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ICE-CUTTING SHIPS AND HIGH-PRESSURE WATER JETS FOR CUTTING ICE

by

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Translated by

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ICE-CUTTING SHIPS

Icebreaker operations in consolidated, stationary ice (fast ice) are very difficult, especially in winter in freezing conditions. A clear track is not provided for the vessels following the icebreaker, as the channel formed remains filled with broken ice. Whereas the use of icebreakers is fully justified in pack ice, where the basic task is to move aside freely floating ice floes, for breaking fast ice they are not fully effective. It is essential to seek a better mechanical means of breaking fast ice.

One such means is the construction of special bow attachments or special ships in the form of an ice-cutter (proposed by the author in association with Z.I. Shvayshteyn and F.D. Sokolov).

The ice-cutting ship is a vessel equipped with a complex mechanism for cutting, breaking, and transporting the ice. It is designed to provide an open ice-free channel in fast ice for the passage and towing of ships.

The special feature of the ice-cutting ship is that by its forward movement it cuts a strip of ice supported at one end (a cantilever beam) rather wider than the ship itself. The cutting may be achieved by means of mechanical cutters, high-pressure hydraulic jets, or other applied physical principle. Owing to the forward motion of the ship and the configuration of the bow, which slopes at an angle of 15° to the sea surface, the ice strip is bent, reaches the critical point and breaks into pieces by its own weight.

In view of the practical problems of extending the navigation season on the one hand in arctic harbors, bays, and straits, and on the other in non-arctic sea and river harbors and other water bodies subject to freezing, two types of ice-cutter may be recommended, as follows:

Type 1 — For non-arctic harbors, where periodic clearing of the channel is required throughout the winter.

Type 2 — For northern and arctic bays and straits, where repeated clearing is not required, but where the thickness to be cleared is 1.5 to 2.0 m.

The first type would cut the ice by means of mechanical saws. The strip (cantilever) of ice moves up onto the ship's bow and breaks. Then the plates of ice are carried up conveyor belts fitted with special gripping devices, slide over a smooth sloping surface and are thrown off on both sides of the ship beyond the edges of the channel just cut. Fig. 1 shows a schematic diagram of this type of ice-cutter.

Fig. 2 is a photograph of a model of Type 1 being tested in ice. The experiments showed that owing to the freezing conditions the pieces of ice thrown aside increase the total thickness of the ice beyond the edges of the channel and so reinforce the channel. Fig. 3 shows the channel after repeated clearings.

The second type of ice-cutter is designed as a vessel to be either self-propelled or pushed. This type is based on the principle of combined hydraulic and mechanical breaking of the ice and the disposal of the broken pieces under the ice. As it was considered that cutting of thick ice by mechanical saws would be difficult, it is proposed to cut the ice strip by means of supersonic water jets (see last section, below). This will considerably simplify the design of the cutting mechanism and raise the efficiency of its operation.

Fig. 4 shows a schematic diagram of an ice-cutter of the second type. Because the bow of the vessel has a downward-sloping surface with an angle of 15° to the horizontal, the strip of ice cut by the jets is immersed, the ice reaches a critical bending point and breaks. Then by means of special guides mounted on the bottom the pieces are pushed aside and under the ice. Fig. 5 shows the channel left by the passage of a model of Type 2.

The principle of breaking and removal of ice by means of the ice-cutter has a number of advantages over the icebreaker. These advantages were shown in model experiments and are as follows:

a) The ice-cutter forms a straight, even channel, wider than that cut by an icebreaker;

b) The ice-cutter expends less energy on the whole operation — cutting, breaking, and removing the ice — than does the icebreaker.

We know from the study of statics that to break a cantilever beam demands an exertion of power several times less than that needed to break a plate or beam. By applying this principle, the ice-cutter requires half the power that the icebreaker needs to break ice of the same thickness. Calculations showed that to break ice one meter thick and leave a clear channel an ice-cutter needs 4000-4500 h.p., whereas an icebreaker for the same conditions demands 10,000 h.p.

The results of laboratory tests are summarized in Table 1.

c) The channel left by the ice-cutter remains clear and suitable for the passage of even the most thin-skinned ships. The channel left by an icebreaker is full of broken ice and passable only to ice-class ships sufficiently reinforced. In many cases the passage of ships is difficult or even impossible.

Thus the ice-cutter would make it possible:

a) to cut channels in sea and river bays for the passage of ships into ports in winter;

b) to cut fast ice and so allow earlier navigation in arctic seas;

c) to cut channels in the autumn and so extend the navigation season after the ice forms;

d) to cut channels in reservoirs in winter.

It must once more be emphasized that the advantages of the ice-cutter are only for work in continuous, stationary fast ice. In pack ice, where it is essential to have a powerful ship capable of moving aside drifting ice, the icebreaker obviously will remain the only type of vessel for a long time to come.

HIGH-PRESSURE WATER JETS FOR CUTTING ICE

Hydraulic excavators have been widely used in earth- and peat-cutting operations. The ground is eroded by a stream of water at a pressure of 30 to 50 atmospheres.

The idea of cutting ice by means of high-pressure water jets originates with the engineer V.P. Chizhikov, who conducted a series of experiments. A stream of water up to 50 atm. pressure was directed at the ice and was found to cut it to a depth of from 0.2 to 0.8 m. Further experiments pointed to the necessity of raising the water pressure. Special nozzles were prepared which permitted a pressure of up to 250 atm. The cutting effect on the ice rose considerably. With a cutting speed of 0.3 m./sec. such a jet cut into pieces ice samples of several cubic meters volume. Further work was carried out on the icebreaker Yermak. A special apparatus was built consisting of two aviation diesel engines of 1050 h.p. each.

The water, pumped through pipes at pressures up to 250 atm., was distributed to three hydraulic excavators erected on the deck. Experiments showed that the water jets cut the ice. The ice broke not along the line of incision but along the line of greatest stress. If the incision were to be made in the zone of stress the effect would be greater.

Recently, gas jets at supersonic speeds have come into use for cutting rock and concrete. The jets are at a high temperature and results are extremely encouraging. Obviously, on the analogy of these gas jets, it would be possible to develop water jets at sonic and supersonic speeds, and if a gas jet at such speeds can cut granite, then unquestionably ice can also be cut. The combination of the mechanical action of the jet with the addition of supersonic oscillations would considerably increase the destructive effect on the ice.

TABLE 1

Limiting values of thickness and strength of ice in laboratory tests of icebreaker and ice-cutter models

Model type	Force required to move model when working in ice (kg.)	Limiting thickness of ice (cm.)	Strength of ice (kg./cm.^{2})
Icebreaker	18.0	1.8	Model ice * 4 kg./cm.^{2}
Ice-cutter Type 1 (with hanging vertical saws)	3.8	3.5	Model ice 4 kg./cm.^{2} Freshwater ice 10 kg./cm.^{2}
Ice-cutter Type 1 (with disc saws)	3.0	4.0	Model ice up to 4 kg./cm.^{2} Freshwater ice up to 20 kg./cm.^{2}
Ice-cutter Type 1 (with band saws)	3.0	6.0-8.0	Model ice 1.5-2 kg./cm.^{2}
Ice-cutter Type 2 (with under-water circular saws)	5.0	6.0	Model ice up to 4 kg./cm.^{2} Freshwater ice 20 kg./cm.^{2}

* This is salt-water ice scaled to the stated strength (Trans.).

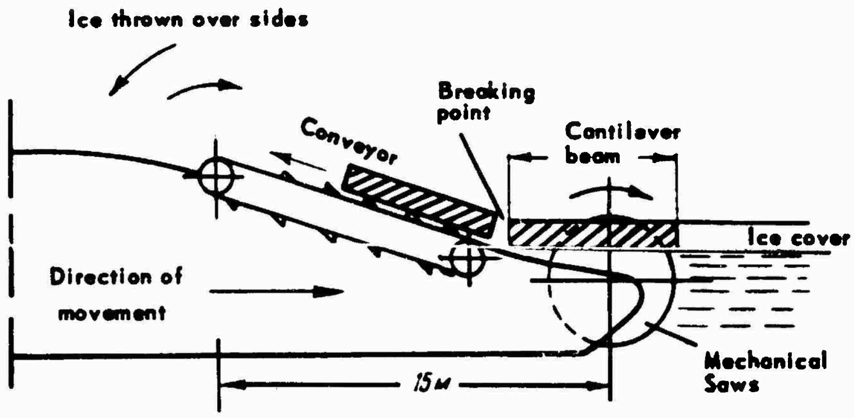

Fig. 1. Sketch showing operating principles of ice-cutter Type 1.

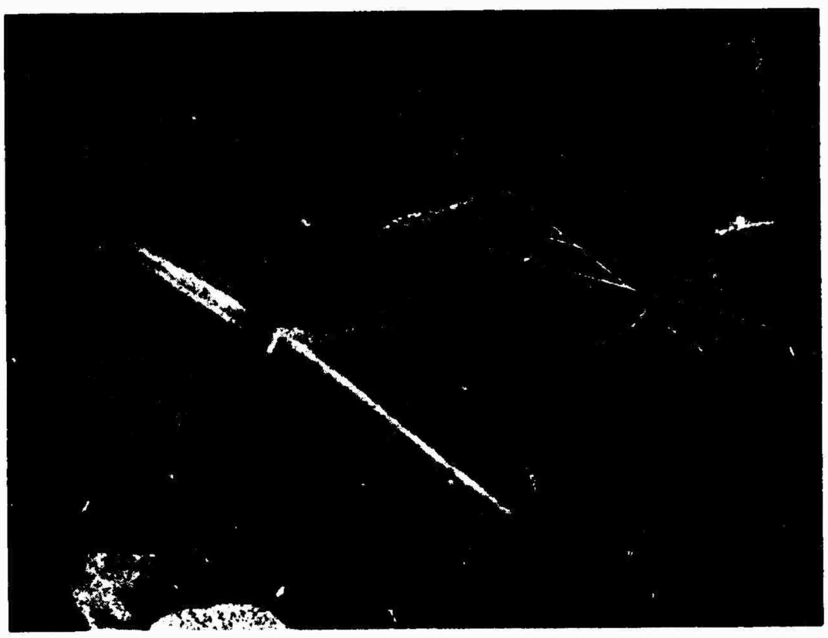

Fig. 2. Model of ice-cutter Type 1 breaking ice (photograph taken in testing tank).

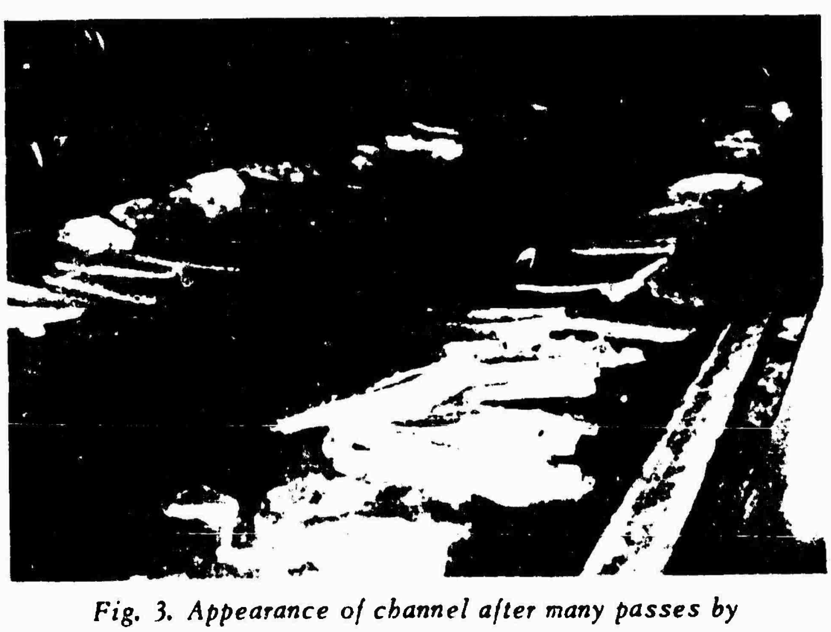

Fig. 3. Appearance of channel after many passes by ice-cutter Type 1.

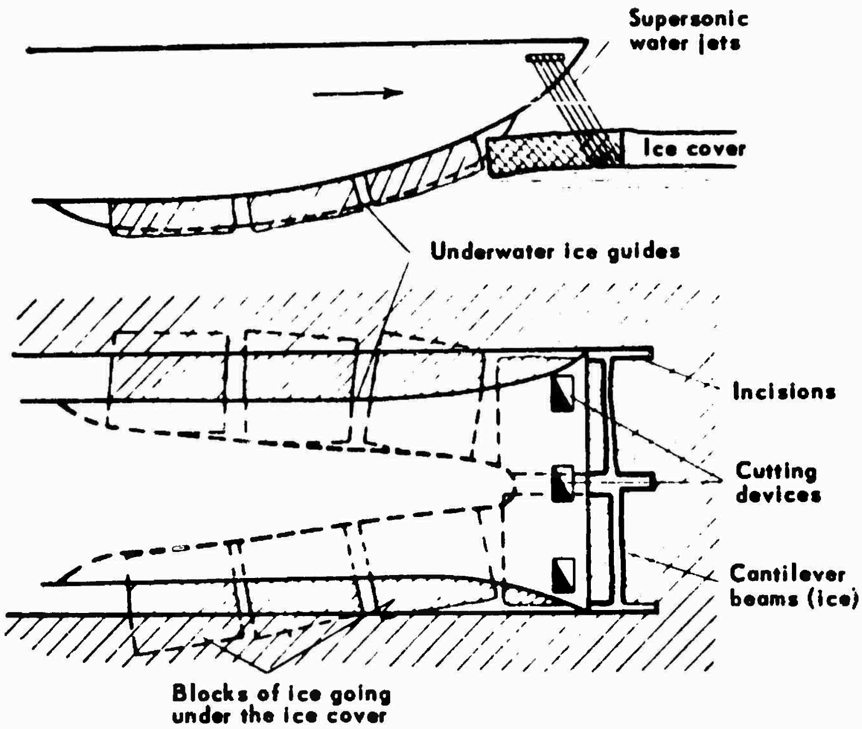

Fig. 4. Sketch showing operating principles of ice-cutter Type 2.

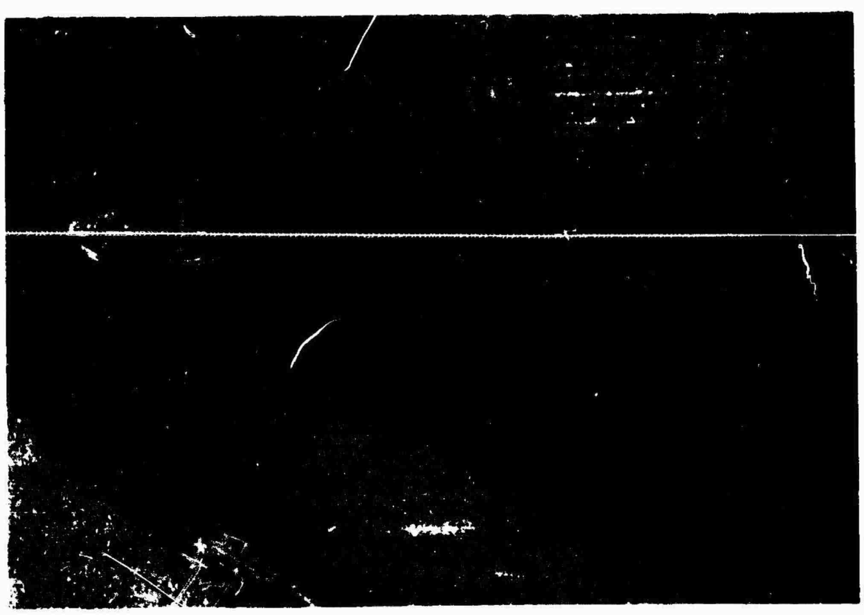

Fig. 5. Appearance of channel formed by ice-cutter Type 2 (photograph taken in testing tank).