Skylight polarization measurements made at Washington on 11 days, with the sun at zenith distance 60°, give a mean of 56 per cent, with a maximum of 65 per cent on the 19th. This latter is 7 per cent less than the highest September polarization measurement previously obtained at Washington.

TABLE 2.—*Vapor pressures at pyrheliometric stations on days when solar radiation intensities were measured.*

Washington, D. C.			Madison, Wis.			Lincoln, Nebr.			Santa Fe, N. Mex.		
Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.	Date.	8 a.m.	8 p.m.
1916.	*Mm.*	*Mm.*	1916.	*Mm.*	*Mm.*	1916.	*Mm.*	*Mm.*	1916.	*Mm.*	*Mm.*
Sept. 1	16.20	14.60	Sept. 2	8.81	6.02	Sept. 8	10.97	18.59	Sept. 2	7.87	8.48
3	6.02	8.18	8	11.38	10.21	13	8.81	10.97	7	9.83	7.57
4	10.97	13.13	14	9.83	7.87	14	3.30	4.57	8	9.83	7.57
5	16.20	16.79	18	4.17	4.37	15	4.37	4.95	13	6.02	6.91
7	17.37	18.59	19	5.36	6.76	16	5.79	7.04	14	5.36	6.27
8	17.37	18.59	21	7.04	6.02	18	5.16	7.57	15	5.79	5.16
9	12.28	9.83	29	4.17	4.75	19	7.29	10.97	26	3.99	2.74
10	7.29	8.48				20	9.83	5.79	27	4.37	3.00
11	9.83	9.14				21	5.16	4.95	29	4.57	4.37
13	14.10	17.37				22	5.16	7.57			
16	8.48	9.14				23	5.36	8.48			
18	9.83	13.13				25	11.81	10.97			
19	5.79	7.29				30	3.30	4.75			
20	7.29	8.18									
21	8.81	10.20									
22	11.38	13.61									
23	12.68	7.87									
24	7.57	10.59									
25	8.48	10.59									
27	10.97	11.81									
30	5.16	6.50									

Table 3 shows an excess of radiation as compared with the September average, amounting to 8.1 per cent for Washington, 2.9 per cent for Madison, and 7.4 per cent for Lincoln.

TABLE 3.—*Daily totals and departures of solar and sky radiation during September, 1916.*

[Gram-calories per square centimeter of horizontal surface.]

Day of month.	Daily totals.			Departures from normal.			Excess or deficiency since first of month.		
	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.	Washington.	Madison.	Lincoln.
1916.	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*	*Gr.-cal.*
Sept. 1	480	328	290	63	− 64	−152	63	− 64	−152
2	362	518	457	− 53	129	17	10	65	−135
3	580	423	443	167	37	6	177	102	−129
4	573	299	530	161	− 83	95	338	19	− 34
5	525	244	452	115	−135	20	453	−116	− 14
6	230	506	435	−178	131	5	275	15	− 9
7	321	329	354	− 85	− 42	− 73	190	− 27	− 82
8	408	504	532	4	136	107	194	109	25
9	554	482	426	152	118	4	346	227	29
10	533	119	301	133	−241	−119	479	− 14	− 90
11	402	413	127	4	57	−290	483	43	−380
12	377	180	427	− 18	−173	12	465	−130	−368
13	410	346	551	17	− 3	139	482	−133	−229
14	231	223	539	−160	−122	129	322	−255	−100
15	126	236	506	−263	−105	99	59	−360	− 1
16	498	201	494	112	−136	90	171	−496	89
17	459	466	544	75	132	142	246	−364	231
18	454	498	516	73	168	117	319	−196	348
19	542	489	468	163	163	72	482	− 33	420
20	499	444	482	123	121	88	605	88	508
Decade departure				....	....	....	126	102	598
Sept. 21	542	378	505	168	59	114	773	147	622
22	474	301	498	103	− 14	110	876	133	732
23	358	430	483	− 10	119	97	866	252	829
24	374	447	382	8	139	− 1	874	391	828
25	397	355	423	34	51	43	908	442	871
26	414	200	139	54	−101	−238	962	341	633
27	473	119	422	116	−178	48	1,078	163	681
28	348	164	511	−6	−130	139	1,072	33	820
29	58	421	376	−293	130	7	779	163	827
30	504	423	448	156	135	82	935	298	909
Decade departure				....	....	....	330	210	311
Excess or deficiency since first of year: Gr.-cal.				....	....	....	−5,519	+3,003	....
Per cent				....	....	....	− 5.1	+ 2.8	....

SHADING EFFECT OF WIRE INSECT CAGES.

By HERBERT H. KIMBALL, Professor of Meteorology.

[Dated Weather Bureau, October 28, 1916.]

In the departmental experiments designed to discover methods for protecting plants from insect enemies some plants are wholly inclosed by a "cage" or framework covered with wire window screening. Such a screen of course intercepts a certain amount of the solar energy otherwise supplied to the plant, and it was desired to determine this screening effect as exactly as possible, since the screen must be left over the plant for a considerable period of its growth in order to give effective protection against insects.

The tests here described were made with a wire insect cage submitted by Dr. B. R. Coad, Bureau of Entomology, United States Department of Agriculture, in charge Delta Laboratory, Tallulah, La. The cage is made of 16-mesh wire cloth, the diameter of the wire measuring 0.011 + in. It is therefore presumed to be No. 29 wire, American gage, with a diameter of 0.011257 in. The wires of the woof are straight. Those of the warp are bent in crossing the woof, at an angle whose sine is 225.14/625 = 0.3602, or 21° 7′. The wires of the warp run vertically in the sides of the cage, and if the side containing the door is on the north side they run north and south in the top of the cage.

In measuring the transmission of the wire cloth a Smithsonian silver disk pyrheliometer was read inside the cage, while at the same time the total radiation was measured by means of a Marvin pyrheliometer exposed near by. At intervals the two instruments were compared by exposing both to the total solar radiation, and the results are summarized in Table 1.

TABLE 1.—*Summary of comparisons of Marvin and Smithsonian pyrheliometers.*

[Radiation in gram-calories per min., per sq. cm.]

Date and time. (75th mer.)	Number of readings.	Radiation.		Ratio: Smithsonian / Marvin.
		Marvin.	Smithsonian.	
1916.		*Gr.-cal.*	*Gr.-cal.*	
Aug. 14, 10:35 a. m.	7	1.389	1.405	1.012
14, 1:45 p. m.	7	1.377	1.369	0.994
18, 11:05 a. m.	9	1.051	1.076	1.022
22, 11:06 a. m.	9	1.160	1.178	1.016

In the first transmission tests made the top or a side of the cage was kept normal to the incident solar rays, this adjustment being maintained by watching the shadow cast by the frame. When thus adjusted the bent wires of the warp cast no more shadow than the straight wires of the woof.

The entire area of a unit square of the wire cloth, which is comprised between the axes of the bounding wires, equals (0.0625 in.)^2, or 0.003906 sq. in. The area of the clear space which transmits radiation equals (0.0625 in. − 0.011257 in.)^2, or 0.002626 sq. in. The proportional part of the radiation transmitted should therefore be 2626/3906 = 0.672, and the part cut off by shading = 0.328. The measurements summarized in Table 2 give a somewhat greater shading effect than the above.

TABLE 2.—*Determinations of the transmission coefficent, a, of wire screen when normal to the incident solar rays.*

[Radiation in gram-calories per min., per sq. cm.]

Date and time. (75th mer.)	Number of readings.	Radiation. Total.	Radiation. In cage.	Transmission, *a*	Shading effect.	Remarks.
1916.		*Gr.-cal.*	*Gr.-cal.*			
Aug. 14, 11:13 a. m.	9	1.422	0.941	0.662	0.338	Through top of cage.
14, 1:16 p. m.	11	1.381	0.928	0.672	0.328	Do.
14, 4:30 p. m.	9	1.196	0.778	0.652	0.348	Through side of cage.
17, 11:41 a. m.	9	1.130	0.757	0.670	0.330	Through top of cage.
22, 12:59 p. m.	8	1.145	0.762	0.666	0.334	Do.
Means.				**0.664**	**0.336**	

The receiving surface of the pyrheliometer is always normal to the incident solar rays. The angle of incidence with the wires of the warp and of the woof may be any angle from 0° (normal incidence) to 90°. In studying the shading effect of the wires with the incident angle other than 0° we will for convenience consider a unit mesh of the cloth to consist of the clear space 0.051243 in. square, bounded on one side by a wire of the warp and on an adjacent side by a wire of the woof, the wires overlapping at a corner. The relative lengths of the projections upon the pyrheliometric surface of these three sections of wire—warp, woof, and a corner—if the plane of the cloth is normal to the incident rays, are 0.450, 0.450, and 0.100, respectively. Let the angle of incidence of the solar rays with wires of the woof be 0°, and at right angles to these wires let the angle of incidence with the plane of the cloth be i. An increased number of individual squares of the mesh will now be projected upon the pyrheliometric surface, but their projected area will be the same as before. The projected number of wires of the warp, their length, and in consequence their projected area, remain unchanged. In the case of the wires of the woof, however, while their projected length is unchanged, their number has increased in the proportion $1/\cos i$. Therefore, the area of shadow now cast by the three sections of wire may be expressed by the equation

$$S = 0.450/\cos i + 0.450 + 0.100 \qquad (1)$$

where S is the area of shadow cast by the wires as compared to the area when the wire cloth is normal to the incident rays.

In Table 3 are summarized measurements made under the conditions described above. It is to be noted that the average value of $(100-a)/S$ is practically what would be expected from the size of the wire and the mesh of the cloth.

Assuming that the solar rays are parallel rays, complete shading by the wires of the woof will occur when cosine $i = 112.57/625 = 0.1801$. Substituting in equation (1) we obtain $0.450/0.1801 + 0.55 = 3.05$. Also, $1.000/0.328 = 3.05$; or, the area shaded when the wire cloth is normal to the incident rays must be increased 3.05 times for complete shading.

The angle i has been determined from h, the computed altitude of the sun at the time of the measurements, the top of the screen having been kept horizontal by means of a spirit level. With the top horizontal it has been assumed that the sides are vertical. With the sun shining through the top of the cage, $i = 90° - h$; when shining through a side, $i = h$.

TABLE 3.—*Determinations of the transmission coefficient, a, of wire screen with the wires of the woof at normal incidence, and at right angles to these wires the angle of incidence with the plane of the cloth=i.*

[Radiation in gram-calories per min., per sq. cm.]

Date and time.	No. of readings.	Radiation. Total.	Radiation. In cage.	Transmission, *a*	*i*	*S*	$\frac{100-a}{S}$	Remarks.
1916.								
Aug. 14:		*Gr.-cal.*	*Gr.-cal.*		° ′			
11:42 a. m.	11	1.417	0.928	0.654	25 28	1.05	0.329	Through horizontal top of cage.
3:28 p. m.	9	1.311	0.763	0.582	49 22	1.24	0.337	Do.
Aug. 17:								
10:41 a. m.	9	1.042	0.691	0.663	32 48	1.09	0.310	Do.[b]
11:11 a. m.	9	1.108	0.746	0.673	29 04	1.06	0.307	Do.[c]
1916.								
Aug. 18:								
10:01 a. m.	7	1.041	0.642	0.617	39 13	1.13	0.338	Do.[b]
10:28 a. m.	9	1.051	0.702	0.668	34 44	1.10	0.302	Do.[c]
Aug. 22:								
1:25 p. m.	9	1.115	0.737	0.662	31 50	1.08	0.313	Do.
Mean							**0.319**	
Aug. 14:								
9:55 a. m.	7	1.353	0.771	0.574	51 02	1.27	0.336	Through vertical side of cage.
10:11 a. m.	5	1.372	0.756	0.551	53 42	1.31	0.343	Do.
4:01 p. m.	9	1.258	0.820	0.652	34 23	1.10	0.318	Do.
Aug. 17:								
9:52 a. m.	7	0.989	0.568	0.574	49 41	1.25	0.342	Do.
Aug. 18:								
9:24 a. m.	1	1.008	0.602	0.596	44 50	1.19	0.339	Do.
9:26 a. m.	1	1.022	0.616	0.604	45 16	1.19	0.333	Do.
9:28 a. m.	1	1.021	0.609	0.597	45 36	1.19	0.339	Do.
9:30 a. m.	1	1.013	0.607	0.601	45 58	1.20	0.332	Do.
9:32 a. m.	1	1.017	0.600	0.588	46 20	1.20	0.343	Do.
9:34 a. m.	1	1.024	0.620	0.608	46 42	1.21	0.324	Do.
9:36 a. m.	1	1.028	0.629	0.611	47 03	1.21	0.321	Do.
9:38 a. m.	1	1.028	0.620	0.602	47 24	1.22	0.326	Do.
9:40 a. m.	1	1.021	0.602	0.590	47 51	1.22	0.336	Do.
Mean							**0.333**	
Aug. 22:								
11:26 a. m.	1	1.172	0.580	0.496	61 04	1.48	0.341	Do.
11:28 a. m.	1	1.185	0.587	0.495	61 14	1.49	0.339	Do.
11:30 a. m.	1	1.170	0.584	0.499	61 22	1.49	0.336	Do.
11:32 a. m.	1	1.191	0.577	0.485	61 30	1.49	0.346	Do.
11:34 a. m.	1	1.180	0.562	0.476	61 38	1.50	0.349	Do.
11:36 a. m.	1	1.144	0.554	0.486	61 46	1.50	0.341	Do.
11:38 a. m.	1	1.155	0.553	0.479	61 54	1.51	0.345	Do.
11:40 a. m.	1	1.158	0.553	0.477	62 00	1.51	0.346	Do.
11:42 a. m.	1	1.179	0.547	0.464	62 09	1.51	0.355	Do.
Mean							**0.344**	
Weighted mean							**0.327**	

[b] Pyrheliometer outside door of cage, at distance from screen.
[c] Pyrheliometer on high box close to screen.

Let the angle between the horizontal projection of a solar ray and a wire of the woof be called θ. Also, project the solar ray upon two planes perpendicular to the plane of the cloth and to each other, one of which contains a wire of the woof and the other is perpendicular to these wires; and designate by α and i, respectively, the angles between these projections and a line vertical to the plane of the cloth. Further let L = the length of a section of the warp between intersecting corners, and p = its projection upon the pyrheliometric surface. Expressed in terms of the length of a section of the woof between these intersecting corners,

$$L = \frac{1}{\cos(\sin^{-1} 0.3602)} \qquad (2)$$

and

$$p = \frac{1/2 \cos(i + \sin^{-1} 0.3602) + 1/2 \cos(i - \sin^{-1} 0.3602)}{\cos(\sin^{-1} 0.3602) \cos(\sin^{-1} 0.3602 \sin\alpha)}$$

$$= \frac{\cos i}{\cos(\sin^{-1} 0.3602 \sin\alpha)}. \qquad (3)$$

The equation for S now becomes

$$S=\frac{0.450}{os\ i}+\frac{0.100}{\cos i}+\frac{p\,(0.550-0.100/\cos i)}{\cos i\ \cos \alpha} \qquad (4)$$

In the above equation, for transmission through the horizontal top of the cage

$$\sin i=\frac{\cos h \sin \theta}{\sqrt{1-\cos^2 h\ \ \cos^2 \theta}} \qquad (5)$$

and

$$\sin \alpha=\frac{\cos h \cos \theta}{\sqrt{1-\cos^2 h \sin^2 \theta}} \qquad (6)$$

For transmission through a vertical side of the cage,

$$\cos i=\cos h \sin \theta, \qquad (7)$$

and

$$\cos \alpha=\sin \theta. \qquad (8)$$

For computing the shading effect of a vertical side of the screen equation (4) may be expanded to

$$S=\frac{0.45}{\cos h \sin \theta}+\frac{0.100}{\cos h \sin \theta}+\frac{0.550-0.100/\cos h \sin \theta}{\sin \theta \cos\,(\sin^{-1} 0.3602 \cos \theta)}. \qquad (9)$$

The expanded equation for computing the shading effect of the horizontal top of the screen becomes very complicated. For all practical purposes, however, we may employ the equation

$$S=\frac{0.450}{\sin h}+0.550+C, \qquad (10)$$

where C is a correction to be applied for the effect of the bend in the wires of the warp. It is negligible for small values of the angle α, is about 1 per cent for $\alpha=45°$, 2 per cent for $\alpha=60°$, and for larger values of α will rarely exceed 3 per cent.

In Table 4 are summarized measurements made through the horizontal top or a vertical side of the cage, and reduced by equations (9) and (10). The angle θ has been obtained by measuring the angle between the side of the cage and the edge of the shadow cast on the ground by an upright corner. Some irregularities appear in the results, partly due no doubt to lack of accuracy in the determinations of θ and h, and partly to the fact that the wire cloth is not stretched perfectly flat on the frames. It is to be noted, however, that the weighted mean of $(100-a)/S$ differs by less than 1 per cent from the mean of the results given in Tables 2 and 3.

The mean value of $(100-a)/S$ as derived from Tables 2, 3, and 4, is 0.332. This value indicates a diameter of the wire of 0.01139 inch instead of 0.011257 inch, an increase that may easily have been brought about by oxidation. Apparently there is little reflection from the wires to the pyrheliometric surface.

The angle α that produces complete shading by the wires of the warp is not so easily determined as the angle i that produces complete shading by the wires of the woof, on account of the bend in the former. With the cloth horizontal, and $\theta=0°$, every other row of overlapping corners will come together so as to produce a line of complete shading on a wire of the woof when $h=29° \ 35'$. Complete shading between the four wires of the warp thus meeting will have extended to their centers when $h=10° \ 23'$, and complete shading of the pyrheliometric surface will have been accomplished when $h=5° \ 10'$. With $\theta=45°$ the shading becomes complete when $h=7° \ 19'$.

TABLE 4.—*Determination of the transmission coefficient,* **a**, *of wire screen when exposed in a horizontal or vertical plane.*

[Radiation in gram-calories per min., per sq. cm.]

Date and time (75th Mer.).	No. of readings.	Radiation. Total.	Radiation. In cage.	Transmission coefficient, *a*.	*h*	*θ*	*S*	$\frac{100-a}{S}$	Remarks.
1916.		*Gr.-cal.*	*Gr.-cal.*		° ′	° ′			
Aug. 14:									
2:23 p. m..	9	1.360	0.872	0.642	52 12	25 40	1.13	0.317	Thru hor. top.
Aug. 22:									
10:12 a. m..	8	1.099	0.704	0.640	52 12	34 30	1.13	0.319	Do.
Aug. 14:									
2:53 p. m..	9	1.340	0.415	0.310	47 02	30 00	2.15	0.321	Thru vert. side.
Aug. 22:									
9:43 a. m..	9	1.100	0.203	0.184	47 32	26 14	2.36	0.345	Do.
10:39 a. m..	9	1.142	0.379	0.332	56 05	44 20	1.85	0.361	Do.
Sept. 21:									
4:08 p. m..	9	1.101	0.671	0.610	21 58	51 45	1.30	0.301	Do.
9:30 a. m..	1	1.292	0.397	0.308	38 27	31 00	1.98	0.349	Do.
9:32 a. m..	1	1.284	0.400	0.312	38 50	31 30	1.96	0.351	Do.
9:34 a. m..	1	1.273	0.403	0.317	39 08	32 00	1.94	0.352	Do.
9:36 a. m..	1	1.278	0.416	0.325	39 25	32 30	1.93	0.350	Do.
9:38 a. m..	1	1.285	0.420	0.327	39 44	33 00	1.91	0.352	Do.
9:40 a. m..	1	1.306	0.432	0.330	40 02	33 30	1.90	0.353	Do.
9:42 a. m..	1	1.299	0.438	0.337	40 20	34 00	1.88	0.353	Do.
9:44 a. m..	1	1.289	0.441	0.341	40 38	34 30	1.87	0.351	Do.
9:46 a. m..	1	1.298	0.453	0.345	40 56	35 00	1.85	0.352	Do.
9:48 a. m..	1	1.303	0.464	0.357	41 14	35 30	1.84	0.349	Do.
9.50 a. m..	1	1.304	0.468	0.360	41 35	36 00	1.82	0.352	Do.
Mean..								*0.351*	
1:42 p. m..	1	1.382	0.323	0.234	45 19	28 00	2.22	0.345	Do.
1:44 p. m..	1	1.379	0.312	0.226	44 59	27 23	2.25	0.344	Do.
1:46 p. m..	1	1.372	0.284	0.207	44 44	26 46	2.28	0.346	Do.
1.48 p. m..	1	1.362	0.271	0.199	44 28	26 09	2.31	0.317	Do.
1:50 p. m..	1	1.360	0.251	0.185	44 14	25 32	2.34	0.348	Do.
1:52 p. m..	1	1.361	0.235	0.173	43 58	24 55	2.37	0.349	Do.
1:54 p. m..	1	1.352	0.212	0.157	43 44	24 18	2.40	0.351	Do.
1:56 p. m..	1	1.359	0.209	0.154	43 28	23 41	2.43	0.348	Do.
1:58 p. m..	1	1.356	0.200	0.147	43 14	23 04	2.46	0.347	Do.
2:00 p. m..	1	1.365	0.185	0.136	42 58	22 26	2.50	0.346	Do.
2:02 p. m..	1	1.376	0.172	0.125	42 43	21 48	2.54	0.344	Do.
2:04 p. m..	1	1.377	0.157	0.114	42 26	21 10	2.58	0.343	Do.
2:06 p. m..	1	1.381	0.138	0.100	42 10	20 32	2.62	0.344	Do.
2.08 p. m..	1	1.374	0.120	0.088	41 54	19 54	2.66	0.343	Do.
2:10 p. m..	1	1.371	0.101	0.074	41 38	19 16	2.70	0.343	Do.
2:12 p. m..	1	1.358	0.088	0.065	41 22	18 38	2.74	0.341	Do.
2:14 p. m..	1	1.351	0.070	0.052	41 02	18 00	2.78	0.341	Do.
Mean..								*0.345*	
Weighted mean.								**0.334**	

In the customary use of the cage it is necessary to consider not only the transmission of direct solar radiation, as it has been determined above, but also the transmission of diffuse sky radiation. If the latter has the same angle of incidence as the former the transmission coefficient for the two should not differ. But we must consider the angle of incidence for sky radiation as a weighted mean of all possible angles, small angles having the greater weight. This mean may be either greater or less than the angle of incidence for solar radiation, and, unlike the latter, it will vary but little throughout the day.

Furthermore, while the radiation reflected from the small section of wire cloth to which the Smithsonian pyrheliometric surface is exposed may be inappreciable in amount, the reflection from the entire interior surface of the cage may be a measurable quantity.

The proportion of the total solar and sky radiation received at different points within a wire cage has been determined by alternately exposing a Callendar recording pyrheliometer inside and outside the cage.[1] This pyr-

[1] The pyrheliometer is described in this REVIEW for August, 1914, 42: 474-480; and the factors by which its records may be reduced to heat units are given in this REVIEW for January, 1916; 44: 4.

heliometer has its receiving surface exposed horizontally to the whole hemispherical vault of the sky. The top of the wire cage has also been kept horizontal. Figures 1, 2, and 3 are reproductions of records obtained, the solid portions of the traces indicating actual record, and the dotted portions the record supplied by interpolation. The upper curve is the record of the total radiation. The intermediate curve represents the radiation recorded inside the cage.

In Table 5 are computations by equations (9) and (10) of the value of S, from data obtained in connection with the originals of the above curves. The "radiation record" gives the distance in tenths of inches from the zero line on the record sheet to the respective traces at the times specified, a tenth of an inch being the distance between the horizontally ruled lines on the record sheets. In figures 1 to 3 every fifth line only is drawn in full, the spacing for the remaining lines being shown on the right and left margins.

The method of determining h and θ has already been described.

It is to be noted that the values of $(100-a)/S$ are systematically lower than in Tables 3 and 4. We may compute the intensity of radiation inside the cage, that would have given for $(100-a)/S$ the value 0.332, from the equation

$$\text{Radiation in cage} = (100-0.332S)\times\text{total radiation.} \quad (11)$$

TABLE 5.—*Determination of the transmission coefficient, a, of wire screen for solar and sky radiation.*

Date and time. (75th mer.)	Radiation record. Total.	Radiation record. In cage.	Transmission, a	h	θ	S	$\frac{100-a}{S}$	D	Remarks.
1916.									
Aug. 25:	$\frac{1}{10}$-*in.*	$\frac{1}{10}$-*in.*		° ′	° ′				
9:30 a. m.	31.0	9.8	0.316	46 18	28 00	2.24	0.305	2.0	Sun through south side.
10:00 a. m.	34.3	13.5	0.394	51 10	34 10	2.06	0.294	2.9	Do.
10:30 a. m.	37.5	16.5	0.440	55 19	41 40	1.90	0.295	2.9	Do.
11:00 a. m.	39.9	19.2	0.481	58 47	54 00	1.71	0.304	2.2	Do.
11:30 a. m.	41.3	21.2	0.513	60 57	72 00	1.55	0.314	1.3	Do.
NOON.....	42.0	22.5	0.536	61 49	90 00	1.50	0.309	1.6	Do.
12:30 p. m.	41.3	22.5	0.545	60 57	75 00	1.52	0.299	2.2	Do.
1:00 p. m.	40.4	22.1	0.547	58 47	64 30	1.56	0.290	2.8	Do.
1:30 p. m.	39.5	20.6	0.522	55 19	53 30	1.62	0.295	2.6	Do.
2:00 p. m.	38.2	18.2	0.476	51 10	42 00	1.79	0.293	2.9	Do.
2:30 p. m.	35.1	15.1	0.430	46 18	32 30	2.03	0.281	3.9	Do.
3:00 p. m.	31.1	11.9	0.383	41 06	27 40	2.17	0.284	3.4	Do.
3:30 p. m.	26.5	9.0	0.340	35 36	21 10	2.49	0.265	4.6	Do.
Sept. 19:									
9:30 a. m.	35.3	22.5	0.637	39 13	54 10	1.37	0.265	3.4	Sun through east side.
10:00 a. m.	41.0	23.2	0.566	43 34	46 15	1.56	0.279	3.6	Do.
10:30 a. m.	44.4	21.0	0.473	47 12	36 00	1.90	0.277	4.7	Do.
11:00 a. m.	46.6	13.0	0.279	50 05	24 00	2.54	0.284	6.1	Do.
1:00 p. m.	44.5	9.0	0.202	50 05	21 00	2.73	0.290	5.2	Sun through west side.
1:30 p. m.	41.2	18.6	0.451	47 12	30 45	2.12	0.259	6.7	Do.
2:00 p. m.	37.4	21.1	0.564	43 34	40 25	1.71	0.255	5.1	Do.
2:30 p. m.	33.8	20.7	0.612	39 13	49 20	1.45	0.268	3.3	Do.
3:00 p. m.	29.7	18.6	0.628	34 26	55 30	1.31	0.284	1.9	Do.
3:30 p. m.	24.7	16.2	0.656	29 20	62 00	1.20	0.287	1.4	Do.
4:00 p. m.	19.5	13.3	0.682	23 52	68 30	1.12	0.284	1.1	Do.
4:30 p. m.	13.4	8.6	0.642	18 16	75 00	1.06	0.338	0.0	Do.
Sept. 20:									
9:30 a. m.	29.9	18.2	0.619	38 56	35 46	1.28	0.298	1.1	Sun through top.
10:00 a. m.	35.1	21.1	0.601	43 16	43 55	1.22	0.327	0.4	Do.
11:00 a. m.	41.7	26.3	0.631	49 44	64 00	1.14	0.324	0.5	Do.
NOON.....	43.4	28.7	0.661	52 09	88 00	1.12	0.303	1.6	Do.
1:00 p. m.	41.0	26.0	0.634	49 44	68 45	1.14	0.321	0.7	Do.
2:00 p. m.	34.0	21.8	0.641	43 16	49 00	1.21	0.297	1.6	Do.
3:00 p. m.	27.8	17.0	0.612	34 10	32 00	1.37	0.283	2.0	Do.
4:00 p. m.	18.2	9.8	0.539	23 38	22 30	1.69	0.273	1.9	Do.
4:30 p. m.	15.0	6.1	0.407	18 02	17 00	2.03	0.292	1.3	Do.

In the last column of Table 5 is given the difference, D, between the radiation measured in the cage, or the observed radiation, and that computed by means of equation (11). It will be noticed that the difference is at a maximum when the incident angle for direct solar radiation is large.

On September 19, a record of the total sky radiation was obtained at 1:10 p. m. (E, fig. 2). It shows almost exactly the same intensity as that measured at 12:45 p. m. inside the cage, when the pyrheliometer was completely shaded from the sun by the wooden frame of the cage. Since, as will be apparent later from equation (12), we can not suppose that the transmission of sky radiation averages much over 0.5, nearly one-half the radiation measured at 12:45 p. m., or about two spaces on the record sheet, must represent radiation reflected from the wire cloth. The differences in the last column of Table 5 would lead us to expect a value of this order for the reflected radiation.

The measurements summarized in Table 5, and also other measurements not here given, indicate that for the total solar and sky radiation the shading effect is not $0.332S$, as for direct solar radiation, but that it varies between $0.320S$ and $0.270S$, the higher value corresponding to small values of the angle of incidence for solar rays, and the lower value to large incident angles. Probably $0.300S$ is an average value.

In the cage with which these tests were made the wooden frame consists of $2\frac{1}{2}'' \times 1\frac{1}{2}''$ sticks, with a $\frac{1}{2}''$ strip nailed on the outside to secure the wire cloth. Across the center of the top and parallel with the wires of the warp is a $1\frac{1}{2}'' \times 1\frac{1}{2}''$ stick.

For normal incidence of the solar rays with the top of the cage, and considering the rays parallel, the frame shades 15 per cent of the 48-inch cube inclosed by the wire cloth. For normal incidence with the east or west side the shading is 16 per cent, and for normal incidence with the south side it is 20 per cent. With the angles h and θ each equal to 45°, the shading is 18 per cent. The shading by the north side is considerably in excess of the shading by the other sides, on account of the frame of the door it contains. Since, however, this side transmits very little direct solar radiation, it is of relatively small importance, and we shall not be greatly in error if we assume 18 per cent for the average shading by the wooden frame of the cage. The average total shading effect of the wire cage for solar and sky radiation, or S', may therefore be approximately expressed by the equation

$$S' = 0.18 + 0.82\times 0.300S = 0.18 + 0.246S. \quad (12)$$

Still another approximation to the shading effect of the wire cage may be derived from the values of a in Table 5, mean values of which for different hour angles of the sun from the meridian are given in Table 6.

TABLE 6.—*Transmission of wire screen for solar and sky radiation.*

Sun's hour angle from the meridian.	Side of cage through which the sun is shining. East or west.	South.	Top.
	a.	*a.*	*a.*
6–5	0.68	....	....
5–4	0.67	....	0.41
4–3	0.65	0.34	0.58
3–2	0.60	0.37	0.61
2–1	0.45	0.48	0.63
1–0	0.10	0.56	0.65

At midday the altitude of the sun above the horizon is $90° - \phi + \delta$, where ϕ is the latitude of the place and δ is the solar declination.

South of latitude 40° N. the solar altitude at noon will exceed 50°, from the vernal to the autumnal equinox, and more than half of the space within the screened inclosure will therefore receive solar radiation through the top of

CURVES OBTAINED BY CALLENDAR RECORDING PYRHELIOMETER.

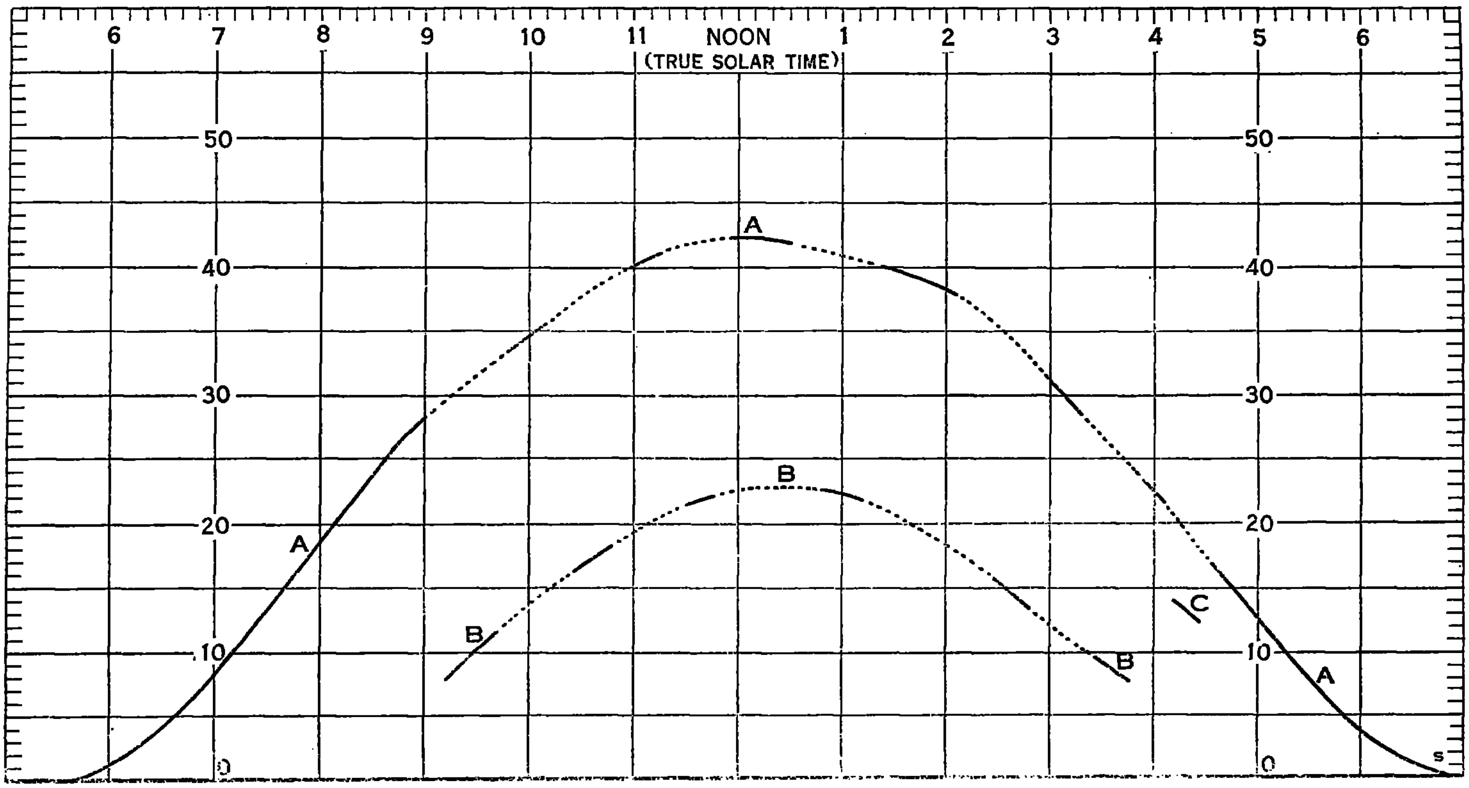

FIG. 1.—Wire insect cage transmission tests, August 25, 1916. Upper curve, *A A*, total solar and sky radiation, measured outside the cage. Intermediate curves, radiation measured inside the cage: *B B*, with sun shining through south side; *C*, with sun shining through the west side.

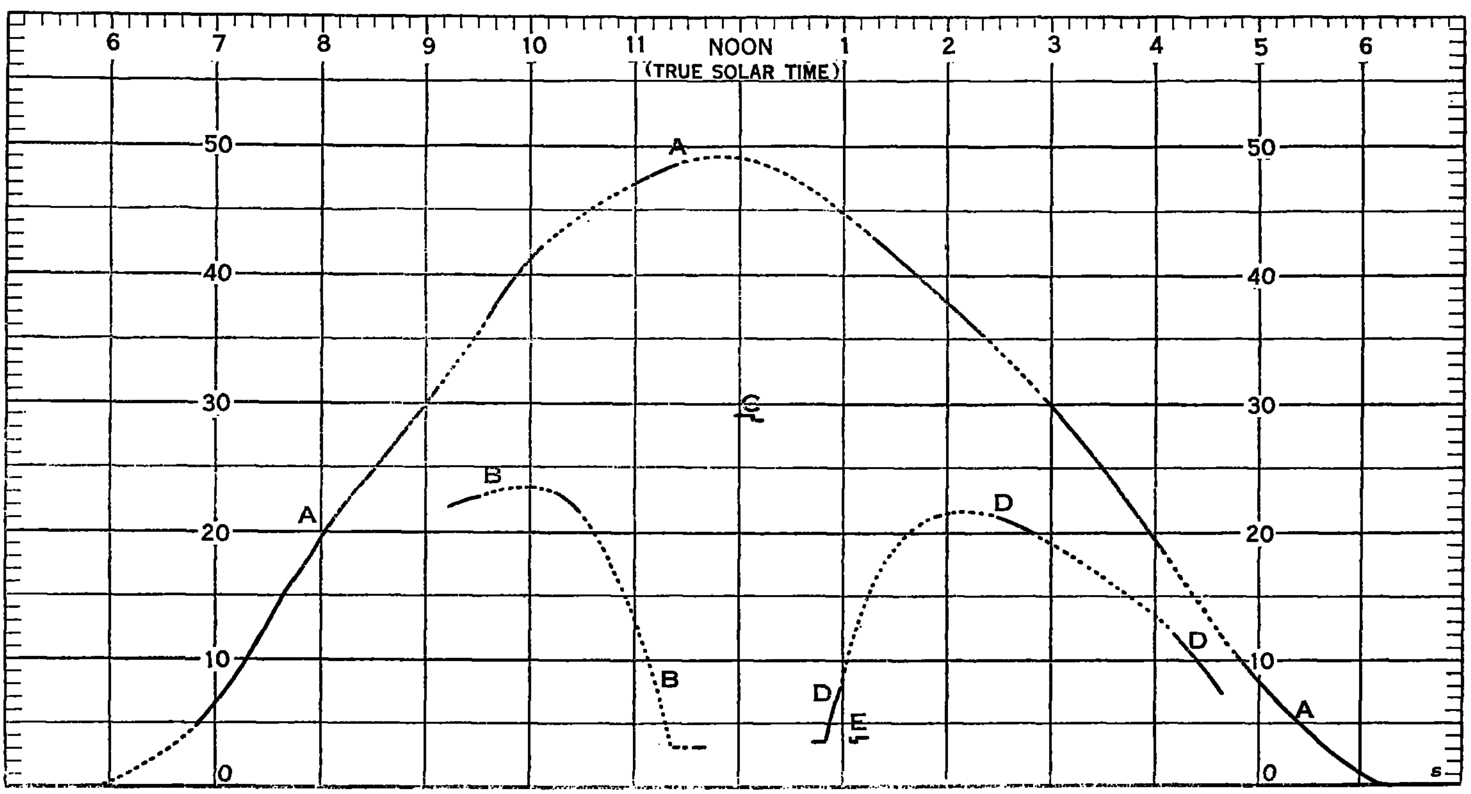

FIG. 2.—Wire insect cage transmission tests, September 19, 1916. Upper curve, *A A*, total solar and sky radiation, measured outside the cage. Intermediate curves, radiation measured inside the cage: *B B*, with sun shining through east side; *C*, with sun shining through south side; *D D*, with sun shining through west side. *E*, total sky radiation, measured outside the cage.

the cage. During most of this period this is true for two hours each side of true solar noon, and south of latitude 35° it is true for about three hours.

With h greater than 45° the average value of a for solar and sky radiation, with the sun shining through the top of the cage, exceeds 0.60. With h less than 45°, with the sun shining through the east or west side of the cage, the value of a generally exceeds 0.60, and it will not fall below this value unless θ is a small angle.

Plants far enough back from the south side of the cage to receive solar radiation through the top during the middle of the day will therefore receive about 65 per cent of the total radiation, except when shaded from direct solar radiation by the wooden frame of the cage, and this will average about 18 per cent of the time. During this time they will receive about 8 per cent of the total radiation. Therefore the proportion, A, of the total radiation

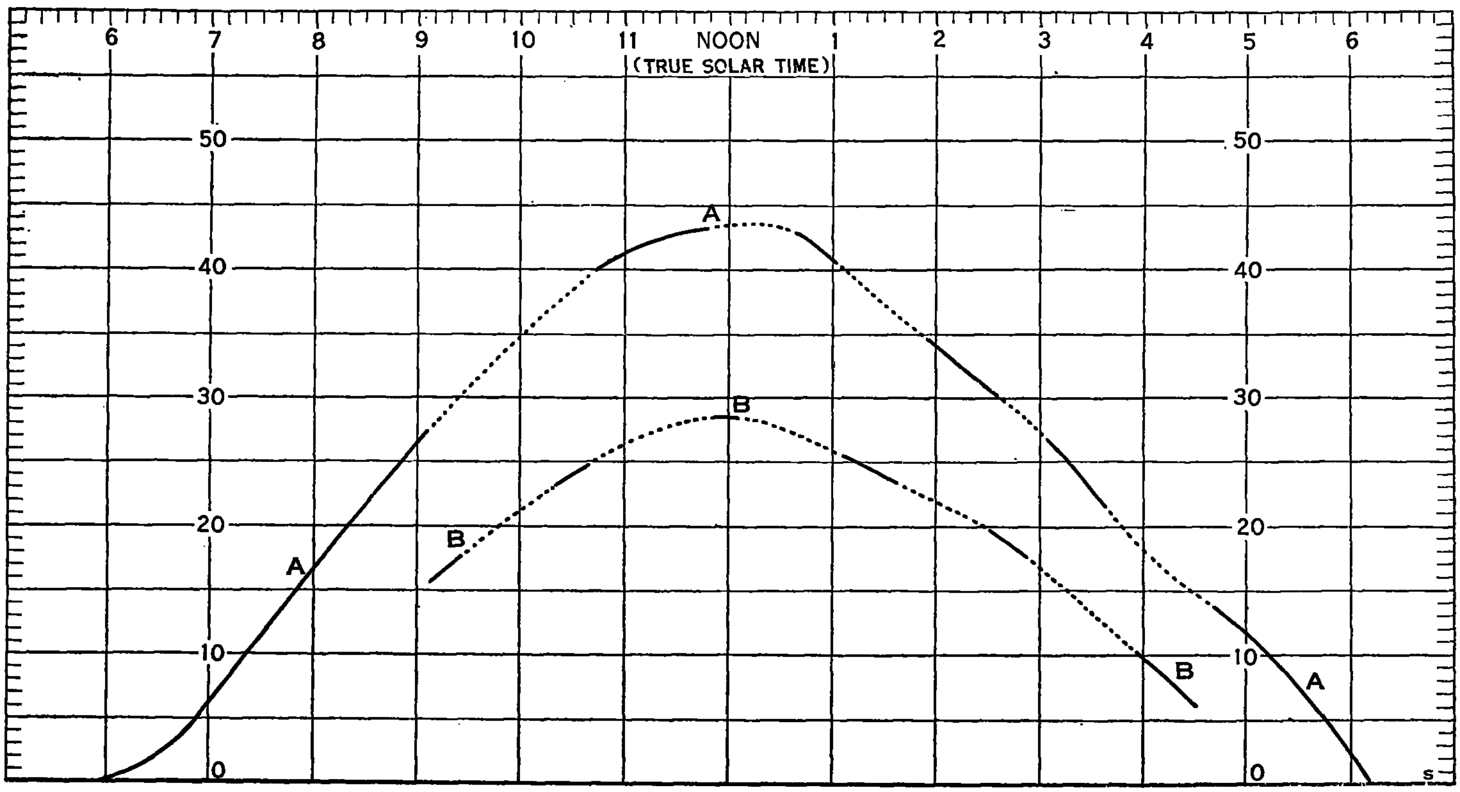

FIG. 3.—Wire insect cage transmission tests, September 20, 1916. Upper curve, A A, total solar and sky radiation, measured outside the cage. Intermediate curve, B B, radiation measured inside the cage, with sun shining through top.

received by the plant, may be expressed approximately by the equation

$$A = (0.08 \times 0.18) + (0.65 \times 0.82) = 0.55 \qquad (13)$$

If the plant is so near the east or the west side of the cage that it does not receive solar radiation through the top of the cage until nearly noon, the transmission for the two hours preceding or following noon may be reduced to about 0.30, and the proportion for the day may be less than 0.50.

If the plant is so near the south side of the cage that it receives its midday solar radiation through this side, the transmission for the four midday hours may be reduced to from 50 to 30 per cent, depending on the values of h and θ.

The lower the latitude the less will be the amount of radiation transmitted through the south side of the screen, and, likewise, the smaller will be the area receiving radiation through this side. Therefore, a plant in any part of the cage should receive on an average at least one-half the total solar and sky radiation, unless it is very close to the south side of the cage, and is considerably south of latitude 40° N.

SUMMARY.

1. Pyrheliometric measurements show that at normal incidence with the wire cloth the wires intercept 0.332 of the solar radiation, or about what we would expect of 16-mesh cloth made of No. 29 wire, American gage.

2. Pyrheliometric measurements show that equation (9) applies for the transmission of solar radiation through a vertical side of the cage, and equation (10) for transmission through the horizontal top of the cage, except for very large incident angles.

3. For the total solar and sky radiation, measurements with a Callendar recording pyrheliometer indicate that equation (12) gives approximate results, where S is determined from equation (9) or equation (10).

4. From equations (12) and (13), it appears that a plant in any part of the cage, except close to the south side, should receive about 50 per cent of the total radiation.

Equations (1) to (10) can be adapted to wire cloth of any character by changing the constants in equations (1), (2), and (4), which are derived from the mesh of the cloth and the diameter of the wire. Equations (12) and (13), which are at best only approximately correct, are not easily derived mathematically.

CIRCUMZENITHAL ARC WITH A BLACK BAND.

By HOWARD H. MARTIN, Assistant Observer.

[Dated: Fort Worth, Tex., Aug. 12, 1916.]

An exceptional opportunity to make accurate observations of the circumzenithal arc was afforded the writer on the afternoon of August 6, 1916. The phenomenon was