

PROPOSALS FOR MEASURING THE THICKNESS OF ICE SHEETS

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INTRODUCTION

Fresh water ice abounds in Canada and the northern parts of the United States, yet we know so little about it, either qualitatively or quantitatively. Hydrologists expend considerable effort to measure snow depth and quality with a view to predicting spring run off, but little is done to measure ice thickness on lakes or streams or the type of ice, despite the fact that flooding is profoundly effected by ice conditions. The whole process of breakup may be better understood if antecedent ice conditions are known. Ice is used extensively for transportation arteries in the north and is increasingly in use in the south, by ice fishermen, snowmobilers and cross-country skiers. When is the ice safe? How long until it breaks up? These are becoming almost common questions today in the northern half of this continent. (Appendix 1 is a Russian answer to safety of ice.)

This paper is not a scientific treatise; rather, the authors wish to share with others their experience in measuring fresh water ice thickness over a period of four years. It is hoped that the simple methods for measuring ice thickness which are outlined herein may lead to a more extensive measurement of ice thickness being taken as a matter of course in hydrologic and other surveys.

METHODS OF MEASURING ICE THICKNESS

Traditionally, measuring the thickness of an ice sheet involves making a hole in the ice and inserting a shovel or some crude gauge in the hole. At best this is a tedious process and for years men have striven to develop easier and remote methods of measuring ice thickness. Most of these have failed for one reason or another, but there is a new idea every year.

One scheme that bears mentioning was a project, undertaken by an air force during World War II, to develop a device which when dropped from an aircraft would signal whether the ice was safe for landing. After some considerable investigation, involving ultrasonics and the most sophisticated instrumentation of the day, the solution which was recommended required each aircraft to carry stones of appropriate weight which were to be dropped from a given altitude over the ice sheet. If the stone went through the ice sheet - don't land!

The authors were faced with the necessity of measuring ice thickness in connection with a project respecting static ice forces. They did not have the resources to develop sophisticated measuring techniques so they had to rely on their ingenuity and use common materials.

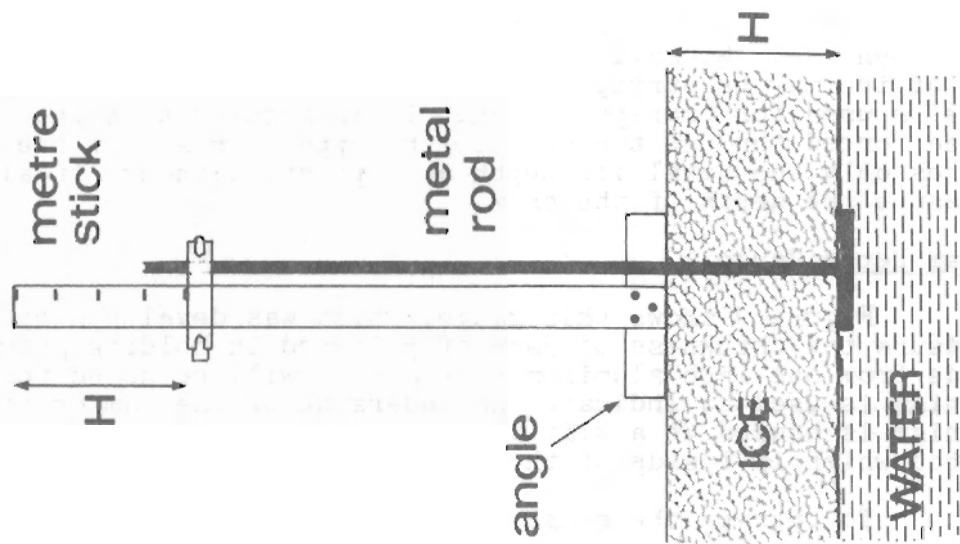
1. Meter Stick Gauge

This gauge, shown in Figure 1, consists of a meter stick to which an aluminum angle is attached at the foot. A brass (or aluminum) rod, with a T-bar on its lower end, passes through the angle and through a metal collar

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fig. 1
Metre Stick Gauge
for Ice Thickness



around the meter stick. The collar may be secured to the rod by a set screw.

To use this gauge -

- (a) a slit is cut through the ice by a chain saw,
 - (b) the T-rod is lowered into the slit until the cross is below the ice,
 - (c) the rig is turned through 90 degrees with the foot angle across the slit and the meter stick vertical, and
 - (d) the rod is raised until the T touches the under side of the ice,
- whereupon, the reading on the meter stick is noted.

The zero may be set at any convenient value, depending on the purpose of the measurements. For example, if only the change in ice thickness is required, then at the very first reading the collar may be set to some convenient integer on the meter stick and subsequent readings will indicate the change in the thickness in the ice sheet.

This is an absurdly simple device which is very portable, accurate and inexpensive. Normally, a reading takes less than two minutes. A large sheet of ice may be surveyed quickly by one person, especially if a snowmobile is used for transportation. It is assumed that the foot of the gauge will be forced through the snow to the upper surface of the ice. This gauge measures only the total ice depth at a point, although it also may be used to measure the depth of the snow.

2. Jam Depth Gauge

Figure 2 shows this gauge, which was developed by Kennedy (1962), to measure the thickness of jams of pulpwood in holding grounds. The gauge is made from one inch aluminum pipe and it will be noted that a retractable mechanism is used to indicate the underside of the jam or ice sheet. The mechanism is housed in a slit at the lower end of the gauge and is actuated by a rod which is inside of the pipe.

To operate the gauge -

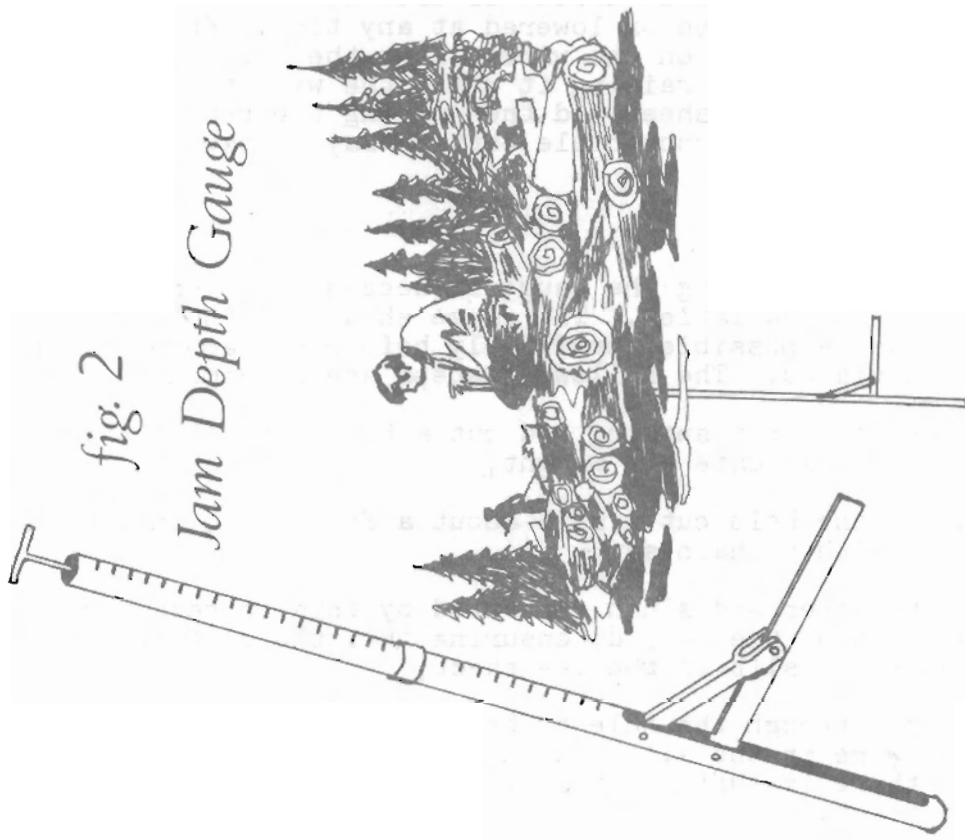
- (a) about a four inch hole must be drilled or cut through the ice sheet,
- (b) the gauge is inserted in the hole with the actuating rod pulled up,
- (c) when the lower part of the gauge is under the ice sheet the actuating rod is lowered and the foot pops out at right angles to the pipe, and
- (d) the gauge is then raised gradually and, when the actuating rod moves, the foot is in contact with the under side of the ice sheet,

whereupon, the ice thickness is read off the scale on the pipe (and the water level also may be noted).

This gauge may be made up in as many sections as required to measure the ice thickness. It is very useful for surveying the under side of the ice sheet at pressure ridges. It is a very rugged and reasonably light device, and is almost foolproof in operation.

3. Electric Ice Thickness Gauge

The two gauges described above have the disadvantage of requiring a hole to be made in the ice sheet each time they are used. This takes time



and usually disturbs the character of the sheet particularly at the top. An electric gauge (after Untersteiner (1961)) allows readings of three important variables to be taken at a fixed point. These are -

- (a) the thickness of columnar ice,
- (b) the thickness of snow ice, and
- (c) the depth of the snow.

The gauge, shown in Figure 3, may be installed at a site and left there during the ice season. Readings of the variables may be taken as required. Basically, the gauge consists of a length of piano wire to which a weight is attached. An electric current is used to melt the ice around the wire so that it may be raised or lowered at any time. Knowing the distance from the weight to a mark on the wire allows the ice depth to be determined by heating the wire, raising it until the weight comes in contact with the under side of the ice sheet and then noting the reading at the reference mark. A twelve volt snowmobile battery may be used as a power source.

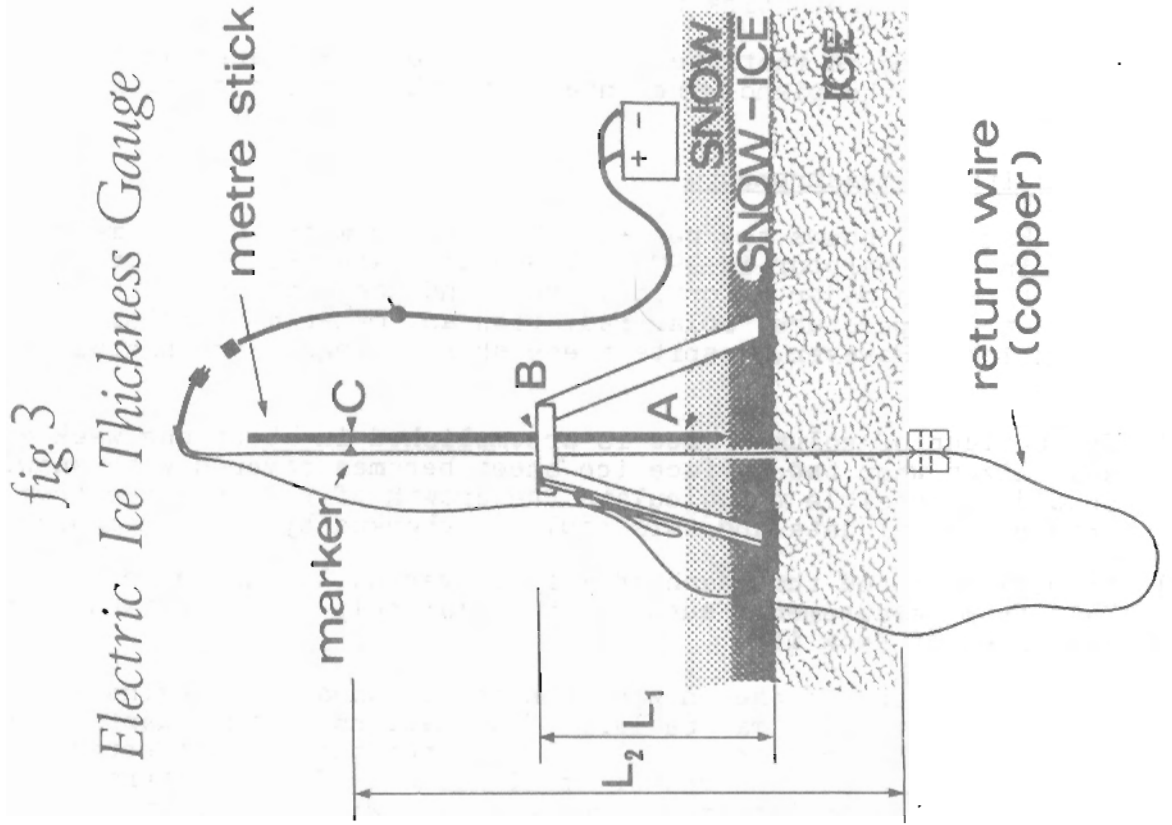
(i) Installation of gauge

Some care in installing the gauge is necessary to ensure accurate measurements of the three variables. The gauge should be installed as early in the season as is possible, preferably before any amount of snow or snow ice has accumulated. The following steps are recommended -

- (a) pick a day when it is not snowing and cut a hole through the ice sheet large enough to accommodate the weight,
- (b) from one side of the hole cut a slit about a foot or so in length through the ice with a chain saw,
- (c) clear up all the water and slush generated by this process and then freeze in the feet of the tripod, ensuring that the slit in the tripod is directly over the slit in the ice sheet,
- (d) lower the weight through the hole to below the ice sheet and then introduce the piano wire in the slits in the ice and tripod respectively, ensuring that there is sufficient slack in the return both above and below the ice sheet,
- (e) take a reading of the ice thickness with say a meter stick gauge, if there is snow ice, remove a sample from nearby and measure the thickness of the snow ice, and
- (f) from the measurements in (e) the constants L_2 and L_1 (and thus $L_2 - L_1$) may be determined.

(ii) Reading the gauge

- (a) Measure the snow depth at three points around the tripod, reading "A",
- (b) insert the meter stick in tripod and force it down to the ice surface and record reading "B" (Note: $L_1 - B =$ snow ice thickness),
- (c) connect the gauge to the power source ensuring that the switch is OFF,
- (d) switch ON for one second and lift the weight until it touches the under side of the ice sheet, switch OFF, record reading "C", and



(e) switch ON for one second and lower weight, switch OFF.

Ice thickness is $(L_2 - L_1) - (C - B)$
Snow ice thickness is $(L_1 - B)$; Snow depth is "A"

Notes:

- a. If power is applied for very long the drain on the battery will be excessive. Some experimenting is required to determine the safe duration of power ON, because this depends on the wire size and the output of the power source. In general, a small upward force should be applied to the handle at the top of the wire, then switch ON and when the weight can be lifted, switch OFF. Similar procedures should be followed when lowering the weight.
- b. The top of the weight should be coated with varnish or its equivalent so that it will not stick to the under side of the ice sheet.
- c. It should be noted that the corners of the weight are carefully rounded where the piano wire enters it; this avoids cutting the piano wire.

(iii) Results of measurements

Figure 4 shows the results obtained from one set of measurements taken in Kingston harbour in 1972. These data are only incidental to the work that formed a major effort that year and they have not yet been correlated to temperature, solar radiation and other meteorological conditions for the period. However, despite these shortcomings, some useful remarks may be made:

- (a) The buildup of columnar ice is accomplished in about one week and stabilizes when the surface ice sheet becomes covered with snow. It should be possible to calculate the growth of columnar ice from meteorological data and this could be checked by field measurements.
- (b) It will be noted that each snow fall eventually turned into snow ice. Data from measurements such as these may help in understanding the phenomena of snow ice.
- (c) Towards the end of the snow season the columnar ice begins to melt slowly whilst there may be large fluctuations in the quantity and quality of the snow ice. It will be noted that the effective ice thickness on about the 2nd of April was only 8 centimeters of columnar ice, plus another 8 of snow ice, overlain with rotten snow ice (not recommended for automobiles!).

COMMENTS

1. All the gauges described herein are inexpensive and are easy to install and operate.
2. In the case of the electric gauges, they are not worth salvaging and so there is no need to remove them; thus, readings may be taken until the ice is unsafe to walk on. A number of these gauges will be used in the St. Lawrence River during the 1972-73 ice season by Dr. R. O. Ramseier (Canada Department of the Environment).
3. The electric gauge gives, at one location, the values of three important parameters - columnar ice thickness, snow ice thickness and snow depth.
4. More sophisticated gauges have been made which have worked very well; an example of these is given by Schwerdtfeger (1968). This paper

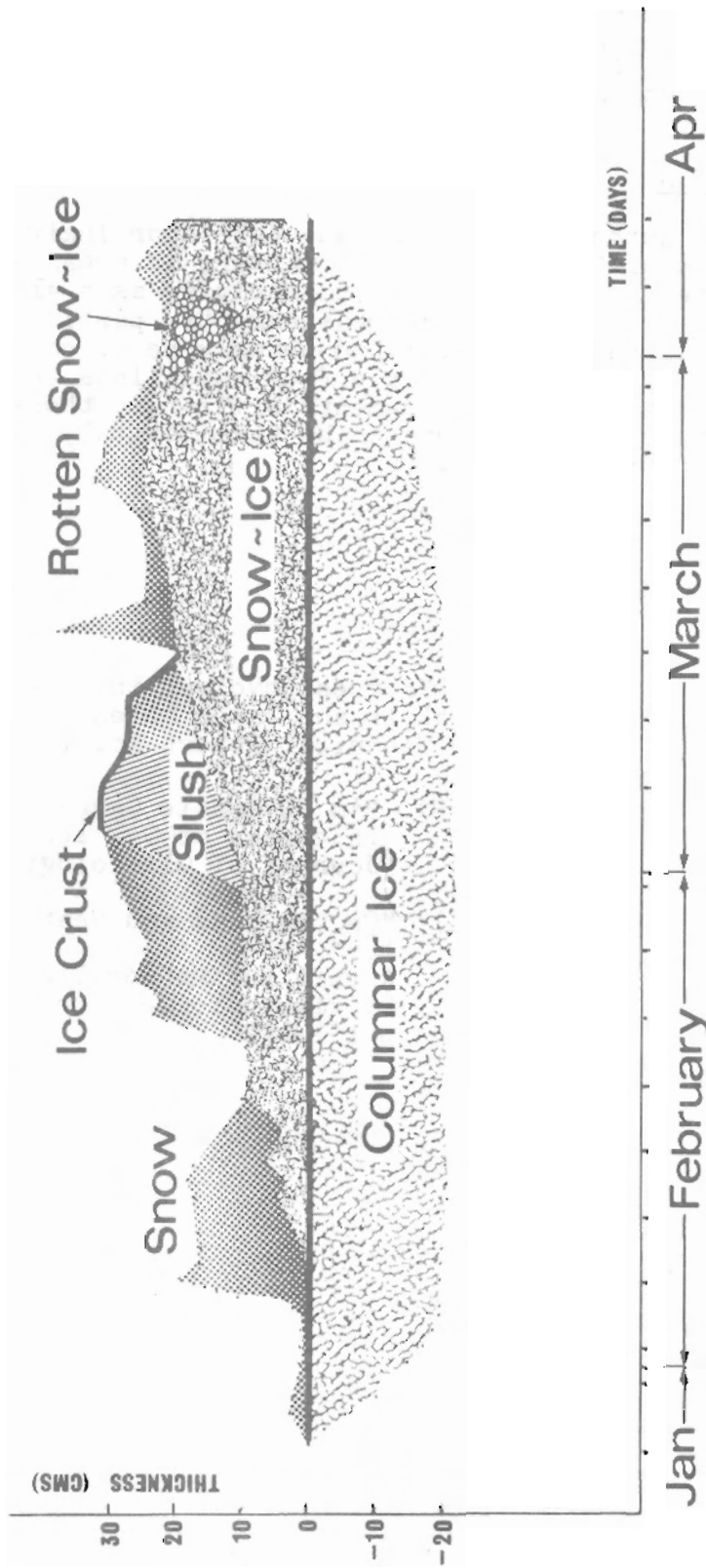


fig. 4 History of Ice Growth

described a similar gauge having a recording apparatus which is actuated at appropriate intervals during the day. However, as described, it is a very bulky device and required an external power supply. Some thought might be given to powering one of these devices with a wind driven generator.

RECOMMENDATIONS

The authors urge those who take hydrological and meteorological data on a regular basis during the winter, in areas where ice sheets are present in the lakes and rivers, to include, as a matter of routine, ice thickness measurements. These measurements, particularly after an extensive body of data is gathered, will undoubtedly be of considerable interest and use to a growing number of people from scientists to recreational skiers and snowmobilers. Using instruments similar to those described in this paper allow these measurements to be taken quickly and at a minimum cost in terms of instrumentation.

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APPENDIX 1

CARRYING CAPACITY OF RIVER ICE¹

Load	Gross Weight Lb.	Axle Rear Lb.	Loads Front Lb.	Minimum Thickness of Ice Inches	Minimum Distance Between Loads Feet
One soldier	220			2	15
One horseman	1,100			4	30
Two wheeled cart	1,100			4 $\frac{3}{4}$	35
Ammunition cart	1,800			6	45
Wheel loads	7,700	6,000	1,700	10	45
" "	13,000	8,800	4,200	12	60
" "	33,000	22,000	11,000	24	90
Caterpillar treads	7,700			8	45
" "	22,000			12	60
" "	55,000			24	125
" "	100,000			27 $\frac{1}{2}$	150

¹ Richter, G. D. "Snow Cover Its Formation and Properties"
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USSR 1945, Table 24, p. 44