

INSTRUMENTS AND METHODS

AN AUTOMATIC GAUGE FOR MEASURING SEA-ICE THICKNESS

By PETER SCHWERTDFEGER

(Meteorology Department, University of Melbourne, Parkville, Victoria 3052, Australia)

ABSTRACT. A device is described which automatically measures the thickness of a floating ice cover at regular or any desired times and allows the result to be printed together with the time on a shore-based recorder. This instrument has been proven by a year's operation near Mawson, Antarctica.

RÉSUMÉ. *Mesure automatique de l'épaisseur d'une couverture de glace.* L'auteur décrit un appareil qui mesure automatiquement l'épaisseur d'une couverture de glace flottante à intervalle régulier et aux temps fixés, et permet d'imprimer le résultat des mesures avec le temps sur un enregistreur placé à terre. L'instrument a été mis à l'épreuve pendant une année près de Mawson, Antarctique.

ZUSAMMENFASSUNG. *Ein automatisches Eisdickenmessgerät.* Es wird ein Gerät beschrieben, welches die Dicke einer Meereis-Schicht automatisch zu regelmässigen oder sonstig gewünschten Zeiten misst. Das Ergebnis der Messung wird zusammen mit der Zeit von einem landfesten Druckschreiber registriert. Das Instrument hat sich während einer einjährigen Erprobung an der Station Mawson in der Antarktis als zuverlässig erwiesen.

FLOATING ice covers have been subjected to increasingly rigorous studies, particularly with regard to their heat and mass budgets, e.g. by Untersteiner (1961), Schwerdtfeger and Pounder (1963), Schwerdtfeger (1964) and Weller (in press). The latter two of the above reports showed the need for, and application of, more nearly continuous ice accretion data. A number of techniques and instruments have been devised and reported on whose primary aim was merely to simplify ice thickness measurement. These methods range from the filling of an inspection hole in the ice cover with a low freezing-point liquid such as kerosene, to installed mechanical probes and acoustical and electromagnetic sounding devices. The contamination caused by kerosene and other similar liquids is probably unsatisfactory for most purposes of physical measurement, and those devices depending on the sonic or electrical properties of ice are not always sufficiently accurate because of a dependence of these on density, temperature and salinity of the ice. This leaves only mechanical probes for precision measurements. A probe of this type must disturb the thermal and physical processes in the ice as little as possible, a requirement which would preclude use for all but the most approximate routine measurements of the bulky tubular metal device described by Adams and Shaw (1966).

Untersteiner (1961) devised a novel apparatus consisting of a metal flange attached to a suitable resistance wire which was initially passed through a vertical bore hole in the ice. The flange, which subsequently remained in the water below, held the wire taut whilst it froze into the ice. At any time an electrical heating current could be passed through the wire, a return path occurring through the sea-water and a second immersed electrode. The wire could then easily be drawn until the attached metal flange reached the ice-water interface. The total length of wire above the flange being known, the ice thickness could then be observed by noting the length of wire exposed at the surface.

A precise heat- and mass-budget study of floating ice requires detailed information on the rate of growth and ice thickness change. Accordingly, the instrumentation developed for a detailed investigation of the sea ice near Mawson during 1964 included an automatic ice thickness recorder capable of providing data at six-hourly or even more closely spaced time intervals. Essentially, Untersteiner's basic method described above was improved and completely automated.

The diagram, Figure 1, and photograph, Figure 2, show the essential details of the instrument, whilst Figure 3 shows the actual installation at Mawson. The apparatus consisted

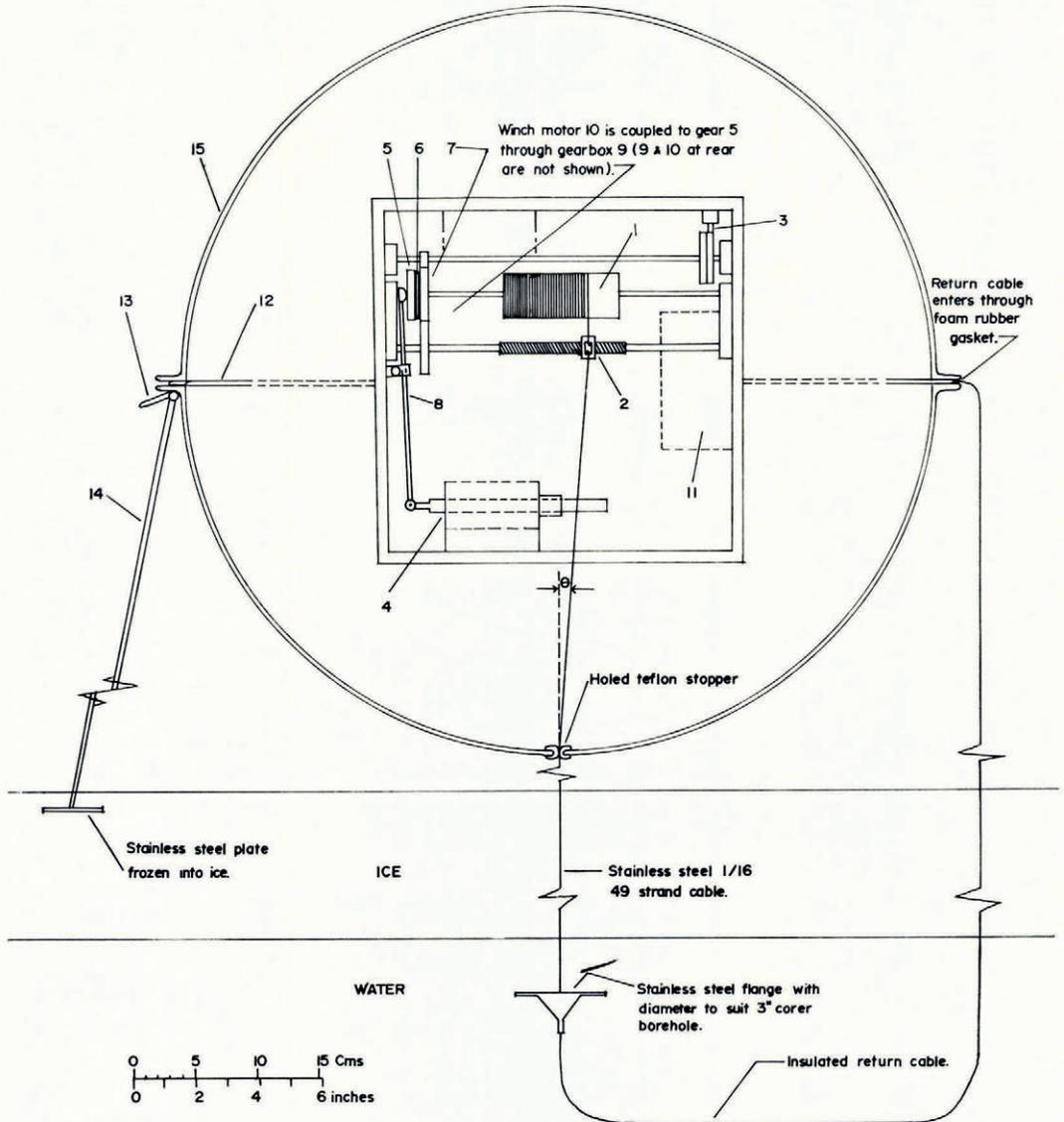


Fig. 1. Cross-section through sea-ice thickness gauge showing principles of construction and installation.

The key to the numbers shown on the diagram (as well as the photograph, Figure 2) is given below:
 1, Cable winch. 2, Cable winding feed mechanism. 3, Star cam and micro-switch rotation transducer. 4, Clutch solenoid.
 5, Gear wheel driven by winch motor. 6, Nylon clutch facings attached to gear wheels 5 and 7. 8, Clutch linkage. 9, Gear
 box housed on winch motor 10 (both shown only in photograph, Figure 2). 11, 6 V transformer (with primary voltage
 controlled by remote adjustable 100–250 V supply) for cable heating. 12, Link between central mechanical assembly and
 outer perspex sphere. 13, Anchor point for guy wire (if required) welded to stainless steel legs, 14, which are attached to
 a rod encircling and supporting the outer protective perspex sphere, 15

of a stainless steel flange silver-soldered to a 49-strand flexible stainless steel cable $\frac{1}{16}$ inch (0.16 mm) in diameter. The cable passed right through the flange, which was installed below the ice-water interface, and both ends (the slack section being insulated with polyvinylchloride) returned through the ice to complete an electrical circuit at the main body of the

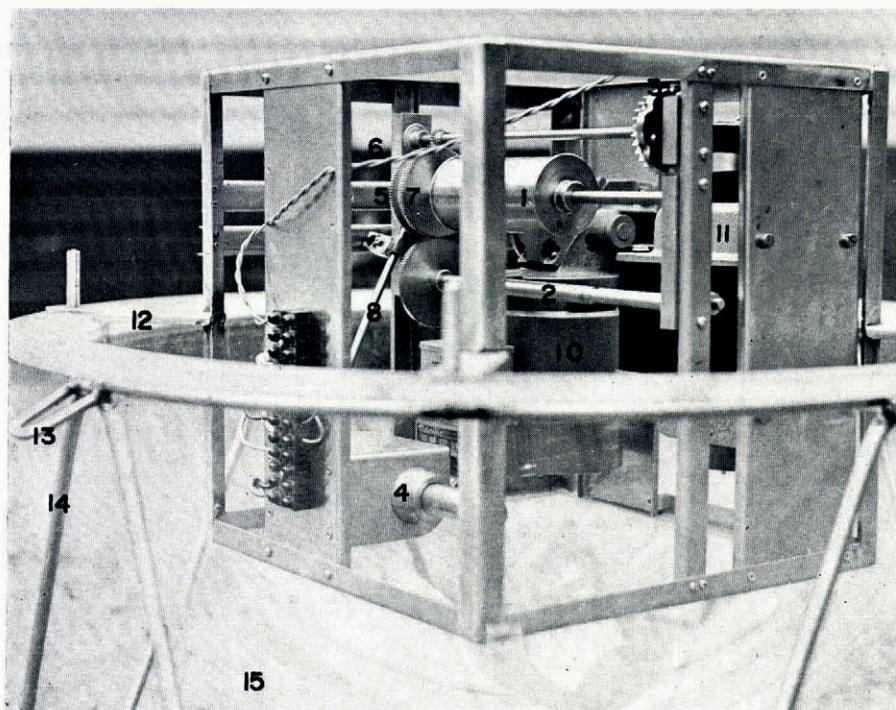


Fig. 2. Photograph of sea-ice thickness gauge with the upper perspex hemisphere and the cable removed. The key to the numbers is as for Figure 1

instrument above the ice. This body consisted of a perspex (polymethylmethacrylate) sphere 2 ft (60 cm) in diameter supported on stainless steel legs, this minimized the shading of the ice from solar radiation. A stainless steel winch inside was driven by an electric motor through a limited-slip nylon clutch, allowing the electrically heated cable to be wound on until the flange reached the ice-water interface. The ice thickness was therefore a monotonic, but not quite linear, function of the number of rotations of the winch drum, which were counted electro-mechanically by a printing impulse counter equipped with an additional digital time channel. In Figure 1, it is seen that the change in the angle θ which occurs during winding could lead to a maximum variation from linearity of 2 mm per metre change of ice thickness.

The printing counter was housed remotely from the mechanical sensor, together with an electro-mechanical programming unit which determined the duration and sequence of the separate operations as well as the actual monitoring frequency. This programmer consisted essentially of two synchronous motors I and II, having a 12 h and 5 min period of rotation respectively. Each motor drove a number of cams which actuated micro-switches. The following was the sequence pattern set up for the Mawson sea-ice study:

- (1) Cam-driven switch of motor I triggers the starting of motor II either every 6 or 12 h as required; this second motor then initiates the following switched operations at times t :
- (2) $t = 0$: Stainless steel cable heated electrically by a previously adjusted current.
- (3) $t = 20$ s: Winch motor started.
- (4) $t = 40$ s: Nylon clutch pulled in magnetically to commence winch rotation.



Fig. 3. Sea-ice thickness gauge installed at Mawson, showing heating light globe, power and command cable to control and recording unit on shore, with ice cliffs in the background

- (5) $t = 70$ s: Number of drum rotations (and fractions thereof) counted and printed, together with the time, on a paper strip chart.
- (6) $t = 90$ s: Operation (5) repeated to provide a check that the cable flange has reached the ice-water interface.
- (7) $t = 95$ s: Winch clutch released to allow flange to sink to its former lower starting position in the water.
- (8) $t = 100$ s: Winch motor turned off.
- (9) $t = 110$ s: Cable heating turned off.
- (10) $t = 115$ s: Printing impulse counter zero-ed in preparation for the next cycle.
- (11) $t = 120$ s: Motor II switched off and associated circuits reset to permit commencement of next cycle by operation (1).

A single 60 W light globe kept the interior of the perspex sphere sufficiently warm to keep the electrical and mechanical components functional. The small teflon (polytetrafluoroethylene) holed stopper at the bottom of the sphere was important in allowing the exit of the heated cable as well as in excluding excess brine otherwise transported by the cable to the winch and counting mechanism.

Results of the data provided by one season's fault-free continuous operation at Mawson in 1964 have been discussed in detail by Weller (in press), who also showed, by frequent reference to bore-hole ice thickness measurements, that the automatic gauge did not detectably affect ice growth.

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