A NEW SPECTROPYRHELIOMETER AND MEASUREMENTS OF THE COMPONENT RADIATIONS FROM THE SUN AND FROM A QUARTZ-MERCURY VAPOR LAMP

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CONTENTS

I. INTRODUCTORY STATEMENT

In a previous investigation[1] attention was called to the importance that artificial light is assuming in dye fading and in other photochemical tests, and data were given on the decrease in ultra-violet radiation with usage of a quartz-mercury vapor lamp.

The apparatus used was exceedingly simple and well adapted for the purpose for which it was then employed. But it did not permit a reliable intercomparison of the radiation components of the mercury-vapor lamps and of the sun. In the present investigation this need has been met by simple means.

The apparatus, to be described presently, is merely a spectroradiometer employing a wide receiver which permits measuring

[1] B. S. Scientific Papers, 15, p. 1; 1918.

a wide region of the spectrum, and hence the whole spectrum, in a few steps.

The device is easy to operate and may prove a valuable adjunct in meteorological observatories, in connection with the measurement of solar-radiation intensities and the solar constant.

For example, some years ago Ångström[2] fitted to his pyroheliometer a water cell and a blue glass, which combination transmitted only the violet and ultra-violet. In this manner he was able to avoid the question of absorption by water vapor. He had to consider only atmospheric diffusion which is greatest in the ultra-violet, where a variation in solar radiation should be manifested with the greatest force and, hence, easily recognized. His experimental procedure was (1) to measure the total radiation with his pyrheliometer, which gives the solar-radiation intensity on the earth, and (2) to eliminate atmospheric absorption (diffusion) by observing the solar-radiation intensities at different times of the day—that is, different solar altitudes—by means of his ultra-violet radiometer.

While the present apparatus was designed for measuring different parts of the spectrum, it could be simplified in case one desired to measure radiation intensities in only one part—for example, the ultra-violet—of the spectrum.

The apparatus in the form of a simple spectroradiometer will be useful in determining the decrease in the ultra-violet component radiation with usage of a quartz-mercury vapor lamp, and in testing eye-protective glasses for opacity to ultra-violet light. The latter is a tedious (usually photographic) process which can be performed in a few minutes by utilizing the spectroradiometer described in the present paper.

This form of spectroradiometer, suitably modified, should prove useful in measuring the spectral radiation from stars.

It is beyond the scope of the present paper to discuss the relative efficiency of the radiations from the sun and from the quartz-mercury arc in testing the fastness of dyes, paints, etc. In a very complete paper on this subject, Mott[3] states that the action of the ultra-violet light from the mercury arc is often different from that of sunlight, and he advocates the use of a white-flame carbon arc. This paper should be consulted concerning the practical applications.

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[2] Ångström, Nova Acta Reg. Soc. Sci. Upsala (4), **1**, p. 19; 1907.

[3] Mott, Trans. Amer. Electrochem. Soc., **23**, p. 371; 1915.

In this connection it is important to remember that sources of strong ultra-violet radiation—for example, the quartz-mercury lamp—produce ozone and nitrous oxide. It is, therefore, desirable to determine the effect of these gases in dye-fading and in other photochemical tests.

II. DESCRIPTION OF THE SPECTROPYRHELIOMETER

This instrument was constructed of material at hand, without any attempt to properly proportion it for permanent use. The scale, Fig. 1, which is 51 cm (20 inches) long, serves for comparison of dimensions.

1. EQUATORIAL MOUNTING

In order to avoid the absorption which occurs in a heliostat mirror, the spectropyrheliometer was mounted upon a polar axis, *P*, which rests in a wooden frame, as illustrated in the photograph Fig. 1. This permitted projecting the solar image directly upon the slit, by means of a planocylindric quartz lens, *L*, 6 cm in diameter and 18 cm focal length.

The essential feature of the instrument, which makes it easy to operate without clockwork, is the cylindrical lens, with its axis parallel with the slit. The solar image, which is focused lengthwise on the slit, travels but slowly along the slit, and hence it is possible to make a series of readings without resetting. Displacing the center line of the solar image 1 cm along the slit introduced a variation of only 1 to 2 per cent in the radiation measurements. In practice, the solar image was kept accurately adjusted to within 1 mm lengthwise on the slit. By making a slight turn of the worm gear, *W*, it was easy to follow the sun. The gear is clamped to the polar axis by means of a screw, *S*, which is provided with a handle. A slight turn of this screw releases the gear for quick hand setting of the spectroscope in right ascension.

The declination setting is made by means of a screw clamp, *K*, Fig. 2, and the fine adjustment in declination is obtained by means of a screw, *D*, Figs. 1 and 2, working in a nut which was attached in a pivot to the board supporting the spectroscope.

A counterweight, *Cw*, was provided, and when weights were placed upon the cross boards, *CB*, which are attached to the base of the mounting, there was no vibration from the wind or from operating the worm gear. The apparatus was placed directly on the lawn when making the solar-radiation-intensity measurements, and, with the weights on the cross boards, there was no unsteadiness in operating the device.

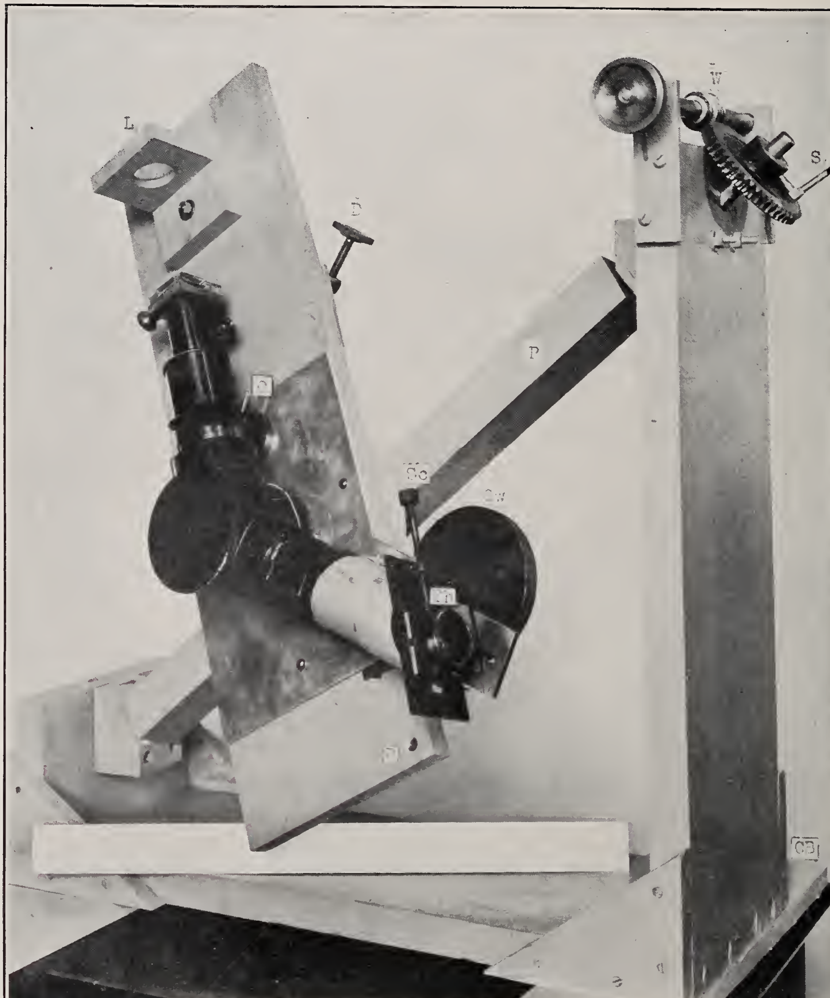

Fig. 1.—*Spectropyrheliometer, consisting of a quartz lens spectroradiometer, Th, and cylindrical quartz condensing lens, L, mounted upon a polar axis, P, which is rotated by means of a worm gear, W*

2. QUARTZ SPECTOGRAPH

The spectrum was produced by means of a quartz prism and two plano-convex quartz lenses, 6 cm in diameter and 18 cm focal length, used in previous work. They were mounted upon an aluminum plate, which was then attached to the board *B*, which, in turn, is attached to the declination axis. The telescope tube supporting the collimating lens could be rotated a small amount and clamped at *C*, Fig. 1, which permitted making small adjustments of the spectrum upon the thermopile receiver.

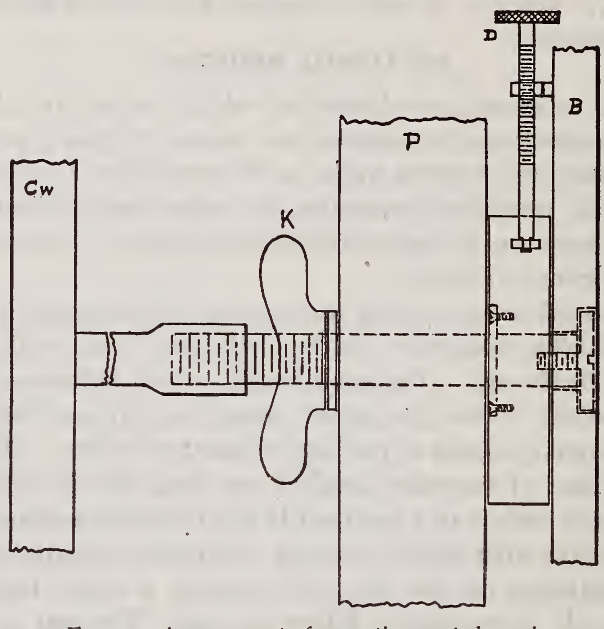

FIG. 2.—*Arrangement of mounting on polar axis*

The cylindrical lens of quartz, already mentioned, was used only in the solar-radiation-intensity measurements.

To exclude stray light, a black flannel cloth was placed over the spectrograph when making the measurements on the sun.

3. RADIOMETER

In view of the fact that in this work relative measurements sufficed, no use was made of a regular pyrheliometer,[4] which consists of a thin blackened strip of metal, back of which is placed a thermopile.

Instead of this, a specially constructed thermopile was used. The thermopile consisted of nine couples of bismuth silver, with

[4] B. S. Bulletin, 11, p. 157; 1914.

receivers 1.1 by 3 mm; the dimensions of the whole receiver were 3 by 9.5 mm. The bismuth wire, 0.1 mm in diameter, was pressed flat in order to obtain good contact with the receivers. This, no doubt, shortened the time to attain thermal equilibrium (the maximum steady galvanometer deflection) which was attained in 10 to 12 seconds. In this work the ballistic throw was used, the maximum of which was attained in about 3 seconds. It was therefore possible to make a complete measurement in about 6 seconds.

The height of the spectrometer (collimator) slit was 3 mm, and, although the spectrum was only 3 mm high (width of collimator slit = 0.5 mm), there was sufficient intensity for making accurate measurements. This is partly owing to the fact that the length of the spectrum, falling upon the thermopile, was 8 mm, which was sufficient to intercept the whole of the visible, and also the whole of the infra-red spectrum, each in one setting, and the ultra-violet spectrum in two settings. This was determined by photographing the spectrum, using helium and quartz-mercury lamps.

The electric current generated by the thermopile, on exposure to radiation, was measured by means of an ironclad Thomson galvanometer of sensitivity $i = 4 \times 10^{-10}$ ampere. But it was necessary to place from 7000 to 15 000 ohms in series, as indicated in Table 1. A much-less sensitive galvanometer would have sufficed for the work.

The thermopile, *Th*, Fig. 1, is mounted in a brass case with adjustable knife-edge slits. The telescope tube is fixed and the different parts of the spectrum are measured by moving the thermopile in accurately made ways, by means of a screw, *Sc*. The settings are made to a scale, not very clearly shown in the photograph. There was but little backlash, and, by careful setting to the scale, the radiometric measurements could be accurately repeated on resetting the thermopile in different parts of the spectrum.[5]

4. CALIBRATION

As already stated, the object of this test was to obtain a comparison of the ultra-violet radiation in the spectrum of the sun and of the quartz-mercury vapor lamp. This is accomplished by determining the total radiation and the relative spectral components.

[5] See B. S. Bulletin 9, p. 293, Fig. 1, for a similar arrangement of scale and sliding mechanism.

The violet helium line $\lambda = 0.3889\mu$ appeared to be a convenient line at which to terminate the "visible spectrum." Accordingly, the knife-edge slit was set so that this spectral line entered the thermopile case. The other knife-edge slit, distant 8 mm, permitted the red helium radiation, of wave length $\lambda = 0.7065\mu$, and the continuous spectrum of a gas-filled tungsten lamp, up to $\lambda = 0.75\mu$, to enter the thermopile case. This is scale setting 53 in Table 1, and includes wave lengths 0.75μ to 0.3889μ.

Scale setting 61, Tables 1 and 2, comprises wave lengths beginning at 0.75μ and extending to the limits of transmission of quartz at 4μ. This part of the spectrum is much compressed, and it is certain that all of it entered the thermopile case. From the photographs it was determined that the slit opening of 8 mm comprised the spectrum of wave lengths beginning at (but not including) $\lambda = 0.3889\mu$ and extending beyond $\lambda = 0.3\mu$ to perhaps $\lambda = 0.28\mu$. This is scale setting 45 in Tables 1 and 2.

Similarly from the photograph it was found that scale setting 37, Tables 1 and 2, intercepted all wave lengths less than $\lambda = 0.3\mu$ and extending to the limit of the spectrum transmitted by quartz and by air in the ultra-violet.

The device would be useful also for measuring narrower intervals of the spectrum, but this is time consuming and would decrease the accuracy in the final summation of the parts. For example, in the mercury spectrum there is a continuous spectrum superposed upon a few strong emission lines and the spectral energy distribution has but little meaning unless it is determined for each lamp at the time it is being used.

5. DIFFUSE-LIGHT TESTS

As mentioned in previous papers, it is important to determine the amount of diffuse light in different parts of the spectrum.[6] For determining the amount of infra-red scattered into the visible spectrum a combination of red-purple and of noviol (shade *C*) glass, which transmits only radiations of wave length greater than 0.75μ, was placed over the spectrometer slit.

For scale setting 45 a Corning noviol glass (shade *A*) which is opaque to radiations of wave length less than 0.42μ was used.

For scale setting 37—that is, the spectrum of wave lengths less than 0.3μ—a colorless glass was used (A. O. C. Lab. No. 57). It is opaque [7] to radiations of wave length less than 0.34μ.

[6] B. S. Bulletin, **14**, p. 534; 1918.

[7] Gibson and McNicholas, B. S. Technologic Paper No. 119, p. 29.

The tests showed that only in the extreme ultra-violet region (scale 37) of the spectrum was a correction necessary for diffuse light, amounting to only about 2 to 3 per cent in the case of the quartz-mercury vapor lamp.

III. EXPERIMENTAL DATA

Under this caption are given the results of radiometric measurements on the sun, on a quartz-mercury vapor lamp, and on a gas-filled tungsten lamp. No attempt was made to use the present apparatus to measure the radiations from the carbon arc or the magnetite (iron) arc in view of their unsteadiness and the uncertainty of the amount of infra-red emitted by the electrodes.

1. SPECTRAL COMPONENTS OF RADIATION FROM THE SUN

The spectral radiation data were obtained mainly for the purpose of determining the different components relative to that of the quartz-mercury arc lamp. The solar radiation is so variable that the whole test can serve only as a rough estimate of what may be expected under various conditions. For example, the data given in Table 1 for September 13 illustrate conditions on a day when the sky contained thin, fleeting (sometimes almost invisible), white clouds. On September 16 there was a low-hanging haze, or smoke, which prevented one from seeing the Soldiers' Home buildings 3 miles away. Later in the day the sky cleared and the ultra-violet light transmitted was almost doubled in intensity. On September 24, after several days of rain, the sky was exceedingly clear and the ultra-violet component was 2 per cent of the total radiation intensity.

The data for the early morning hours indicate (for a sea-level station) that, as a result of increased scattering of light, the ultra-violet component radiation intensity is only about one-half that which obtains at noonday. While it is of no importance in connection with the question of dye fading, it is interesting to notice the reverse condition for the infra-red component, which is the greatest in the morning and evening and is a minimum at noon. This is, of course, to be expected from a consideration of the well-known phenomenon of scattering of light of short wave lengths.

From the data at hand, showing the great variation in the intensity of the ultra-violet radiation, it would appear that important meteorological data might result from an extended investigation of this subject. This is shown in Table 1, which gives the solar-radiation intensity as observed at the U. S. Weather Bureau.

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TABLE 1.—Spectral Components of Solar Radiation

[Scale reading: 45=0.3μ to 0.3889μ, 53=0.3889μ to 0.75μ, 61=0.75μ to 3μ]

Time, 1919	Scale reading—						Remarks
	61		53		45		
	Galvanometer deflection	Per cent of total	Galvanometer deflection	Per cent of total	Galvanometer deflection	Per cent of total	
September 13:	cm		cm		cm		
10.05			25.7	49.1			Faint clouds.
07	25.8	49.2					
10					0.80	1.7	Solar-radiation intensity=1.29 gr. cal.
12			25.8				cm—² min.—¹
15			24.0				Clouds.
17	26.4						
11.11	26.8						
12			29.5				Clear.
September 16:							
10.04	42.0	57.0					7000 ohms.
06			31.0	42.0			Low haze, smoky.
08					.72	.98	Can not see Soldiers' Home build-
26					.75	1.01	ings, 3 miles distant.
28			30.8	41.3			
31	43.0	57.7					
45	40.5	59.0					Sky more hazy.
46			27.5	40.0			
48					.70	1.02	
50			26.8	40.0			Clouds gathering.
51	39.5	59.0					
12.20	43.5	55.8					
22			33.5	43.1			
24					.85	1.09	Solar-radiation intensity=1.00 gr. cal.
31					.83	1.14	
32			31.2	42.7			
34	41.0	56.2					
40	46.5		41.5				7000 ohms.
41	32.8		28.5				10 000 ohms.
50					.88	1.35	10 000 ohms.
52			29.2	45.1			
55	34.7	53.5					Sky clear, Soldiers' Home buildings
57		52.7	30.2	45.9			visible.
59					.92	1.30	
1.14					.80	1.23	Solar-radiation intensity=0.99 gr. cal.
18			27.6	41.1			
22	34.2	54.6					
45	33.4	54.8					
48			26.8	44.0			
52					.68	1.13	Solar-radiation intensity=0.97 gr. cal.
2.03			26.3	44.0			
05	32.8	54.9					
07	33.0	53.6					
08			27.9	45.3			
10					.70	1.13	
37					.63	1.08	
38			24.9	43.7			
39	31.5	55.2					

TABLE 1.—Spectral Components of Solar Radiation—Continued

Time, 1919	Scale reading— 61		53		45		Remarks
	Galvanometer deflection	Per cent of total	Galvanometer deflection	Per cent of total	Galvanometer deflection	Per cent of total	
September 24:	cm		cm		cm		
8.47			30.2	43.9			7000 ohms.
49	38.8	55.0				1.13	
51			31.8				Very clear sky.
54					.80	1.08	
58			33.0	44.4			Solar radiation intensity=1.14 gr. cal.
59	40.5	54.5					
10.46			34.1				10 000 ohms.
48	31.4	46.1					
50			35.5	52.0			
52					1.28	1.87	Solar radiation=1.31 gr. cal.
54					4.15		3000 ohms (The total radiation of wave lengths less than 0.3μ is less than 1 mm; or one-fiftieth of the radiation between λ=0.3 and λ=0.4 μ)
11.00					1.20	1.82	
02			34.0	51.4			
04	30.9	46.8					
12.13	31.3	45.8					
14			35.9	52.4			
15					1.35	1.97	Solar radiation=1.32 gr. cal.
16			35.2	51.6			
17	31.7	46.4					
19			35.8	52.0			
22					1.36	1.98	
2.41	32.1	48.5					Solar radiation=1.3 gr. cal. at 2 p. m.
43			33.1	50.0			
45					.97	1.45	
3.23	29.5	50.2					
25			28.6	48.6			
27					.75	1.28	Solar radiation=1.14 gr. cal. at 3 p. m.
28			28.4	48.5			
30	29.5	50.2					
September 25:							
8.45	36.4	48.1					10 000 ohms.
47			38.2	50.4			Very clear sky.
49					1.10	1.44	
51			38.1	49.5			Solar radiation=1.22 gr. cal.
53	37.8	49.1					
11.43	32.0	46.5					15 000 ohms.
46			35.4	51.4			
48					1.45	2.10	
12.00			34.9	52.1		2.16	Solar radiation=1.35 gr. cal.
02	30.7	45.8					
03		46.1			1.43	2.15	
10			34.5	51.8			
2.57	26.7						15 000 ohms.
3.00	30.3	48.5					12 000 ohms.
01			31.4	50.1			Solar radiation=1.21 gr. cal.
02					.92	1.48	
04			30.7	49.4			
06	30.5	49.1					
07			30.6	49.3			

It is of interest to note the great seasonal variability of the intensity of solar radiation.[8] The maximum normal solar radiation at perpendicular incidence varies from 1.37 gram calories per minute per square centimeter in January to 1.5 gram calories in May and September. The total radiation on a horizontal surface, with a clear sky, varies from 0.77 gram calories per minute in December to 1.55 gram calories in June. Clouds nearly in line with the sun, but not obscuring it, increase the radiation by about 0.15 gram calories.

Assuming that in the fading tests, etc., the material is exposed so that the solar rays are incident normally upon the surface, the average seasonal solar radiation intensity for, say, three hours at noonday may be taken 1.2 gram calories per minute per square centimeter of normal surface. Of this amount from 1 to 2 per cent is in the ultra-violet of wave lengths less than 0.3889μ, or about 0.02 gram calories per minute per square centimeter. Usually it is perhaps only about one-half this value. In comparison with this we have the quartz-mercury vapor lamp,[9] which at a distance of 40 cm from the burner has a radiation intensity of 0.0017 gram calories per square centimeter per second. Table 2 shows that about 30 per cent of this radiation is in the ultra-violet of wave lengths less than 0.3889μ. From this we obtain a radiation intensity of 0.0306 gram calories per minute per square centimeter for a new lamp. After some usage the ultra-violet component would be less, say 0.02 gram calories per minute per square centimeter, which is about the same as obtained from solar radiation. But, as will be discussed on a subsequent page, the spectral quality of this ultra-violet component is entirely different in these two sources of radiation. In an interesting paper by Lyman,[10] attention is called to the observations of Cornu, who found that the spectrum of the sun terminates quite abruptly at about 0.3μ.

From the present measurements it appears that the ultra-violet component of solar radiation of wave lengths less than 0.3μ under the best conditions (at sea level), if anything, is less than 5 per cent of the total ultra-violet component. In the quartz-mercury arc the ultra-violet component of wave lengths less than 0.3 is 20 per cent of the total ultra-violet component radiation.

In concluding the discussion of the data on the components of solar radiation, it is important to notice the probable accuracy of

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[8] Kimball, Monthly Weather Rev., 42, p. 486; 1914.

[9] B. S. Scientific Papers, 15, p. 19, Table 7; 1918.

[10] Lyman, Monthly Weather Rev., 42, p. 487; 1914.

the measurements, in view of the fact that the spectropyrheliometer is not adapted to measuring radiation from sources emitting appreciable infra-red of wave lengths greater than 3μ. The data given in Table 1 show that on some days the infra-red component is larger than the component in the visible spectrum. On clear days the two components are about equal, or the visible component is the larger. For comparison we have the solar spectral-energy curves, published by Abbot.[11] A rough integration of the spectral-energy curve, for air mass = 1, indicates the areas of the infra-red component and the visible component are, respectively, 51.5 and 48.5 per cent, while for an air mass = 2 these areas are 55 to 45 per cent. In other words, these two types of data are in satisfactory agreement, which was to be expected in view of the fact that but little solar radiation of wave lengths greater than 2μ is transmitted by the earth's atmosphere.

Some years ago it was observed[12] that the Callendar sunshine receiver seemed to be selective in that its constants appeared to be different for morning and noon measurements. This instrument consists of a bolometer bridge of bright and of blackened platinum wires. Platinum has a low reflecting power in the visible and in ultra-violet,[13] and the present writer's suggestion was that the apparent selective action was caused by the increased absorption by the platinum wire, of ultra-violet, which is more abundant at noon. Another contributory cause to this selectivity is probably to be found in the dark-blue glass enamel used as a covering of the "blackened" arm of the bridge. This glass is selective in its absorption (similar to cobalt blue glass) and a change in the relative components of solar radiation may affect the constants of the instrument, as observed. The enamel absorbs relatively less, while the platinum absorbs more of the ultra-violet as the spectral components vary throughout the day.

2. SPECTRAL COMPONENTS OF RADIATION FROM A QUARTZ-MERCURY VAPOR LAMP.

The lamp examined was a 220-volt type of Cooper Hewitt quartz-mercury vapor burner. It was new, and it was operated in the regular automatic self-lighting mounting, without the outer glass globe. A voltmeter was connected across the terminals of the burner, and an ammeter was placed in series with the burner,

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[11] Annals Astrophys. Obs., Smithsonian Institution, 2, pp. 104–108; 1908.
[12] Kimball, Monthly Weather Rev., 42, p. 475; 1914.
[13] B. S. Bulletin, 5, p. 344, Fig. 1; 1914.

in order to determine the energy input. The energy input was varied by means of a resistance connected in series with the burner.

TABLE 2.—Spectral Energy Radiated from a Quartz-Mercury Vapor Lamp (Cooper Hewitt 220 volt)

Energy input, watts / Energy radiated	Wave-length scale reading: 61		53		45		37	
	Galvanometer deflection	Per cent of total	Galvanometer deflection	Per cent of total	Galvanometer deflection	Per cent of total	Galvanometer deflection	Per cent of total
	cm		cm		cm		cm	
250	2.1	15.4	7.4	54.5	3.3	24.3	0.8	5.9
300	3.7	16.8	11.5	52.3	5.4	24.6	1.4	6.3
350	6.1	18.6	16.7	51.0	7.9	24.1	2.1	6.4
400	9.6	19.4	25.2	50.8	11.6	23.4	3.2	6.4

The data obtained are given in Table 2 and illustrated in Fig. 3 and need no explanation. The galvanometer deflections are in centimeters. The data are instructive in showing the rapid increase in the radiation components with energy input. This is, of course, not entirely new. In a previous paper [14] similar data were given, which accounted for the decrease in luminous efficiency which occurs after passing beyond a certain energy input. This maximum luminous efficiency was not attained, however, in the present tests. On normal operation (400 watts) the ultra-violet radiation amounts to 30 per cent of the total radiation.

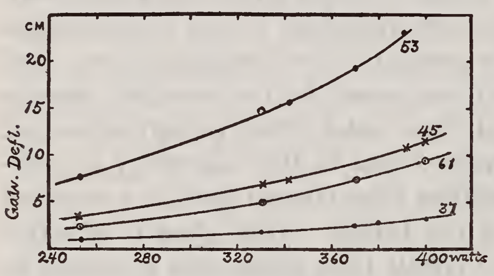

FIG. 3.—*Spectral energy radiated from a quartz mercury vapor lamp with energy input. The numbers (e. g., 45) refer to the scale settings*

It is important to notice that over 6 per cent of the total radiation of the incandescent mercury vapor is of wave lengths shorter than 0.3 μ (scale 37; $\lambda = 0.2\ \mu$ to $0.3\ \mu$). In this same spectral region the radiation from the sun, transmitted by the earth's atmosphere, as observed at sea level, is quite imperceptible, being less than 0.1 per cent of the total solar-radiation intensity.

Because of this great difference in the quality of the radiation from these two sources of actinic rays, it is quite impossible to

[14] B. S. Bulletin, 9, p. 96; 1912.

compare their effects in photochemical work, such as, for example, in dye-fading tests. Luckiesh,[15] in discussing the region of the spectrum which causes fading of a given dye, mentions that radiations from a quartz-mercury arc of wave lengths between 0.30 and 0.35μ were most effective in blackening lithophone ($ZnS.BaSO_4$).

In addition to the quality, the intensity must also be considered. The visual rays may not produce very rapid photochemical action. However, the visual rays from the sun are so much more intense than those from the quartz-mercury arc that, in comparison, they may contribute appreciably to the total photochemical effect produced.

The data obtained by this method of observation are in good agreement with the previous estimations,[16] which are less reliable.

As already stated, the apparatus will be useful in determining the decrease in the ultra-violet radiation with usage of a lamp.

3. SPECTRAL COMPONENTS OF RADIATION FROM A GAS-FILLED TUNGSTEN LAMP

The gas-filled tungsten lamp is of little use in dye-fading tests Luckiesh focused the image of a gas-filled tungsten lamp upon a lithophone surface for hours without producing a blackening effect.

In the present tests it was found that the total radiation of wave lengths between 0.3μ and 0.3889μ was only about 0.3 per cent of the total radiation of wave lengths in the visible spectrum extending from 0.3889μ to 0.75μ, or perhaps only about 1/10 000 of the total radiation emitted by the lamp.

4. ULTRA-VIOLET COMPONENT OF RADIATION FROM AN IRON ARC AND FROM A CARBON ARC

The foregoing measurements of the ultra-violet component of the radiation from the quartz-mercury vapor lamp are in substantial agreement with previous measurements,[17] using simply a glass screen which was opaque to radiations of wave lengths less than 0.4μ. The previous measurements are therefore verified and may be considered sufficiently accurate for comparison.

The ultra-violet component of the total radiation of wave lengths less than 1.4μ emitted by an iron (magnetite) arc may be deduced from Table 1 of the previous publication which gives

[15] Luckiesh, Trans. Amer. Electrochem. Soc., 28, p. 399; 1915.
[16] B. S. Scientific Papers, 15, p. 19, Table 7; 1918.
[17] B. S. Bulletin, 14, p. 675, Table 1; also Scientific Papers, 15, p. 19, Table 7; 1918.

the transmission through a Corning noviol glass, shade *B*, which is opaque to radiations of wave lengths less than 0.44μ to 0.45μ.[18] The transmission is 56 per cent.

In other words, the ultra-violet component of wave lengths less than 0.45μ is 44 per cent as compared with 68 per cent for the quartz-mercury arc for the same spectral region.

Similar measurements [19] on a dye-fading, carbon arc, with the glass globe in place, gave an ultra-violet component of 59 per cent of the total radiation of wave lengths less than 1.4μ.

The great difference in the ultra-violet component of these lamps, as determined by this test, is attributable to the much greater amount of visible radiation emitted by the carbon and the magnetite arc lamps. The spectra of these two arcs are more continuous, and there is no exact method for making a comparison of the radiation from these sources with that of the mercury arc.

IV. SUMMARY

In this paper a new spectropyrheliometer is described and data are given showing the applicability and the performance of the instrument. This device will be useful also in measuring ultra-violet radiation of sources and in determining the opacity of eye-protective glasses to ultra-violet light.

The spectropyrheliometer consists of a quartz spectrograph and a cylindrical quartz condensing lens placed upon a simple equatorial mounting. The collimating telescope is pointed directly toward the sun, thus avoiding the ultra-violet absorption which occurs in heliostat mirrors.

An important part of the device is the planocylindric lens, which enables one to operate the mechanism by hand.

The radiometric measurements are made by means of a specially constructed bismuth-silver thermopile. In this investigation the measurement of the whole spectrum was made in four settings. From a separate measurement of the total radiation from the source the values of the components were obtained in absolute measure.

The object of the measurements was to obtain a comparison of the ultra-violet component of the radiation from the sun and from a quartz-mercury arc lamp, which data are useful in dye-fading and other photochemical investigations.

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[18] B. S. Technologic Paper No. 119, pp. 30–32; 1919.

[19] B. S. Scientific Papers, 15, p. 19; 1918.

Data are given showing that there is no marked difference in the total ultra-violet radiation of wave lengths less than about 0.4μ from these two sources. However, the spectral quality of the ultra-violet (the energy distribution) is entirely different. The ultra-violet of the solar spectrum terminates at about 0.3μ. On the other hand, in the quartz-mercury vapor lamp the ultra-violet component of wave lengths less than 0.3μ is about 20 per cent of the total ultra-violet component radiation from this lamp.

It therefore remains to be shown which rays, irrespective of their thermal-radiation intensity, produce the greater photochemical action. This, no doubt, depends, in part, upon the absorptivity of the substance upon which they impinge.

Comparative data are given also on the ultra-violet component of the radiation from the gas-filled tungsten lamp, the iron arc, and the carbon arc.

In two appendixes methods are discussed for excluding ultra-violet light from buildings—for example, balloon hangars—and for protecting photographic films from the heat of a projection lamp.

WASHINGTON, November 11, 1919.

APPENDIXES

Having dealt with methods for producing and measuring the radiation components, particularly those of sunlight, it is relevant to add a few suggestions on methods for preventing injurious effects which may be caused by their excessive heating or photochemical action.

Appendix 1.—EXCLUSION OF ULTRA-VIOLET LIGHT FROM BUILDINGS [1]

The problem was presented to provide a substitute for colored glass to exclude ultra-violet solar rays from the interior of buildings, for example, balloon hangars, etc., containing material which may be injured by these rays.

Tests were made showing that varnishing common window glass with dilute asphaltum varnish is very efficient in absorbing the ultra-violet rays. A better method is to provide a sort of Venetian blind, or louver, of wide slats, painted buff to reflect the light into the building. The buff or red paint absorbs the ultra-violet, thus protecting the contents of the building from photochemical action. Colored window glass is expensive. By placing the windows on the north side of the building, by placing them low, so that the direct sunlight impinges on the floor, and by other simple expedients, thousands of dollars may be saved on glazing alone.

Appendix 2.—PROTECTION OF A PHOTOGRAPHIC FILM FROM THE HEAT OF A PROJECTION LAMP

In ordinary optical projection it is a common experience to have the photographic plate injured by the intense rays from the lamp, which was transmitted by the water cell.

As ordinarily used, the moving-picture film is partly protected from injury by the intense infra-red rays from the lamp, because it is exposed to these rays for only an instant.

As shown in a previous paper [20], a solution of cupric chloride is very opaque to infra-red rays. A dilute water solution (say 1 to 2 per cent) of cupric chloride absorbs but little in the visible spectrum, and it absorbs practically all the infra-red. The color of the arc or a tungsten lamp is not appreciably modified on transmission through the cell.

Another method is to provide the water cell with windows of Corning "heat-absorbing" glass, which is very opaque to infra-red radiation.[21]

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[20] B. S. Bulletin, **7**, p. 658; 1911.

[21] B. S. Bulletin, **14**, p. 663; 1918.

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