RP517

MEASUREMENTS OF ULTRA-VIOLET SOLAR RADIATION IN VARIOUS LOCALITIES

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ABSTRACT

In the present paper a description is given of the calibration of a selective photochemical, ultra-violet dosage intensity meter against a balanced thermocouple and filter radiometer, used as a standard. Data are given of the ultra-violet intensities of solar radiation in various localities at various elevations at various stations in Europe and upon the ocean.

The measurements show a high ultra-violet reflection from clean fresh snow. The ultra-violet intensities over the ocean are not conspicuously higher than at a sea level, dust-free station on land at the same latitude and the same season of the year.

CONTENTS

I. INTRODUCTION

During the past summer one of the writers (W. W. C.) was delegated to visit various European heliotherapy stations. The occasion presented an excellent opportunity for measuring the ultra-violet solar intensity at various stations, thus obtaining some idea of the amount available under various atmospheric conditions. Unfortunately, and contrary to the usual experience, there was an excessive amount of cloudy weather in Switzerland which greatly interfered with the attempted survey.

Nevertheless, in spite of the fragmentary data collected, a study of the tabulated measurements discloses highly interesting information on the amount of ultra-viloet radiation transmitted through fog and clouds and reflected from ocean waves, clouds, snow, and the north sky. Incidently, it is relevant to comment on the excessive erythema experienced by travelers on the ocean during cloudy weather. This physiological reaction appears to be far greater than would be experienced under similar conditions on land when the sky is completely overcast. Evidently the "sunburn" is not caused solely by ultra-violet radiation, but is accelerated by the wind and the fine, almost imperceptible, ocean spray.

II. EXPERIMENTAL PROCEDURE

The primary instrument for measuring ultra-violet radiation is a balanced thermocouple and filter radiometer (1)[1] calibrated against a standard of radiation which equates the measurement in absolute value (microwatts per $cm^2 = \mu w/cm^2$).

The reliability of this device is indicated by the accuracy with which the ultra-vioelt radiation of a source (having a discontinuous spectrum of strong emission lines distributed fairly uniformly throughout the ultra-violet spectrum) can be evaluated (*a*) by summation of the intensities of the individual lines, each one measured separately in absolute value and (*b*) by means of the filter method which measures the ultra-violet component in the undispersed source.

In this comparison good agreement was found not only in the ultra-violet radiation emitted by lamps, as measured by both methods in our own laboratory, but also by comparing the summation of the spectral radiation intensities (in absolute value) as observed in other laboratories with measurements on the same lamps by the balanced thermocouple and filter method as used in our laboratory.

Fortified with this agreement in measurements on a discontinuous spectrum which does not involve subsidiary calculations to reduce the data to a normal spectrum, it is assumed that the filter method is equally reliable for making measurements of short wave length ultra-violet in sources emitting a continuous spectrum. The fact that there is good agreement in the correlation of the physiological (erythemal) and the radiometric determinations on the various sources (2) seems to indicate that this agreement can not be fortuitous.

In this connection, it is relevant to cite an earlier research (3) in which the process was reversed, and a close agreement was found between the observed and the calculated transmission of the filters, for wide bands of the ultra-violet spectrum.

As a secondary instrument, convenient for field use it was decided to use an ultra-violet dosimeter, made by the I. G. Farbenindustrie (4). This is a photochemical device, consisting of a solution of a leuco-cyanide of triphenylamine dye which is colorless in the dark and turns pink in color temporarily when exposed to short wave length ultra-violet radiation. The pink color is reduced to a neutral gray by insertion of green filters of different densities. As issued by the factory the various filters (called "fields" which are numbered 0 to 9) are calibrated arbitrarily (against a quartz mercury arc lamp, used as a standard) to indicate intensities and corresponding times of exposure to produce a minimum perceptible erythema.

Two instruments were used: No. 1 obtained in March, 1932, and calibrated as will be described on a subsequent page, and No. 2, which was shipped from the factory to Davos, Switzerland in July, 1932. The latter was found less sensitive (for the same intensity, filter 2 = filter 3 of No. 1) owing to the fact that in the later model a less sensitive solution having a smaller temperature coefficient is used.

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[1] Figures in parentheses here and throughout the text indicate references given in the bibliography at the end of this paper.

1. STANDARDIZATION OF DOSIMETER

The question of standardization of selective (photo-electric and photochemical) dosage intensity meters was discussed in previous communications (1) and (5) where an actual example of such a calibration is given.

For the present investigation, the ultra-violet dosimeter (No. 1) was calibrated against the standard balanced thermocouple and filter radiometer (1) by simultaneous measurements of the ultra-violet solar intensity on the clearest days in Washington in June before going to Europe, and again soon after the return in September. Good agreement was observed in the two calibrations indicating that the portable instrument had not changed appreciably in the mean time.

The procedure in obtaining a calibration of the dosimeter for measuring solar radiation is relatively simple. The measurements were begun in the forenoon when the ultra-violet solar intensity was relatively low, and continued through midday when the intensities were a maximum ($85\mu w/cm^2$ in June, $55\mu w/cm^2$ in September for ultra-violet radiation of wave lengths less than 313 $m\mu$ as observed with the balanced thermocouple and filter radiometer).

A uniform time of exposure was adopted—1 minute, 2 minutes, etc., and the "field number" was determined for neutralizing the pink color. This, of course, varies with the intensity. Manifestly for zero intensity there is no chemical reaction. Hence, for intensities less than 10 to 20 $\mu w/cm^2$ (as observed with the balanced thermopile) requiring neutralizing fields No. 1 to No. 2, there is no need of making observations with the dosimeter. In order to avoid heating of the dosimeter the exposures were not continued longer than three minutes, except when the intensities were low.

In Figure 1 is shown a series of calibration curves of dosimeter No. 1 for different exposures of 1, 2, 3, 5, and 10 minutes, obtained by comparison against the standard thermopile and filter radiometer.

In this illustration the abscissas represent the observed field numbers of the filters in the eyepiece of the dosimeter required to neutralize the pink color of the solution after an exposure (of say two minutes) to the intensities in microwatts per cm^2 as observed by the balanced thermopile and filter radiometer.

As used in practice, the dosimeter was exposed for, say, two minutes, and the filter necessary to neutralize the pink color was noted. The corresponding intensity was then read from Figure 1. After a little experience, it was found possible to estimate fractional numbers. For example, if, after a certain exposure, field No. 3 appeared slightly pink and No. 4 appeared deep green, the neutralizing field was estimated 3.2 (see Table 1); if, say, field No. 3 was appreciably pink it was estimated at 3.5; and if field No. 3 appeared decidedly pink and field No. 4 appeared only faintly green, the estimate was No. 3.8 (see Table 1).

In order to shield the end of the tube containing the solution from reflected skylight, it was covered while making measurements, although exposure of only the end of the glass tube for one to two minutes showed no appreciable reddening of the solution.

While making observations in bright sunlight, the eyes were shielded to keep them adapted to color discrimination at low intensities, such as encountered in looking into the eyepiece of the dosimeter. This method of observing was adopted after making some erratic field settings which seemed to be caused by a change in the color estimation while the eye adapted itself to lower intensities.

Since all the measurements (except in the ice fields of Jungfraujoch, temperature 1.5° C.) as well as the calibration against the standard instrument, were obtained at average summer temperatures, no attempt was made to apply a temperature coefficient, which is reported to be small in the newer model.

When this instrument had not been used for several days the first reading seemed to be appreciably lower than those made subsequently, just as though the end point in decolorizing was a slower process than estimated by the eye. Furthermore, field "No. 0"

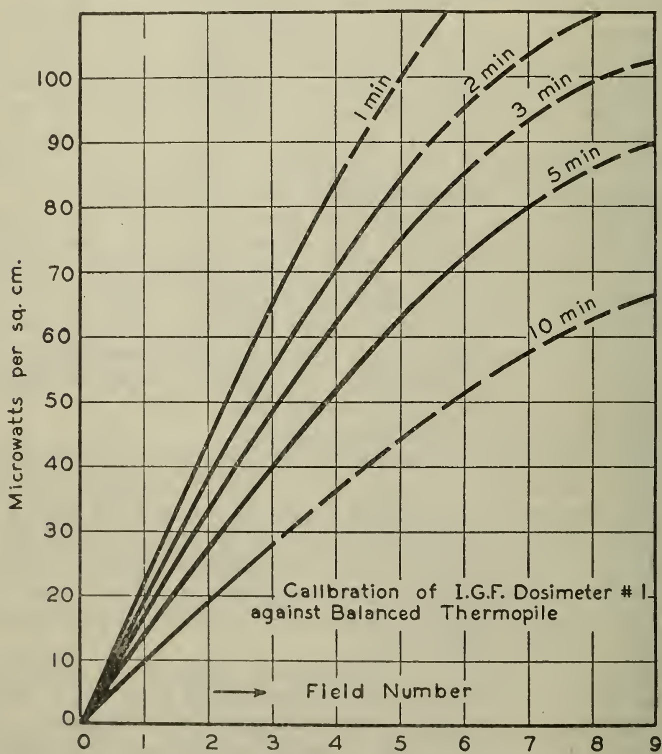

FIGURE 1

always appeared greenish, rather than neutral after extended rest periods. Hence, just sufficient time for field "No. 0" to become neutral was allowed to elapse between successive measurements.

III. OBSERVATIONAL DATA

The tabulated measurements, though meager, contain useful information that can be only briefly summarized in the text.

The observations made in different localities are recorded in Table 1. The time of the day is eastern standard time (E. S. T.) for Washington and the Atlantic Ocean, and western Europe standard time for stations in Europe.

The "angle" given in column 7 of Table 1 is the estimated solid angle (circular area) of the sky, as viewed by the radiometer, that was free from clouds.

Since the dosimeter intercepts radiation from practically the whole hemisphere, it is inclined to register uniform values for a longer period during the noon hour than the thermopile which subtends an angle of 45°.

The ocean measurements were made at a great distance from the shore, hence, should not be affected by smoke and dust. An impressive physiological observation was the severe "sunburn" experienced by ocean travelers when there was cloudiness and mist throughout the day.

TABLE 1.—*Ultra-violet solar radiation intensity, U.-v. Q. in microwatts per cm² (μw/cm²) as observed in different localities (Switzerland, Denmark, etc.) by means of a photochemical dosage intensity meter (an I. G. Farbenindustrie dosimeter) calibrated against a balanced thermocouple and filter radiometer which is standardized to indicate the ultra-violet intensity of wave lengths less than and including 313 mμ*

[The time is the beginning of the observation. The asterisk (*) indicates measurements of ultra-violet reflected from clouds, snow, water, etc.]

Date	Exposure	Neutralizing filter No.	U.-v. Q. in μw/cm²	Location	Elevation	Remarks
1	2	3	4	5	6	7
1932						
June 3:	Min.				Feet	
11.17 a. m.	2	5	84	Washington (latitude, 38° 55′ N.).	350	Sky very clear, blue.
11.52 a. m.	2	5.1	86			
12.20 p. m.	3	3	*48			North sky, clear blue.*
1.49 p. m.	2	5	83			
June 8:						
9.46 a. m.	2	3.8	67			Sky cloudless.
10.39 a. m.	2	4	71			
11.10 a. m.	2	4.5	79			
11.38 a. m.	2	5	84			
12.11 p. m.	3	2.5	*40			North sky, very clear.*
12.22 p. m.	2	5	84			
1.23 p. m.	2	4.5	79			
2.12 p. m.	2	4	71			
3.11 p. m.	2	3	54			
4.12 p. m.	2	2	37			
June 29:						
10.25 a. m.	5	2.3	30	Atlantic Ocean (latitude 41° 21′ N.).	100	Faint sunlight through mist 400 miles from New York.
July 3:						
9.43 a. m.	5	2	27	(Latitude 49° 20′ N.)		Broken clouds, no direct sunlight; 650 miles from Plymouth.
10.00 a. m.	5	4.5	58			Sun through broken clouds.
10.12 a. m.	1	2.5	55			Direct sunlight.
12.15 p. m.	3	3.5	54			Fracto-cumulus clouds.
12.55 p. m.	3	5.5	80			Sun through fine cirrus.
1.15 p. m.	1	4.5	90			Sky clear; cumulus to west.
1.39 p. m.	2	5	85			Sky clear.
2.00 p. m.	2	5	85			Fine cirrus haze, otherwise clear over hemisphere.
2.19 p. m.	2	4.5	80			Sky clear; fine cirrus for last 20 seconds exposure.
2.48 p. m.	1	3.3	70			Observations terminated by thin fleeting clouds.
3.15 p. m.	3	1	*17			Reflection from waves in line with sun.*
3.58 p. m.	1	2	43			Observations stopped by fracto-cumulus near sun.
6.20 p. m.	5	1	10			Sky hazy, clouds west of sun.

TABLE 1.—*Ultra-violet solar radiation intensity, U.-v. Q. in microwatts per cm² (μw/cm²) as observed in different localities (Switzerland, Denmark, etc.) by means of a photochemical dosage intensity meter (an I. G. Farbenindustrie dosimeter) calibrated against a balanced thermocouple and filter radiometer which is standardized to indicate the ultra-violet intensity of wave lengths less than and including 313 mμ*—Continued.

Date	Exposure	Neutralizing filter No.	U.-v. Q. in μw/cm²	Location	Elevation	Remarks
1	2	3	4	5	6	7
1932	*Min.*				*Feet*	
July 4:						
1.08 p. m.	5	4.5	58			Coast of England, broken clouds no direct sunlight.
1.40 p. m.	2	4	71			Sun through thin clouds.
July 14:						
1.15 p. m.	2	4	71	Chamounix (latitude 45° 55′ N.).	3,200	Sun through fine cirrus.
1.49 p. m.	2	3.8	70			Sun through rift in dense cloud banks.
July 17:						
9.35 a. m.	2	2	37	Lausanne (Ouchy)	1,250	Thick cirrus haze.
10.06 a. m.	2	3.5	63	Lake Geneva	1,240	Sky clear, but hazy.
10.18 a. m.	2	4.0	71	(Latitude 46° 30′ N.).		Sky clear, cirrus coming from south. Sky overcast at 10.35 a. m.
5.38 p. m.	2	0	0	Ouchy		Sky clear.
July 18:						
9.10 a. m.	2	2	37	Aigle	1,368	Sky clear; cirrus S.E. of sun.
10.14 a. m.	1	3	65	Leysin Village (latitude 46° 20′ N.).	4,420	Exposure terminated by cumulus clouds.
12.36 p. m.	1	2	43			Sun through fine clouds.
12.56 p. m.	1.5	3.3	65			Sun through thin clouds; observations terminated by thick cumulus.
1.47 p. m.	2	4	70			Sun through thick cirrus.
2.19 p. m.	2	5	84			Sun through thick cirrus; clearer for 20 seconds.
2.59 p. m.	2	2.1	*40			Sky radiation reflected from clouds on mountain (east) opposite the sun which shines through thin cirrus.*
July 19:						
10.34 a. m.	1	2	45	Brigue	2,260	Sky clear, angle 30°, clouds to side.
1.23 p. m.	2	4.3	75	Gletch	5,780	Sky clear; smoke from engine interfered.
1.44 p. m.	1	3	65	Furka Pass	7,990	Sky clear blue; thin cirrus interfered for 20 seconds.
2.24 p. m.	1	3	65	Andermatt	4,740	Sky perfectly clear blue; best set.
July 20:						
10.11 a. m.	2	4	70	Peist	3,000	Sky clear; thin cirrus for 15 seconds.
11.12 a. m.	2	5	85	Arosa	5,795	Sky clear blue between rift in thick clouds.
2.00 p. m.	5	1	*8			Reflection from thick cloud on mountain S.E. of sun which is clouded.*
July 22:						
12.44 p. m.	1	2.5	55	Davos Platz (latitude 46° 47′ N.).	5,120	Sky clear, angle 45°, clouds to side.
12.50 p. m.	3	5	75			Sky clear, angle 45°.
1.52 p. m.	1	2.5	55			Sky hazy.
2.17 p. m.	1	2.3	50			Fine cirrus.
July 27:						
11.08 a. m.	2	1	*18	Jungfrau-joch (latitude 46° 32′ N.).	11,350	Sunlight through fog; bright glare. Roof of Forschunginstitut.*
11.49 a. m.	5	2.5	*34			Sunlight reflected from glacier through thin fog.*
1.29 p. m.	5	2	*28			Reflection from fresh snow from glacier below Berghaus. Sky overcast. Glare uncomfortable to the eye.*
2.15 p. m.	5	3	*40			Reflection from snow across valley from roof of Forschungsinstitut. Temperature, 1.4° C.*
2.28 p. m.	5	2.5	*34			Sky radiation; sun obscured by mist. Light snow falling.*

TABLE 1.—*Ultra-violet solar radiation intensity, U.-v. Q. in microwatts per cm² (μw/cm²) as observed in different localities (Switzerland, Denmark, etc.) by means of a photochemical dosage intensity meter (an I. G. Farbenindustrie dosimeter) calibrated against a balanced thermocouple and filter radiometer which is standardized to indicate the ultra-violet intensity of wave lengths less than and including 313 mμ*—Continued

Date	Exposure	Neutralizing filter No.	U.-v. Q. in μw/cm²	Location	Elevation	Remarks
1	2	3	4	5	6	7
1932 July 27—Con.	*Min.*				*Feet*	
2.40 p. m.	5	3.5	*46			Reflection from fresh glacier snow. Sun obscured by mist and fine ice spicules.*
2.55 p. m.	5	2.5	*34			Sky radiation; light snow falling.*
3.10 p. m.	5	3.5	*46			Reflection from glacier snow; sun obscured. Temperature, 1.3° C. Humidity, 74 per cent.*
July 28:						
10.05 a. m.	1	3	65	Jungfraujoch	11,350	Fine snow falling part of time.
10.19 a. m.	1	3	65			Blowing cloud wisps.
10.27 a. m.	3	3.5	*56			Reflection from snow banks 3 to 4 feet distant.*
10.45 a. m.	1	1	*23			Reflection from snow, cloud wisps over sun.*
10.59 a. m.	1	2.5	55			High wind, cloud wisps for last 10 seconds.
11.12 a. m.	1	1.5	*34			Reflection from snow in valley.*
11.25 a. m.	1	3.2	70			Sky cloudless most of time, no wind.
11.42 a. m.	1	3.5	75			Sky cloudless.
11.50 a. m.	1	3.5	*75			Reflection from snow bank distant 3 feet. Sky clear; bright sun.*
11.59 a. m.	2	2.5	*45			Sky radiation to west; perhaps a little from snow peaks.*
12.07 p. m.	2	4.5	78			Sky perfectly clear. Temperature, 2.8° C.
1.04 p. m.	1	3.5	76			
1.11 p. m.	1	3	*65			Reflection from snow bank.*
1.21 p. m.	1	3.5	76			Temperature, 1.7° C. Humidity, 61 per cent.*
1.32 p. m.	2	5	84			Sky perfectly clear; light wind.
1.43 p. m.	1	3.8	80			
1.54 p. m.	1	3.5	*76			Reflection from snow bank Sun's rays normal to surface.*
July 29:						
10.32 a. m.	1	2.5	54	Harder Kulm near Interlaken (latitude, 46° 41′ N.).	4,350	Sky perfectly clear.
10.40 a. m.	2	4.5	78			
10.52 a. m.	3	6	85			
11.08 a. m.	1	4	85			
11.26 a. m.	1	3.5	75			
11.39 a. m.	1	3.8	82			
11.50 a. m.	1	3.8	82			
12.21 p. m.	1	3	65	Interlaken (latitude, 46° 41′ N.).	1,870	Funiculare station at foot of Kulm; street dust reduces intensity.
1.26 p. m.	1	3	65	do	1,866	In open field near Ost Bahnhof.
1.39 p. m.	1	3	65			Sky perfectly clear to horizon.
1.53 p. m.	1	3	65			
2.13 p. m.	1	3.5	75			
2.28 p. m.	3	5	75			
2.46 p. m.	3	5	75			Sky cloudless.
3.07 p. m.	3	5	75			
3.46 p. m.	3	3.8	60			
4.08 p. m.	3	3.5	55			
4.23 p. m.	3	3	48			
4.41 p. m.	3	3	48			Sky clear. Small cloud north of sun.
4.58 p. m.	3	2.5	40			
5.18 p. m.	3	2.2	36			Small cirrus north and west of sun.
5.42 p. m.	5	1.5	20			Small cloud north of sun.
August 11:						
1.24 p. m.	2	3.5	63	Copenhagen (latitude 55° 30′ N.)	150	Raadhusplads. Sky clear to horizon; sun has wide corona.
1.37 p. m.	2	3.8	66			Christianberg Palace Canal.

TABLE 1.—*Ultra-violet solar radiation intensity, U.-v. Q. in microwatts per cm² (μw/cm²) as observed in different localities (Switzerland, Denmark, etc.) by means of a photochemical dosage intensity meter (an I. G. Farbenindustrie dosimeter) calibrated against a balanced thermocouple and filter radiometer which is standardized to indicate the ultra-violet intensity of wave lengths less than and including 313 mμ*—Continued

Date	Exposure	Neutralizing filter No.	U.-v. Q. in μw/cm²	Location	Elevation	Remarks
1	2	3	4	5	6	7
1932 Aug. 11—Con.	*Min.*				*Feet*	
1.53 p. m.	2	3.5	63			Faint cirrus southwest of sun; in front of palace.
2.20 p. m.	2	3.2	58			Fine cirrus southwest of sun; court of Royal Library.
3.16 p. m.	2	2.8	51			Fine cirrus on horizon; observatory on top of Runde Taarn.
4.12 p. m.	3	1.2	20			Sky clear. Street corner; Turist Hotel.
August 14:						
11.41 a. m.	2	2.8	51	Copenhagen		Sky hazy. City square.
12.01 p. m.	2	3.8	66			Near railroad station.
August 23:						
8.01 a. m.	5	.5	7	North sea (latitude 54° N.)	50	Thin cirrus. Enroute Esbjerg to Harwich.
8.16 a. m.	5	1.2	16			Clear sky.
9.40 a. m.	2	2.5	45			Forward deck, no smoke; sky clear.
9.55 a. m.	3	2.5	45			Sky clear through angle 60°.
10.26 a. m.	3	3	48			Cirrus on horizon.
11.21 a. m.	3	4	62			Small cloud south of sun.
11.42 a. m.	2	3.8	67			Clouds on horizon.
12.05 p. m.	2	4	70			Sky clear through angle 90°.
12.54 p. m.	2	4	70			Sky clear through angle 90°. Large clouds to north.
1.46 p. m.	2	3.8	67			Cirrus clouds around sun. Clear through angle 45°.
2.01 p. m.	2	3.5	63			Fine cirrus. Clear through angle 30°.
2.41 p. m.	2	3	54	(Latitude 52° N.)		Approaching Harwich. Sky clear except horizon.
3.06 p. m.	2	3.5	63			Sky clear. Clouds on north horizon.
3.27 p. m.	2	3.2	57			Less hazy and smaller corona.
September 12:						
1.16 p. m.	2	3	54	Atlantic Ocean (latitude 48° N.).	100	Thick cirrus.
2.05 p. m.	2	3	54			Cirrus; high wind.
2.31 p. m.	2	3.5	63			Fairly clear.
2.49 p. m.	2	2.8	51			Clear sky.
September 13:						
8.49 a. m.	2	2	37	Atlantic Ocean (latitude 46° 40′ N.) (longitude 38° 30′ W.).		Sky clear between fleeting clouds.
8.57 a. m.	2	2.5	45			Wide corona.
9.09 a. m.	2	3	54			Sky clear except on horizon; no smoke.
9.21 a. m.	2	3.5	62			Sky clear except horizon southeast of sun.
9.36 a. m.	2	3.8	67			Same as preceding; small corona.
9.49 a. m.	2	3.5	65			Fine cirrus in west; covers sun at 9.58.
11.49 a. m.	2	3.3	58			Fire haze and cirrus; wisps of smoke.
September 14:						
9.41 a. m.	2	2	37	Atlantic Ocean (latitude 42° 50′ N.) (longitude 50° 58′ W.).	100	Thin fracto cumulus.
10.21 a. m.	2	2.5	45			Fleeting clouds.
September 15:						
1.09 p. m.	2	3	55			Thick cirrus moved over the sun.
1.30 p. m.	2	2.8	51	(Latitude 41° 20′ N.) (longitude 63° 50′ W.).		Thin cirrus over the sun.

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Date	Exposure	Neutralizing filter No.	U.-v. Q. in μw/cm²	Location	Elevation	Remarks
1	2	3	4	5	6	7
1932 September 29:	*Min.*				*Feet*	
9.24 a. m.	2	1.5	30	Washington (latitude 38° 55′ N.).	350	Sky clear of dust after rain.
9.37 a. m.	2	2	36	----	----	
10.00 a. m.	2	2.2	38	----	----	
10.21 a. m.	2	2.2	38	----	----	Fracto-cumulus over sun at 10.35 a. m.
September 30:						
8.06 a. m.	5	.5	8	Washington	350	Sky clear.
9.06 a. m.	5	1.1	15	----	----	
9.38 a. m.	2	1.5	28	----	----	Sky cloudless. Small corona.
10.01 a. m.	2	2	38	----	----	
10.24 a. m.	2	2.5	46	----	----	Observed with balance thermocouple=47μw/cm².
10.45 a. m.	2	2.8	50	----	----	Observed with balance thermocouple=50μw/cm².
11.07 a. m.	2	3	54	----	----	
11.28 a. m.	2	3.3	57	----	----	
11.49 a. m.	2	3.3	57	----	----	Fracto-cumulus southeast of sun.
12.07 p. m.	2	3.3	57	----	----	Fracto-cumulus to north and east of sun. Sky clear through angle 60°.

The observed high ultra-violet reflecting power of fresh clean snow is in agreement with physiological observations, and is to be expected from our knowledge of the high transparency of water for ultra-violet radiation. Some of these measurements were made on ultra-violet solar radiation reflected from freshly fallen snow on a glacier, situated several miles across a mountain valley from the observing station (the hotel and the Forschungs Institut on Jungfraujoch).

The observation on Jungfraujoch showing that the ultra-violet component in sunlight is not much greater than at lower altitudes is in agreement with previous measurements in Arizona, showing that while the spectral quality is changed the loss in ultra-violet intensity in the direct solar rays is compensated to some extent by scattering, in the lower altitudes.

The reflection from numerous "breakers" on a rough sea and the churned white surface near the boat, all viewed in line with the sun, seems low. However, the frequent reports of sunburn by reflection from water probably means the combined effect of direct and reflected sunlight, that is incident upon a skin that is sensitized by moisture.

The observed ultra-violet solar radiation intensities over the ocean do not appear to be conspicuously higher than at a sea level, dust-free station on land, at the same latitude and season of the year. This is to be expected in view of the fact that after traversing the extensive atmospheric envelope of the earth (21 miles in thickness if it were homogeneous) the lower layer over the ocean can not increase the intensity and the similar layer over the solid earth, when dust free, does not deplete the ultra-violet intensity to the extent that might be inferred from the observed, relatively greater, physiological (erythemal) reaction experienced on the ocean.

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IV. BIBLIOGRAPHY

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