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INTRODUCTION

For some of the biophysical investigations (1)[1] in progress at the laboratory of the Division of Radiation and Organisms of the Smithsonian Institution an absolute measure of the energy in the lines of the mercury arc spectrum was needed in greater detail than is available in the literature. This has been obtained for a common type of commercial arc (Cooper-Hewitt 220 volt D.C. quartz mercury arc), and it is believed that these results will be of interest to users of this type of mercury lamp. Although this source is not ideal from a spectroscopic standpoint the present measurements cover a wide spectral range and are accurate enough to show a smooth and regular decay in the sharp and diffuse series. Also it is found that the theoretical intensity relation for these triplets is approached by higher members of the series.

A preliminary report of these measurements was presented at a meeting of the American Physical Society (2) and the preliminary curves—uncorrected for instrumental transmission—were included in the Report of the Secretary of the Smithsonian Institution for the year ending June 30, 1931 (p. 133). The transmission of the two monochromators used has since been determined and the spectrum remapped under steadier operating conditions, so that the data may now be presented as absolute measurements of radiant flux.

Coblentz in his extensive examination of light sources (3) used in phototherapy has given data on this type of arc. His data consists mainly of filter observations that give in absolute measure the energy distribution in the different spectral regions. In a recent paper (4) he has given relative intensities of the prominent lines in the ultra-violet. Harrison and Forbes (5) and Hulburt (6) show energy

[1] Numbers in parentheses refer to the list of literature cited, found at the end of this paper.

curves of the quartz mercury arc using an effective slit width of 200 A. and 100 A. at λ 4,000 A. respectively. Hulburt supplemented his thermopile measurements with photocell observations and obtained a smaller effective slit width. (10 A. at λ 2,500 A., 20 A. at λ 3,000 A.). The present work was done with an effective slit width of 2 A. at λ 2,300 A. which increased to 12 A. at λ 4,000 A. Since the present experimental work was completed the text " Lichtelektrische Zellen " by Simon and Suhrmann (7) has been published. In it appear energy curves of the mercury arc spectrum obtained by Suhrmann which apparently have not been published elsewhere. The resolution attained is nearly identical with the writer's, and the measurements are given as absolute. The relative intensities agree fairly well with the present work, even though the arcs were of different type. However, the absolute values disagree by more than two orders of magnitude. This will be discussed later.

EXPERIMENTAL

These measurements were made on the Cooper-Hewitt 220 volt D.C. quartz arc in the spectral region 2,100 A. to 7,000 A. Observations were taken on four " vertical " arcs and one " horizontal " arc. Two sets of measurements were made: 1, the arcs running under normal power consumption of 4.5 amperes with 150-volt drop across the arc, and 2, a low power consumption of 3.0 amperes and 44 volts. Subsequently these will be called " high intensity " and " low intensity " operating conditions respectively. Radiation from a 20-mm length of the arc midway between electrodes was measured with the monochromator and thermocouple combination, care being taken that no scattered light of any consequence was included. Filter measurements with a bare (windowless) thermocouple were taken of the radiation from this 20-mm midsection, as well as the radiation from the total arc. These filter observations provide a measure of the energy in different spectral regions with which the summation of the line intensities can be compared. Also they provide a factor that can be used—with no serious error—to reduce the line intensities for the midsection of the arc to " total arc " intensities. A bank of storage cells was used as a source of current for the low-intensity observations. A D.C. motor-generator outfit—regulated with a synchronous motor—was used for the high-intensity work. In both cases the choke coil and series resistance furnished by the manufacturer were used to steady the arc.

A single-junction vacuum thermocouple provided with a crystal quartz window and of a type described elsewhere (8) was used for the monochromator observations. A Leeds and Northrup H.S. galvanometer with a curved (circular) scale was used and calibrated for current versus deflection in the usual manner. The thermocouple galvanometer combination was calibrated in terms of a radiation standard furnished by the Bureau of Standards. By using an auxiliary windowless thermocouple and a monochromatic beam of light—λ 4,358 through the monochromator of which the window of the vacuum couple transmitted 91.0 per cent—it was determined that 86 per cent of the radiant energy from the standard of radiation was transmitted by the window of the vacuum thermocouple. The thermocouple was provided with a slit 0.10 mm wide, which is immediately in front of the receiver. The receiver is 2.8 mm high. At a distance of 2 m from the standard of radiation the flux is 64.2 microwatts per cm^2. This produced a deflection of 41.5 mm. Hence a deflection of 1.0 mm corresponds to an intensity of 1.33 microwatts per cm^2 on the receiver. For the bare thermocouple a deflection of 1.0 mm corresponds to an intensity of 8.51 microwatts per cm^2.

For dispersion two Bausch & Lomb quartz monochromators were used, both singly and in tandem as a double monochromator. When used singly the exit slit of the monochromator was removed and replaced by the thermocouple which is provided with a slit. When the two were used in tandem the curved exit slit of the first monochromator served as the entrant slit of the second. This arrangement straightens out the image falling on the thermocouple and improves the resolution. The two were maintained in permanent alignment on a cast-iron table with seats provided for the leveling screws of the monochromators. A special sleeve held the collimator of the second instrument in proper position with respect to the telescope of the first. The use of two instruments greatly reduces the scattered light which in an instrument of numerical aperture f4 is to a certain extent inevitable. The source to be examined was rigidly attached to the cast-iron table so that no change in illumination could occur during a series of observations. The length of the entrant slit was reduced to 2.75 mm by two knife edges and the arc placed 250 mm from it. No condensing lens was used. Since the section of the arc exposed was nearly square the illumination produced at the collimator lens of the monochromator was square in form and covered about one half the area of the aperture. The corners of the square were well inside the circle limiting the aperture, the illumination being observed by placing the eye at the exit slit with an intervening screen to reduce the intensity. In measuring the absolute intensities of isolated spectral lines a single monochromator with a 0.10-mm slit was used. To obtain the greater resolution required for close groups and reduce the effect of scattered light the double monochromator set-up was used with a 0.05-mm slit.

The transmission of the monochromators for the wave lengths used was obtained with the aid of a photronic cell provided with a quartz window. This was used instead of a thermocouple because its characteristics render it relatively insensitive to a change in position behind the monochromator. For a constant amount of incident energy the cell's response is practically independent of the area exposed. One of the vertical arcs operating at high intensity was used for this calibration. It was placed 250 mm from the slit so as to give an illumination identical with that used in the intensity measurements. Another photronic cell connected to a microammeter was placed so as to receive total radiation from the arc. This microammeter, which indicated the output of the arc, and a voltmeter and ammeter measuring the input were mounted near the galvanometer scale so that the observer could glance at them before taking a reading. For both the transmission measurements and the intensity measurements galvanometer readings were taken only when this photronic cell indicated the same output from the arc. The intensity of 19 of the stronger lines was observed at the exit slit of one monochromator. Then the second instrument was placed in tandem and readings taken on the same lines. The ratio of the latter reading to the former for a particular wave length is the transmission of the second monochromator for that wave length. The positions of the instruments were then reversed and the process repeated. The transmissions so obtained were plotted and smooth curves drawn. Points taken from the smooth curve for the instrument used in the intensity measurements are included in Table 1. The transmission of one instrument differed by less than 1 per cent (*i. e.*, 46 per cent compared with 47 per cent) from that of the other and was consistently higher. The transmission of either machine with the field illuminated as stated was several (2 to 4) per cent higher than that given by the manufacturer. This difference is probably due entirely to the difference in illumination, as the manufacturer's figures are for a completely filled aperture.

Measurements were made with a bare thermocouple of the energy in the spectral regions transmitted by the following filters—taken in the order given: 1, no filter (all wave lengths); 2, rock salt (all wave lengths up to 19μ); 3, fused quartz water cell (all wave lengths up to 1.4μ with a slight diminishing of the deep ultra-violet below 2,500 A.); 4, filter No. 3 plus barium flint glass (wave lengths below

3,200 A. excluded). These wave-length limits are only approximate because the filters do not have a sharp "cut-off." There is a region of 200-300 A. in which the change from opaqueness to transparency takes place. A typical change is seen in Table 1, column 4, which is

TABLE 1. *Instrumental constants*

1 Wave length (A.)	2 Transmission of monochromator	3 Transmission of thermocouple window	4 Amount excluded by barium flint and transmitted by fused quartz water cell
6908	0.520	0.918	0.00
6234	.507	.917	.00
5780	.499	.916	.00
5461	.493	.915	.00
4916	.485	.912	.00
4358	.474	.910	.00
4047	.468	.905	.008
3906	.466	.904	.014
3654	.461	.902	.030
3341	.456	.900	.405
3130	.452	.900	.894
3022	.450	.900	.90
2967	.449	.900	.89
2925	.448	.899	.88
2894	.448	.898	.88
2804	.445	.897	.88
2752	.443	.897	.88
2699	.442	.896	.88
2652	.440	.895	.88
2602	.438	.895	.85
2576	.436	.895	.80
2536	.434	.894	.76
2483	.431	.894	.69
2463	.430	.894	.69
2447	.429	.893	.68
2399	.426	.892	.67
2378	.425	.892	.64
2352	.422	.891	.60
2323	.420	.891	.58
2300	.418	.890	.57
2283	.416	.890	.55
2250	.413	.890	.51

the difference—transmission of fused quartz water cell minus the transmission of the barium flint filter. A series of four diaphragms was used to exclude radiation other than that coming directly from the arc. The results of these measurements are given in Table 3. They are compared with the summation of the monochromator measurements and correlated with the measurements of other observers in the discussion.

RESULTS AND DISCUSSION

Using the double monochromator—with the entrant slit set at 0.05 mm and the middle slit 0.075 mm—and the vacuum thermocouple, the high-intensity spectrum was mapped by taking readings one slit width apart throughout. The arc was operated at 4.5 amperes and an average of 143.5 volts.

In the region 7,000 to 6,000 A.	readings	were	taken	every	50 A.,
6,000 to 5,000 A.	"	"	"	"	25 A.,
5,000 to 4,000 A.	"	"	"	"	20 A.,
4,000 to 3,500 A.	"	"	"	"	10 A.,
3,500 to 2,500 A.	"	"	"	"	5 A.,
2,500 to 2,100 A.	"	"	"	"	2.5 A.

Readings were also taken at the peaks of the maxima. This gave a map of the spectrum of the highest resolution attainable with the setup. Fifty maxima many of which are complex were observed. Then a single monochromator was used with 0.10-mm slit, and readings were taken on 32 of the stronger lines. The intensities obtained with the double monochromator were then corrected slightly where necessary so that they agreed with the more accurate values obtained with the single monochromator. The arc was then operated at low intensity and observations were made with the single monochromator. The galvanometer deflections were read with a telescope. These data are given in Table 2. Columns 2 and 3 are the galvanometer deflections for the same arc run at high and low intensity respectively. This arc had been used about 400 hours. These deflections were reduced to absolute intensities by multiplying by 1.33 (microwatts per cm^2 for 1 mm deflection) and dividing by the product of corresponding values for the transmission of the monochromator and of the thermocouple window given in Table 1, columns 2 and 3. These intensities are given in Table 2, columns 4 and 6, and are in microwatts per cm^2 for a distance of 250 mm from the center of the arc and on the perpendicular bisector of a line from the cathode to the mercury pool. The values in Table 2, columns 7 and 8, show the amount of flux excluded by the barium flint and transmitted by the fused quartz water cell. These values are obtained by multiplying the absolute intensities in Table 2, columns 4 and 6, by corresponding values in Table 1, column 4. The sums at the bottom of columns 4, 6, 7, and 8 in Table 2 are for comparison with the filter observations.

The sum of the intensities of all the lines of wave length less than and including λ 3,130 is of interest, as it is this part of the radiation from the mercury arc that is useful in curing rickets and produces

TABLE 2. *Monochromator measurements of high and low intensity arcs*

1 Wave length (A.)	2 Galvanometer reading (mm) High int.	3 Galvanometer reading (mm) Low int.	4 Absolute intensity 250 mm from a 20-mm midsection of the arc (mcw cm⁻²) High int.	5 High int. new arc	6 Low int.	7 Amount excluded by barium flint and transmitted by quartz water cell (mcw cm⁻²) High int.	8 Low int.
6908	2.7	0.06	7.5	....	0.17	0.0	0.0
6234	0.9	.03	2.6	....	0.09	.0	.0
5780	161	3.73	468	473	10.85	.0	.0
5461	130	9.05	384	384	26.70	.0	.0
4916	4.5	.03	13.5	....	.09	.0	.0
4358	106	7.90	327	353	24.40	.0	.0
4047	62	4.80	195	204	15.10	1.5	.12
3906	2.6	.04	8.2	....	.13	.1	.00
3654	183	5.50	585	643	17.60	17.6	.53
3341	16	.36	52	54	1.17	3.4	.47
3130	110	5.10	359	377	16.70	321	14.92
3022	57	1.16	187	194	3.82	168	3.44
2967	29.5	1.05	97.1	95.1	3.46	86.5	3.08
2925	4.0	.11	13.2	....	.36	11.6	.32
2894	10.7	.33	35.4	34.7	1.09	31.2	.96
2804	22.4	.44	74.7	71.7	1.47	65.9	1.29
2752	7.0	.18	23.4	....	.60	20.6	.53
2699	9.5	.16	31.9	....	.54	28.1	.48
2652	40.5	.86	137	130	2.91	121	2.56
2602	2.7	.04	9.2	....	.14	7.8	.12
2576	5.4	.07	18.4	....	.24	14.7	.19
2536	52	4.73	178	154	16.20	136	12.30
2483	15.8	.44	54.6	48.6	1.52	37.8	1.05
2463	2.1	.06	7.3	....	.21	5.0	.15
2447	1.8	.03	6.3	....	.10	4.3	.07
2399	5.8	.14	20.3	23.3	.49	13.6	.33
2378	4.9	.11	17.2	22.6	.39	11.0	.25
2352	4.5	.07	15.9	16.7	.25	9.6	.15
2323	1.8	.03	6.4	....	.11	3.7	.06
2300	1.4	.06	5.0	....	.21	2.9	.12
2283	0.9	.04	3.2	....	.14	1.8	.08
2250	0.7	...	2.6	....	....	1.3	....
Total for 143.5 volts			3,302.3		147.3	1,126	43.6
Total corrected to 150 volts			3,450			1,180	
Total less than and including λ 3,130 for 143.5 volts			1,303		51.0		
Total less than and includ- λ 3,130 (corrected to 150 volts)			1,362				

For "total arc" multiply all values by 7.1

"sunburn" or erythema (4). The percentage of the total radiation which falls in this region is shown in Table 3.

Measurements were made on the more prominent lines in the spectrum of a new arc. These are shown in Table 2, column 5. The differences between these values and those in column 4 are not large but are greater than experimental error and probably indicate the variation to be expected.

Observations were also made upon two new arcs operating at low intensity. These two arcs are to be used only as standards, and since there is very little evaporation of the tungsten cathode or deterioration of the quartz at this temperature and wattage, they have never been run at any condition other than that of low intensity. Their output is different (by an amount greater than experimental error) from that of the 400-hour-old arc only in the 2,536 A. region. In this region one arc is 7.6 per cent lower and the other 2.7 per cent higher than the value given in Table 2, column 6.

Figure 1 is a map of the high-intensity spectrum obtained with the double monochromator. The effective slit width used is 2 A. at λ 2,300 A. which increased to 12 A. at λ 4,000 A. The intensities are mapped above a spectrogram (taken with a type E2 Hilger quartz spectrograph) of the arc operating at high intensity. The ordinates in Figure 1 are the values given in Table 2, column 4, and are for the 20-mm midsection of the arc. In order to obtain approximate values for the full length of the arc exposed, multiply these midsection values by 7.1. This factor is obtained from the filter measurements given in Table 3.

Figure 2 is a map of the low-intensity spectrum made from Table 2, column 6. It is plotted above a low-intensity spectrogram of the same source. The same factor, 7.1, will convert these ordinates and the values in Table 2, column 6, to approximate total arc values.

Figure 3 shows two microphotometer curves of spectrograms of the 2,536 A. region. The upper curve is from a high-intensity spectrogram and the lower curve from one of low intensity. The exposure times were 20 seconds for the low intensity and 1 second for the high intensity. For the sake of comparison the slit width used in the thermocouple observations is indicated. The resonance line, λ 2,536.5 A., which is partially self reversed at low-intensity conditions and completely reversed at high intensity, the line λ 2,534.8 A. and a background of continuous (and band?) spectrum are superimposed when observed with this 5 A. slit width. The reversal of the resonance line and the appearance of the background near it are more critical functions of the operating conditions and of the presence of small amounts of foreign gases than are the intensities of the rest

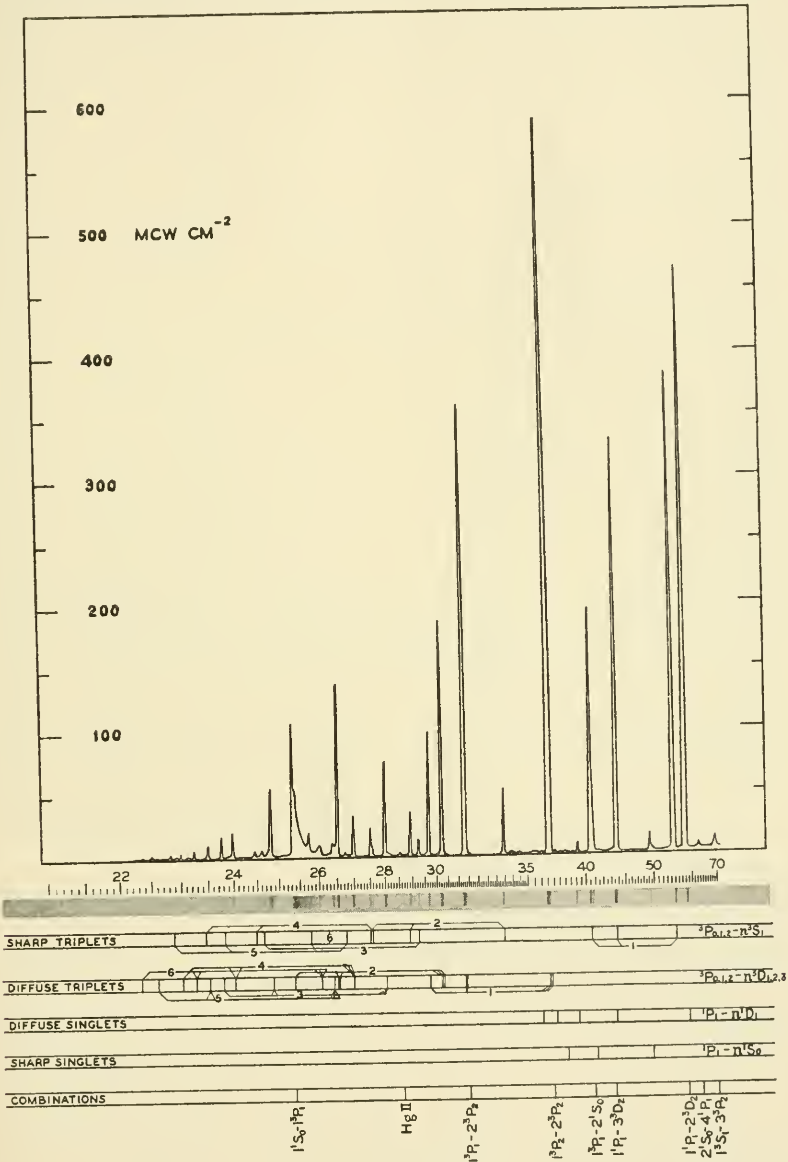

FIG. 1.—Absolute intensities 250 mm from a 20 mm mid-section of the "high intensity" arc.

of the spectrum. Hence in a commercial product one would expect such a variation as is observed in comparing one arc with another.

It is evident from these curves that the intensity in the 2,536 A. region as measured by the thermocouple is largely due to the resonance

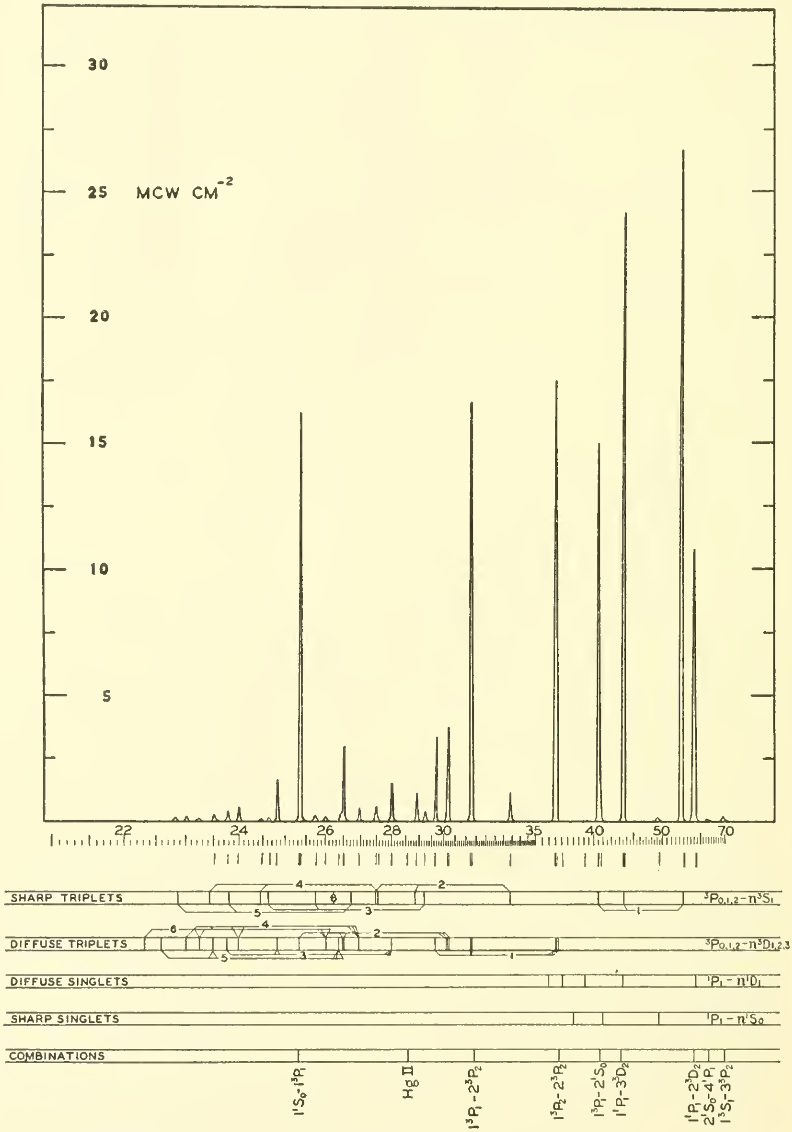

FIG. 2.—Absolute intensities 250 mm from a 20 mm mid-section of the "low intensity" arc.

line in the low-intensity arc, while λ 2,534.8 and the background are practically all that affect the thermocouple in the high-intensity arc.

Table 3 gives the intensities of radiation in the different spectral regions for a distance of 1 m from the arc. They are expressed in

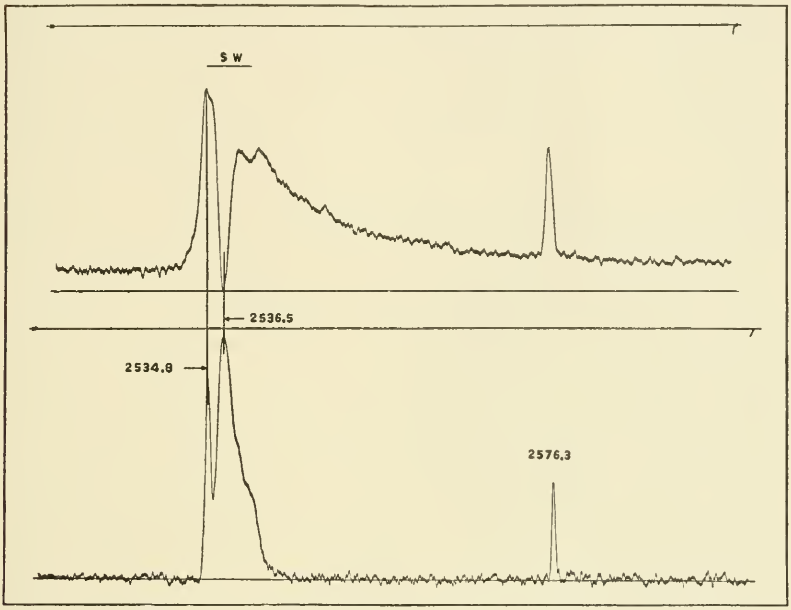

FIG. 3.—Microphotometer curves of spectrograms of the 2,536 A. region for the "high" and "low intensity" arcs.

microwatts per cm ^{2}. Column 1 shows the intensity of the therapeutic (4) radiation .2μ to .35μ, column 2 the near ultra-violet, visible, and

TABLE 3. *Filter measurements*

		1 .2-.35μ	2 .35-1.4μ	3 1.4-19μ	4 > 19μ	5 Total
HIGH INTENSITY						
20 mm of vertical arc...	mcw cm^{-2}	84	167	245	68	564
	per cent	14.8	29.7	43.4	12.1	100
Total vertical arc......	mcw cm^{-2}	600	1,130	2,710	350	4,790
	per cent	12.5	23.6	56.6	7.3	100
Total horizontal arc....	mcw cm^{-2}	615	995	2,700	370	4,680
	per cent	13.2	21.2	57.7	7.9	100
LOW INTENSITY						
20 mm of vertical arc...	mcw cm^{-2}	2.8	7.7	77.5	8.0	96
	per cent	3.0	8.0	81.7	8.3	100
Total vertical arc......	mcw cm^{-2}	19.8	59.6	704.8	124	908
	per cent	2.3	6.6	77.6	13.5	100

near infra-red .35μ to 1.4μ, column 3 the infra-red from 1.4μ to 19μ, column 4 the deep infra-red beyond 19μ, and column 5 the total radiation. The percentage of the total radiation is given immediately below each intensity value. Observations were made on the radiation from the 20-mm length of the midsection as well as from the total length of the arc for both high and low intensities. The data given in the table were obtained using a bare thermocouple, the procedure being as follows: Observations were made on: 1, the total radiation —no filter used; 2, radiation transmitted by 2 mm of rock salt, which includes all wave lengths less than 19μ; 3, radiation transmitted by a fused quartz water cell, all wave lengths below 1.4μ, and 4, radiation transmitted by a combination of the water cell and 2 mm of barium flint glass which includes all wave lengths between $.35\mu$ and 1.4μ. These observations were then corrected for reflection and absorption by the following transmission factors: rock salt 0.91, water cell 0.90, water cell and barium flint 0.81. After these corrections are applied the data in Table 3 are obtained as follows: values in column 1 are the difference between observation 3 and observation 4; column 2, observation 4; column 3, observation 2 minus observation 3; column 4, observation 1 minus observation 2; and in column 5, observation 1. As the filter "cut-offs" are not sharp, appreciable error might be introduced by this method. For instance the short wave length "cut-off" for the barium flint filter is not sharp. However, in the mercury spectrum this is not serious because the "cut-off" occurs in a region where there are no strong lines. The sum of the monochromator values for all wave lengths less than and including λ 3,130 A. for the 20-mm midsection of the high-intensity arc is given at the bottom of Table 2, column 4. It is 1,362 microwatts per cm^2 at 250 mm from the arc. The filter measurement for this region is given in Table 3, column 1, as 84 microwatts per cm^2 at 1 m. Multiplying this by 16 to reduce it to the intensity at 250 mm from the arc we get 1,330 microwatts per cm^2, which is 2.1 per cent lower than the monochromator sum.

For the sake of a more rigid check on the monochromator observations one may compare the intensities given in Table 2, columns 7 and 8, with the uncorrected thermocouple measurements. Table 2, columns 7 and 8, give the radiation excluded by the barium flint filter and transmitted by the fused quartz water cell for the 20-mm section of the high- and low-intensity arc. These can be compared with the filter measurements as follows: the radiation transmitted by the fused quartz water cell minus the radiation transmitted by the cell in combination with the barium flint filter, the latter value being corrected for the transmission of the barium flint alone is 1,210 microwatts per cm^2 at 250 mm from the high-intensity arc. This is

2.5 per cent higher than the monochromator value 1,180 microwatts per cm^2 given at the bottom of column 7 in Table 2. For the low-intensity arc the filter measurement is 44.8 microwatts per cm^2 at 250 mm from the arc. The monochromator value given at the bottom of column 8 in Table 2 is 43.6 microwatts per cm^2 which is 2.7 per cent lower than the filter observation. This is a fairly satisfactory agreement between the monochromator sums and the filter measurements.

From Table 3 we obtain the factor 600/84 (or 19.8/2.8) = 7.1 which can be used to reduce the intensities for the midsection of the arc to total arc intensities. This factor applies to Figures 1 and 2 and to the data in Table 2.

Coblentz (4) gives a value of 623 microwatts per cm^2 for the intensity of radiation of wave lengths less than and including λ 3,130 A. at 60 cm from a 260-watt arc of this type. Assuming his arc to be equally efficient in producing radiation in this region and neglecting the absorption of air this reduces to 582 microwatts per cm^2. This is 3 per cent lower than the value 600 microwatts per cm^2 given in Table 3. Hulburt (6) gives a value for the radiation from a 650-watt arc in the region 2,000 A. to 6,500 A. His value is given as 22.0 mm deflection (with a thermopile sensitivity of 0.97 microwatts per cm^2 for 1 mm deflection) measured at a distance of 240 cm from the arc. Of the 45 mm length of his arc, 4 mm was exposed. Assuming this 4 mm length to be typical and that the arcs are equally efficient we can reduce this to "total arc" at a distance of 25 cm to compare with the monochromator sum in Table 2 at the bottom of column 4. The calculation gives a value of 23,000 microwatts per cm^2 which is 6 per cent lower than the monochromator sum 24,500 microwatts per cm^2 ($3{,}450 \times 7.1$). This agreement is better than could be expected because of the uncertainty in calculating the radiation from the "total arc" from the ratio of the total length to the length exposed. Suhrmann's measurements (7) are given as absolute but differ by two orders of magnitude from the present work. The monochromator he employed has a numerical aperture of 12.5 and the entrant slit (5 mm by 0.20 mm) was placed 25 mm from the arc. Thus probably less than 1/100 of the radiation coming through the monochromator slit passed through the collimating lens and was measured. This very likely explains his very low values.

To obtain an "overall" value of the probable errors involved in the intensity measurements given in Table 2 a hypothetical line whose intensity is the average of all the lines measured has been assumed. Although the probable error calculated for it will be somewhat too small for more intense lines and too large for very weak lines it will indicate the accuracy of the measurements. For the high-intensity values, Table 2, the average galvanometer deflection was 40 mm. The probable error of the mean of 10 readings was 0.7 mm or ± 1.4 per cent. Values in Table 1, column 3, are subject to a probable error of ± 0.5 per cent and values in column 2 to ± 2 per cent. The probable error of the value 1.33 (the thermocouple sensitivity) is ± 1.4 per cent. Hence the probable error of the mean value, 100 mcw cm^{-2}, is about 3 per cent or ± 3 mcw cm^{-2}. For the values given that are of the same order of magnitude as the probable error of the mean, ± 3 mcw cm^{-2}, the predominant error is in the galvanometer reading. Hence the probable error for these entries in Table 2, column 4, is about ± 1.5 mcw cm^{-2}. For the low-intensity values in Table 2, the average galvanometer deflection was 1.9 mm and the probable error of the mean of 10 readings was 1/20 mm, or ± 2.6 per cent. Here the deflections were read with a telescope, and the arcs output was much steadier than for the high-intensity observations. The other errors are the same so the probable error of the mean value, 4.6 mcw cm^{-2}, in Table 2, column 6, is about ± 4 per cent or .18 mcw cm^{-2}. As before the probable errors of values of this order of magnitude in Table 2, column 6, are determined by the error of reading the galvanometer; hence the probable error of these entries is about 0.12 mcw cm^{-2}. The average deviation of the values in Table 2, column 5 (new arc) from those in column 4 (arc 400 hours old) is 5.3 per cent, which is about twice the probable error. Thus it is reasonable to assume that the differences are real—especially so in the short wave length region where the new quartz is more transparent.

Figure 1 shows 50 maxima. Thirty-two of the strongest and most clearly resolved of these are included in Table 2. The intensity of the weaker lines and of the unresolved components omitted from Table 2 will be reported in the near future. A new crystal quartz spectrograph of higher dispersion now in the process of construction will be used for this work.

These absolute intensity measurements are interesting from a spectroscopic standpoint. The pressure of the mercury vapor in the high-intensity arc is about one atmosphere, and in the low-intensity arc it is several millimeters of mercury. This amount of vapor will cause considerable self reversal as is most evident for the resonance line λ 2,536.5 A. and so make difficult the comparison of experimental and theoretical intensities of related spectral lines. However, because these measurements cover a wide spectral range it is interesting to

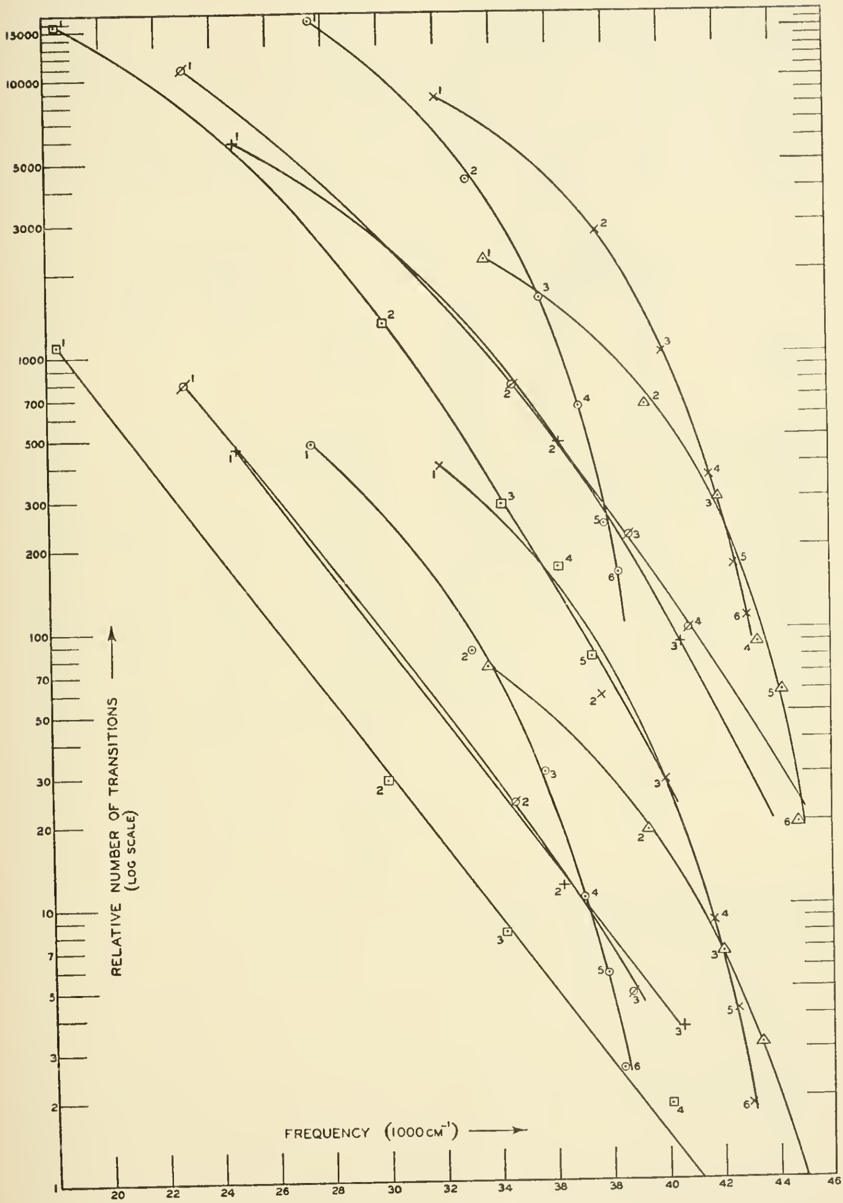

FIG. 4.—Decay of intensity in the sharp and diffuse series of Hg I.

note the decay of intensity in the sharp ($^3P_{0,1,2}$-n^3S_1) and diffuse ($^3P_{0,1,2}$-$n^3D_{1,2,3}$) series as well as the relative intensities of the components of these multiplets.

The classification of the lines measured is given below the spectrograms in Figures 1 and 2. More than two thirds of these lines are members of the sharp and diffuse series. Table 4 gives the relative intensity of these triplets that were of measurable intensity. The

TABLE 4. *Relative intensities of the multiplets*

	Sharp lines				Diffuse lines		
	High int.	Low int.			High int.	Low int.	
λ	I/ν^4	I/ν^4	ν (cm^{-1})	λ	I/ν^4	I/ν^4	ν (cm^{-1})
5461 ⊡[1]	50	50	18308	3655 ⊙[1]	50	50	27388
4358 φ[1]	17[a]	34[a]	22938	3130 ×[1]	18	27	31984
4047 +[1]	8[a]	15[a]	24705	2967 ⟁[1]	4	4	33691
3341 ⊡[2]	50	50	29918	3022 ⊙[2]	50	50	33087
2894 φ[2]	19	27	34549	2652 ×[2]	22[a]	24[a]	37696
2753 +[2]	10	12	36316	2535 ⟁[2]	..	..	39440
2925	50	50	34173	2804	50	50	35660
2576	25[a]	21[a]	38804	2480	21[a]	31[a]	40278
2464	10	13	40572	2378	6	7	42034
2760	50	..	36225	2699	50	50	37042
2447	26	..	40856	2399	19	29	41665
2345	..	..	42624	2302	4	5	43426
				2640	50[a]	50[a]	37869
				2352	21	26	42496
				2259	8	..	44257
				2603	50	50	38404
				2323	23	25	43030
				2232	..	..	44830

[a] Value given includes minor unresolved lines not related to the triplet (symbols given after wave length are those used in fig. 4).

diffuse series is really composed of sextets, but the closely spaced components were unresolved in the present work. The intensities of these groups have the same theoretical relation (1 : 3 : 5 for the Int/ν^4) as do the sharp triplets. It is evident here that the theoretical intensity relation is not attained but that it is approached by higher members of each series. The component whose intensity is most affected by changing from high intensity to low is the central one in both series. Also the component that deviates most from the theoretical rule is the central one in the sharp triplets and the high frequency one in the diffuse triplets.

Figure 4 shows the intensity decay in these series. This is a plot of the logarithm of the relative number of transitions (intensity/ν) that occur in the whole of the 20-mm section of the arc in unit time against the frequency (6). The symbols shown in Table 4 are used to identify the series and its multiple numbers. The smooth and regular decay shown here is not present in previous work and verifies the small experimental error given. The upper curves are for the high-intensity arc and the lower are for the low. The curves appear to approach asymptotic lines of the same slope in a given series. This slope is greater for the diffuse series which indicates a lower "Boltzmann" temperature for the ^3D than for the ^3S levels as was pointed out by Hulburt (6).

SUMMARY

Absolute measurements of the intensity of 32 of the more intense lines in the visible and ultra-violet spectrum of a quartz mercury arc have been made with a vacuum thermocouple and double monochromator. The effective slit width employed was 2 A. at λ 2,300 A. increasing to 12 A. λ 4,000 A. This yields a resolution about one order of magnitude greater than that of previous work of this nature. The probable error in the intensity measurements is ± 3 per cent. Observations made upon four arcs showed significant differences in intensity for many of the spectral lines. These differences averaged about 5 per cent, the maximum being 10 per cent for λ 2,537 A. This is probably the deviation in output to be expected from different arcs of this same make (operating with the same current and voltage) that are reasonably new and have not been mistreated.

About two thirds of the lines measured are members of the sharp and diffuse series. The present measurements show a smooth and regular decay of intensity in these series. The theoretical intensity relation for these multiplets is not attained but is approached by higher members of both series.

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