A MINIATURE THERMOPHOTOMETER FOR LAKE AND MARINE ECOLOGY

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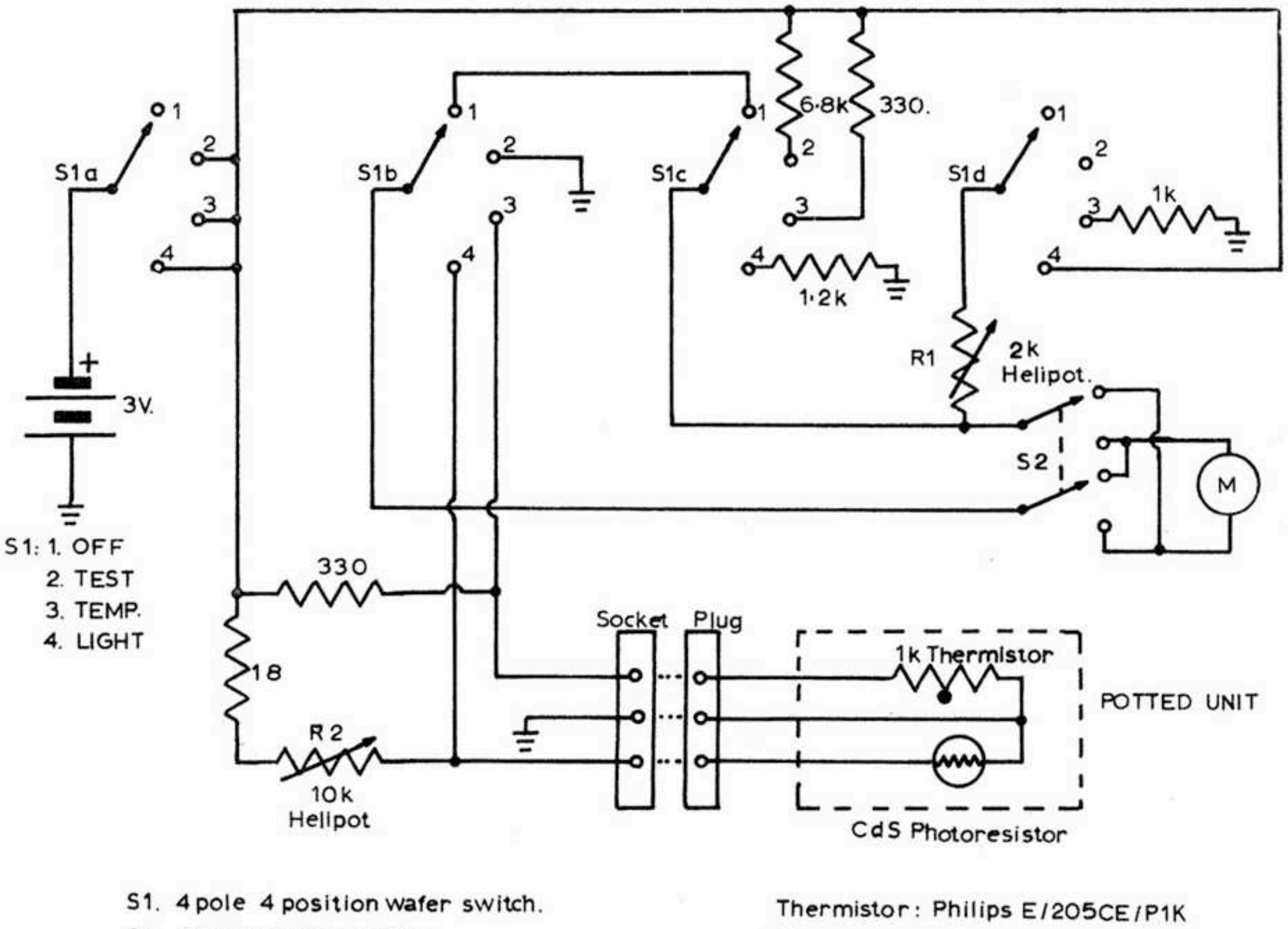
ABSTRACT

A description is given of a compact, portable instrument suitable for measuring water temperature and light intensity in studies of lake or marine ecology.

INTRODUCTION

The instrument to be described was originally developed for use in Antarctic lakes but is equally suitable for studies of lake and marine environments in temperate regions.

Many lakes in the McMurdo Sound region of Antarctica contain blue-green algae, as well as other simple plants and animals (*Science in Antarctica*, 1961). The manner in which these survive the long Antarctic night is unknown and its elucidation requires a full description of their ecology. In that study the primary physical factors are water-temperature and light intensity. Commercially-available instruments to measure these variables were found



S1. 4 pole 4 position wafer switch.

S2. DPDT Spring return.

R1, R2. Ten Turn Helipot with Duodial.
Set at zero for minimum resistance.

Thermistor: Philips E/205CE/P1K

Photoresistor: Philips B8 731 03

Unspecified resistors: W.W., 2W, ±5%.

M, 1 mA centre-zero.

FIGURE 1. *Circuit diagram of thermophotometer.*

to be inconveniently large and insufficiently portable for field use in the Antarctic (e.g. see Atkins *et al*, 1949; Gall, 1949). A simple, portable instrument has therefore been constructed and was used by The Ninth Victoria University of Wellington Antarctic Expedition (1964-65 summer).

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SPECIFICATION

The McMurdo lakes, many of them saline and density-stratified, contain waters at temperatures from −5°C. to +25°C.; an accuracy of ±0.5°C. in determining these was considered sufficient for ecological purposes. (Wilson and Wellman 1962; Hoare *et al*, 1964).

Most of the lakes are permanently ice-covered and the net transmission of light through this layer varies from 0.1% to 10%, depending primarily on the surface condition. The incident solar radiation also fluctuates according to the time of day. Underwater attenuation is normally exponential with depth and was not expected to exceed 96% even in Lake Vanda, the deepest to be studied. To separate effects due to varying incident radiation and ice conditions, the absolute intensity of the surface light and its relative transmission to various depths in the lake water were to be measured. An accuracy of ± 5% in each scale was required.

In the McMurdo region, especially in the Dry Valleys where many lakes occur, clear skies are normal so that over periods of less than an hour insolation is effectively constant and a monitor of surface light unnecessary.

The instrument itself had to be readily portable, rugged, stable, and simple to operate in bad weather. The measuring probe had to be small enough to lower through a three-inch diameter hole in the ice, and to withstand water pressure at depths to 220 feet.

TRANSDUCERS

For temperature measurement a thermistor was chosen in preference to a thermocouple because it was more sensitive, required no constant temperature junction or voltage reference and was sufficiently stable for the intended purpose.

A CdS photoresistor was used to measure light intensity. It was small and convenient in a miniature probe. CdS photoresistors have the advantages over selenium ones of higher stability and better linearity between their electrical conductance and in incident illumination, as well as a higher resistance, so making the effect of long probe leads unimportant.

The spectral response curves of two types of CdS photoresistor are shown in Figure 5. Type A (e.g. Phillips ORP 63 and RPY 14) is most sensitive to green light, whereas type B (e.g. Phillips ORP 12 (B8 731 03)) is more sensitive in the red-orange region. Both exhibit a similar range of resistance variation and if each is used in a probe the extinction rates of green and red-orange light underwater may be investigated separately. These may vary considerably from lake to lake (Hutchinson 1957). The particular photoresistor referred to in figure 1, 2, and 4 was of type B.

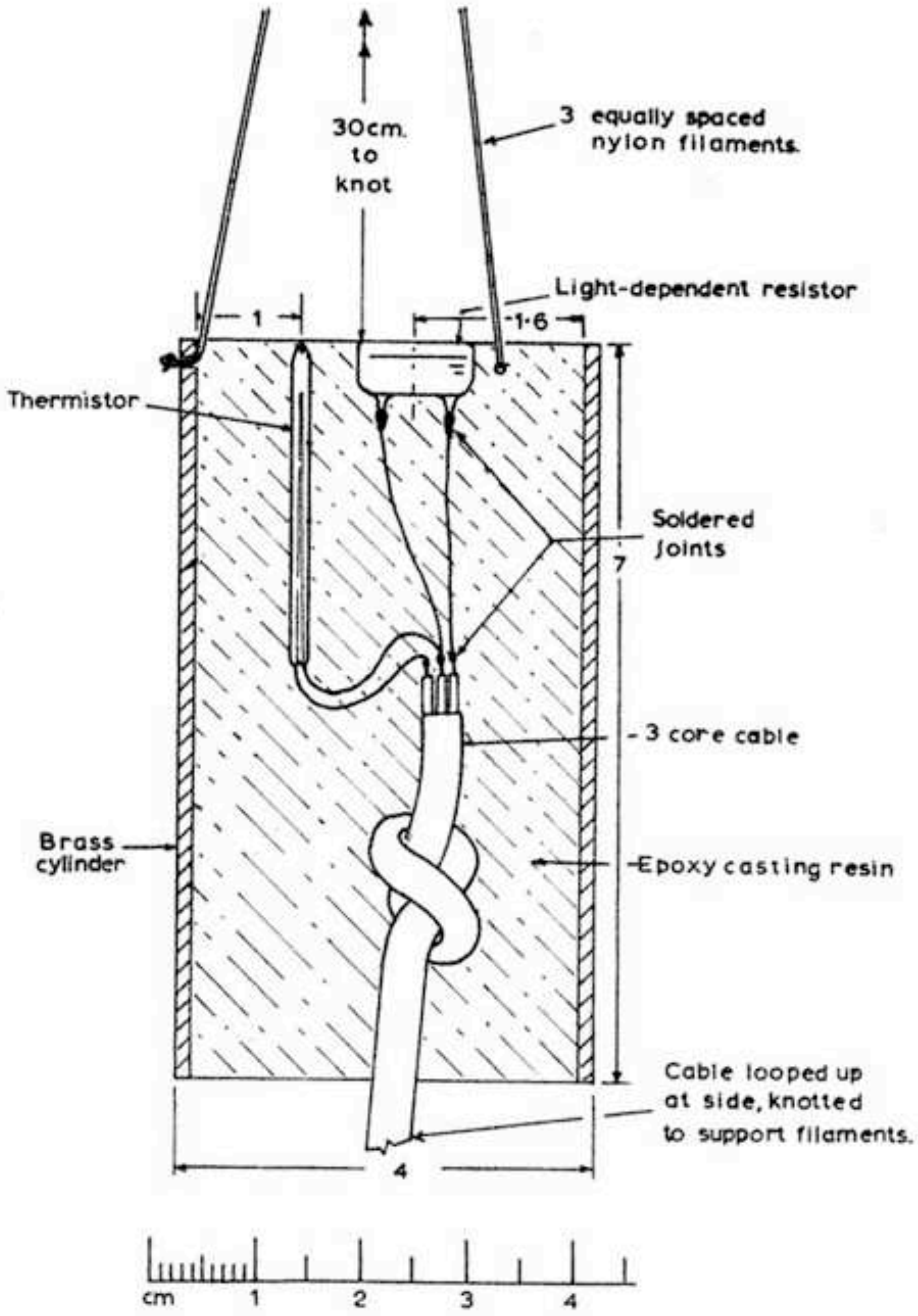

FIGURE 2. *Construction and suspension of probe head.*

PROBE CONSTRUCTION

The thermistor and light-dependent resistor were potted together in a colourless, transparent plastic resin (Araldite Casting Resin D, plus 10% Hardener 951) which provided a rigid, waterproof mounting as well as protection from dirt and shock. The probe is shown in Figure 2, which also shows how it was suspended. The three clear nylon filaments are adjusted to hold the probe level when hanging from a knot in the main cable.

To improve the bonding of the resin to the PVC sheathed cable, the end of the latter was washed in acetone to remove plasticiser oils from its surface, and knotted at a point within the resin.

ELECTRICAL CIRCUITRY

The resistance range of each of the transducers is suitable for comparison with a 2000 ohm, ten-turn, high resolution potentiometer using a Wheatstone Bridge. The circuit adopted is shown in Figure 1. All resistors are wirewound. An 18 ohm resistor in series with potentiometer 2 prevents the photoresistor carrying excessive current when exposed to very bright light.

Because of its comparative ruggedness a 1 milliampere, centre-zero meter is used as the bridge balance detector. A current-reversing switch increases null sensitivity as well as making it unnessary to zero the meter accurately.

The entire electrical circuitry was assembled in a brass case measuring 7½″ x 4½″ x 5″ and weighed 6 pounds.

Changes in the ambient temperature of the bridge components have a negligible effect on measurements. Knowledge of the temperature coefficients of the bridge resistors (− 40 to + 150 ppm/°C.) and potentiometers (+ 130 ppm/°C.) shows that a change of 1°C. in ambient temperature will produce less than 0.1°C. change in indicated probe temperature, and less than .015% change in indicated light intensity.

By far the greatest source of error arises from the effect of temperature changes on the photoresistor. For an illumination of about 1500 lux, the temperature coefficient of the photoresistor was measured by the writer as + 0.81% per °C. from − 10°C. to + 10°C., and + 0.46% per C°. from + 10°C. to + 30°C. (Within each of these ranges the variation is effectively linear). The calibration graph of Figure 4 refers to an ambient temperature of 15°C. and therefore illuminations deduced from it should be corrected as follows: Let T°C. be the probe temperature, let I_m lux be the measured illumination, and let I_t lux be the true illumination, then

(a) if $+10 < T < +30$:

$$I_t = I_m\,(1 + .0046(T - 15)),$$

(b) if $-10 < T < +10$:

$$I_t = I_m\,(0.977 - .0079(10 - T)).$$

If the water temperature varies appreciably these corrections should be applied to relative illumination measurements as well as absolute ones. The correction coefficients may be slightly dependent on mean illumination intensity. For the most accurate work each photoresistor (as with selenium cells) should be individually calibrated.

OPERATION

(a) *Temperature measurement*

With the selector switch set to 'temperature' the bridge is balanced using potentiometer 1. The reading so obtained is converted to degrees centigrade using a previously-prepared calibration graph (Fig. 3).

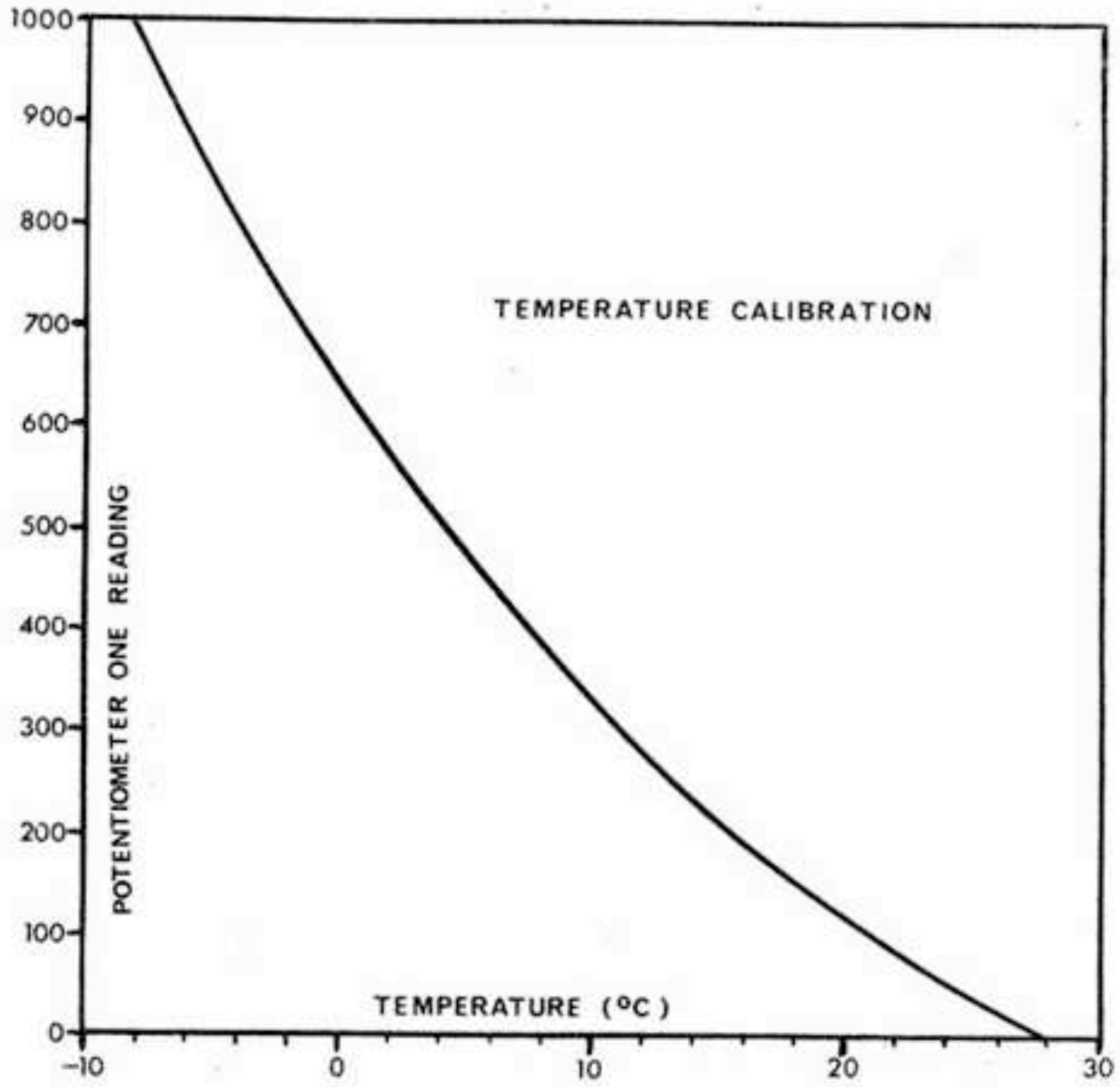

FIGURE 3. *Temperature calibration graph.*

(b) *Light intensity measurements*

The absolute incident light intensity (usually at the air-ice interface) is measured by setting the selector switch to 'light' and potentiometer 1 to full scale (maximum resistance), and then balancing the bridge using only potentiometer 2. This reading may then be converted to absolute illumination (Fig. 4), and corrected as described above, if necessary.

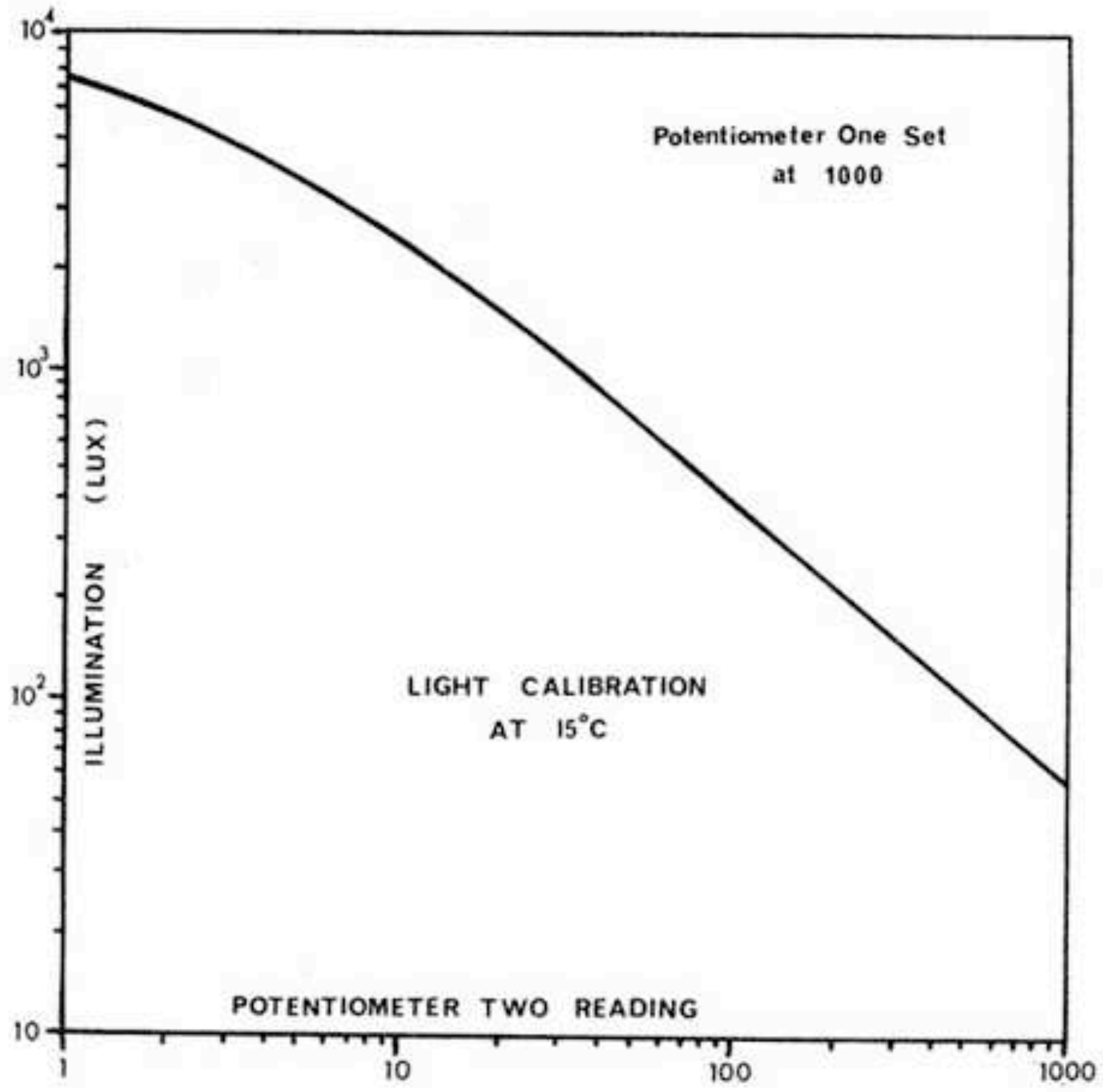

FIGURE 4. *Incident light calibration graph.*

The rate at which light is absorbed as it penetrates water is frequently required. If potentiometer 2 is left at the value corresponding to the surface light intensity, and potentiometer 1 is adjusted to retain bridge balance as the probe is lowered, the number indicated on the potentiometer 1 gives the percentage transmission to any depth directly (provided the surface light intensity is constant over the time of the measurement). From this the absorption rate is readily determined.

CALIBRATION

The thermistor was calibrated against a high-quality mercury thermometer in circulating constant temperature water-baths (salt being added at temperatures below 0°C.). As constructed, the range was − 10°C. to + 30°C., but could, if desired, be raised or lowered by changing the bridge resistors. Repeatability was better than ± 0.5°C.

A disadvantage of potting the thermistor in resin was the increase of its time—constant to about two minutes. In field use, however, it was found that equilibrium was attained within the time taken to measure light flux, which was therefore taken first at each depth.

The photometer section (potentiometer 2) was compared with a Weston photoelectric cell under direct sunlight. The range was then extended using lights of varying intensities which had been compared with sunlight using potentiometer 1 as described above. After three months of use the calibration had not altered appreciably.

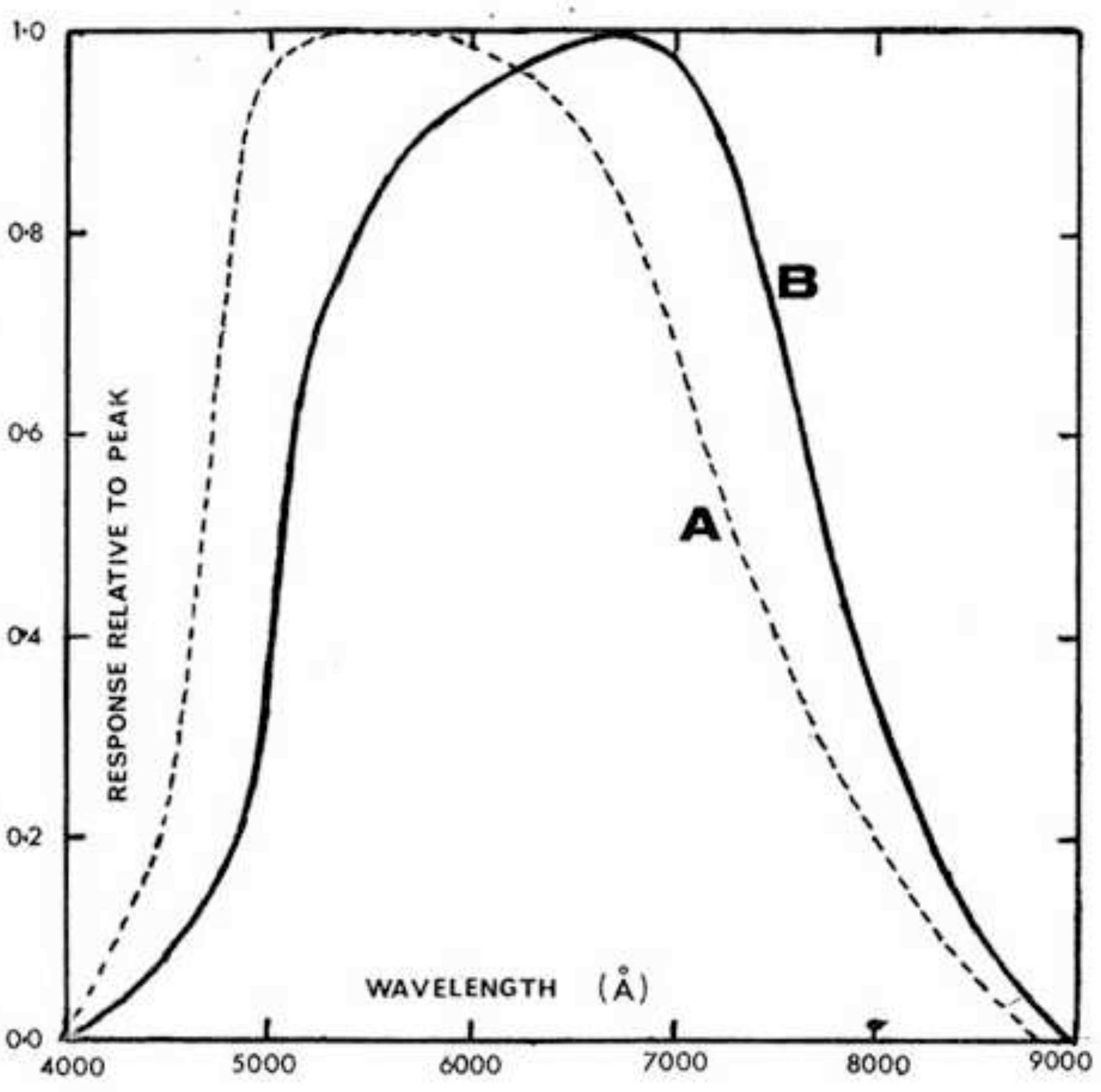

FIGURE 5. *Spectral responses of light-dependent resistors.*

CONCLUSION

In the field the instrument was found to be rugged and simple to operate and to give consistent results which agreed well with thermocouple and bolometer determinations of temperature and light intensity in Lake Vanda. No troubles resulted either from water pressure on the probe or from the cold temperatures.

With little or no modification of the thermistor bridge the instrument would be suitable for use in temperate or tropical lakes, or in the pelagic region of oceans. If while under tow the thermophotometer were stabilised by means of a paravane, it could provide valuable information on light and temperature. In particular, it could be used while towing nets for phytoplankton. Additional photoresistors could be introduced to measure illumination in other planes if scattering were expected to be important. Use of unbalanced bridge circuits of the type described by Mitvalsky (1964) would provide from each transducer a continuous linear electrical output suitable for chart recording.

Cloud cover rarely caused inconvenience arising from fluctuating surface light intensity. But for temperature applications where this might apply, it would be simple to modify the circuit to include a second light-dependent resistor (mounted on gimbals to remain horizontal) as a monitor of surface light. This could be incorporated in the bridge (replacing R3) to permit direct measurement of instantaneous transmission.

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