The lolly ice met with in large quantities in the Straits is very difficult to force a ship through. There is no give to it and it squeezes up under the ship, forcing out the necessary water to float the ship. When any headway is made, this soft ice is carried along with the ship, rendering progress almost impossible. One of the great problems of the winter navigation of the Straits is the handling of the ship in the soft sponge-like lolly ice. It is formed chiefly over the surface with a high cold wind, and agglomerates, forming large masses, which attach themselves to the hard pans and make them very difficult to break. The lolly ice is really salt water frazil ice, and can be handled in the same way. I have recommended the use of steam or hot water around the ship to prevent the ice from adhering, and believe that such a method would very considerably assist navigation. Further on it will be seen what a great effect the circulation water from the pumps has on frazil ice.

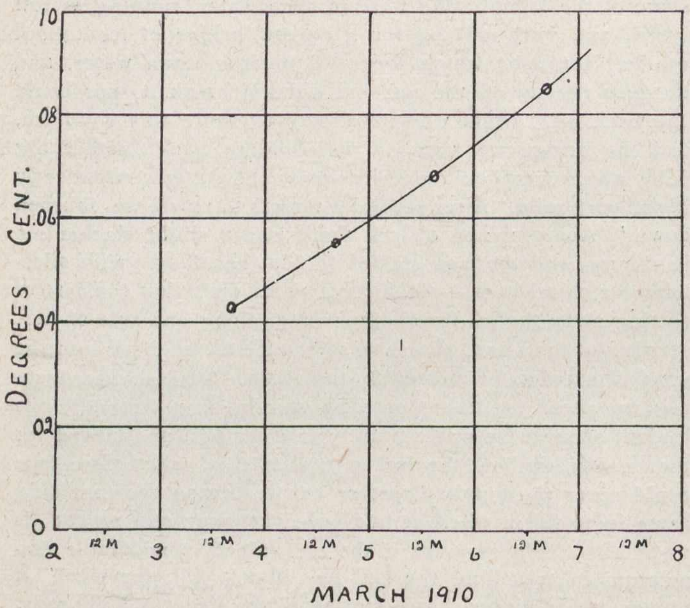

Fig. 7.—Curve showing rise of water temperature in the channel at St. Nicholas due to the open river and the sun.

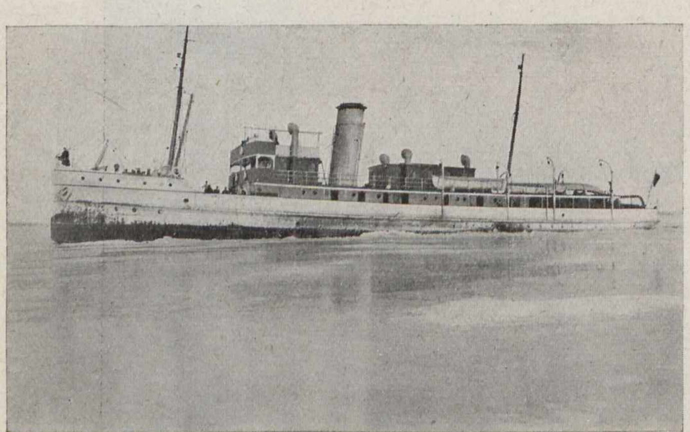

Fig 8.—C.C.S. "Lady Grey" at the end of a ram on the ice of Lake St. Peter. Engines are reversed in order to back off. Clear blue ice 18 inches thick.

Fresh Water Ice.

Surface Ice:—In fresh water, the surface ice is brittle, even in the thinnest layers. A wave set up in the water cracks it, and a ship plows through it with a hard rattling sound, totally wanting in salt water ice.

Sheet ice forms only when the surface is still, the water at or near the freezing point, and the air temperature below 32° F. The current must be small (one mile per hour or less) and all conditions must obtain before ice is able to spread. Wind waves will prevent surface ice from forming. Water temperatures above 32° F. will render ice possible only at air temperatures low in proportion to the slight elevation of the water temperature above the freezing point. Thus, for various air temperatures there are corresponding water temperatures, measured in hundredths of a degree, which will effectually prevent surface ice. It sometimes happens that open patches of water occur in a lake or river otherwise frozen over. These are due to warmer currents coming to the surface, either by the undercurrents being deflected upwards by a shoal, or by a warm spring of water in the lake. The first crystals of ice on still water form with the long axis (or principal axis) parallel to the surface. As soon, however, as these become cemented together the sheet thickens by conduction of heat through the ice from the water to the cold air. Such ice is always noticed to have its crystalline axis at right angles to the plane of freezing, and it is this that forms the clear hard ice. A surface sheet grows rapidly at first, but more and more slowly as it thickens. If the underwater is at 32° or a little below, as it sometimes is (a few thousandths of a degree), then there is no limit to the thickness of the ice. More frequently, a lake or river frozen over is a little above the freezing point, and hence a limiting thickness of ice results. This limiting thickness depends on the mean air temperature and water temperature elevation measured in hundredths of a degree. Thus the following table gives approximately the limiting thickness which ice will attain for various air and water temperatures. These data were obtained from observations made by my assistant, Mr. L. V. King, on the rate of growth of surface ice in the St. Louis Basin, at Quebec.

Table 1.—Limiting Thickness to Which Surface Ice Can Grow.

Limiting thickness.	Water temp. + .01° C.	Water temp. + .02° C.	Water temp. + .03° C.
2 inches	29.4° F.	25.2° F.	21.7° F.
1 foot	20.5° F.	9.3° F.	-2.2° F.
2 feet	11.1° F.	-9.8° F.	....

There is no doubt that surface ice prevents the formation of fine floating ice (frazil ice), but it also prevents access of the sun's heat to the water, and will retard the disintegration of ice in the spring. The effect of the sun in elevating the temperature of the water, even in the severest weather, is very remarkable, and has not been sufficiently appreciated. I am inclined to believe from recent observations that, on the whole, there would be less ice formed in a river kept continually open than in one which is allowed to freeze over.

Frazil Ice.

Wherever a river flows too swiftly to freeze, then surface contact of cold air produces fine needle crystals of ice, which are called "frazil ice." A rapid or water chute forms abundant surface action, and a correspondingly large amount of frazil. Whenever the cold is very great, the running water may be cooled a few thousandths of a degree below the freezin point, in consequence of which frazil production is rapid throughout the whole mass of water. These crystals grow and become cemented together into lumps. They are carried down by currents and stick to objects immersed in the water which are also supercooled. Frazil ice forms an obstacle to hydraulic development, but fortunately not now considered a serious one. The temperature effect is so small