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MEASUREMENT OF INCIDENT STREAM ILLUMINATION WITH AN INEXPENSIVE LIGHT INTEGRATING UNIT

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Calculation of the efficiency of autotrophic production depends upon assessment of the quantity of solar energy received at the stream surface. Orientation of the sun's arc with respect to direction of flow together with its relationship to shading by adjacent vegetation, stream banks and surrounding terrain, make precise measurement of incident light received by a stream a difficult task. To make possible comparison of the photosynthetic efficiencies of several sections of stream, which have different vegetational cover and different orientation to the sun, we have constructed a simple but efficient light integrating unit which measures the total light received at any desired point under the water surface for any desired length of time. In this paper we wish to describe this unit and compare the quantity of radiation it receives on stream sections with different cover and sun-orientation.

In a section of stream shaded by trees, intensity of light changes from point to point depending upon the orientation of the sun in relation to

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openings. Since openings are more or less random the only feasible approach to measurement of the quantity of incident radiation over a given surface area is a random sampling procedure, using light recording units that can be easily moved from point to point. Increasing the number of available units increases the efficiency of sampling during a given period and under a single set of meteorological conditions. To permit construction of a large number of such units with a modest budget we have designed a unit that is relatively simple and inexpensive.

Description of light integrating unit

A unit consists of (1) an underwater element consisting of a selenium photovoltaic cell which can be located at any desired point in the stream bed, (2) a transmission cable and (3) a streamside element consisting of a counter and batteries (Fig. 1). Light enters the underwater unit through a glass hemisphere with a finely ground surface. The ground glass reduces errors arising from variation in the angle of incidence of incoming light. The cell output is collected by a capacitor which discharges to a solenoid which, in turn, energizes a counter. Internal resistors compensate for temperature drift and establish a capacitor discharge time which is compatible with operation of the solenoid (Fig. 2).

The maximum reliable counting speed depends upon the operating time of the solenoid counter. The inexpensive counters used operated reliably with 2 counts per second or less. A rate of 2 counts per second was equivalent to approximately 400 foot-candles.

To use the apparatus in stronger light we employed neutral density filters with a factor of 50 (density 1.7) and 5 (density 0.7). Filters of the higher density were used in habitats receiving direct sunlight (up to 8,000 foot-candles). Filters of lower density proved satisfactory for shaded section (up to 2,500 foot-candles). By using these filters incoming light was reduced in intensity to a range in which the cell response was essentially linear. Filters also prevented damage from high intensity light. Because of dark current leakage, approximately 0.1 foot-candle was required to activate the counter. Hence, about 5 foot-candles were required to activate the units with the high density filter and approximately 0.5 foot-candle was required with the low density filter.

Units were calibrated by placing the sensing elements in an unshaded pan of water and recording the sunlight accumulated during successive 30-minute intervals by each unit and by an Eppley pyrheliometer located at the same height and with similar exposure. Plots of counter readings against light recorded by the pyrheliometer fitted a straight line very closely. From these plots a conversion equation was determined by least squares for each unit.

Units can be mounted at any depth in the stream, however, in the present instance they were mounted 2 inches below the water surface on horizontal racks containing substrates used for the collection of periphyton. The total assembly consisting of substrates and sensing unit was anchored securely in the stream with a metal stake.

Measurement of accumulated light in stream section of different orientation and shading

The light accumulated by six sections of the West Branch of the Sturgeon River, Otsego County, Michigan, possessing different orientations to the sun and different amounts of cover was measured between August 1, and September 5, 1962. One light unit was used in each of the six areas. The location of each unit within the section was determined in advance using a table of random numbers. After a 7-day exposure at a given location the accumulated light was recorded and the unit was moved to another randomly located position. Thus during the period of study, accumulated light was measured at six locations within each section. Of the six sections studied, sections 1, 2 and 3 were all within a 200-yard portion of the stream that was relatively open. Sections 4, 5 and 6 were adjacent to one another in a 200-yard portion receiving relatively little light because of a more or less continuous tree canopy. Each section within the shaded and open areas had a different stream orientation and/or type of canopy (Table 1). Weekly light accumulations within the six stream sections can be compared with the accumulation of an unshaded unit located in an adjacent open field (Table 1).

An analysis of variance of weekly light readings indicated that differences between means for stream sections (habitats) and for weeks were significant at the 1% level (Table 1). As expected the largest differences in light input were between open areas and areas with a tree canopy. A Duncan's numerical range test indicated that the mean of section 2 (open, east-west orientation) was significantly greater (at the 1% level) than the means of sections 1 and 3 (partially open). Similarly means of sections 1 and 3 were greater than of 4, 5 and 6 (sections with a tree canopy). However, in section 1 and section 3 rather obvious differences in stream orientation and a seemingly important difference in canopy density arising from tree cover type did not give significant differences in light energy recorded below the water surface by these units.

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Table 1.--Incident light accumulated by integrating units (kg-Cal/cm^2/week) during six weekly intervals between August 1 and September 5, 1962. Units relocated at random each week within six stream sections of different cover and orientation to the sun. Simultaneous readings from an adjacent open field are included for comparison.

Section and habitat characteristics	Weeks 8/1-8/7	8/7-8/15	8/15-8/22	8/22-8/29	8/29-9/5	9/5-9/12	Mean
1 Mostly open, some afternoon shading, S.W.-N.E. orientation of stream	1.56	1.65	1.64	1.49	1.52	1.52	1.56
2 Open, E.-W. orientation of stream	1.68	1.91	1.85	1.66	1.66	1.55	1.72
3 Mostly open, some morning shading, N.W.-S.E. orientation	1.66	1.68	1.64	1.48	1.56	1.46	1.58
4 Full dense canopy (cedar), shading entire day, E.-W. orientation	1.54	1.51	1.48	1.45	1.42	1.39	1.46
5 Partial dense canopy (birch cedar), afternoon penetration, E.-W. orientation	1.51	1.61	1.51	1.47	1.42	1.39	1.48
6 Partial canopy of intermediate density (cedar, balsam), E.-W. orientation	1.55	1.62	1.49	1.44	1.42	1.40	1.49
7 Open field [a]	2.07	2.21	2.03	2.15	1.86	1.86	2.03

Source	df	SS.	MSS	F
Habitats	5	0.26924723	0.05384944	26.26[b]
Weeks	5	0.18878056	0.03775611	18.41[b]
Error	25	0.05126944	0.00205077	
Total	35	0.50929723		

[a] Data not used in analysis of variance.

[b] Significant at 99% level of probability.

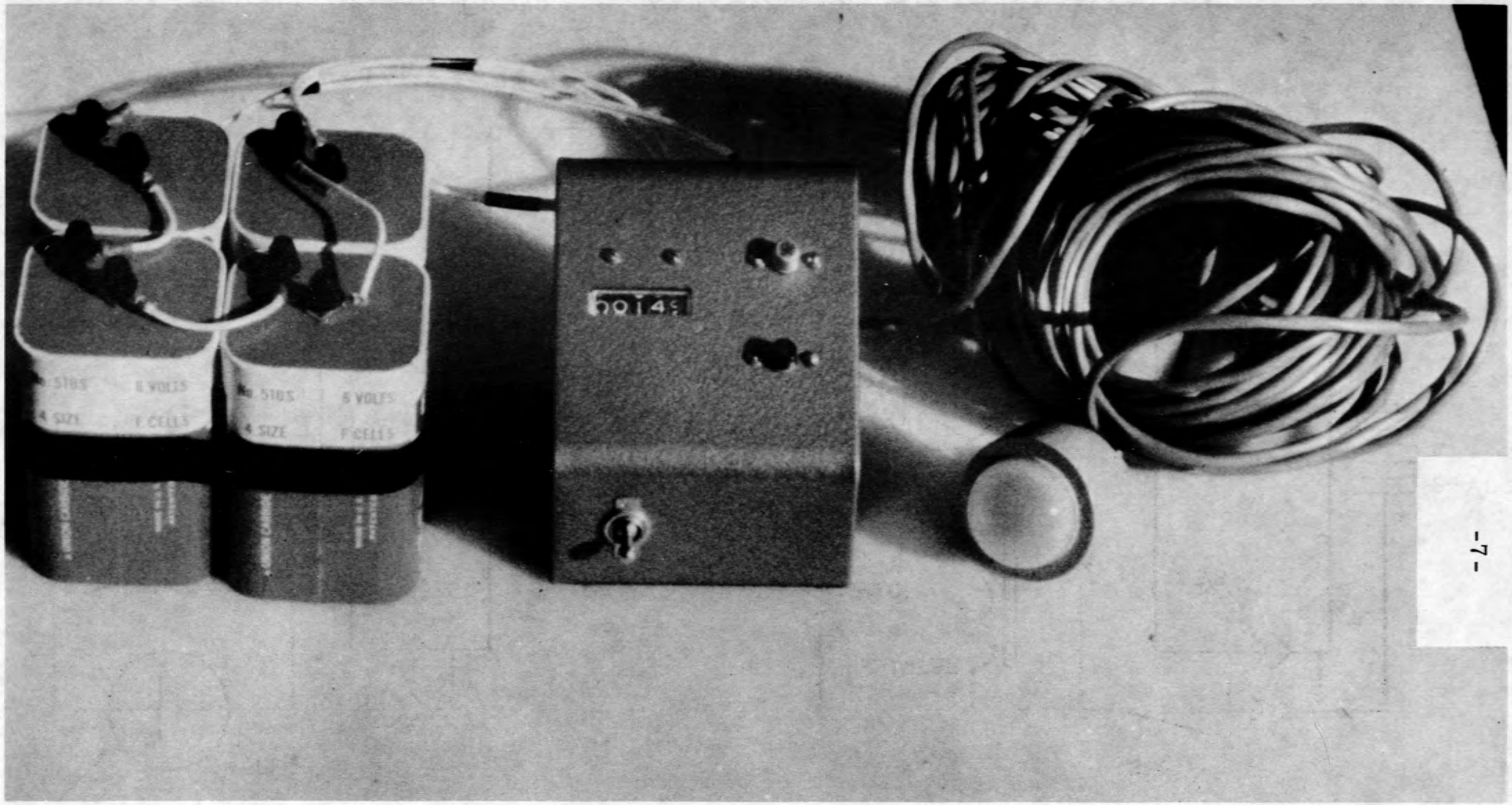

Figure 1. --Light integrating unit

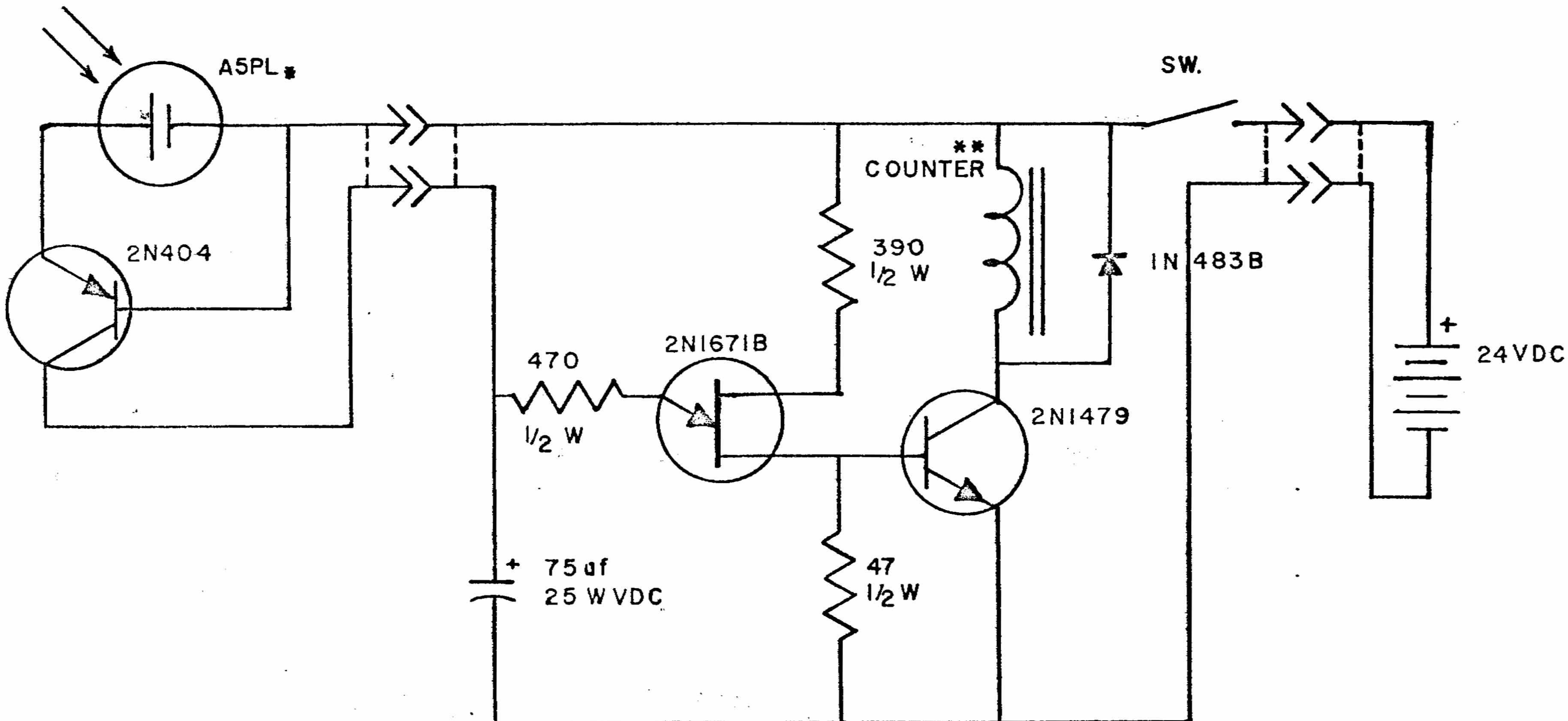

Figure 2. --Circuit diagram of light integrating unit

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