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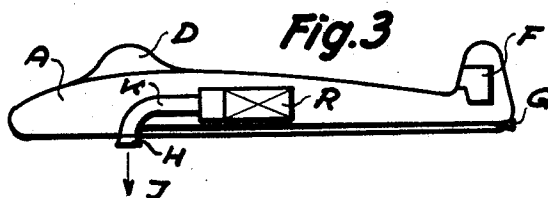
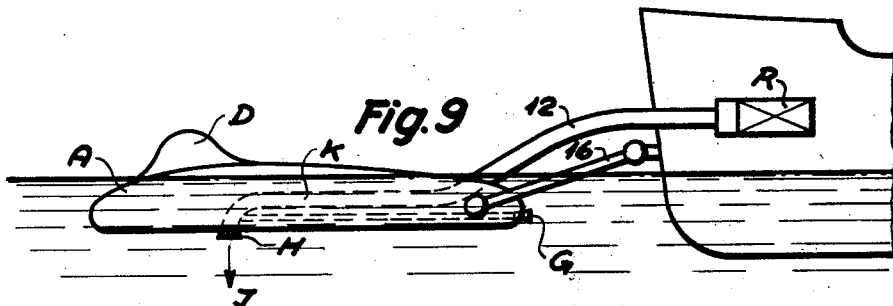
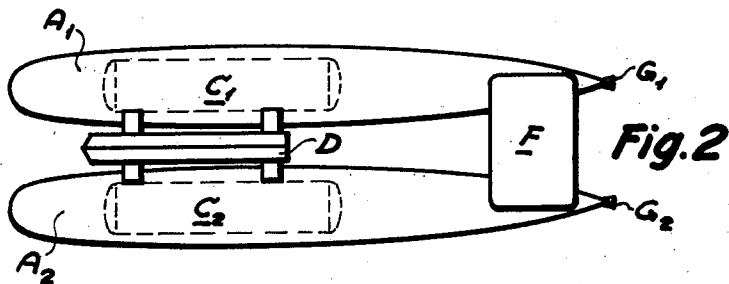
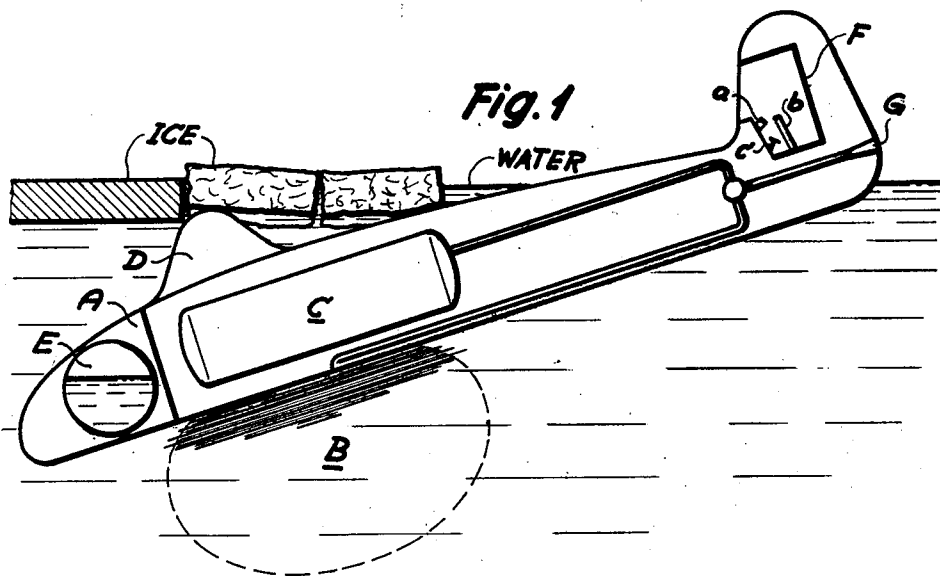
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ICEBREAKERS

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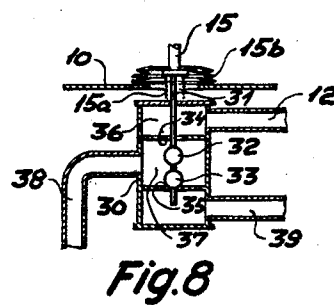
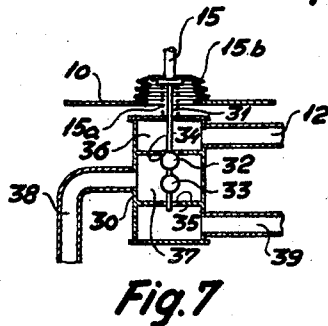
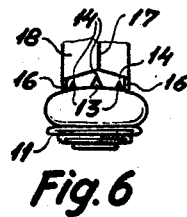
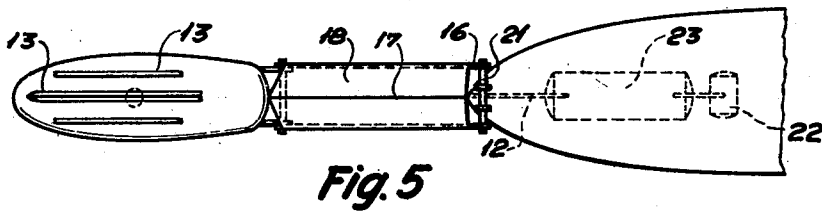
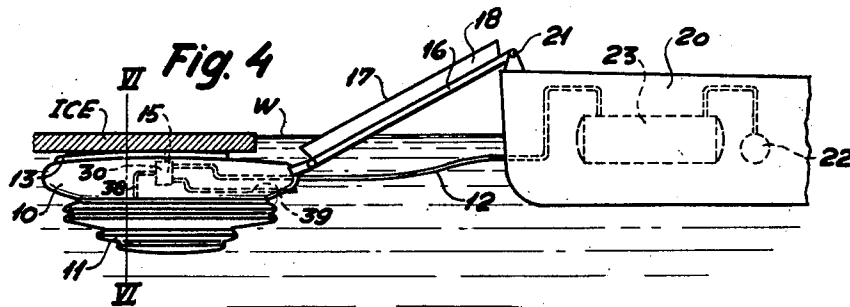
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ICEBREAKERS

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The invention relates to icebreaking apparatus which comprises a submersible vessel which is provided with means for varying the buoyancy thereof.

Thus, when the vessel is submerged beneath the ice floe and subsequently the buoyancy of the vessel is increased—either by the evacuation of ballast water or, as in a preferred embodiment of the invention, by inflating an expansible bottom portion or “belly” of the vessel—an upwardly directed breaking force will be exerted on the underface of the ice floe.

In accordance with the above it is an object of the invention to break up ice floe by exerting an upward breaking force on the floe.

Numerous advantages are obtained by breaking the ice from below instead of crushing it from above as in conventional icebreaking methods, and these advantages and the various features of the invention whereby they are achieved will appear from the following description of the embodiments of the invention illustrated in the accompanying drawings. In the drawings:

FIG. 1 is a sectional side view of a submersible icebreaking vessel according to one embodiment of the invention;

FIG. 2 is a plan view of a twin submersible icebreaking vessel in a modified embodiment of the invention;

FIG. 3 is a sectional side view of a submersible icebreaking vessel in a further embodiment of the invention;

FIG. 4 is a sectional side view of a still further embodiment showing an inflatable submersible vessel and a surface vessel swingingly connected with the breaking vessel;

FIG. 5 is a plan view of the embodiment shown in FIG. 4;

FIG. 6 is a section taken along the line VI—VI in FIG. 4;

FIGS. 7 and 8 are sectional side views schematically illustrating a control valve for an automatic inflation device according to the invention showing said valve in two positions thereof; and

FIG. 9 is a sectional side view showing a modification of the embodiment illustrated in FIG. 3.

Fundamentally, the invention comprises three types of submersible icebreaking vessels:

Type I.—The hydraulic type, in which the buoyancy of the submersible icebreaking vessel is varied by varying the contents of ballast water in ballast tanks incorporated in the body of the vessel.

Type II.—The pneumatic type, in which the buoyancy is varied by inflation of an expansible body forming part of the bottom of the submersible vessel.

Type III.—The jet type, in which the buoyancy is varied by means of a fluid jet which is discharged through a downwardly directed exhaust nozzle at the bottom of the vessel.

Type I is schematically illustrated as an additional feature of the vessel shown in FIG. 1.

Type II is illustrated in FIGS. 1, 2, 4, 5 and 6.

Type III is shown in FIGS. 3 and 9.

Referring to the drawings and, more particularly, to FIGS. 1 and 2 thereof, the icebreaker comprises a submersible vessel A substantially in the form of a conventional submarine and comprising an expansible and inflatable bottom portion B, hereinafter referred to as “the belly,” a source of compressed gas C which may be at-

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mospheric air, a reinforced upper shell portion comprising an icebreaking cam D, one or more water ballast tanks E in the front of the vessel A, a control cabin F located at the rear end of the vessel A in an elevated part of the shell thereof, and an exhaust nozzle G at the rear end of the vessel A.

In the embodiment of the invention according to Type I, the belly B may be omitted and the vessel operated solely by variation of the buoyancy by pumping ballast water into or exhausting ballast water from the tanks E. When removing ballast water from the tanks the buoyancy is increased thereby providing an upwardly directed breaking force exerted on the underface of the ice through the breaking cam D.

However, since the space available for locating the ballast tanks will normally be limited and since the breaking force depends on the volume of the ballast tanks, icebreakers of Types II and III appear to be preferable. In fact, in these types of icebreakers, to which the following description will be confined, the breaking force may be increased to relatively large magnitudes by suitable dimensioning of the belly or by increase of the power jet generation plant used in Type III.

Type II, as illustrated in FIGS. 1, 2 and 4, depends for its operation, on the inflation of the belly B which comprises a substantially balloon-shaped body of a kind similar to that used for observation balloons.

The source of compressed air C may be of any conventional type, and since the construction thereof forms no part of the present invention it is illustrated schematically as a reinforced storage container for accumulating compressed air under high pressure. Compressed air derived from this container and directed to the exhaust nozzle G through suitable control valves in the cabin F may be used for the propulsion of the vessel A until it has reached its operation position adjacent an ice floe ICE, as shown in FIG. 1. In this position the vessel is submerged beneath the ice to allow the breaking cam D to contact the underface of the ice. The belly B is now inflated by connecting the interior thereof with the compressed air container C through suitable valve arrangements *a*, *b* and *c* in the control cabin, and the belly swells to the position indicated by the broken lines in FIG. 1, thereby tending to raise the vessel to cause the latter to exert a breaking force on the ice through the cam D corresponding to the increased buoyancy of the belly.

The inflation of the belly may be controlled automatically by means of a pressure sensitive feeler device explained in the following with reference to the embodiment shown in FIGS. 4, 7 and 8.

When the ice has been broken, the air is exhausted from the belly B through the exhaust nozzle G, and the belly is deflated due to the pressure of the surrounding water.

The ice breaker is now ready for further submersion under the non-broken part of the ice where the operation just described takes place again in the same sequence.

The embodiment shown in FIG. 2 refers to the same type of submersible icebreaker as shown in FIG. 1 but differs therefrom in the provision of twin submersible vessels A1 and A2 arranged side by side with the belly and icebreaking cam located between them. With this arrangement, which is intended for exerting very strong breaking forces, an increased stability of the icebreaker is achieved.

It will be appreciated that submersible icebreaking as described above with reference to FIG. 1 provides substantial economical and technical advantages as compared with the conventional icebreaking methods depending on the use of very costly and powerful surface vessels for crushing the ice from above. In particular, it will be observed that the breaking force required for cutting up

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the ice from beneath will be lower than the crushing force, because in the latter case it is necessary to overcome the buoyancy exerted on the ice floe and on the vessel. Moreover, elaborate machinery is required for the propulsion and maneuvering of the conventional surface icebreakers which likewise require a comparatively large crew.

The embodiment of Type II illustrated in FIGS. 4, 5 and 6 is intended for relatively small units for icebreaking in small fjords or harbors where the freezing of the waters may cause considerable inconvenience, but generally does not justify the large costs of utilizing conventional heavy icebreakers.

This type of icebreaker depends on the use of an unmanned submersible vessel 10 provided with an inflatable belly 11 and connected with a surface vessel 20 by means of a pair of swingingly mounted beams 16 and a flexible conduit 12 connecting the belly of the vessel 10 with a source of compressed air comprising a conventional compressor 22 and container 23 located in the vessel 20. The vessel 10 is provided with icebreaking cams 13 and 14, as shown in FIG. 6, and further comprises a feeler element 15 for an automatic inflation device, the function of which will be described with reference to FIGS. 7 and 8.

The beams 16 connecting the vessels 10 and 20 carry a plough-shaped structure comprising a ridge 17 and two inclined faces 18. This structure operates as a shovel for lifting and removing the broken ice pieces floating in the space between the two vessels during the swinging movement of the beams.

The feeler element 15, as shown in FIGS. 7 and 8, is depressible and is mounted in the shell of the vessel 10 by means of a water tight compressible element 15b, a compressible spring 15b and a valve stem 31 operatively associated with the feeler element 15. The stem 31 extends into the housing 30 of a double valve comprising three chambers: an upper chamber 36 communicating with the compressed air conduit 12, an intermediate chamber communicating with a conduit 38 terminating at the interior of the inflatable belly 11, and a lower chamber communicating with a conduit 39 terminating at an exhaust nozzle, corresponding to G in FIG. 1, at the rear end of the vessel 10. Valve ports 34 and 35 cooperating with closing members 32 and 33 respectively mounted on the stem 31 are provided in the partition walls between the intermediate chamber and the upper and lower chambers.

With this arrangement there is provided an automatic inflating device which operates as follows:

When the feeler 15 is depressed by contacting the underface of the ice during breaking thereof, the stem 31 with closing members 32 and 33 is moved downward to the position shown in FIG. 8, where closing member 32 is removed from port 34 and closing member 33 closes port 35. Conduit 12 is connected with conduit 38 through chambers 36 and 37, and the belly 11 is inflated. The vessel 10 with breaking cams 13 and 14 is lifted upwardly by the buoyancy of inflated belly 11, the ice is broken and the feeler 15 is lifted by spring 15a carrying the stem 31 back to the position of FIG. 7. In this position the compressed air conduit is closed by closing member 32 and the belly is connected with the exhaust nozzle through conduit 38, porthole 35 and conduit 39.

It will be appreciated that the feeler 15 may conveniently be located at a distance from the change-over valve 30, in which case the stem 31 thereof is operated by a conventional transmission device not illustrated, as for example, a hydraulic transmission system of the kind used in hydraulic automobile brakes.

Type III of the submersible icebreaker according to the invention is schematically illustrated in FIGS. 3 and 9.

In FIG. 3 the icebreaking vessel A is self-propelled and comprises a breaking cam similar to D in FIG. 1, but

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instead of the belly B this vessel is provided with a downwardly projecting exhaust nozzle H which communicates through a conduit K with a power jet generating plant within the hull of the vessel A. This plant may be a conventional reactor R of the kind used in jet propelled aircraft. The gas jet produced by this plant may be diversified in various secondary jets for the propulsion and maneuvering of the vessel by means of control valves arranged in the control cabin which will always be above water level. The main power jet J produced by reactor R is directed through the nozzle H during the icebreaking operation and the jet J will be powerful enough to provide the upwardly directed thrust required for breaking the ice.

In the embodiment shown in FIG. 9 the breaking vessel is an un-manned submersible vessel similar to the one shown in FIG. 4. The power source comprising a conventional reactor R is located in a surface vessel connected with the submersible breaking vessel A in the same manner as in FIG. 4 and which may be provided with equipment for remote control of the vessel A.

Numerous variations and modifications of the illustrated embodiments will be apparent but these are deemed to fall within the scope of the invention as defined by the following claims.

What is claimed is:

1. In an icebreaker a source of compressed air, a submersible vessel including a reinforced icebreaking shell at the upper face thereof and an expansible and inflatable bottom, means for automatically inflating said bottom when said icebreaking shell is subjected to the pressure of the ice, said means for automatically inflating said bottom comprising a compressible spring loaded feeler element in said icebreaking shell, a shift valve operably associated with said feeler element and connected with said source of compressed air and said inflatable body for inflating the expansible bottom when the valve is moved into one position by depression of the feeler element and to evacuate said bottom when the valve is moved into another position by release of the pressure on the feeler element.

2. In an icebreaker comprising a source of compressed air, a submersible vessel having an upper rigid shell portion, an exhaust pipe for said vessel, an inflatable bottom portion on said vessel adapted to be connected alternately to said source of compressed air and to said exhaust pipe, automatic inflating and exhaust means for said bottom portion comprising a spring loaded feeler member extending upwardly from the upper surface of the shell and capable of being depressed therein when contacting the underface of an icefloe during the submersion of the submersible vessel therebeneath, a change-over air valve operatively associated with said feeler member and adapted to connect the inflatable body with the source of compressed air when the feeler is in its depressed position and with the exhaust pipe, when the feeler is in its unloaded position.

3. In a submarine icebreaker comprising a source of compressed air, a submersible vessel having an upper rigid shell portion, an exhaust pipe for said vessel, an inflatable bottom portion on said vessel and adapted to be connected alternately to said source of compressed air and to said exhaust pipe, an automatic inflating and propelling mechanism comprising a spring actuated feeler member extending upwardly from the upper surface of the shell and capable of being depressed therein when contacting the underface of an icefloe during the submersion of the vessel therebeneath, a change-over air valve operatively associated with said feeler member, said air valve comprising an air inlet chamber communicating with said source of compressed air, an exhaust chamber communicating with said exhaust pipe and an intermediate chamber communicating with the interior of the inflatable bottom portion of the vessel said air valve further comprising closing members connected with said feeler

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member and adapted to connect said intermediary chamber with the source of compressed air when the feeler member is depressed to the lowermost position thereof and with the exhaust pipe when the feeler member is returned to the unloaded uppermost position thereof.

4. An icebreaker comprising a submersible vessel including an expansible and inflatable bottom and a reinforced shell including a fixed icebreaking cam at the upper surface thereof, a source of a compressed gaseous medium within said vessel, means for inflating said expansible bottom by said compressed gaseous medium to modify the volume thereof, and means for propulsion of said vessel by exhausting the compressed gaseous medium from said expansible bottom during deflation thereof.

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