technical notes

An Electrical Device for Recording Small Fluctuations and Accumulated Increment of Tree Stem Circumference

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"... an instrument that measures changes in stem circumference... and that does not damage meristematic tissue."

Abstract

A device is described which employs a displacement transducer affixed to a metal band to measure and record, continuously, changes in stem circumference.

Résumé

Appareil électrique pour enregistrer les petites variations ainsi que les accroissements cumulatifs de la circonférence d'un arbre.

Description d'un appareil muni d'un potentiomètre à fonction linéaire monté sur lame métallique. L'appareil mesure et enregistre continuellement les changements de la circonférence de la tige.

Potential uses of data recorders and data logging systems in ecological research seem limited only by the development of appropriate sensing devices. Instruments which permit recording of small fluctuations in tree stem radius have been reported by Phipps and Gilbert (1960) and by Impens and Schalck (1965). These instruments are limited to measuring only one radius and, as they are fastened to the tree stem with screws that damage cambial tissue, may be affected by traumatic growth responses. This paper de-

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scribes an instrument that measures changes in stem circumference thus averaging variation among radii, and that does not damage meristematic tissue.

The measuring device and circuitry

The instrument is essentially a displacement transducer with an extendable shaft which responds to the movements of a metal band circumscribing a tree stem (Figs. 1 and 2). The displacement transducer, a linear-motion potentiometer, is mounted on an aluminum "plate" which is attached to one end of a metal band (Fig. 2, A) and, when in place, rests on a tangent to the tree stem. The "plate" was fabricated from right-angle stock. The other end of the band passes around the stem, over the face of the aluminum plate and is attached to the shaft of the potentiometer. Movement of the outer end of the plate is prevented by a rigid aluminum strip (Fig. 2, B) which tucks between the band and the stem. A stainless steel spring maintains sufficient tension on the band to hold the device in place. The brace, transducer, and the fixed end of the band were attached to the aluminum place with a plastic tape having adhesive on both sides. A punch and eyelet-setting tool was used to fasten the spring bracket to the band.

Fig. 1. Displacement-transducer mounted on a tree stem.

The band is constructed of .003 x .5 inch invar (a nickel-steel alloy) that has a thermal expansion coefficient of 0.8×10^{-6} units of expansion per unit of length per Centigrade degree.¹ This very low coefficient precludes significant errors due to thermal expansion and contraction of the measuring band. Indeed, the mechanical arrangement is such that error tendencies due to thermal expansion of the band partially cancel those arising from expansion of the aluminum plate. It can be shown that the net error from thermal expansion is zero for a stem diameter of about 12 inches. Because invar is subject to corrosion, it is necessary to spray the band with acrylic or some similar substance.

When a linear-motion potentiometer is placed in an appropriate circuit with a fixed voltage source and a millivolt recorder (Fig. 3), the reading on the

Fig. 2. Diagram of displacement-transducer band showing construction details.

¹Handbook of chemistry and physics, 1960-1961. The Chemical Rubber Publ. Co., Cleveland, Ohio. 42nd Edition.

recorder will depend on the resistance between two contacts which depends in turn on the position of the potentiometer shaft. In this study, data from up to 23 displacement transducers were periodically and automatically recorded on a 24-line recorder. One line was reserved for recording variations in a circuit containing a fixed resistor (R_f) instead of a displacement transducer. Constant readings on this line indicated that variables other than shaft displacement (e.g. electrical interference and temperature fluctuations) were not affecting the data.

Combinations of resistance and voltage values other than those shown in Fig. 3 are quite feasible. It is important, though, that the potential drop (PD) across the displacement transducer (R_{dt}) approximates the range of the recorder. Also, about 10% of the voltage-drop resistance ($R_1 + R_2$) should be controlled with a trimming potentiometer (R_2) so the millivolt range of each circuit may be independently adjusted to a given shaft displacement.

Fig. 3. Diagram of circuitry used. R_1 is a 2200K ohm $\pm 10\%$ carbon resistor. R_2 is a 250K ohm carbon-film potentiometer. R_{dt} is the displacement transducer, a 5K ohm linear-motion potentiometer. R_f is a 4.5K ohm fixed resistor.

Calibration and installation

Before being attached to the aluminum plate, each linear-motion potentiometer should be wired into its circuit and the trimming potentiometer adjusted so a given shaft displacement results in an appropriate recorder response. Each circuit should be adjusted so each division on the recorder chart represents a convenient shaft displacement. Precise shaft displacements for adjustment purposes may be obtained by mounting the transducers on a jig with a dial-gauge micrometer (Fig. 4). The linear relationship between shaft displacement and electrical resistance precludes the need for calibration curves.

Stem circumference should be measured where the instrument is to be placed and the band constructed to fit as the threaded shafts on the transducers permit only minor adjustment upon installation. Petroleum jelly or other inert lubricant should

Fig. 4 Displacement calibration jig with dial-gauge micrometer and multi-point recorder. Chart shows diurnal dimension variations of several bands.

be applied to the bark under the band to reduce friction; on rough stems, it may be desirable to remove some of the corky outer bark with a wood rasp. Polyethylene envelopes should be stapled over the tangential plates to protect the transducers from the elements.

Performance

Two models of linear-motion potentiometers have been successfully used: The Bourns² Model 108 and the Bourns Model 141. The shaft of the Model 108 has a rated mechanical travel of 1.31 inches which, generally, is sufficient to measure annual circumference increments. The Model 141, with a shaft

²Bourns, Inc., 6135 Magnolia Ave., Riverside, Calif.

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travel of 0.44 inch, may have to be remounted one or more times during a growing season. On the other hand, the Model 141 will register circumference changes in the order of .0015 inch. The Model 141, as used on young Douglas-fir, detected hourly changes in stem circumference. The Model 108 will register circumference changes of .002 inch. However, if the circuit is adjusted to record total shaft displacement on the strip chart, this model's useful minimum is in the order of .004 inch.

Fluctuations in air temperature and humidity did not cause readable changes in circuit voltages and therefore did not significantly effect the recorded data. This was repeatedly demonstrated throughout the 2-year research period by recorded data from transducers wired up and in place on study trees but which were not functioning mechanically. During this time, there was no change in recorded millivoltages.

These instruments have proved ideal for studying patterns of diurnal dimensional change. They should prove useful in physiological studies of tree-water relations and annual-ring development by providing a means of electrically recording stem circumference fluctuations.

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Literature Cited

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PHIPPS, R. L. and G. E. GILBERT. 1960. An electric dendrograph. *Ecol.* 41: 389-390.

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