Improved Heat Pulse Velocity Meter¹

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Highlight

A heat pulse velocity meter useful for studying sap movement is described. The instrument is updated electronically and is slightly more compact than previous units.

Study of transpiration from grass, shrub, and tree species has long been of interest to wildland hydrologists. Though many techniques are available for studying transpiration, few are rapid or measure individual plants.

In recent years several researchers have utilized the heat pulse technique to study sap movement. Swanson (1967b) has provided a brief summary of the heat pulse method, and the following is taken from his paper:

"In any pulse velocity measuring technique, a quantity of heat is injected into the stem of a plant, and its rate of travel to some point downstream, indicated as a rise in temperature, is detected by thermocouples or thermistors. Huber (1932) empirically related the first onset of heat at the point to sap velocity. Marshall (1958) derived the theoretical relation between heat rise with time at the point and sap movement in conifers. Marshall's relation is exact at any sap speed, but because of ambient temperature changes within a tree stem in the field, it yields useful values only at relatively high flows—those causing heat pulse velocities greater than 10–15 cm/hr. Such sap velocities are uncommon in Rocky Mountain conifers. A better technique for these lower velocities requires two temperature measurement points, one upstream and one downstream from the heat insertion point (Huber and Schmidt, 1937; Swanson, 1962).

According to Marshall (1958), heat pulse velocity is a weighted average of the velocity of moving sap and station-

FIG. 1. Microvoltmeter with heat pulse and timing circuits in box attached to side.

ary wood. At low sap velocities, the effect of the wood predominates, and heat pulse velocity is an underestimate of real sap velocity. At high sap velocities, the effect of the wood is less and heat pulse velocity is very close to real sap velocity. The weighting effect of the wood is a function of the area occupied by sap streams. This area is unknown and not necessarily constant. Therefore, true sap velocity is unknown; heat pulse velocity indicates whether or not there is sap flow, and to some degree its relative, but not true, magnitude."

Field and laboratory tests for verification of theory were undertaken by Skau and Swanson (1963), Decker and Skau (1964), and Ladefoged (1960). Measurement of sap movement by this procedure, or slight modifications thereof, have been undertaken on a variety of plants; Bloodworth et al. (1955, 1956, 1960) studied sap flow in cotton, Marshall (1958) and Decker and Skau (1964) in conifers and junipers, Gale and Poljakoff-Mayber (1964) in pine and orange trees, Wendt et al. (1965, 1967) in corn, sorghum, oats, and mesquite, Swanson (1967) in lodgepole pine and engelmann spruce, Doley (1967) and Doley and Grieve (1967) in eucalyptus, Hart et al., (1969) in aspen, and Gifford (1968) in big sagebrush.

Swanson (1967a) outlined several important changes in the basic instrumentation which he developed earlier. The purpose of this paper is to describe recent changes which update the instrument electronically as well as present a somewhat more compact unit. The reader is referred to Swanson (1967a, Appendices) for discussion of temperature measuring, heat sources, connections and spacing of probes, and drilling.

The Instrument

A Hewlett-Packard² 419 A DC Null Voltmeter is the basic unit used to determine, following heat input, when temperature probes are again at an equal temperature (Figs. 1 and 2). The voltmeter can detect a difference of ± 0.1 microvolt and can operate 30 hours per recharge.

The model SK-1 Heat Pulse Controller and Clock Display³ is designed to mount on the side of the voltmeter. The self-contained portable controller provides approximately 6.25 v at the output terminals for precisely 2 seconds. The Controller may be operated

¹ Development of this instrument was supported by the Ecology Center, Utah State University, under Project 28. Received December 1, 1970.

² Hewlett-Packard, 1501 Page Mill Road, Palo Alto, California 94304.

³ Instruction manual may be obtained by writing the senior author.

FIG. 2. Microvoltmeter and Heat Pulse Controller set up for measuring sap velocities in pinyon trees.

for 30 hours (1 pulse every 5 minutes) per charge.

Operation Procedures

As soon as the power switch is turned on, the Controller is ready to operate. To start a heat pulse sequence, the start button is depressed and released. A red light indicates that the heater voltage has been applied to the output terminals. At the end of a 2-second heat pulse, the 1-second counter displays the number of seconds until the reset button is depressed.

During cold weather (below freezing), operation of the unit is facilitated by addition of an external heat source (small hand warmers, etc).

Practical Applications

The instrument can be used to study water movement in plants, plant response to herbicide applications, or for studying influence of insects, disease, or grazing on physiology of wildland plants.

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