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REFLECTIVITY OF DIFFERENT KINDS OF SURFACES

By HERBERT H. KIMBALL and IRVING F. HAND

The reflection measurements and notes given in Table 2 were made by Mr. Hand while a passenger in an Army airplane, using the same photometer that was employed in obtaining the measurements given in the REVIEW, July, 1929, volume 57, pp. 291–295. The object of these flights was to measure the albedo, or the reflection coefficient for different kinds of surfaces under winter conditions.

On account of the cold, it was important that the photometer be read with minimum exposure of the observer to the wind. It was therefore necessary to reverse the position of the graduated spur wheel, *J*,[1] so that it could be read from above. In this new position the diameter of the projection of the iris opening from the white wedge, as read by the glass scale furnished with the instrument, increases with the reading of the photometer dial instead of decreasing as formerly. Compare in Table 1, calibration readings Nos. 3, 4, 5, and 6, made after the change, with Nos. 1 and 2, made before the change. In reading tenths of divisions on dial *K*,[1] it is now necessary to take the compliment of the reading instead of the direct reading.

TABLE 1.—*Iris diaphragm calibration—Photometer Munro No. 3*

Reading of photometer dial	Diameter of projection of iris from white wedge on glass scale in connection with outside of large window—iris closing					
	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6
	Centimeters	*Centimeters*	*Centimeters*	*Centimeters*	*Centimeters*	*Centimeters*
20	1.48	1.51	----	----	----	----
21	1.36	1.36	----	----	----	----
22	1.20	1.26	----	----	----	----
23	1.10	1.12	----	----	----	----
24	.96	1.01	----	----	----	----
25	.84	.88	----	----	----	----
26	.73	.73	----	----	----	----
27	----	.59	----	----	----	----
27.5	----	.53	----	----	----	----
28.0	----	.46	----	----	----	----
28.2	----	.41	----	----	----	----
15	----	----	1.66	----	1.63	1.64
14	----	----	1.52	----	1.51	1.51
13	----	----	1.41	----	1.38	1.40
12	----	----	1.30	----	1.26	1.28
11	----	----	1.17	----	1.14	1.16
10	----	----	1.04	1.050	1.01	1.04
9	----	----	.91	.920	.88	.92
8	----	----	.79	.790	.75	.80
7	----	----	.64	.660	.63	.67
6	----	----	.51	.505	.51	----
5.8	----	----	----	.485	----	----
5.6	----	----	----	.465	----	----
5.4	----	----	----	.420	----	----
5.2	----	----	----	.405	----	----
5.0	----	----	----	.380	.39	----
4.8	----	----	----	.350	----	----
4.6	----	----	----	.320	----	----
4.4	----	----	----	.290	----	----
4.2	----	----	----	.260	----	----
4.0	----	----	----	.240	----	----
3.8	----	----	----	.210	----	----
3.6	----	----	----	----	----	----

No. 1.—Mean of two readings each by Messrs. Kimball and Hand, Jan. 11, 1930.
No. 2.—Mean of one reading each by Messrs. Kimball and Hand, Jan. 11, 1930, paper separator in place holding neutral glass filter. This calibration for use with measurements over snow.
No. 3.—First calibration after dial was reversed. Mean of readings by Messrs. Kimball and Hand on Jan. 15, 1930.
No. 4.—Readings same date by same observers but with neutral glass and paper washer in place. For use with snow observations.
No. 5.—Check readings made Feb. 7, 1930.
No. 6.—Check readings made May 12, 1930.

[1] Richardson, L. F. Report on photometers for a survey of the reflectivity of the earth's surface. Union Géodésique et Géophysique Internationale, Section de Météorologie. Troisième Assemblée Générale. Prague, 1927. Cambridge, Eng., 1928.

Cloud conditions during the winter of 1929–30 were seldom favorable for reflectivity measurements. On days when there was a cloud cover of uniform thickness precipitation generally occurred before a flight could be made. Fortunately, February 1, following the only considerable snow storm of the winter (11.5 inches on January 30), was cloudy during the morning, and by flying north a snow cover that had been but little affected by the sunshine of January 31 was found. The results of the flight are given in Table 2, flight No. 1.

TABLE 2.—*Flight No. 1: Took off from Bolling Field at 10 a. m., February 1, 1930: returned at noon. Lieutenant Willis piloting OH-1 Douglass plane, "The Alabama." Ground covered with snow, which was 11.5 inches deep at Washington at 8 p. m. of January 30, 9.5 inches on January 31, and 5.5 inches on February 1. Neutral-glass filter transmitting 49 per cent ± 1 per cent covers sky window*

Ratio $\frac{A_s}{A_g}$	Reflection (unit=0.001)	Height above sea level (feet)	Filter	Position and notes
166	423	1,000	None	Over St. Elizabeths.
243	620	1,500	None	Park in Washington; very smoky and hazy.
196	500	1,500	None	Hyattsville, Md.
308	786	1,500	None	White field.
97	247	1,500	None	Forest.
291	742	1,500	None	White field.
338	862	1,500	None	Very white field.
349	890	1,500	None	Do.
283	722	1,500	Green	White field.
49	125	1,500	None	Dark forest.
36	92	1,500	None	Very dark forest.
291	742	2,000	None	White field.
248	633	2,000	Geeen	White field (near Sugar-Loaf Mountain).
299	763	2,500	None	Large white field.
54	138	2,500	None	Forest.
275	702	3,000	None	White field.
147	375	3,000	Red	White field; difficult setting.
38	97	3,000	None	Forest.
294	750	4,000	None	White field.
86	219	4,000	None	Forest; too cold at this height.
38	97	2,000	None	Baltimore; very smoky beneath.
38	97	2,000	None	Chesapeake Bay; smooth surface.
275	702	2,000	None	White field.

NOTE.—To obtain the reflection coefficient, or albedo, the ratio A_s/A_g has been multiplied by 1.25/.49=2.55, where the factor 1.25 makes allowance for the fact that the sky window admits light to the photometer from a sky area near the zenith, which is the brightest point in a completely overcast sky. The factor 0.49 is the transmission of the neutral glass screen.
The designation "White field" simply means a patch of snow large enough to give time in passing over it for an accurate setting of the photometer.

This was the first time that the plane had been taken out since it had been given a light overhauling. The flight was therefore serving a dual purpose—for observational work, and for a test flight. This latter necessitated at times speed in excess of 150 miles per hour with attendant vibrations, particularly of the photometer; but since this speed was maintained for brief periods only, it did not interfere with observations.

The photometer had been recalibrated with its dial changed from the lower to the upper side. Without this change it would have been impossible to read the instrument; in fact, with the heavy clothing needed for protection from the extreme cold, it would have been impossible to have even gotten into the plane with the photometer as originally mounted, with half of it projecting into the cockpit.

The neutral filter was used during the entire series owing to the difficulty in removing it during flight.

Weather conditions.—Upon arrival at Bolling Field the sky conditions were ideal, but as it was inspection day, and the plane was still undergoing repairs, some hours elapsed before we were able to take off. Good conditions prevailed for 10 minutes, after which the sun came out. We headed north and within half an hour were again under a totally cloudy sky; in fact, the best sky we have yet had for observing. We turned back near the Maryland-Pennsylvania State line, returning by way of Baltimore, and obtained some measurements over Chesapeake Bay.

Our attempt to locate pine or evergreen forests of large enough area for observational work was futile, so we had to be satisfied with deciduous trees. We were fortunate in locating many large open fields completely snow covered. The composite view from the air of mixed terrain (forests, fields, streams, cities, and towns, etc.) following a heavy snow storm, did not present as white a surface as had been anticipated due to the darkening effect of large forest areas.

Observations were made at various heights, but the temperature was so low at 4,000 feet and the wind so strong that readings at this height were soon abandoned.

Very few measurements of the various components of light were obtained. The condensation of moisture on the inside of the observer's goggles, together with the filtration of the light beam by the color screens, diminished the illumination intensity to a point where photometric settings were of doubtful value.

TABLE 2.—*Flight No. 2. Took off from Bolling Field at 11 a. m., February 5, 1930; returned at noon. Lieutenant Willis piloting OH-1 Douglass plane, "The Alabama"*

Ratio $\frac{A_s}{A_g}$	Reflection (unit=0.001)	Height above sea-level (feet)	Filter	Position and notes
47	59	1,000	None	Washington, D. C.
38	48	1,000	None	Grassy fields.
34	42	1,000	None	Forest.
120	150	1,000	None	Field; some snow.
65	81	1,000	None	Forest; some snow.
29	36	1,000	None	Pine forest; no snow.
86	108	1,000	None	Deciduous forest; some snow.
48	60	1,000	None	Deciduous forest; no snow.
36	45	1,000	None	Grassy fields (greener than would be expected; probably spring wheat).
52	65	1,000	Green	Same kind of field; no snow.
34	42	1,000	Green	Forest on hillside; very little snow.
27	34	2,000	None	Pine forest. Now in Virginia; no snow during remainder of flight.
31	39	2,000	None	Deciduous forest.
35	44	2,000	None	Green fields.
[1] 55	69	10–20	None	Over Potomac River.
44	55	10–20	Green	Do.
83	104	10–20	Red	Do.

[1] Came down low over the river on account of the extreme cold aloft which made reading the photometer unbearable, as my flying suit had been torn open by the wind. It is necessary to lean out of the cockpit when making settings on the photometer and perfect fitting clothing is required to stand the strain. This was by far the coldest of the flights which explains the paucity of readings obtained.

TABLE 2.—*Flight No. 3: Took off from Bolling Field at 11.50 a. m., May 12, 1930; returned at 1.10 p. m. Lieutenant Willis piloting OH-1, Curtis motored plane, "The Nevada"*

Ratio, $\frac{A_s}{A_g}$	Reflection (unit=0.001)	Height above sea level (feet)	Filter	Position and notes
481	60	1,000	None	Green fields.
272	34	1,000	None	Green forest.
289	36	2,000	None	Do.
389	49	2,000	None	Light green forest.
490	61	2,000	Green	Do.
537	67	2,500	Green	Ploughed white fields.
520	65	3,000	Red	Do.
388	48	3,000	Red	Forest.
272	34	3,000	None	Mixed; trees, fields, etc.
358	45	3,000	None	Forest.
509	64	3,000	None	Patuxent River.
351	44	3,000	None	Forest.
466	58	3,000	Green	Do.
596	74	3,000	None	Fields; apparently wheat.
516	64	3,000	Green	Do.
273	34	3,000	None	Chesapeake Bay, near shore.
275	34	3,000	None	Chesapeake Bay; one-half mile out.
291	36	3,000	None	Chesapeake Bay; 1½ miles out.
325	42	3,000	Green	Chesapeake Bay; well out.
317	40	3,000	Green	Do.
315	39	3,000	Green	Do.
359	45	3,000	Red	Do.
359	45	3,000	Red	Do.
363	45	3,000	Red	Do.
278	35	3,000	None	Do.
284	36	3,000	None	Do.
296	37	2,000	None	Do.
300	38	2,000	None	Do.
386	48	2,000	Green	Do.
390	49	2,000	Green	Do.
362	45	2,000	Green	Do.
277	35	2,000	Red	Do.
324	40	2,000	None	Chesapeake Bay, near shore.
532	66	2,000	None	Broken ground; trees, bare ground, etc.
442	55	2,000	None	Patuxent River.
634	79	200	Green	Light green wheat field.
409	51	100	Green	Forest.
1,083	112	100	None	Very white bare ground.

NOTES.—(1) *Tried blue filter but had no success, as the light transmitted was too* weak to admit of accurate settings.

(2) Bay seemed smooth but close inspection showed presence of white caps. Bay appeared much darker near shore. Headed for the ocean but clear skies made return trip necessary. It is thought, however, that bay measurements closely approximate those over ocean, as the bay is so large at this point and close to the ocean.

(3) Patuxent River appeared to be lighter in color than the bay.

(4) At elevation of 200 feet and less it was impracticable to attempt readings over forests or over green fields with no filter, owing to extreme color difference, which is much greater than at higher levels.

(5) Excellent visibility; Blue Ridge plainly visible from extreme eastern point of flight, an estimated distance of over 100 miles. The individual peaks stood out clearly when flying at a height of 3,000 feet. Visibility to the east was rather poor, due chiefly to clear skies over the ocean.

(6) Altogether the sky conditions during the flight were as good or better than during any other flight. The only interference from uneven sky conditions came at the extreme eastern point of the flight, when observations were discontinued for a few minutes.

(7) Most of the terrain covered was rather broken—that is, alternate small forest areas, wheat fields, ploughed ground, villages, rivers and small streams. There are few large farms, the average size probably not exceeding 100 acres, and each farm itself being broken up into various kinds of surfaces.

(8) Although readings have been recorded at 2,000 feet, the height varies from 1,950 to 2,050 feet owing to bumpy conditions at the 2,000-foot level. Aside from this one bumpy layer, the flying was very smooth, although the usual bumps occurred when flying from over a land surface to over a water surface, or vice versa.

(9) The plane used during this flight is extremely fast; being of a new type recently adopted by the Army. Nevertheless, excellent exposure was obtained with little or no obstruction from plane parts.

The reflection measurements given in Table 2, flight No. 1, over snow-covered fields are in good accord with measurements over similar surfaces made with a pyrheliometer by Kalitin at Sloutzk, near Leningrad (MONTHLY WEATHER REVIEW, February, 1930, vol. 58, p. 59), if we take into account the fact that flight No. 1 was made on the second day following the snowfall, and that in the meantime in the vicinity of Washington there had been material settlement of the snow. The measurements by Kalitin over bare ground in April and May give much higher values than are given in Table 2, flight No. 2, and this is also true of similar measurements by Ångström using a pyrheliometer (MONTHLY WEATHER REVIEW, November, 1926, vol. 54, p. 453). In explanation of these differences it should be remembered that the Richardson photometer measures the vertical reflection from an area of small angular extent immediately below it, while the pyrheliometer employed by Kalitin and Ångström measures the light received from a full hemisphere. Since newly fallen snow gives an almost perfect matt-surface, it has the same brightness from whatever angle it is viewed. The vertical reflection is the same as the reflection from various angles of incidence. This is not the case with water surfaces, plowed ground surfaces or sod surfaces. The first named becomes nearly a perfect reflector at low angles of incidence, as compared with the low reflection obtained at normal incidence. Fields of growing grain or grass present a deeply pitted surface with the bottoms of the pits poorly illuminated. When viewed at normal incidence it is principally the illumination from the bottom of these pits that is measured, while as the angle of incidence increases the reflecting surfaces present an increasing percentage of leaf surface. For this reason measurements with the pyrheliometer give values of reflection from sod surfaces approaching in value the reflecting power of leaf surfaces as measured by Coblentz and others.

RAINFALL CATCH AS AFFECTED BY DIFFERENT DEPTHS OF FUNNELS IN THE RAIN GAGE

By BENJAMIN C. KADEL

[Weather Bureau, Washington, April 18, 1930]

The standard 8-inch rain gage of the United States Weather Bureau is equipped with a collecting funnel having a vertical wall 2¼ inches deep to the sloping part, then a slope angle of 41½° below the horizontal to the outlet.

From time to time honest doubts as to the sufficiency of the depth of this funnel have been communicated to the instrument division of the Weather Bureau, and in an effort to obtain some facts several comparisons were carried on:

The first comparison was voluntarily undertaken by one of these honest doubters, Mr. C. A. Hurlbutt, cooperative observer, Elk Creek station, Pine Grove, Colo., who was provided by the instrument division with a second gage exactly like his standard, but with the vertical wall of the funnel 6 inches deep as compared with the 2¼-inch standard. Mr. Hurlbutt made readings of both gages daily, May to October, 1923. The total catch in the standard funnel was 23.59 inches and in the funnel with 6-inch wall 23.97, an increase of 1.4 per cent. Of the 97 comparisons made, 78 showed exact agreement between the two gages, 7 showed 0.01 inch more caught in the deeper funnel, 7 showed 0.02 inch more, 1 showed 0.03 inch more, 1 showed 0.05 inch more, while one instance showed 0.03 inch less.

Differences for each rain can not well be expressed in percentages, and it seems needful for a complete understanding to present, as Table I, the tabulated measurements as Mr. Hurlbutt reported them. Wind velocity was not recorded:

Through the cooperation of Dr. Oliver L. Fassig in charge of the San Juan, P. R., station of the Weather Bureau and his assistants a more extended set of comparisons was carried out on the grounds of the San Juan Weather Bureau station. Two standard 8-inch gages, one with vertical wall of funnel 2¼ inches deep, the other with wall 6 inches deep were exposed side by side. Detailed measurements are presented in Table II. The total catch in the 2¼-inch funnel was 47.41 inches and in the 6-inch funnel 47.96 inches, or 1⅛ per cent more. Of the 145 measurements made, 77 showed exact agreement, 23 showed 0.01 inch more for the deeper funnel, 12 showed 0.02 inch more, 5 showed 0.03 inch more, and 1 showed 0.06 inch more, 20 showed 0.01 inch less, 2 showed 0.02 inch less, and 1 showed 0.04 inch less.

TABLE 1.—*Daily catch of rainfall (inches) two 8-inch gages equipped with 2¼-inch and 6-inch funnels, respectively. Elk Creek Station, Pine Grove, Colo.*

	May		June		July		August		September		October	
	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches	2¼ inches	6 inches
1					0.37	0.38	0.75	0.75	0.02	0.02	0.10	0.12
2					.05	.05					.08	.09
3	0.03	0.03	0.20	0.20	.02	.02	.01	.01			.23	.25
4			.02	.02	.01	.01	.11	.13			.64	.67
5	.09	.09	.22	.22			.05	.05	.02	.02	.06	.08
6	.03	.03	.07	.07			.25	.25				
7	.02	.02	.05	.05	.37	.37	.81	.85				
8			.65	.65	.53	.55	.36	.36				
9			2.02	2.02			.26	.26				
10			.10	.10	.21	.21	.05	.05				
11	.04	.04					.45	.45	.02	.02		
12	.08	.08	.02	.02	.30	.30	.32	.32			.68	.68
13	.10	.10							.07	.07	.08	.09
14	.29	.31			.36	.36	.15	.15	.10	.10		
15	.23	.23			.72	.72	.55	.55				
16	.01	.01	.20	.20	1.25	1.30	.34	.34	.03	.03		
17	.03	.03			.54	.54	.25	.27	.12	.12		
18							.04	.04	.43	.47		
19					.29	.29	.42	.43			.01	.01
20	.01	.01			.06	.06	.20	.20				
21	.01	.01	.13	.13	.36	.36	.16	.16				
22	.35	.32					.18	.18				
23	.07	.07					.55	.55	.20	.21	.23	.23
24							.05	.05			1.28	1.28
25	.17	.17			.06	.06	.07	.07			.14	.14
26					.53	.54						
27					.95	.96	.01	.01				
28					.08	.08			.21	.21		
29											.05	.05
30									.04	.04		
31							.06	.06				
Sums	1.56	1.55	3.68	3.68	7.06	7.16	6.45	6.54	1.26	1.31	3.58	3.69