Ice movement farther up Walsh Glacier has been much less than in the lower valley during the past year. In the vicinity of the first tributary (Post, 1966, fig. 1, table I) surface features were displaced down-valley about 2,100 m.; near Cadorna Glacier the movement was approximately 1,500 m. The reduced rate of flow in the upper part of the valley is considered evidence that the surge is about over. This surge is unusual both in the maximum movement recorded (about 11,500 m.) and in the period of time during which the surge has been in progress (more than 4 years). The former position of the Logan Glacier medial moraines indicates that no former surge of Walsh Glacier of this magnitude has occurred in the past 100 years or more.

Increased activity of at least three other glaciers in the vicinity of Walsh Glacier in 1966 may be evidence of new surges developing. These are: (1) Baldwin Glacier; (2) the first tributary of Logan Glacier east of Baldwin Glacier; (3) the next valley glacier west of Baldwin Glacier. The last-mentioned glacier had started to advance slightly in 1966. There was also evidence (in the form of increased marginal crevassing) that the large Anderson Glacier, the major source of ice for Chitina Glacier, is now moving more rapidly than in 1960. Unstable conditions in the Chitina Glacier system, similar to those of Muldrow Glacier prior to its surge (Post, 1960), and Steele Glacier, which surged in 1965–66, suggest that a large-scale glacier surge may occur in these glaciers in the next few years.

U.S. Geological Survey,
Tacoma, Washington, U.S.A.
1 November 1966

AUSTIN POST

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SIR,

Measurement of the permittivity of ice

S. Evans writes in his very interesting publication (Evans, 1965, p. 785): "We have shown that pure ice has a relaxation spectrum, related to temperature, but more measurements are needed on naturally occurring snow and ice. It may then be possible to develop a technique for temperature measurement in deep ice by investigating the relaxation spectrum with electrodes on the surface." For such a technique it is important to measure the permittivity* of deep ice layers under the original conditions of temperature, pressure and grain structure. This could be done by means of electro-thermal deep drilling. I want to suggest a simple device for achieving this.

The flat or pyramidally pointed bottom of the deep-drilling probe (Philberth, 1966) is one electrode, the cylindrical side wall of the probe is the earthed electrode; both electrodes together form a capacitor. Its capacitance can be measured as follows: A capacitor C of high precision is connected parallel to it (in order to reduce the loss tangent) and by means of a transistor–amplifier A auto-oscillation is caused; this is brought about by parallel connection of an inductor L, or by one of the known RC-circuits.

The frequency of the oscillation is a function of the real part of the complex permittivity; the maximum sensitivity of the real part to changes of temperature is in the range where the imaginary part (loss factor) reaches its maximum. For ice temperatures between −20°C. and 0°C., this range is realized for frequencies in the order of 3 kHz. For Greenland conditions frequencies of the order of 3 to 10 kHz.

* Permittivity is the term recommended by the Commission on Symbols, Units and Nomenclature of the International Union of Pure and Applied Physics for the quantity sometimes known as dielectric constant. As the quantity is not a constant but varies with frequency and temperature—in the case of ice the relative permittivity can be anywhere between 3 and 100—a term which does not use the word constant is to be welcomed. *Ed.*

seem to be suitable. Perhaps higher frequencies are less influenced by impurities in the ice. The use of two or more frequency bands gives much more information on the permittivity.

It is a special advantage of this method, that the measurements can be made while the probe is actually melting its way down. This may be surprising; but it is a fact that the excess temperature of the ice under a penetrating probe is exponentially decreasing with the vertical distance from the bottom of the probe (Philberth, 1962). For a probe-velocity of 2 m./hr. the temperature some millimetres away from the probe bottom is nearly undisturbed. The warmed ice layer in the immediate neighbourhood of the probe bottom has practically no influence on the measurement, because it is very thin; furthermore the measured values can be compared and be corrected with the values measured for the frozen-in state of the probe. The calibration is simple: It can be done by putting the probe in media of well-known permittivity, e.g. air, petroleum, alcohol, water, ice.

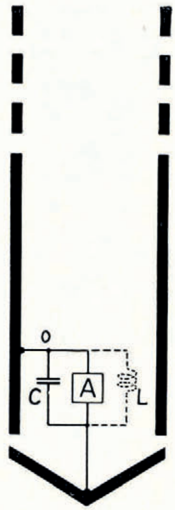

Fig. 1. Diagrammatic sketch of proposed method of measuring permittivity and hence temperature of ice using a thermal boring head

The described method is a way to measure the permittivity of the ice at its natural temperature. For the measurement of this temperature itself, electric thermometers (thermistors) are installed in the probe. Some days after the interruption of the heating, the temperature of the probe has sufficiently approximated the natural temperature.

The relationship between permittivity and temperature once being fixed by some calibration measurements, the measurement of the permittivity by the penetrating probe gives an indication of the temperature. Such an indirect measurement of the temperature may be less precise than the measurement by the thermistors, but it has the advantage of procuring a continuous series of values and of avoiding the risk and the loss of time during the freezing-in and the cooling down of the probe. There is another advantage: the approach of the probe to stones or to the bedrock is indicated by a rapid rise of the frequency.

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