U. S. DEPARTMENT OF AGRICULTURE,
WEATHER BUREAU.

INSTRUCTIONS

FOR THE

CARE AND MANAGEMENT OF ELECTRICAL SUNSHINE RECORDERS.

CIRCULAR G, INSTRUMENT DIVISION,
FIFTH EDITION.

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CARE AND MANAGEMENT OF ELECTRICAL SUNSHINE RECORDERS.

1. *Registration of sunshine.*—While apparatus for continuous registration of the intensity of sunshine is now regularly employed at a few places, such apparatus is delicate, complicated, and expensive, and requires for successful operation and maintenance, and for the interpretation of the records, the attendance of specialists. Such instruments, known as pyrheliometers, pyranometers, pyrgeometers, etc., are described in papers that have appeared in the MONTHLY WEATHER REVIEW from time to time.

2. *Registration of duration of bright sunshine.*—The Campbell-Stokes recorder, which consists of a ground and polished glass sphere that acts as a lens or burning glass, and scorches a trace showing the duration of bright sunshine upon a strip of cardboard placed at the proper focal distance from the sphere, is much used in Europe and other parts of the world. The Jordan photographic recorder, in which the apparent movement of the sun across the sky traces a line on slips of sensitized photographic paper, was formerly used to some extent in the Weather Bureau, but it has now been practically discontinued in favor of the electrical sunshine recorder, because the latter is well adapted to registration along with other meteorological data on the triple register maintained at all first-order Weather Bureau stations.

3. *The electrical sunshine recorder.*—The principle employed is similar to that of Leslie's differential air-thermometer, which has been known more than a hundred years.[1] A glass tube containing a liquid terminates in two bulbs, both containing air. In the original Leslie thermometer both bulbs were uppermost, and were joined together by the tube., bent into the form of a U, the liquid occupying one leg and only part of the other leg of the U. If both bulbs have the same temperature, the liquid must remain stationary; but if one of the bulbs be warmed, the expanding air will depress the liquid in the stem; or if it be cooled, the contracting air allows the liquid to rise. In the original Leslie instrument the stem was suitably graduated to indicate numerically the difference in temperature between the two bulbs, and it was used in a number of interesting ways, such as to measure the flow of heat from a fireplace, the strength of sunshine, the depression of the wet bulb, etc.

[1] Leslie, John, esq.: Description of Instruments (Meteorological) Edinburgh, 1820.

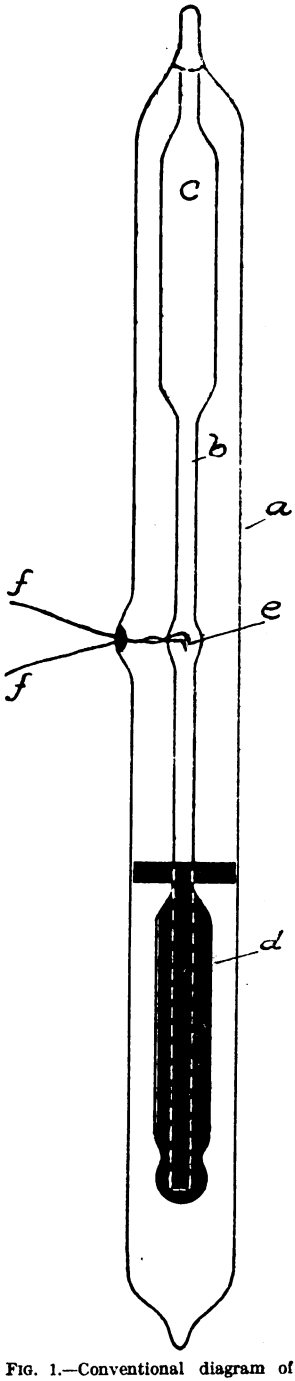

FIG. 1.—Conventional diagram of glass part of sunshine recorder, unmounted.

4. The glass portion of the instrument is shown in Figure 1. The upper chamber *c* is narrowed into a slender tube, *b*, which extends almost to the bottom of the lower chamber *d*. Now when mercury is introduced, generally by means of a long, slender funnel extending to the bottom of chamber *d*, the mercury rises in both the tube *b* and the chamber *d*, so that the height to which the surface of the mercury ascends in chamber *d* is limited by compression. Hence if more mercury is added it will continue to rise in the tube *b* until the desired quantity has been introduced—generally enough to fill the tube to a point about one-half inch below the upper chamber when the instrument stands vertically in the shade. A little alcohol is then added to serve as a lubricant and a preventive of undue sparking, and the top end sealed off. Both mercury and alcohol should be of a high degree of purity, since experience has shown that slight impurities, particularly alcohol containing a small per cent of water, interfere with the proper performance of the instrument, and hasten deterioration.

5. *Vacuum jacket.*—The outer glass jacket *a* serves to inclose the thermometric device in a space from which the air has been exhausted to render the thermometer insensible to ordinary air-temperature changes, on the principle of the thermos bottle.

6. *Platinum wires.*—Two platinum wires, *f*, *f*, fused through the walls of both glass sheath and thermometer tube are connected through suitable binding posts with a pair of wires that join in series a battery and the registering device in the office.

7. *Operation.*—The lower bulb is coated with lampblack; hence when sunshine falls upon the instrument the air in the lower bulb will become warmer than the air in the upper clear glass bulb. The consequent expansion of the air in the lower bulb exerted against the surface of the mercury

FIG. 2.—Sunshine recorder, assembled.

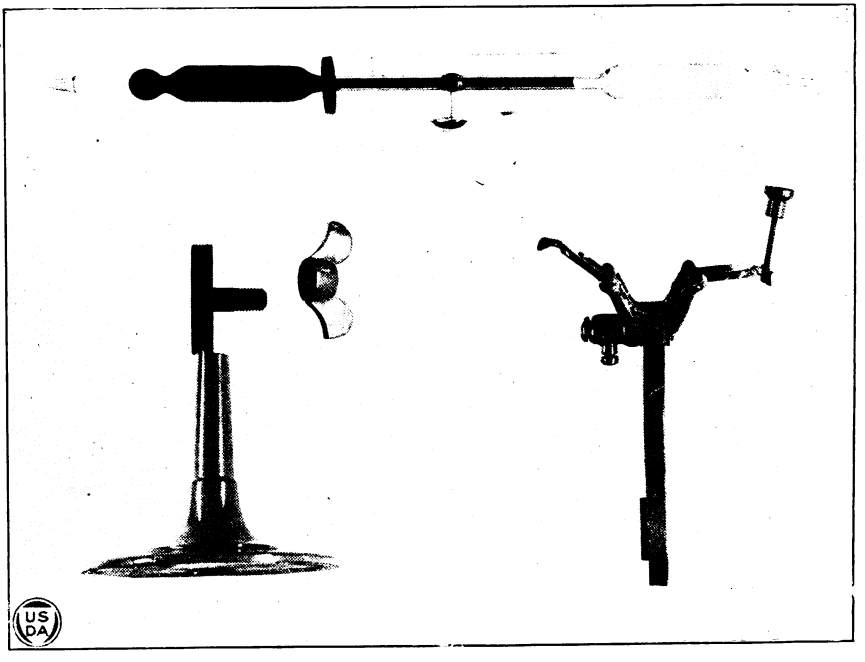

FIG. 3.—Parts of sunshine recorder and mounting, disassembled.

causes a corresponding rise of the mercury in the tube. Registration begins when the mercury reaches the inner ends of the two platinum wires *e*, and continues until it has receded below them. Excess of mercury, due to stronger sunshine, merely stands higher in the tube, the registration being the same.

8. *Mounting.*—The mounting is in two sections as shown in Figure 2, the lower section being in the form of a flanged base with screw holes conveniently arranged for attaching it to a support, and bearing a serial number. The upper section is clamped to the lower section in a way to form a hinged joint that permits angular adjustment to the critical condition for registration.

9. *Requisition for sunshine recorders or parts.*—As instruments of different styles are in use at stations, requests should clearly indicate what is desired by appropriate reference to illustration, or by specific description. Sketches are helpful. The latest pattern is shown dissembled in Figure 3.

10. The lower flanged base section has remained unchanged in design for many years, and is practically uniform throughout the Bureau; but the upper section, which was formerly constructed in a way that rendered it practically integral with the glass tube, has been redesigned to permit the insertion of a new tube at stations.

11. *Caution to be observed in assembling parts.*—As the tubes are made of thin glass, which is easily crushed, the clamp should be drawn only tight enough to insure a firm grip. *Necessary bends in the platinum wires should be made at some distance from the glass*, since they are liable to break if bent short where they emerge.

12. *Exposure.*—It is obvious that the instrument should be placed where the sun will fall upon it every day throughout the year with the least possible interference. Ideal conditions of exposure are not always to be had, and it is, hence, necessary to select the best available. Fortunately the sunshine recorder does not require frequent attention, hence the question of accessibility is less important than in the case of other meteorological instruments. A slender flagstaff or similar object may intervene with no more serious result than to produce a slight break in the continuity of the record at the same hour every day. Low objects near the horizon do not materially affect the instrumental record, since the sunshine is not strong enough to cause registration during the early morning or late evening hours.

13. *Rigidity of support.*—The support should be sufficiently rigid to prevent vibration due to wind, which may cause objectionable momentary contacts of the mercury with the platinum wires.

14. *Orientation.*—The black bulb should be toward the south.

15. *Adjustment.*—The instrument is quite likely to be so disturbed in shipment as to require adjustment of the mercury column. This

is effected by passing a portion of air from the lower to the upper bulb if the mercuy column stands too high, or from the upper to the lower bulb if the column stands too low.

16. *When the mercury stands too high.*—First, holding the instrument vertically, jostle the instrument up and down to reunite the mercury column, if broken, as is generally the case. Then to pass air from the lower to the upper bulb, grasp the instrument with black bulb downward and let the hand and arm perform a reverse circular movement as indicated in Figure 4. The hand should be kept reasonably close to the body, and the circle need not be large nor the movement rapid. At the lowermost part of the throw the inertia of the mercury carries a portion into the lower bulb and permits a corresponding amount of air to escape into the upper bulb.

17. *When the mercury stands too low.*—In this case air must be passed from the clear to the black bulb. Invert the instrument and get as much mercury into the clear bulb as convenient. Then rather quickly invert the instrument again so that as the mercury falls into the narrow tube it may form a stop to imprison the air in the tube. The instrument is then jerked up and down in a way to force the imprisoned air into the lower tube. The processes are repeated or alternated until the desired adjustment has been accomplished.

18. *Installation.*—The adjustment having been perfected, the instrument attached to its hinged metal base, and the base secured to the support on the roof so that the blackened lower end of the glass tube points south, it remains to incline the tube at such an angle that the instrument will begin and cease to record sunshine with the proper degree of cloudiness. This inclination will be approximately 45° from the vertical, at which angle the upper end of the mercurial column should stand about half an inch below the connecting electrodes.

19. *Critical condition for registration.*—The inclination of the recorder will be adjusted at such an angle that the mercury column will just close the electrical circuit during times when the disk of the sun can be just faintly seen through the clouds. If the cloudiness is such that the observer can not clearly distinguish the sun's disk, then the mercury should not rise high enough to close the circuit. Several trials on successive days may be necessary to secure the best adjustment. In altering the inclination of the recorder it is best to first make a chalk or pencil mark across the edges of the hinge joint of the support before it is loosened. Any change made in the inclination of the tube is then clearly shown by the amount the lines on the two parts of the hinge separate from each other. If it is desired to make a subsequent adjustment, the first lines are easily erased and a new mark made.

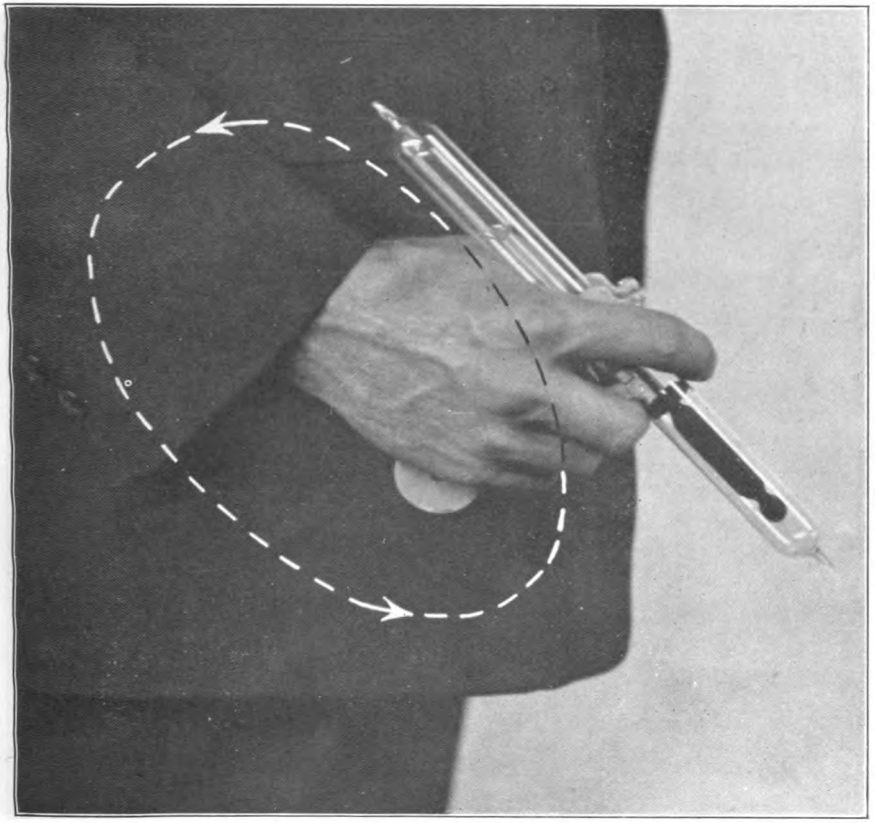

FIG. 4.—Illustration of method used to force mercury into the lower bulb.

20. *Seasonal adjustment.*—Slightly different adjustments will probably be found necessary at different seasons of the year, from the fact that the normal position of the mercurial column is slightly changed by extremes of low and high temperatures.

21. It will also be found that an adjustment that gives the best results during the middle of the day fails to record all the sunshine when the sun is near the horizon, as the thermal effect of the sun is much greater when the sun is near the meridian. It is therefore best to adjust the recorder for a mean condition; that is, the adjustments should be made at about 9 a. m. or 3 p. m., under the critical conditions described in paragraph 19.

22. It must also be borne in mind that a thermometer constructed on the principle of this sunshine recorder is somewhat sluggish, so that when the sky is partly covered with floating clouds it must not be expected that the mercurial column will drop low enough to open the electrical circuit the exact instant the sun disappears behind a cloud, or rise high enough to close it the exact instant the sun comes out again. Small clouds and few moments of sunshine may, therefore, escape being recorded, but, in general, the time lost after the sun commences to shine should equal the time gained after the sun disappears.

23. During partly cloudy weather the instrument should be watched carefully, and if it is found to be making an incorrect record a note to that effect will be made on Form No. 1017. After the observer has satisfied himself that the instrument systematically records either too little or too much sunshine, as indicated by the rule given above, he should endeavor to correct the error by a readjustment of the instrument. Frequent adjustments should, however, be avoided, but whenever made they should be noted on Form No. 1017, stating whether the new adjustment is more nearly horizontal or more nearly vertical than the old.

24. The elecrtical connections for attaching this sunshine recorder to the triple register will be found in Circular D, Instrument Division.

25. *Caution.*—The sunshine recorder should be removed to the office or otherwise protected when painting or structural work is being done. Eye observation of sunshine with appropriate notation should be entered on the forms for the missing period.

26. *Compilation of data.*—The meteorological data compiled from records obtained from the thermometric sunshine recorder (Form No. 1017) will be tabulated on Form No. 1001. Detailed instructions relative thereto are given in Circular A, Instrument Division, third edition, and in Instructions for Preparing Meteorological Forms.

27. *Sunshine tables.*—Monthly card tables giving sunshine data in the local standard of time authorized to be used will be prepared in

duplicate sets at each station where required in compiling sunshine data. Each set will comprise a card table for each month of the year with the appropriate data entered for each day of the month. For this purpose the necessary blank card forms and a complete set, Parts I, II, and III, of the sunshine tables, in mean solar time (Edition 1905), will be sent as required. One set of the station tables will be retained and used in the tabulation of sunshine data, in accordance with existing instructions. The duplicate set, after having been carefully compared and verified, will be forwarded to the central office in a package marked "Climatological Division."

28. *Time limit.*—Thirty days after receipt of cards are allowed for the completion of the tables, but the card for the month in which sunshine forms are first compiled from the tables must be forwarded as soon after the receipt of cards as practicable.

29. *Time correction.*—The correction, in minutes of time, that is required to reduce mean solar time to the local standard of time in current use at the station, will be entered with its appropriate algebraic sign at the head of each card. The minus sign will be used if the correction is to be subtracted from mean solar time, and plus if the correction is to be added. If mean solar time is the standard time in use at any station, the time correction will be zero, and the card tables will be prepared accordingly.

30. *Latitude.*—The station table will be computed from the printed table for the whole degree of latitude nearest that of the station, following the usual rule for dropping fractions; for example:

46° 30′ will be taken as 46°.
41° 30′ will be taken as 42°.

31. *Sunrise and sunset.*—The times of sunrise and sunset will be first computed from the printed table by applying the "time correction" at the top of the card.

32. *Fractional hours.*—The possible sunshine during hours ending shortly after sunrise and sunset will, for brevity, be styled fractional hours, and these data will be entered on the card in the columns provided, and will be computed in hundredths of hours, as follows:

33. The minutes in the time of sunrise, as tabulated on the card, will be subtracted from 60; the remainder thus obtained divided by 60, and the quotient, in hundredths of hours, placed in the appropriate "A. M." column. The minutes in the time of sunset will be divided by 60 and the quotient, in hundredths of hours, set in the appropriate "P. M." column.

34. Enter at the top of these "A. M." and "P. M." columns the morning and evening hours, in sequence, at which fractional hours of sunshine terminate during any portion of the month.

35. *Totals.*—The total sunshine for each day of the month will be computed by adding together the a. m. and p. m. fractional hours and the number of whole hours of sunshine that is possible between the fractional hours.

36. The monthly totals for each column of possible sunshine will also be computed.

37. These daily and monthly totals will finally be entered upon the cards to the nearest tenth of an hour only, but, in order to check and adjust the computation, as further explained in the next paragraph, it is best to first set down on pencil paper all totals in hundredths, since otherwise, the usual rule for dropping decimals will sometimes fail to give the necessary agreement in the final results.

38. *Checks.*—The total sunshine for the month, in hundredths, should check exactly with the sum obtained by adding all the totals for the fractional hours, plus the intervening whole hours of sunshine multiplied by the number of days of the month.

39. The computation having been thus checked, the daily and monthly totals will be entered upon the cards to the nearest tenth, the hundredths being dropped according to the usual rule, except that the total possible sunshine for the month will always be taken directly from the printed table, even if it differs slightly from the sum of the daily totals.[2]

40. *Station tables.*—The verified values on the cards will constitute the sunshine tables used in the preparation of all station forms and records.

41. *Divisors.*—The monthly sums of the a. m. and p. m. fractional hours constitute the "divisors" which are to be employed at the end of the month in computing the monthly percentages of possible sunshine recorded during the hours ending shortly after sunrise and sunset, as tabulated on Form No. 1001, page 4.

42. *Example.*—The foregoing instructions are elucidated by the sample computation which follows.

[2] The values in the printed table are derived directly from fundamental data computed to the tenth of a minute, and are more accurate than modified values obtained therefrom.

February.

[Local standard time, 90th meridian; time correction used, 10 minutes; Chicago, Ill.; latitude, 41° 53′ north.]

Sunrise.		Sunset.		Date.	Possible sunshine during hours ending—				Total for day.	Trial total.
					A. M.		P. M.			
Hrs.	Min.	Hrs.	Min.		7	8	6			
7	03	5	05	1	.....	0.95	0.08	.....	10.0	10.03
	02		06	2	.....	.97	.10	.....	.1	.07
	01		07	3	.....	.98	.12	.....	.1	.10
	00		08	4	.....	1.00	.13	.....	.1	.13
6	59		10	5	0.02	1.00	.17	.....	.2	.19
	58		11	6	.03	.....	.18	.....	.2	.21
	56		12	7	.07	.....	.20	.....	.3	.27
	55		14	8	.08	.....	.23	.....	.3	.31
	54		15	9	.10	.....	.25	.....	.4	.35
	53		16	10	.12	.....	.27	.....	.4	.39
	52		18	11	.13	.....	.30	.....	.4	.43
	50		19	12	.17	.....	.32	.....	.5	.49
	48		20	13	.20	.....	.33	.....	.5	.53
	47		22	14	.22	.....	.37	.....	.6	.59
	46		23	15	.23	.....	.38	.....	.6	.61
	45		24	16	.25	.....	.40	.....	.6	*.65
	43		25	17	.28	.....	.42	.....	.7	.70
	42		27	18	.30	.....	.45	.....	.8	*.75
	40		28	19	.33	.....	.47	.....	.8	.80
	39		29	20	.35	.....	.48	.....	.8	.83
	38		30	21	.37	.....	.50	.....	.9	.87
	36		31	22	.40	.....	.52	.....	.9	.92
	34		33	23	.43	.....	.55	.....	11.0	.98
	33		34	24	.45	.....	.57	.....	.0	11.02
	32		35	25	.47	.....	.58	.....	.0	*.05
	30		36	26	.50	.....	.60	.....	.1	.10
	29		37	27	.52	.....	.62	.....	.1	.14
	27		39	28	.55	.....	.65	.....	.2	.20
Total.....					6.6	27.9	10.2	.....	296.6	296.71
6	25	5	40	29	.58	1.0	.67	.....	11.2	11.25
Total.....					7.2	28.9	10.9	.....	307.8	307.96

Trial totals (28 days)..... 6.57+27.90+10.24+(28×9)=**296.71**
Trial totals (29 days)..... 7.15+28.90+10.91+(29×9)=**307.96**

43. It should be noticed in this example that the trial totals for 28 days agree, but are one-tenth of an hour greater than in the printed tables. It will also be noticed that the daily totals in tenths differ from the printed table in each case marked thus (*), although the total for the month agrees with the tables, except for 29 days, where the sum of the horizontal totals is two-tenths of an hour too large.