it is practicable to obtain. They should be inflated so as to cause them to ascend at the standard rate. A balloon weighing 30 grams inflated so as to give it a free lift of 132 grams will, it is believed, be found to be a convenient combination to use. Such a balloon should ascend at the rate of approximately 183 meters (600 feet) per minute. The use of balloons of the same weight and the same free lift has the effect of eliminating some of the possible sources of error made in computing the results of the ascensions. Observers making two-theodolite observations will become familiar with the conditions that produce variations from the expected rate of ascent of the balloons and it is believed that ultimately desirable data on this problem may be collected. Increasing considerably the free lift of a balloon above 132 grams does not increase the rate of ascent sufficiently to justify the additional expense involved in securing larger balloons.

To compensate for the increase of rate in the lower levels, certain corrections may be introduced in the computations of the altitude of the balloon during the first five minutes of the ascent. It has been found that for balloon ascensions made in the United States the computed altitudes of the balloons agree best with the actual altitudes if the rate of ascent as indicated by the Signal Corps formula be increased by 20 per cent for the first minute of the ascension, 10 per cent for the second and third minutes, and 5 per cent for the fourth and fifth minutes, respectively. A long series of observations will probably indicate that an individual series of corrections should be used for each station, and, as Table 1 indicates, these corrections vary for the different hours of the day and for the different weather conditions. However, it is evident from an examination of the data in Tables 1 and 2 and it is shown also in Table 3 that the introduction of these corrections for the first five minutes of the ascension improves the accuracy of one theodolite observation.

Table 3 shows the agreement of one-theodolite observations with two-theodolite observations with and without the corrections named above.

TABLE 3.—*Number of one-theodolite observations.*

	Within 2 per cent.	Within 5 per cent.	Within 10 per cent.	Within 25 per cent.	Within 50 per cent.	In excess of 50 per cent.	Number of observations.
Without corrections	74	178	324	560	686	18	704
With corrections	92	212	389	646	700	4	704

Table 4 indicates the agreement of one-theodolite observations with two-theodolite observations and, therefore, the degree of accuracy that may be expected from one-theodolite observations.

TABLE 4.—*Showing how single-theodolite observations agree with double-theodolite observations, made at four stations.*

At end of minutes.	Within 2 per cent.	Within 5 per cent.	Within 10 per cent.	Within 25 per cent.	Within 50 per cent.	More than 50 per cent difference.	Number of observations.
1	12	30	62	118	146	4	150
2	7	36	71	136	157	4	161
3	19	39	79	144	159	4	163
4	17	44	88	140	160	2	162
5	18	49	90	145	162	1	163
10	28	68	113	152	158	0	158
15	18	54	86	105	106	0	106
20	24	42	56	62	62	0	62
25	13	30	41	46	46	0	46
30	11	22	30	30	30	0	30
35	9	15	20	20	20	0	20
40	3	4	7	8	8	0	8
Total	179	433	743	1,106	1,214	15	1,229

In preparing the above tables it was assumed that observations made with two theodolites were correct, and where the one theodolite computations gave different results it was assumed that the one theodolite method was in error. It is recognized that this assumption may be questioned. However, in several cases when three theodolites were used, altitudes computed from the three base lines were in very good agreement, usually within 4 per cent.

A number of ascensions were made with three to five balloons, each of the same free lift, tied together. The results are not conclusive, but these groups of balloons appeared to ascend at a somewhat more nearly constant rate and at about the same rate as the average rate of a number of individual balloons of the same free lift.

SOME RECENT PAPERS ON THE RATE OF ASCENT OF PILOT BALLOONS.

(Abstract and discussion.)

By W. R. GREGG.

In 1917 R. Wenger [1] advanced the theory that variations from average rates of ascent of pilot balloons are caused by turbulence of the air, this turbulence being due to various factors, including topographic irregularities, insolation effects, and marked changes in wind direction or speed as increasing altitudes are reached. As a corollary he states that the observed variations in rates of ascent can not be accepted as indicating the presence of ascending or descending currents in the atmosphere, but rather that they constitute a direct measurement of the degree of turbulence therein. This view is quite at variance with that commonly held before Wenger's paper was published.

Recently there have appeared in *Nature* two notes in which issue is taken with Wenger's conclusions. In the first [2] Van Bemmelen presents results based upon three very complete series of observations at Batavia, Bandung, and on a small coral island in the Java Sea. Insolation was very active at the first two places, but negligible at the third. The results show at the land stations a marked increase in ascent in the first kilometer during the daytime, this increase being greatest between noon and 6 p. m., and no increase whatever at night; at the small island station there was no variation either day or night. Van Bemmelen concludes, therefore, that variations are due almost entirely to vertical currents, more especially since in his observations there was rarely found a velocity as high as 15 m. p. s., above which, according to Wenger, the effects of turbulence become most pronounced. [Wenger states that a *new* turbulent state

[1] Die Steigegeschwindigkeit der Gummiballone und die Turbulenz in der Atmosphäre. Annalen der Hydrographie und Maritimen Meteorologie, 1917, 45: 121-137.

[2] High Rates of Ascent of Pilot Balloons, *Nature* (London), June 17, 1920, pp. 485-486; abstr. in *Sci. Abs.*, Dec. 30, 1920, pp. 614-615.

enters at these high velocities. This, however, is only one of several conditions causing turbulence.—W. R. G.]

In the second note referred to,[3] Mr. J. S. Dines compares Van Bemmelen's results with those obtained in a series of observations in the Scilly Islands [4] and arrives at the same conclusion. He states that the islands are so small that no convection effects would be expected, but that, owing to the rocky and hilly nature of these islands, considerable turbulence during strong winds *would* be expected. Nevertheless, the averages show little variation in the rate of ascent with altitude, the rate being, if anything, slightly less below than above 1 kilometer. It should be noted, however, that turbulence due to the islands would not extend to any great height, since they cover only a small area and do not rise above 40 or 50 meters. In the original publication referred to [4] the average rates of ascent are given for 5 minute periods, all observations being included. For the first 5 minutes, the rate is 161 m. p. m., but if we consider the first and second minutes only we find that the rates are higher than the average, viz, 164 and 168, respectively. Moreover, 7 of the ascents, viz, Nos. 4, 18, 19, 24, 31, 32, and 33, were made under conditions of increasing wind velocity with altitude reaching approximately 15 m. p. s. during the first 5 minutes of ascent. Five of the cases cited show a rate of ascent considerably above the average in the first 2 minutes; one shows nearly the average rate, and one, a rate somewhat below the average. The mean values for the 7 cases are 178 in the first minute, 181 in the second, and 167, 153, and 157 in the third, fourth, and fifth minutes, respectively. The mean for the entire 5 minutes is 167. Averages based on so small a number of observations are not, of course, conclusive, yet the evidence seems to point to the existence of turbulence in the lower levels and a *resulting increase in rates of ascent of the balloons.*

Of considerable interest in this general connection is a recent report of pilot balloon observations at Butlers Cross, Salisbury Plain.[5] The author, Mr. Batty, has used 225 ascents in his analysis and has classified them according to time of day, amount of cloud, surface wind force, and gradient wind direction. His conclusions may be summarized as follows:

1. The average rate of ascent for all observations is greatest in the first minute, decreases during the next four minutes, and remains practically constant thereafter.
2. The rate of ascent is greatest at about noon.
3. It increases somewhat with increasing cloudiness.
4. *It is greater in strong than in light winds.*
5. *"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" (300 to 600 m.).*
6. *"Gusty surface winds produce large variations in the rate of ascent of pilot balloons especially in the first 1,500 feet" (450 m.).*

The last three conclusions strongly support Wenger's view that turbulence, induced by strong winds or by sharp changes in wind direction or velocity, is responsible for much of the observed variation in the ascensional rates of balloons. At the same time conclusion 2 shows clearly that convection likewise has an appreciable effect on rates of ascent. But is not convection merely one of the many forms of turbulence? Undoubtedly so. Unfortunately, the idea has become rather general that convection means air in more or less uniform vertical motion. Instead, the motion is very uneven and unsteady—in no sense regular for any great vertical distance. The balloon, following the line of least resistance, goes from one vertical gust into the next higher one. This is shown by its more active darting, stair-step like motion—a phenomenon familiar to every balloon observer—when convection is active. Hence it can not be assumed that observed variations from an average rate of ascent indicate the existence of uniform vertical movement in the atmosphere.

The paper by Capt. Sherry shows very conclusively that turbulence due to winds is more effective than that due to insolation in producing variations in the ascensional rates of balloons. By referring to Table 1 in that paper we see that departures are greatest when strong winds prevail, and that they are nearly as large when winds rapidly increase with altitude; also, when convection is presumably active. When winds are light and increase but slightly with altitude, there is comparatively little increase in rate of ascent, except during the first minute.

The results given by the authors of the papers thus briefly reviewed are really not contradictory at all. They all show that the rate of ascent is higher than the average when the air through which the balloons rise is in a state of turbulence. This turbulence may be due to unequal heating of adjacent masses of air, to topographic irregularities, to high wind speeds or to different wind directions or speeds, or both, of adjoining layers.

Aside from the additional light that it throws on this subject, Capt. Sherry's paper is of special interest and importance in that it shows that the value of K in the Signal Corps formula is not materially altered by the additional data considered. (See fourth paragraph in Capt. Sherry's paper.) The original value, 71, was adopted in 1918 and has been in use since then in this country. It was based upon about 1,000 observations.[6] In the present study 165 additional observations, carefully made at several stations operated by the United States Signal Corps and the United States Weather Bureau, have been included and the resultant value of the constant is found to be 72. (NOTE.—In reality the difference is slightly less than that indicated, the original value being 71.1 and the new one 71.8.) The constant 72 will be used in this country beginning April 1, 1921. We shall also apply the additive corrections, referred to in the latter part of Capt. Sherry's paper. These are, as there given, 20 per cent for the first minute, 10 for the second and third minutes, and 5 for the fourth and fifth minutes. Without these it is found, in double theodolite observations, that the actual values nearly all lie on one side of the values computed from the formula; by introducing those corrections the results will on the average be in close agreement. Of interest in this connection is the following note by Capt. Sherry, written after the completion of his paper:

Mr. Batty (see footnote 5) used balloons weighing from 20 to 30 grams, the former with 62 grams free lift and the latter with 72 grams free lift. Balloons weighing between these amounts were filled proportionately. The Signal Corps formula indicates that the rate of ascent of a balloon weighing 20 grams and having a free lift of 62 grams will be 151.4 m. p. m.; for a balloon weighing 30 grams with a free lift of 72 grams the rate of ascent will be 151.8 m. p. m. The following is a comparison of the observed rate of ascent of Mr. Batty's balloons

[3] The Rate of Ascent of Pilot Balloons, *Nature* (London), July 8, 1920, p. 58.

[4] Cave, Capt. C. J. P., and Dines, J. S. Soundings with Pilot Balloons in the Isles of Scilly, November and December, 1911. Meteorological Office. Geophysical Memoirs No. 14, London, 1920. M. O. 220d.

[5] Batty, R. P. An analysis of the rate of ascent of pilot balloons at Butlers Cross, Salisbury Plain. Meteorological Office. Professional Notes No. 12. London, 1920. M. O. 240b.

[6] Sherry, Capt. B. J., and Waterman, Lieut. A. T. The Military Meteorological Service in the United States during the War. MONTHLY WEATHER REVIEW, April, 1919, p. 218.

and the rate indicated by the Signal Corps formula if the constant of 72 is adopted and the additions are made to the first five minutes:

Minute.	Mr. Batty's observed rate (m. p. m.).	Signal Corps rate (m. p. m.).
1	181	181.9
2	163	166.9
3	164	166.9
4	159	159.3
5	157	159.3
Mean from 5 to 10 minutes	153.2	151.6

The agreement in this table is remarkably close, and strongly confirms the accuracy of the newly determined constant, as well as the necessity of introducing additive corrections during the first five minutes.

A REPORT ON TWO PILOT-BALLOON ASCENTS MADE AT SHOEBURYNESS.[1]

By N. K. JOHNSON.

(Review reprinted from *The Meteorological Magazine*, London, Dec., 1920., p. 247.)

In the two ascents to which this note is devoted, the pilot balloons were followed with two theodolites and also with a range finder. It so happened that in each case the balloon developed a defect after reaching 25,000 or 30,000 feet; the first dropped rather quickly, the second very slowly. The usual assumption of the single-theodolite method, that the rate of ascent was uniform, would have led to entirely false results, the wind being credited with speed of 100 feet per second at 60,000 feet.

The principal moral of the paper is that when information as to air currents at considerable heights is derived from the one-theodolite method it must be used with the greatest caution; it also brings out how much is to be learned concerning the structure of the atmosphere by the more elaborate two-theodolite method.

VISIBILITY OF PILOT BALLOONS.

By NELSON K. JOHNSON.

[Abstracted from the Meteorological Magazine, December, 1920. Vol. 55, pp. 249-251.]

In order to determine the most suitable color for pilot balloons under various atmospheric conditions, four ascents were made at Shoeburyness, two differently-colored balloons, tied together with about 20 feet of thread, being used in each ascent. In each of the first three cases a red and a white balloon were used, blue having already been found unsatisfactory except against a dense white background. In the fourth ascent a plain white balloon and another white one coated with aluminum paint were used. This treatment was not effective, because the paint dried a drab gray without any metallic luster. The suggestion is made, however, that if pilot balloons can be coated in the same manner as are kite balloons, both their opacity and their reflecting power would be increased. In the three ascents with red and white balloons it was found that the white ones are best in sunshine because of their greater reflecting power, and the red in cloudy weather because of their greater opacity.

The author summarizes his results as follows:

"(1) Against a background of continuous, dense white cloud either red or blue should be used.

"(2) If the sky contains slight cirrus or haze, red is the correct color to employ.

"(3) On occasions on which the sky is cloudless and of a deep blue color, a white balloon should be selected."—*W. R. G.*

[1] *Professional Notes, No. 13.* Brit. Meteorological Office publication.

VERTICAL CURRENT DETECTED BY COMPARING CLOUD MOTION WITH APPARENT SPEED OF PILOT BALLOON.

By JOSEPH LESHAN.

[Weather Bureau, Washington, D. C., Dec. 22, 1920.]

SYNOPSIS.

The pilot balloon ascension made at Washington, D. C., on the afternoon of November 23, 1920, showed a rapid rise in velocity up to the 800-meter level, and an almost equally rapid decline thereafter to the 1,800-meter level, when the balloon entered a roll of strato-cumulus cloud. The appearance of the clouds and a nephoscope observation made at that time seem to show that the balloon gained about 100 meters during the last minute of ascension over the assumed rate of ascent, and that the velocity during the last minute should be corrected from 6.2 to 13.3 meters per second.

A comparison of the altitude-velocity curve for this ascension (the heavy line in the figure) with other altitude-velocity curves for ascensions in the vicinity taken within eight hours, shows that all but one of the

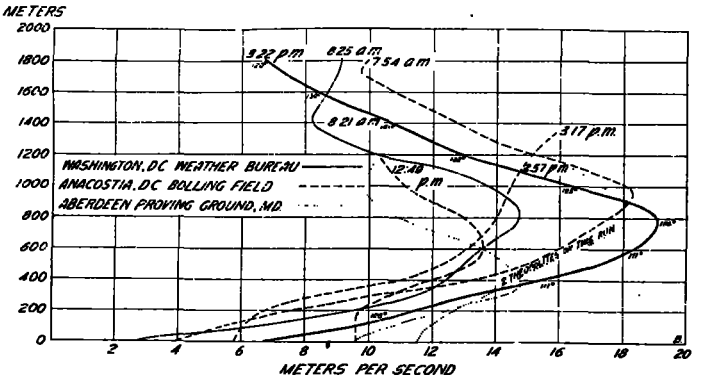

FIG. 1.—Altitude-velocity graphs for pilot balloon observations, Nov. 23, 1920. Wind directions at Washington are indicated at every 200 meters (0°=S., 90°=W.).

curves have approximately the same general characteristics except that none of them reaches as high a velocity at its maximum, nor does any of them reach as low a velocity at its minimum.

The reason for the peculiar features of the curve in question might be explained by the supposition that the balloon was in a downward current of air up to about the 800-meter level, and in an upward current during the latter part of the flight. Such currents in a single theodolite system of observation would give higher and lower computed velocities respectively.

The appearance of the lowest strato-cumulus cloud-layer at the time of observation would tend to bear out this supposition, as the clouds were in bands lying approximately northeast-southwest, and were probably formed on the crests of an air wave moving approximately from the northwest. It can be easily seen that with the balloon in the downward current of the wave the angle would be depressed and give a greater computed velocity, and conversely with the balloon in the ascending portion of the wave.

Nephoscope readings at the time of the observation indicated that the cloud which the balloon entered was moving at the rate of 7 meters per second for every thousand meters of elevation. While it is not certain that