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U. S. DEPARTMENT OF AGRICULTURE
WEATHER BUREAU
CHARLES F. MARVIN, Chief

INSTRUCTIONS
FOR
ERECTING AND USING WEATHER BUREAU NEPHOSCOPE
1919 PATTERN

Circular I, Instrument Division

PREPARED BY
BENJAMIN C. KADEL

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INTRODUCTION.

The nephoscope to be described has been recently developed in the Instrument Division of the Weather Bureau, Messrs. C. F. Marvin, B. C. Kadel, S. P. Fergusson, R. N. Covert, and E. L. G. Rauh, all contributing suggestions. While the principle of the instrument (originated by Aime in 1845) is old, the present form is believed to be the best thus far devised for general use at Weather Bureau stations.

INSTRUCTIONS FOR ERECTING AND USING WEATHER BUREAU NEPHOSCOPE, 1919 PATTERN.

1. *Description of nephoscope.*—The nephoscope adopted by the Weather Bureau in 1919 consists of three main parts, as shown in figure 1: (1) The nephoscope proper, which is a black mirror mounted in a circular frame graduated in degrees, and which is supported on three pegs of equal length, so that when the three pegs are set on a level surface the top of the mirror is likewise level; (2) a substantial support for the nephoscope, consisting of a heavy flange or base designed to be attached to a suitable platform or other mounting, an upright section of standard 3-inch pipe to give proper height, and an upper flange of generous dimensions to support the nephoscope and to support also a movable sighting eyepiece stand; (3) a movable sighting eyepiece stand, which consists of a moderately heavy cast-iron base, whose purpose is to carry the sighting eyepieces always at the selected heights, 166⅔ and 83⅓ millimeters, respectively, above the surface of the mirror. The top of the flange or table has been faced in a lathe, so that when it is properly leveled the sighting holes will be at the same vertical distance above the mirror without regard to the particular position on the table in which the stand is placed. It will be apparent from the above that the eyepiece stand can be moved on the table to suit the convenience of the observer; and this movement, combined with the rotation of the arm on which the sights are supported, makes possible a great variety of positions from which the observer may view the cloud's image in the mirror. A triangular marker to be pushed across the mirror with its apex coincident with the cloud's image, a ruler graduated in centimeters and millimeters, a small spirit level, and a clock to count time, complete the equipment. A large copper cover is also included, so that the nephoscope may be protected from the weather without the necessity of continuous removal to the office.

2. *Setting up the nephoscope.*—In setting up the nephoscope it is first necessary to select upon the roof of the building, or in some other location suited for the purpose, the best position available for observing clouds. While it is desirable to have the entire sky within range, yet this ideal condition can rarely be realized and it is therefore necessary for the official in charge to make the best possible selection as to location. A reasonably firm foundation should be had, and the roof or platform selected must be rigid enough so that the weight

of the observer will not seriously throw the instrument out of level at the time of observation. In choosing the location care must be taken that the observer may have access to the nephoscope on all sides. Where a good wooden platform is available the 19-inch base plate or flange may be bolted directly thereto, but where no such wooden platform is available then it will probably be best to bolt the base plate to the cement or composition roof by means of expansion anchor bolts; or in case the conditions are such that it is undesirable to open the roof, then a concrete foundation may be provided of rather massive proportions so that it will remain in place of its own weight. A block of concrete (fig. 1) 5 inches thick, made in the form of an equilateral triangle, 3 feet on each side, with three sections of three-fourths-inch pipe inserted near the points of the triangles, the pipes being threaded and terminating in floor flanges, offers a satisfactory and convenient means of setting up and leveling the instrument. A block of this size is small enough to be moved by two strong men, and at the same time heavy enough to give reasonable guaranty against accidental change in level or in orientation after it has been placed in position.

Plumbers' lock nuts with suitable washers offer a convenient means of leveling up the block of concrete as may be desired. This leveling is best done after the entire instrument is set up and in place. In making up the concrete block suitable holes for the bolts should be provided, and the lower flange or base plate should rest on top of the concrete, not be sunk down into it. After the concrete has hardened and the lower flange has been properly bolted thereto, the 3-inch pipe should be inserted, and the upper flange should be screwed on as tight as two men can turn it, the men standing on the concrete block at the same time. It will then be impossible for one man alone to unscrew the table top accidentally, a proceeding that would destroy the orientation. A blue print of the concrete block and details may be had upon application to the central office. It is desired that the final leveling of the instrument be accomplished with the mirror in place, in a position approximately that in which it is finally to be used. When the nephoscope is clamped to a wooden platform or to a concrete block that is not itself adjustable, then means have been provided for leveling the instrument by the cap screws to be found on the underside of the table flange. These screws may be withdrawn, and shims, which may be in the form of washers of thin sheet metal or even of paper, should be inserted until a correct level is obtained. The shims may also be used under the base plate in a similar manner. This latter means of leveling will be found somewhat more tedious than is the case where an adjustable concrete block is used, but has the advantage of being less liable to accidental change later on. It is well to test the spirit level for accuracy by reversing it.

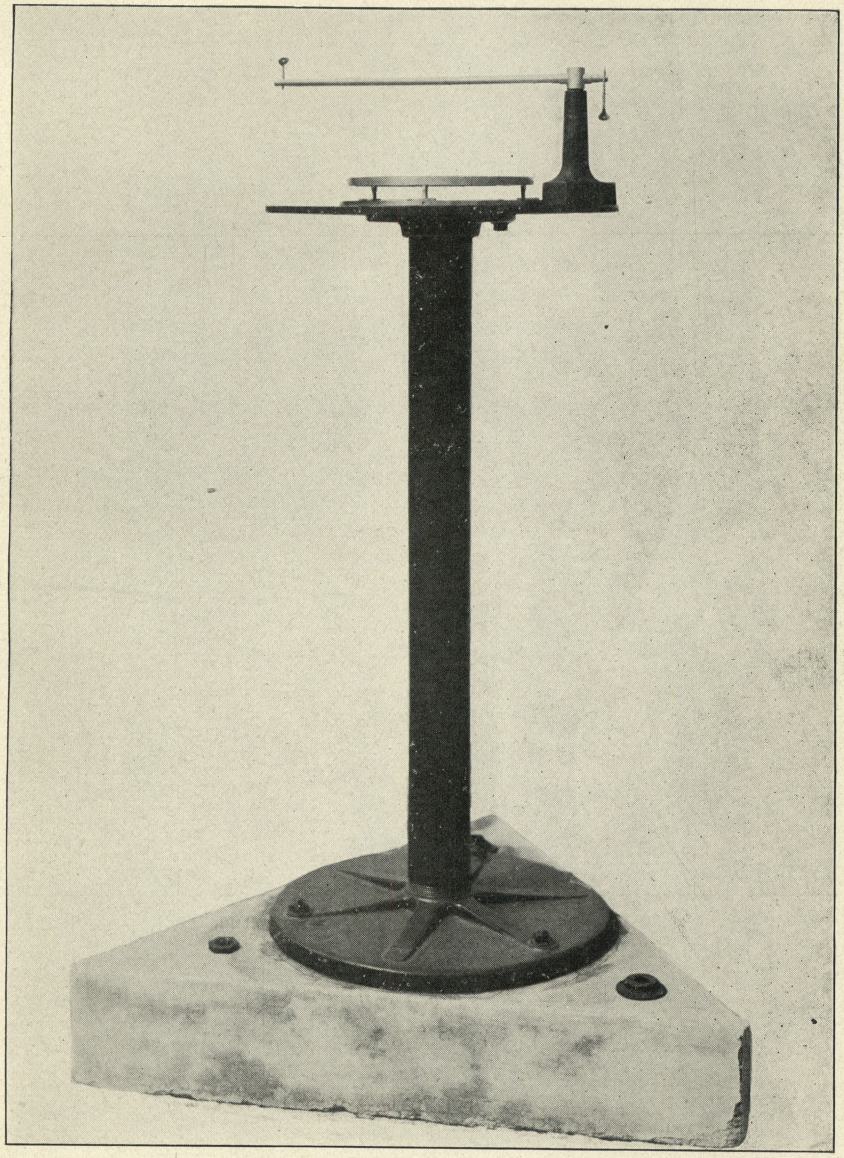

FIG. 1.—Nephoscope mounted on concrete base. (Cover not shown.)

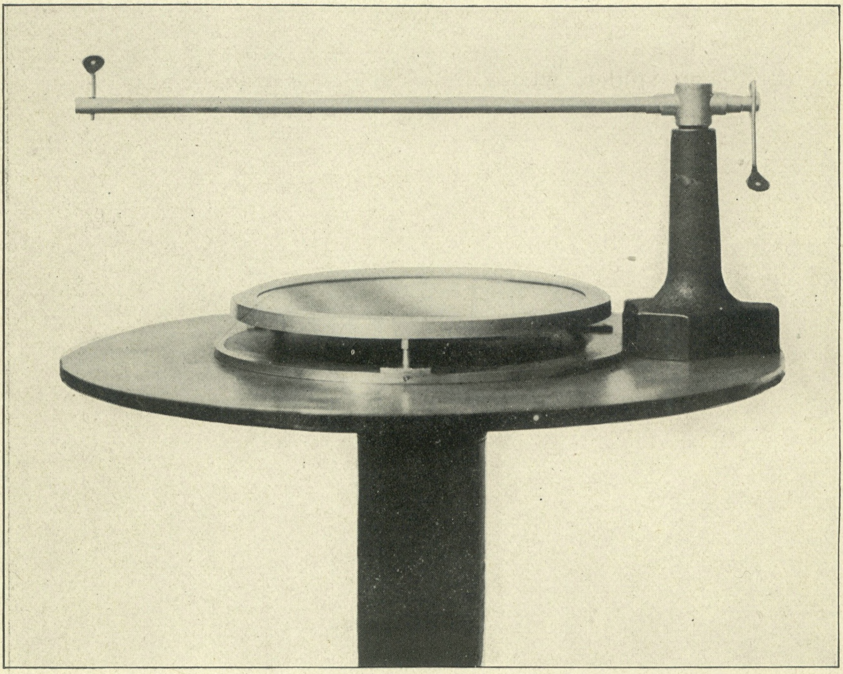

FIG. 2.—Nephoscope, table top, and eyepiece stand.

3. *Orientation*.[1]—The zero of the graduated scale on the mirror frame should be toward true north, the 90° mark toward east, the 180° mark toward south, and the 270° mark toward west. The actual system to be used, zero to the south, 90° to west, etc., has been reversed in graduating the nephoscope in order that the number appearing on the mirror frame where the cloud's image leaves the mirror may give directly the direction from which the cloud is moving. A simple method of orienting the nephoscope is to suspend a plumb bob at the south side of the iron table so that at true solar noon on a sunshiny day, the 180° graduation, the center of the nephoscope, and the zero graduation may all be brought into a line coincident with the shadow of the suspending thread. It is helpful to have the plumb bob immersed in water, especially if the wind is blowing. The three-arm spider, whose function is to provide an easy and positive means of returning the nephoscope to correct position when desired, should then be tightened by drawing up the clamping nut in the center. It is a good plan to determine at this time and to record in station memorandum book some distant object that is exactly north of the station, so that subsequent inspection for correct orientation may be easily made. For the purpose of determining the time the sun is on the meridian the observer must ascertain the exact difference between the standard time in use at his station and the true local time. To this difference must then be added or subtracted, as the case may require, the so-called equation of time, which is the number of minutes before or after local noon at which the sun passes the meridian. The equation of time is given, approximately, in the accompanying diagram (fig. 12), and more exactly in the following table (Circular D, Instrument Division, Fourth Revision, 1914):

[1] For a description of the Marvin nephoscope of 1896 and the system of orientation used, see MONTHLY WEATHER REVIEW, Vol. XXIV, January, 1896, p. 9, "Cloud observations and an improved nephoscope, by C. F. Marvin."

Equation of time for 1899.[1]

Days.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
	m. s.	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*	*m. s.*
1........	+ 3 53	+13 50	+12 29	+3 53	−3 01	−2 24	+3 36	+6 06	− 0 09	−10 23	−16 20	−10 45
2........	4 21	13 57	12 17	3 35	3 08	2 14	3 47	6 02	0.28	10.42	16 21	10 22
3........	4 49	14 04	12 04	3 17	3 15	2 05	3 59	5 58	0 47	11 01	16 20	9 58
4........	5 16	14 10	11 51	3 00	3 21	1 55	4 09	5 53	1 07	11 19	16 20	9 34
5........	5 43	14 14	11 37	2 42	3 26	1 44	4 20	5 47	1 26	11 37	16 18	9 09
6........	6 10	14 19	11 23	2 25	3 31	1 33	4 30	5 41	1 46	11 54	16 15	8 44
7........	6 36	14 22	11 09	2 08	3 45	1 22	4 40	5 34	2 07	12 11	16 12	8 18
8........	7 01	14 24	10 54	1 51	3 39	1 11	4 50	5 26	2 27	12 28	16 08	7 51
9........	7 26	14 26	10 39	1 34	3 42	0 59	4 59	5 18	2 47	12 44	16 03	7 25
10........	7 51	14 27	10 23	1 18	3 45	0 47	5 08	5 10	3 08	13 00	15 57	6 57
11........	8 15	14 27	10 07	1 02	3 47	0 35	5 16	5 00	3 29	13 16	15 50	6 30
12........	8 38	14 27	9 51	0 46	3 48	0 23	5 24	4 50	3 50	13 31	15 43	6 02
13........	9 01	14 25	9 35	0 30	3 49	−0 11	5 31	4 40	4 11	13 45	15 34	5 33
14........	9 23	14 23	9 18	0 15	3 49	+0 02	5 38	4 29	4 32	13 59	15 25	5 05
15........	9 44	14 20	9 01	0 00	3 49	0 15	5 44	4 18	4 53	14 12	15 15	4 36
16........	10 05	14 17	8 44	−0 14	3 48	0 27	5 50	4 06	5 15	14 25	15 04	4 07
17........	10 25	14 12	8 27	0 28	3 46	0 40	5 55	3 53	5 36	14 37	14 53	3 37
18........	10 44	14 07	8 09	0 42	3 44	0 53	6 00	3 40	5 57	14 49	14 40	3 08
19........	11 02	14 01	7 51	0 56	3 42	1 06	6 04	3 26	6 18	15 00	14 27	2 38
20........	11 20	13 55	7 33	1 09	3 39	1 19	6 08	3 12	6 40	15 10	14 13	2 08
21........	11 37	13 48	7 15	1 21	3 35	1 32	6 11	2 58	7 01	15 20	13 58	1 39
22........	11 53	13 40	6 57	1 33	3 31	1 45	6 13	2 43	7 22	15 29	13 42	1 09
23........	12 09	13 32	6 39	1 45	3 27	1 58	6 15	2 27	7 43	15 38	13 26	0 39
24........	12 23	13 23	6 20	1 56	3 22	2 10	6 16	2 11	8 04	15 45	13 08	− 0 09
25........	12 37	13 13	6 02	2 07	3 16	2 23	6 17	1 55	8 24	15 52	12 50	+ 0 21
26........	12 50	13 03	5 43	2 17	3 10	2 36	6 17	1 38	8 45	15 59	12 31	0 51
27........	13 02	12 52	5 25	2 27	3 04	2 48	6 17	1 21	9 05	16 04	12 11	1 21
28........	13 13	12 41	5 06	2 36	2 56	3 00	6 16	1 04	9 25	16 09	11 51	1 50
29........	13 24	....	4 48	2 45	2 49	3 12	6 14	0 46	9 45	16 13	11 30	2 20
30........	13 33	....	4 30	2 53	2 41	3 24	6 12	0 28	10 04	16 16	11 08	2 49
31........	13 42	....	4 11	....	2 33	....	6 09	+0 10	....	16 18	....	3 18

[1] The equation of time changes slightly from year to year, but the values given in the table may be taken as a fair average of those that ordinarily occur.

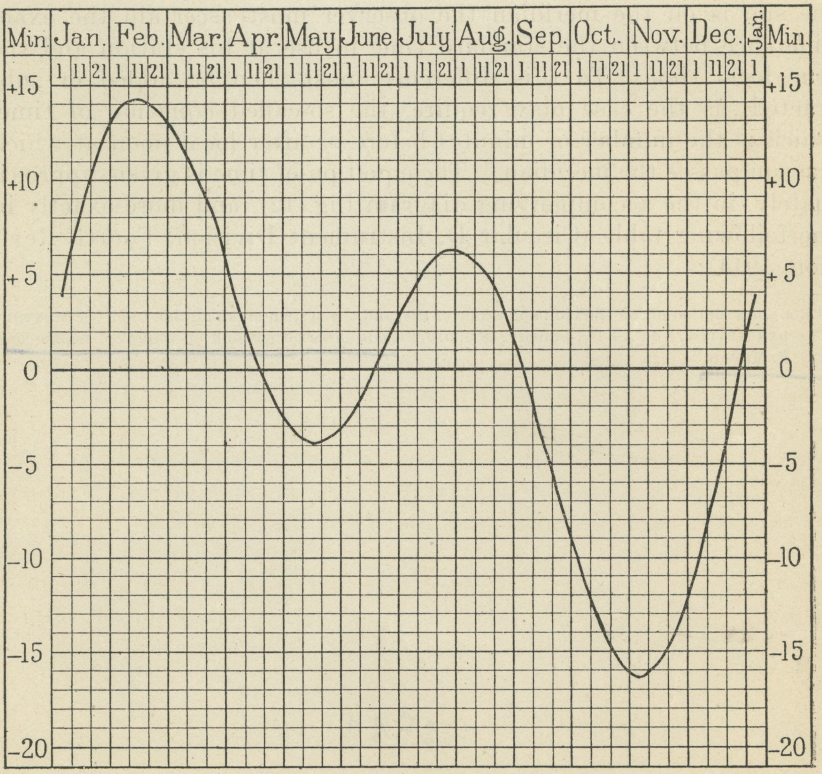

FIG. 12.—Diagram of equation of time.

When the equation of time is +, the sun is slower than the clock and the specified number of minutes must be added to the true local noon to give the time at which the sun passes the meridian, and, similarly, when the sign is −, the number of minutes must be subtracted from local noon.

For example, suppose the north and south line is to be located at some station on October 3, and where the local time is 24 minutes faster than the standard time in use. Hence:

Difference between standard and local time	−24 minutes.
(Use + when standard meridian is east of station and − when west.	
Equation of time, Oct. 3	−11 minutes.
Total correction	−35 minutes.

Therefore the sun will be exactly on the meridian at 12 o'clock, minus 35 minutes = 11.25 a. m., and the shadow of the suspending thread at this moment will be in a true north and south line, which should be permanently fixed by reference to some distant object.

4. *Care of the instrument.*—The iron base plate, the upright pipe and the under side of the top flange require occasional painting; the faced-off portion of the top flange should occasionally be rubbed with a rag saturated with light machine oil; and all brass parts and the glass should be kept clean. The entire instrument is designed to be kept outdoors, but the large copper cover must be replaced after each observation to protect the mirror from deterioration.

An effort has been made to have the bayonet joints by which the copper cover is secured to the top flange spaced exactly 120° apart, but it may be found desirable in practice to mark the position in which the cover fits best, so that it can be returned. Whether or not the little clock may safely be left in place will have to be determined by local conditions.

5. *Observations of direction.*—Having selected in the mirror the image of the cloud whose motion is to be observed, the stand that carries the sighting eyepiece is moved about on the circular table, while at the same time the horizontal arm is shifted until the cloud's image is seen through the hole in the eyepiece at the center of the mirror, indicated by a slight depression drilled in the glass. Keeping the eye at the peephole the image is then kept under observation as it moves toward the graduated rim of the mirror, and the graduation at which the image leaves the mirror is the direction *from which* the cloud is moving. The following table offers a convenient means of converting these angular values into customary 8-point or 16-point values:

8-point system.		16-point system.	
Cloud moving from—	Image leaves mirror—	Cloud moving from—	Image leaves mirror—
N	158 to 202	N	169 to 191
		NNE	191 to 214
NE	202 to 248	NE	214 to 236
		ENE	236 to 259
E	248 to 292	E	259 to 281
		ESE	281 to 304
SE	292 to 338	SE	304 to 326
		SSE	326 to 349
S	338 to 22	S	349 to 11
		SSW	11 to 34
SW	22 to 68	SW	34 to 56
		WSW	56 tó 79
W	68 to 112	W	79 to 101
		WNW	101 to 124
NW	112 to 158	NW	124 to 146
		NNW	146 to 169

6. *Observations of velocity.*—Only the apparent or nephoscopic velocity of the cloud, that is the number of millimeters on the mirror crossed by the image in a given time can be measured, unless the actual height of the cloud is known.

7. *Counting time.*—For the purpose of observing cloud velocities, auxiliary equipment has been provided, consisting of a small triangular sheet of brass, whose apex or point should be kept coincident with the moving cloud by pushing it along the surface of the glass mirror with the finger or with a ruler; a ruler graduated in centimeters and millimeters; and a small clock that beats half-seconds, which is intended to be clamped to the observer's head so that he may by the "eye and ear" method keep the cloud under observation during the required number of seconds. A little practice counting beats while watching the second hand will soon familiarize the observer with the method.

8. *Conversion of observed velocities into actual velocities.*—The rules to be presented later are based upon the relations of similar triangles. In figure 3 let AB be a cloud path, assumed to be level; *m* a level flat mirror in which the cloud is observed through the peephole E. Now, since the angle of reflection is equal to the angle of incidence, the triangles ABE′, *cd*E′ and *cd*E are exactly alike in all respects except as to size. Hence their bases AB (travel of cloud) and *cd* (travel of point of reflection) are to each other as their altitudes BD (height of cloud) and EF (height of peephole above mirror).

That is
$$\frac{AB}{cd}=\frac{BD}{EF}, \text{ or } AB=\frac{cd\times BD}{EF}. \qquad (1)$$

Since it is desired to adopt *meters per second*, as used at aerological stations, for all cloud observations throughout the Weather Bureau, we shall wish to measure the cloud path AB and the cloud's height BD in meters, and the time, *t*, in seconds. The length of the path as seen in the mirror, and the height of the sighting eyepiece above the mirror are measure in millimeters.

For convenience in making the computations the nephoscope has been constructed for the measurement of a cloud path at an assumed height of 1,000 meters, from which velocities for other heights may be easily computed.

The velocity of the cloud is defined as the length in meters of the path AB divided by the time it is observed, in seconds,

$$V=\frac{AB}{t} \qquad (2)$$

Substituting for AB in equation (2) its value found in equation (1), we have

$$V=\frac{cd\times BD}{t\times EF} \qquad (3)$$

Or for a cloud 1,000 meters high and for the nephoscope whose eyepiece is 166⅔ millimeters above the mirror we may write:

$$V=\frac{cd\times 1000}{t\times 166\frac{2}{3}} \qquad (4)$$

Or with eyepiece 83⅓ millimeters above the mirror:

$$V=\frac{cd\times 1000}{t\times 83\frac{1}{3}} \qquad (5)$$

9. *Rules for computations.*—We shall find it convenient in making records and in computing velocities to choose for *t* some suitable fixed value to be regularly followed; and since 60 seconds, or 1 minute, is a value easily remembered, has a large number of factors, and has heretofore been employed satisfactorily,[2] it will be adopted as a standard value of *t*, and all observations will be recorded as of 60 seconds duration. The conversion of the velocity of the image into the velocity of the cloud may then be made by the following rules:

Rule 1. For a cloud 1,000 meters high, and with eyepiece 166⅔ millimeters above the mirror, the number of centimeters crossed by the image in one minute equals the velocity of the cloud in meters per second. (It is generally necessary to express this value in centimeters and tenths.)

Rule 2. For a cloud 1,000 meters high, and with eyepiece 83⅓ millimeters above the mirror, proceed as in rule 1, and double the result.

Rule 3. For a cloud whose height is greater or less than 1,000 meters, multiply the value found for an assumed height of 1,000 meters by the actual height in meters and divide by 1,000.

10. *Examples.*—(1) Suppose the cloud to be 1,000 meters high and the image to move 8 centimeters in one minute, as seen through the higher eyepiece. Its velocity by rule 1 is then 8 meters per secon

[2] Annals of the Astronomical Observatory of Harvard College, Vol. XXX Part LV. "Discussion of cloud observations," p. 274.

(2) Suppose we use the lower eyepiece, $83\frac{1}{3}$ millimeters above the mirror, to observe a cloud 1,000 meters high whose image moves 52 millimeters in one minute. The cloud is moving twice 5.2 or 10.4 meters per second.

(3) Suppose that by noting the time required for a pilot balloon to become lost in the cloud layer we learn that the height is 3,500 meters; and from the nephoscope, using the $166\frac{2}{3}$ millimeter eyepiece, we learn that the image moves 27 millimeters in 30 seconds. Reducing to the one minute basis we have 54 millimeters or 5.4 centimeters in one minute, which gives 5.4 meters per second for an assumed height of 1,000 meters. Multiplying 5.4 by 3,500 and dividing by 1,000 we have 19 meters per second as the actual velocity of the cloud.[3]

11. *Recording the observations.*—Observations of direction require merely that the graduation at which the image leaves the mirror be recorded, either in degrees or in 8-point or 16-point system, as may be desired for the purpose in hand. Observations of velocity require for subsequent interpretation a record of the height of the eyepiece used, the time the image was observed, and the distance crossed by the image. By standardizing the time to one minute, which may be done mentally, we may further simplify the entries. The height of the cloud, estimated or measured, together with notation to indicate the method used to obtain it should also be entered.

[3] In actual practice it will be sufficient to consider the heights to the nearest 100 meters for the lower and intermediate levels, and to the nearest 500 meters for the high levels for computing purposes.

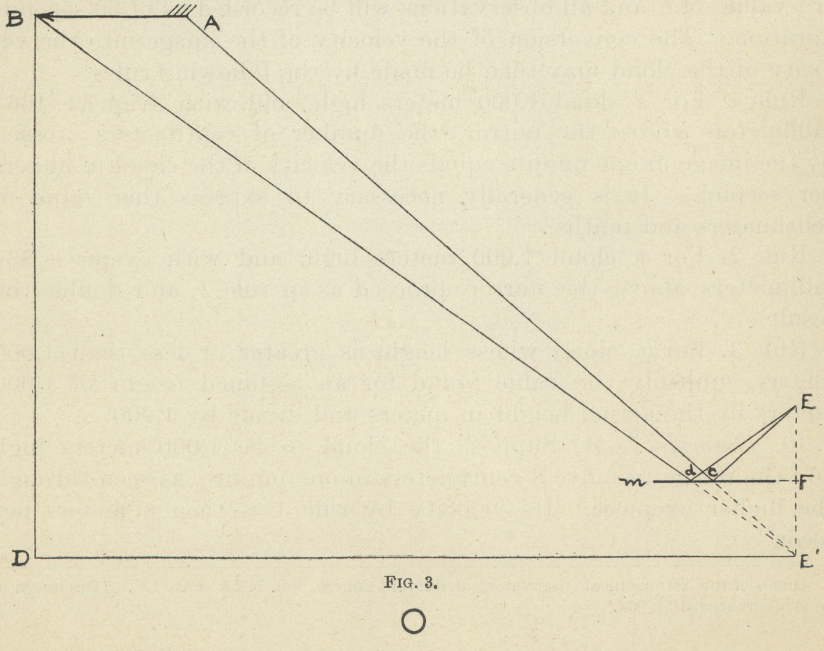

FIG. 3.