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LEADING OPERATIONS OF THE SMITHSONIAN ASTROPHYSICAL OBSERVATORY, 1895 to 1955

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INTRODUCTION

Having been associated with the Astrophysical Observatory almost from its inception in 1890, it seems good to me to print, in small compass in one place, references to the leading researches and instrumental developments carried out there. It may well be that there are now, and will be in future, those who, for one reason or another, may wish to refer to these events, and will appreciate having easy access to the original sources.

The list is far from exhaustive, either as regards the work of the Astrophysical Observatory, or references to it. But I believe it is sufficient to present a fair picture of what has been accomplished.

SECTION A

Part 1.—*Improved and new instruments*

1. The bolometer rebuilt and equipped with a balancing device close beside it and at constant temperature. Result: The drift nearly eliminated and the wiggle greatly reduced.	Annals of the Astrophysical Observatory,[1] vol. 1, pp. 47-56, 105-109, 1900; vol. 3, p. 42, 1913.
2. Galvanometer. Theory investigated and new galvanometer of tenfold sensitiveness built.	Astrophys. Journ., vol. 18, No. 1, July 1903. Annals, vol. 1, pp. 244-252, 1900.
3. Vacuum bolometer with self-contained Wheatstone bridge built. Result: Several-fold increase of sensitiveness, and increased steadiness.	Annals, vol. 4, pp. 45-64, 1922.
4. Silver-disk pyrheliometer invented. About 100 copies have been	Smithsonian Misc. Coll., vol. 56, No. 19, 1911.

[1] Hereafter referred to simply as "Annals."

	built, standardized, and sold at cost to observers throughout the world. Repaired at cost and restandardized free when damaged.	Annals, vol. 3, pp. 47-52, 1913; vol. 7, p. 105, 1954. Smithsonian Misc. Coll., vol. 95, No. 23, 1937; vol. 111, No. 14, 1949.
5.	Water-flow and water-stir standard pyrheliometers invented and used. The world's scale of solar radiation measurements rests on them.[2]	Annals, vol. 3, pp. 52-72, 1913; vol. 7, pp. 99-101, 1954. Smithsonian Misc. Coll., vol. 87, No. 15, 1932; vol. 110, No. 11, 1948.
6.	Pyranometer invented. Used daily on short-method solar-constant observations. Used by Moore in North Carolina and Chile. Copies made and sold at cost world-wide.	Smithsonian Misc. Coll., vol. 66, No. 7, 1916. Annals, vol. 4, pp. 65-84, 1922; vol. 7, pp. 15-16, 21, 138, 1954.
7.	Honeycomb pyranometer, or melikeron, invented. Used by Abbot and Aldrich on human body, and by Sverdrup in polar regions. Copies made and sold at cost world-wide.	Smithsonian Misc. Coll., vol. 72, No. 13, 1922. Annals, vol. 4, pp. 41, 300, 1922; vol. 5, pp. 43-45, 1932.
8.	Balloon recording pyrheliometer invented and used at high altitudes.	Smithsonian Misc. Coll., vol. 65, No. 4, 1915. Annals, vol. 4, pp. 347-365, 1922.
9.	Two-mirror coelostat invented.	Annals, vol. 2, pp. 22-23, 211, 1908.
10.	Slide-rule extrapolator invented. Constantly used in long-method solar observing.	Annals, vol. 4, pp. 84-86, 1922.
11.	High-power lamp and other devices prepared by F. E. Fowle for researches on deep infrared spectrum.	Annals, vol. 4, pp. 23-25, 274-287, 1922.
12.	Highly sensitive radiometer invented for measuring energy spectra of stars.	Astrophys. Journ., vol. 69, pp. 293-311, 1929. Smithsonian Misc. Coll., vol. 104, No. 14, 1945.
13.	A prism of nearly normal wavelength dispersion invented.	Astrophys. Journ., vol. 11, No. 2, pp. 135-139, March 1900. Smithsonian Misc. Coll., vol. 104, No. 22, 1946; vol. 107, No. 19, 1948.
14.	The kampometer invented, a highly sensitive instrument for measuring radiation.	Smithsonian Misc. Coll., vol. 89, No. 3, 1933.
15.	The periodometer invented, a mechanical instrument for discovering periodic changes in data.	Smithsonian Misc. Coll., vol. 87, No. 4, 1932.
16.	A multiple rotating-sector dia-	Annals, vol. 5, p. 96, 1932.

[2] A.P.O. modified form of Ångström pyrheliometer is used in daily observations. See Annals, vol. 6, pp. 50-55, 1942.

phragm combination invented, instantly exchangeable, for bolometer work.	
17. A continuously variable rotating sector invented, of accurate ratio, for photometry.	No published description.
18. A pair of telephoto cameras invented, electrically connected, for simultaneous exposure on flying objects. The invention comprises a belt-focal-plane shutter, surrounding film spools. Shutter and spools operated by a long spring and clockwork. The observer and assistant separated by a measured base line keep both cameras trained. Observer makes a series of exposures by a trigger, and second camera is simultaneously exposed.	One camera on public exhibition in Langley case in the West Hall of the Arts and Industries Building, Smithsonian Institution.
19. Apparatus invented for preventing "personal equation" in observing sudden phenomena. The observer notes the sector where, not the times when, the event occurs.	Apparatus on public exhibition in Langley case (see above).
20. Automatic recording radiation instruments invented.	Annals, vol. 7, pp. 144-146, 1954.

PART 2.—*Various inventions, mainly for military use in World Wars I and II*

1. Variable-speed power-transmission mechanism, Claim 1, allowed "The combination of a driving element, a driven element, and means for establishing, and maintaining constantly, exactly and positively, a desired speed ratio between said elements, or for continuously varying said ratio."	U. S. Patent No. 893416 of July 14, 1908.
2. Variable-speed governor. For a clockwork to be of speed varied at will, without stopping, and continuously, through a several-fold range. Used for a Navy project.	U. S. Patent No. 2367254 of January 16, 1945.
3. Self-propelled rotating projectile for smooth-bore guns. Combination with smooth-bore ordnance.	U. S. Patent No. 1380172, and U. S. Patent No. 1380171, both of May 31, 1921.

4. Gyroscopic navigation instrument. For measuring differences in longitude and latitude without sun or star observations.	General Electric Patent No. 1501886 to C. G. Abbot July 15, 1924.
5. Compass and magnetic-dip indicator. Both this and No. 4 used the principle of neutral flotation in liquid, and electric current therethrough for operating. Germans independently discovered the mathematical principle of No. 4 and built such a machine but it failed. An Englishman from National Laboratory examined patent of No. 4, and said it carried superior features. Work on it stopped with the Armistice, November 1918.	General Electric Patent No. 1533683 to C. G. Abbot April 14, 1925.
6. Instrument for navigating airplanes by daylight star observations. Stars can be seen with a small telescope in daylight if the telescope field contains the star image. The instrument could be set to contain the star in its field before observing. Twelve stars and two planets were easily observed by W. H. Hoover in New Mexico. E. D. McAlister observed Altair from airplane at 21,000 feet.	Built and tested secretly. Never published.
7. Instrument for automatic mapping of airplane course over ocean, to enable return to course of mother ship. The patent, No. 2367254, above cited, was a part of this device.	Built and tested secretly. Never published.
8. Solar distilling apparatus.	Patent No. 2141330, December 27, 1938.
9. Solar heater.	Patent No. 2247830, July 1, 1941.
10. Solar heat collector.	Patent No. 2460482, February 1, 1949.

SECTION B

PART 1.—*Researches*

1. Bolometric map of infrared solar spectrum.	Annals, vol. 1, pp. 5-204, 1900; vol. 5, p. 54, 1932. Smithsonian Misc. Coll., vol. 82, No. 1, 1929.
2. Dispersion of rock-salt and fluorite. (Six-place decimals in re-	Annals, vol. 1, pp. 219-237, 253-262, 1900.

fractive index called ridiculous by Holland physicists. Identical in fifth place with Paschen work, however.)	
3. Structure of water-vapor bands ω_1 and ω_3.	Annals, vol. 1, pp. 263-264, 1900.
4. Total solar eclipses, 1900, 1901, 1908, 1918, 1919.	Astrophysical Observatory special eclipse volume, 1900. Annals, vol. 2, p. 2, 1908; vol. 3, pp. 3-6, 1913; vol. 4, pp. 29, 31, 34, 35, 1922. Smithsonian Misc. Coll., vol. 69, No. 9, 1919.
5. Theory of sensitive galvanometer.	Annals, vol. 1, pp. 244-252, 1900. Astrophys. Journ., vol. 18, No. 1, July 1903.
6. "The cheapest form of light."	Annals, vol. 2, p. 5, 1908.
7. Solar-constant and solar-distribution work, begun in 1902.	Annals, vol. 2, pp. 2, 3, 21-82, 211-228, 1908.
8. Mount Wilson expeditions, begun 1905.	Annals, vol. 2, pp. 7, 83-116, 1908.
9. Theory of atmospheric transmission.	Annals, vol. 2, pp. 13-17, 1908.
10. Methods for measuring the solar constant.	Annals, vol. 2, pp. 17, 57, 117-124, 1908.
11. Transmission of the spectrobolometer.	Annals, vol. 2, pp. 24, 51, 52, 1908.
12. Pyrheliometry.	Annals, vol. 2, pp. 34-49, 1908; vol. 3, pp. 47-72, 1913; vol. 7, pp. 21-23, 1954.
13. Details of solar-constant observing.	Annals, vol. 3, pp. 21-29, 1913; vol. 6, pp. 43-81, 1942.
14. Sources of error in solar-constant work.	Annals, vol. 2, pp. 58-82, 1908; vol. 4, pp. 161-176, 1922; vol. 5, pp. 110-131, 1932; vol. 6, pp. 33-42, 1942.
15. Solar-contant results of stations compared.	Annals, vol. 2, pp. 85-98, 1908; vol. 3, p. 134, 1913; vol. 4, pp. 177-182, 1922; vol. 5, pp. 244-245, 1932; vol. 6, p. 163, 1942.
16. Normal solar-energy curves. Preferred determination.	Annals, vol. 2, pp. 104-106, 1908. Smithsonian Misc. Coll., vol. 74, No. 7, 1923.
17. Sun's temperature.	Annals, vol. 2, pp. 106-107, 1908; vol. 3, pp. 194-201, 1913.
18. Atmospheric transmission, many stations, sea level up to 14,000 feet altitude.	Annals, vol. 2, pp. 96-98, 110-112, 1908; vol. 3, pp. 104-113, 1913; vol. 4, pp. 131-158, 1922; vol. 5, pp. 168-193, 1932; vol. 7, pp. 95-98, 1954.
19. Theory of vacuum bolometer, corrected later.	Annals, vol. 4, pp. 45-64, 1922; vol. 5, pp. 75-81, 1932.

20. Infrared and ultraviolet corrections for solar-constant work.	Annals, vol. 5, pp. 103-110, 1932.
21. Solar variation:	
a. First suspected.	Astrophys. Journ., vol. 19, p. 305, June 1904.
b. Clayton's contributions.	Annals, vol. 2, pp. 98-103, 117-179, 1908.
	Annals, vol. 4, pp. 36, 185, 367-374, 1922.
c. From solar-constant work 1920-1930.	Annals, vol. 5, pp. 246-269, 1932.
d. Short up and down trends and (1) temperatures, (2) ionosphere.	(1) Smithsonian Misc. Coll., vol. 95, Nos. 12 and 15, 1936; (2) vol. 104, No. 13, 1945.
e. Accompanying (1) hurricanes, (2) magnetic storms.	(1) Smithsonian Misc. Coll., vol. 110, No. 1, and (2) No. 6, 1948.
f. Accompanying sunspots.	Smithsonian Misc. Coll., vol. 110, No. 6, 1948.
	Annals, vol. 7, pp. 165-168, 1954.
g. Periodic—(1) 27-day, (2) 6.6485-day.	(1) Smithsonian Misc. Coll., vol. 104, No. 3, 1944; vol. 116, No. 4, 1951; (2) vol. 111, No. 13, 1949.
h. Long periodic and weather.	Smithsonian Misc. Coll., vol. 122, No. 4, 1953.
22. A large family of periodic variations:	Smithsonian Misc. Coll., vol. 122, No. 4, 1953.
a. In the sun.	Smithsonian Misc. Coll., vol. 128, No. 4, 1955.
b. In the weather.	Smithsonian Misc. Coll., vol. 128, No. 3, 1955.
23. Defense of our solar-constant value (Abbot, Fowle, Aldrich).	Annals, vol. 4, pp. 323-366, 1922.
24. Brightness of the night sky.	Astron. Journ., vol. 27, No. 3, pp. 17-24, June 20, 1911.
25. Direct and scattered radiation of sun and stars.	Astron. Journ. vol. 28, No. 16, pp. 129-135, March 1914.
26. Tower telescope on Mount Wilson and solar-drift curves.	Annals, vol. 4, pp. 217-257, 1922.
	Smithsonian Misc. Coll., vol. 78, No. 5, 1926.
27. Nature of the sun's sharp boundary.	Scientia, vol. 19, pp. 171-181, March 1916.
	(See also Abbot, C. G., "The Sun," 1911.)
28. Volcanoes and climate.	Smithsonian Misc. Coll., vol. 60, No. 20, 1913; vol. 65, No. 9, 1916.
29. Summary of the work of the Astrophysical Observatory, 1890-1920.	Annals, vol. 5, pp. 1-5, 1932.
30. Radiometer measurements of stellar-energy spectra.	Astrophys. Journ., vol. 50, pp. 87-107, 1924.
	Astrophys. Journ., vol. 69, pp. 293-311, 1929.

31. Campaign of observations of solar intensity on surfaces of different orientations and with various spectral regions, made at army camps for Quartermaster Corps, for a period of 8 years. — Annals, vol. 7, pp. 144-164, 1954.

32. Daily solar-constant values, 1920-1952, with 10-day and monthly means. — Annals, vol. 5, pp. 177-182, 1932; vol. 6, pp. 85-162, 169-175, 1942; vol. 7, pp. 26-94, 1954.

33. Convenient table for solar-constant tabulations. 10-day and monthly mean excesses over 1.900 in hundredths percentages of 1.94. Thus 1.950 becomes — Smithsonian Misc. Coll., vol. 117, No. 10, pp. 20-24, 1952; vol. 128, No. 4 (table 1), 1955.

$$\frac{1.950-1.900}{1.94} \times 100 = 2.58.$$

Similarly 1.940 becomes 2.06. This difference, 0.52, is 0.53 percent of mean solar constant.

NOTE.—The tables in the two references cited above are printed without the decimal point for economy, and do not correspond with the descriptions above unless this fact is known.

PART 2.—*Work of specialists*

1. L. B. Aldrich:
   - a. The melikeron, an approximately black-body pyranometer. — Smithsonian Misc. Coll., vol. 72, No. 13, 1922.
   - b. Reflecting power of clouds, and earth's albedo. — Annals, vol. 4, pp. 375-381, 1922.
   - c. Eclipse expedition, June 1918. — Smithsonian Misc. Coll., vol. 69, No. 9, 1919.
   - d. A study of body radiation. — Smithsonian Misc. Coll., vol. 81, No. 6, 1928.
   - e. Sunspots and the solar constant. — Annals, vol. 7, pp. 165-168, 1954.
   - f. Various researches on long-wave rays. — Annals, vol. 4, pp. 287-299, 1922.
   - g. Author (with W. H. Hoover) of volume 7 of Annals of the Astrophysical Observatory. — Annals, vol. 7, 1954.
2. F. E. Fowle:
   - a. On atmospheric precipitable water. — Astrophys. Journ., vol. 35, p. 149, 1912.

b. On Avogadro's number.	Astrophys. Journ., vol. 40, p. 435, 1914.
c. On atmospheric ozone.	Smithsonian Misc. Coll., vol. 81, No. 11, 1929.
d. On water-vapor absorption above 3 microns.	Annals, vol. 3, pp. 171-193, 1913.
e. On water-vapor absorption below 3 microns.	Annals, vol. 4, pp. 274-287, 1922.
f. Preparation of Physical Tables.	Smithsonian Physical Tables, 5th ed., 1910; 6th ed., 1914; 7th ed., 1919; 8th ed., 1934.

3. W. H. Hoover:

Besides his large part in volume 7 of the Annals of the Astrophyical Observatory, as coauthor with L. B. Aldrich, he engaged in classic researches on photosynthesis as a member of the staff of the Division of Radiation and Organisms, later a branch of the Astrophysical Observatory.

a. Carbon-dioxide assimilation in a higher plant (with Earl S. Johnston and F. S. Brackett).	Smithsonian Misc. Coll., vol. 87, No. 16, pp. 1-19, January 16, 1933.
b. The dependence of carbon-dioxide assimilation in a higher plant on wavelength of radiation.	Smithsonian Misc. Coll., vol. 95, No. 21, pp. 1-13, February 27, 1937.
c. Improvements in use of standard water-flow pyrheliometer, and in silver-disk pyrheliometer.	Smithsonian Misc. Coll., vol. 122, No. 5, pp. 1-10, August 14, 1953. Annals, vol. 7, pp. 99-104, 1954.
d. Special studies of global sun and sky radiation (with L. B. Aldrich).	Annals, vol. 7, pp. 144-164, 1954.
e. Mechanical integrator for Brown recording potentiometer.	Annals, vol. 7, pp. 138-139, 1954.