

- [54] **APPARATUS FOR CLEARING A PATH THROUGH ICE**
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[73] Assignee: **Global Marine Inc.**, Los Angeles, Calif.

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 [51] Int. Cl.² **B63B 35/08**
 [58] Field of Search **114/40, 41, 42, 67 A; 61/1 R; 180/116, 117, 118-130**

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[57] **ABSTRACT**

An icebreaking arrangement in which air is applied under sufficient pressure to lower the surface of the water at an icewater interface to a level below the bottom of the ice over an area which extends on either side of the interface. The unsupported weight of the ice in the region in which the water level is depressed produces failure and breaking off of pieces of ice at the interface. The increased pressure is produced by an air-tight platform having a downwardly extending skirt around the periphery, air under pressure being admitted to the region below the platform. The platform may be mounted on the bow of a ship or moved ahead of a ship to clear a channel through the ice.

14 Claims, 10 Drawing Figures

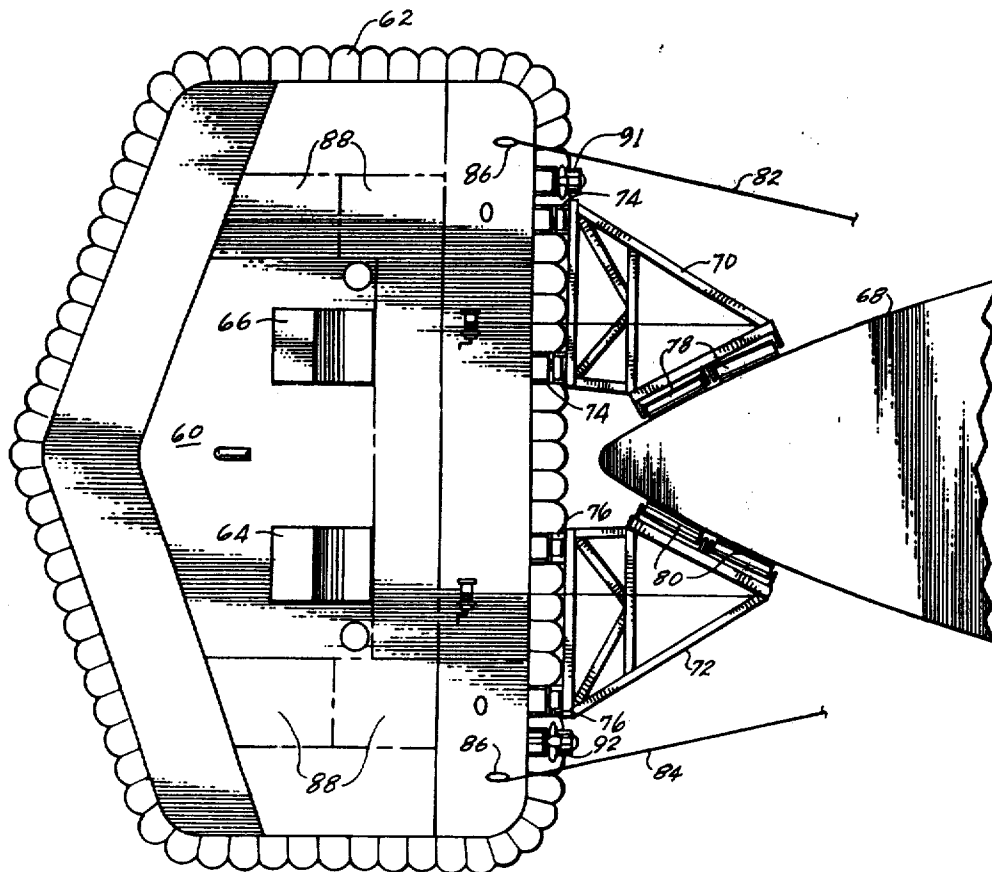


FIG. 1

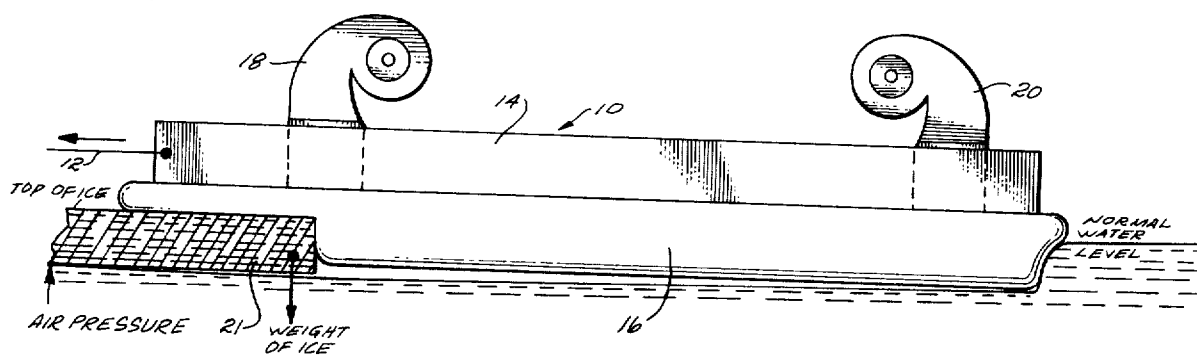


FIG. 2

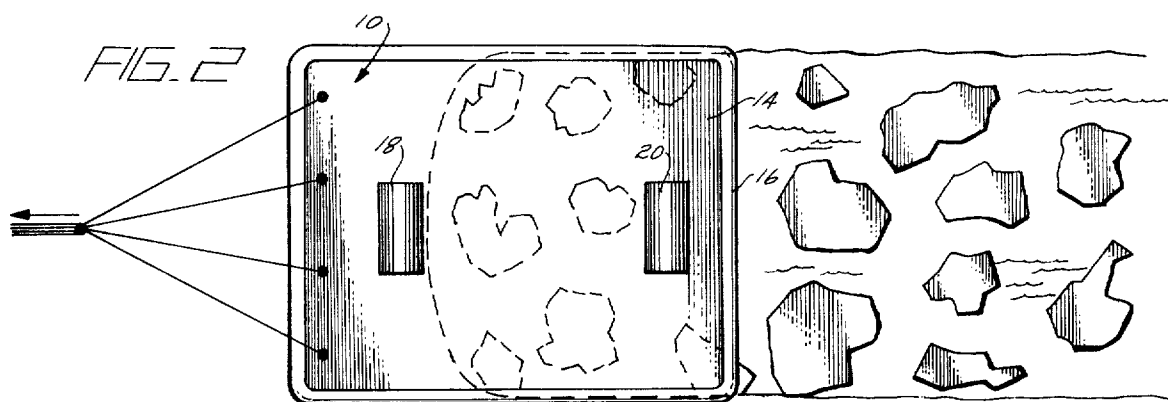


FIG. 3

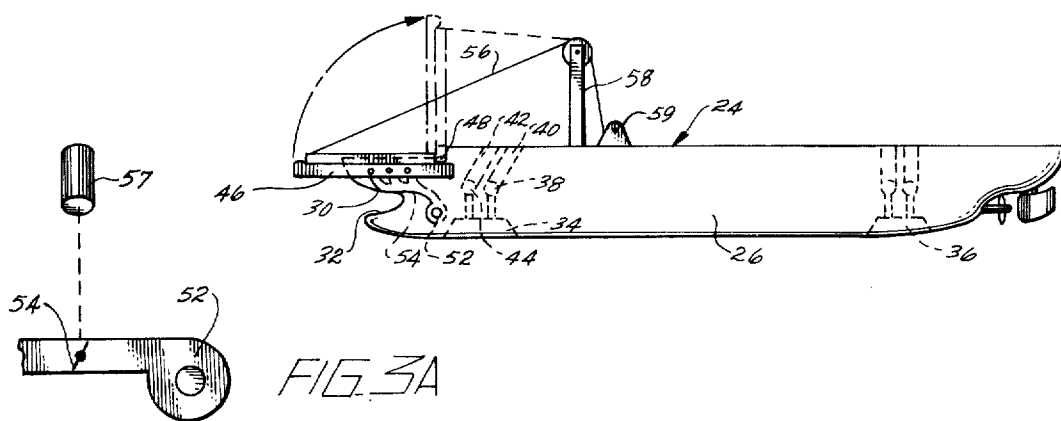


FIG. 4

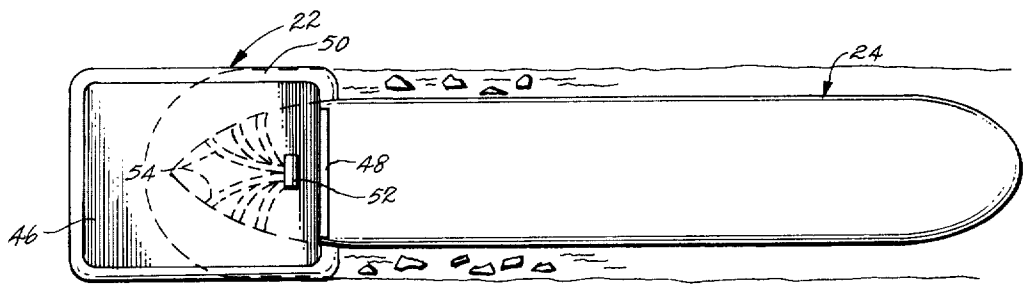


FIG. 7

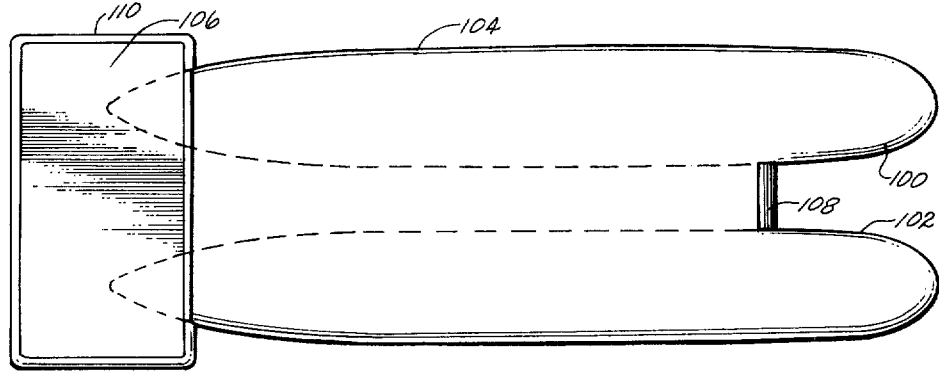


FIG. 8

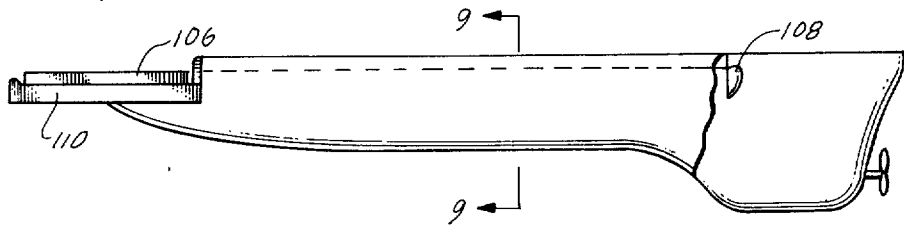


FIG. 9

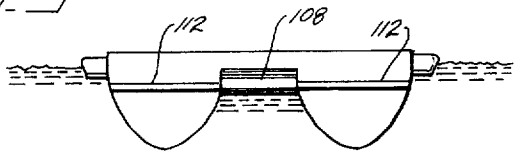


FIG. 6

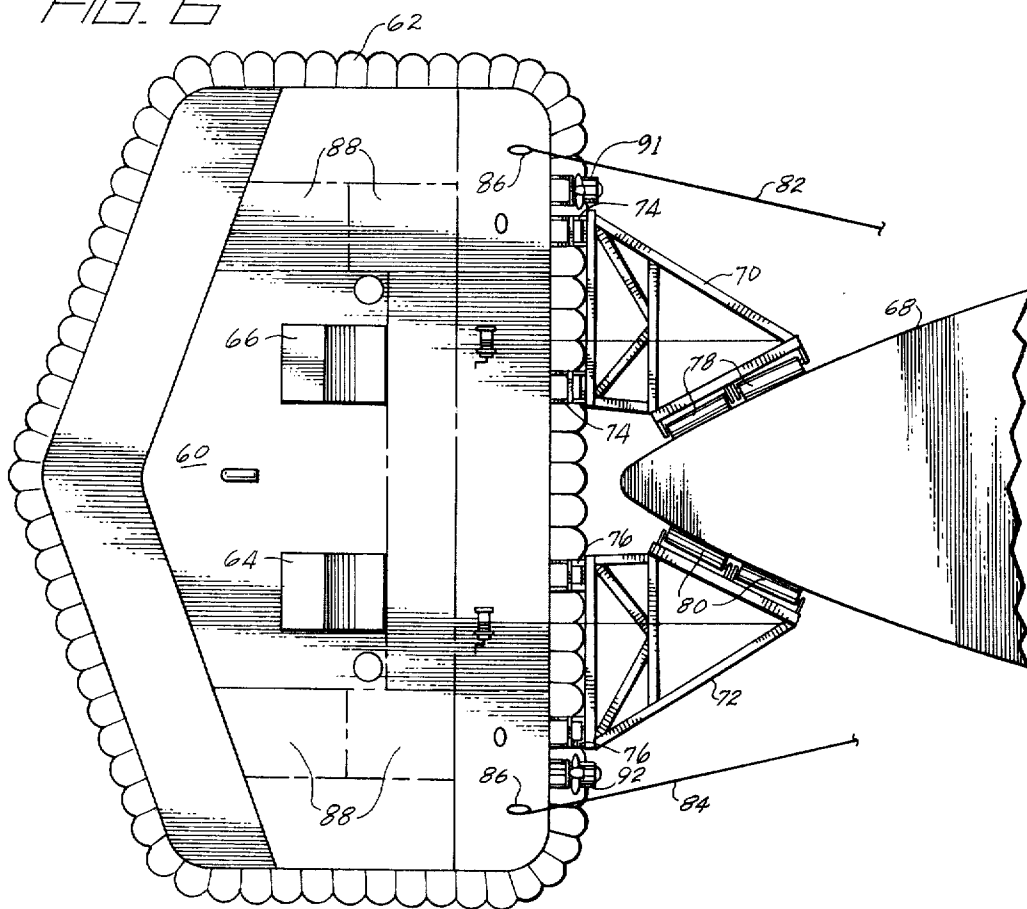
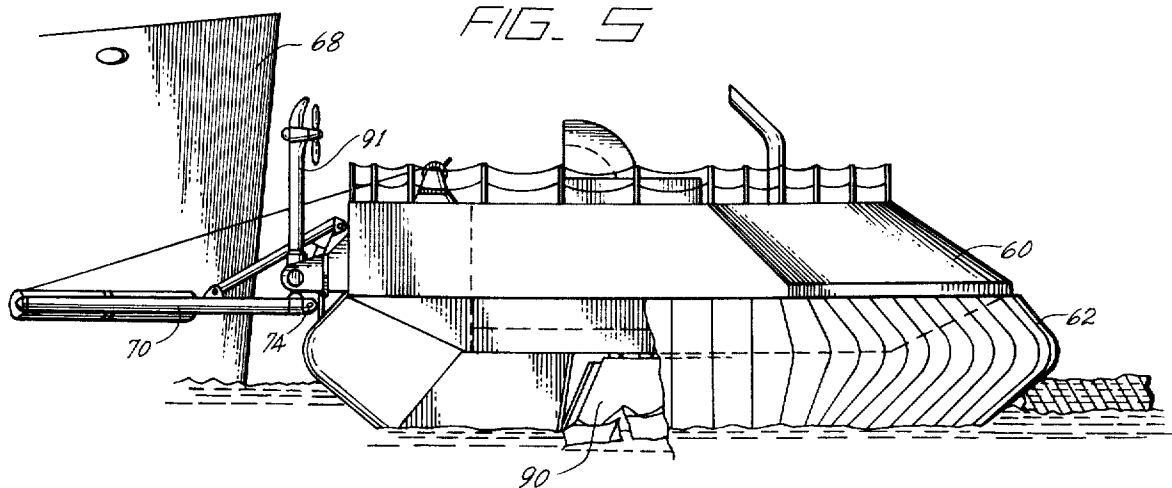


FIG. 5



APPARATUS FOR CLEARING A PATH THROUGH ICE

RELATED CASES

This case is related to copending application Ser. No. 295,804, filed Oct. 10, 1972, now Pat. No. 3,808,997 entitled "Method for Clearing a Path Through Ice," and filed in the name of Clyde Bastian, Jr., now U.S. Pat. No. 3,808,997 and assigned to the same assignee as the present invention.

FIELD OF THE INVENTION

This invention relates to clearing a channel for ships through ice, and more particularly is concerned with an apparatus utilizing air pressure for breaking a path through ice for a ship to pass.

BACKGROUND OF THE INVENTION

Conventional icebreakers which are used to clear a path through ice have relied on mechanical force to break off sections of ice at the edge of interface formed between the ice and the open channel of water being formed. This interface may be rammed or the ship may be allowed to ride up on top of the ice until it applies sufficient weight to the top of the ice to break off the ice. In copending application Ser. No. 183,466, filed Sept. 24, 1971, and assigned to the same assignee as the present invention, there is described, for example, an icebreaking vessel in which pitching motion of the vessel is induced in such a manner that the bow of the icebreaker applies vertical forces to the edge of the ice so as to continuously break away pieces of the ice to open a channel. However, mechanical icebreaking in which the mass of the ship is utilized to apply force to the ice can result in the expenditure of large amounts of energy in continuously accelerating and decelerating the mass of the vessel.

Other icebreaking techniques have been developed which apply vertical forces to the ice at the ice/water interface. One such arrangement, for example, releases high-pressure gases at controlled time intervals at a point beneath the ice slightly ahead of the ice/water interface. This is accomplished, for example, by burning a pressurized air/fuel mixture in a combustion chamber to produce high pressures and then releasing the exhaust gases at a point beneath the surface of the ice. The release of gases acts as an explosion, cracking and lifting the pieces of ice. However, the overall efficiency of such a system is reduced due to the fact that the ice is being lifted against the force of gravity.

Furthermore, it has been established that a substantial portion of the energy expended in breaking a channel through ice is the result of the frictional forces produced between the pieces of ice and the sides of the ship as the ship attempts to move through the broken ice. While some improvement has been provided by bubbling air up along the sides of the ship as it passes through the ice, there still remains a detrimental wedging action between the sides of the ship and the solid ice on either side of the ship as a result of displacing the broken ice outwardly as the ship moves along the channel.

SUMMARY OF THE INVENTION

The present invention is directed to an improved apparatus for breaking a channel through ice which is highly efficient in breaking ice of substantial thickness.

This efficiency is obtained by utilizing the weight of the ice itself in large measure to produce failure of the ice, causing it to break up. In addition, the apparatus of the present invention tends to force the broken pieces of ice outwardly underneath the unbroken ice, thus providing a clearer channel of water for the ship to pass through. Thus drag forces due to friction and the wedging of ice pieces is greatly reduced. In addition, the apparatus of the present invention may be utilized in combination with not only conventional icebreakers, thus being combined with the normal mechanically applied techniques of breaking ice, but may be used in combination with conventional ships, tugs, and particularly catamaran or double-hulled ships which heretofore have not been practical to utilize in frozen waters. The arrangement of the present invention thus permits a vessel designed for other purposes to be converted to use in frozen water by positioning the icebreaking apparatus adjacent the bow of a ship.

BRIEF DESCRIPTION OF THE INVENTION

These and other advantages of the present invention are achieved by providing an arrangement in which air under pressure is applied over an area having a width approximately the same as the width of the open channel to be formed. The pressure is applied at the interface with the ice. The air pressure is built up to a level which is sufficient to force the surface of the water downwardly over the area of increased pressure to a level below the bottom surface of the ice, whereby the ice forms a ledge adjacent the interface that is unsupported by any buoyancy effect of the water. Pressure is applied by apparatus including a platform around the perimeter of which is provided a flexible skirt. In one arrangement, the platform is mounted on the bow of a vessel, extending in cantilever fashion in front of the vessel. Air under pressure is pumped into the space formed by the platform and downwardly projecting skirt to build up the pressure on the underlying ice and water surfaces.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the invention reference should be made to the accompanying drawings wherein:

FIG. 1 is a side elevational view of one embodiment for practicing the present invention;

FIG. 2 is a plan view of arrangement of FIG. 1;

FIG. 3 is an elevational view of an alternative arrangement incorporating the features of the present invention;

FIG. 3-A is a further modification to the arrangement of FIG. 3;

FIG. 4 is a plan view of the arrangement of FIG. 3;

FIG. 5 is an elevational view of a further modification in which the icebreaking apparatus is pushed ahead of the bow of a ship;

FIG. 6 is a plan view of the modification of FIG. 5;

FIG. 7 is a plan view of a further modification of an icebreaker incorporating a twin-hulled or catamaran structure;

FIG. 8 is an elevational view of the modification of FIG. 7; and

FIG. 9 is a sectional view taken on the line 8-8 of FIG. 8.

DETAILED DESCRIPTION

Referring to the arrangement shown in FIGS. 1 and 2, the numeral 10 indicates generally an icebreaking vehicle which structurally is similar in design to the air cushion vehicle described in detail in copending application Ser. No. 130,462 filed Apr. 1, 1971, and assigned to the same assignee as the present invention. By way of example only, the vehicle 10 may be pulled along by a cable 12 using a conventional tractor. The air cushion vehicle 10 comprises a barge-type hull 14 with a flexible air containment skirt 16 around the perimeter. The skirt is preferably constructed of a rubber-coated nylon and is segmented in its construction, in a manner described in more detail in the above-identified application. The segmented construction provides a skirt which is strong enough to contain the air pressure which is built up under the hull, as hereinafter described, and at the same time is flexible enough to yield to obstructions and irregular conditions which are encountered during movement of the vehicle.

Air is forced under the hull, inflating the skirt and lifting the unit, by means of two large fans 18 and 20. The fans build up sufficient pressure within the space formed by the hull 14, the skirt 16, and the surface above which the vehicle is positioned to support and float the unit of the vehicle on a cushion of air.

In operating as an icebreaker, the vehicle 10 after being pressurized is moved on to the ice-covered body of water. The weight of the vehicle, which is transferred to the surface of the ice by the air, is normally sufficient to crack the ice and depress the pieces of fractured ice and the surface of the water in which the ice is floating downwardly immediately beneath the vehicle. This initially forms an exposed edge between the unbroken ice and the broken ice and water. If the weight is insufficient to break and form an exposed ice/water interface, this may be done by some conventional mechanical means.

As shown in FIG. 1, as the vehicle is pulled along, the front of the vehicle tends to ride up on the ice sheet, indicated at 21. Behind the edge of the ice sheet, the water and broken ice pieces are depressed downwardly under the force of the air compressed beneath the hull of the vehicle 10. The weight of the vehicle, and the resulting air pressure required to support this weight, is made sufficiently large to depress the surface of the water to a point at or below the bottom of the ice sheet. The portion of the ice sheet 21 extending under the vehicle therefore is no longer buoyantly supported on the surface of the water. Since the air pressure beneath and above the ice is the same, the full weight of that portion of the ice which is beneath the vehicle is supported entirely by the internal strength of the ice itself.

As the vehicle moves forward, the increasing weight of the unsupported portion of the ice sheet causes it to sag and bend and finally to fail and break off. In addition, the high-pressure air escapes beneath the ice and because the air pressure beneath the ice is greater than the atmospheric pressure, there is net force tending to lift the ice sheet in the region outside of the skirt 16. Escape of air beneath the surface of the ice has been observed to cause a cracking and weakening of the ice in a direction radiating outwardly from the front of the vehicle and on either side, which structurally weakens the ice and makes it less capable of supporting its own weight at the exposed edge of the ice sheet underneath the vehicle.

As best seen in FIG. 2, the edge of the ice sheet, from which chunks of ice continuously break off beneath the vehicle, is curved, since at the center part of the vehicle the ice is less able to support its own weight than at the outer edges of the vehicle where the surrounding ice gives added support.

As the vehicle is pulled forward, the chunks of ice break off at the exposed interface between the ice sheet and the water beneath the vehicle. The effect of the air pressing downwardly tends to move these chunks of ice laterally to the point where many of them are forced beneath the surface of the adjacent ice on either side of the vehicle. The effect is to at least partially clear the channel formed by the icebreaker of broken ice, thereby greatly reducing the resistance to passage of a ship through the channel. As the air cushion vehicle is pulled along, it tends to ride up on the ice until the ice fails and pieces break off. The front of the vehicle then drops. As the pressure builds up and the vehicle is pulled forward, it again rides up on the ledge of ice, increasing the area of unsupported ice and depressing the water level until more ice is broken. Thus a dynamic process in pressure surges takes place and the front of the vehicle rises and falls as chunks of ice are broken away at the interface between the ice and water. The pressure surges can be enhanced by controlling the fans and also by controlling the ballast weight in the vehicle. It should be noted that the greater the ice thickness the wider the beam of the air cushion vehicle must be to produce ice failure due to the unsupported weight of the expanse of ice at the interface, since failure occurs when the span of ice beneath the vehicle is unable to support its own weight in the absence of an upward buoyant force of water.

While the above arrangement has proved very effective in breaking ice several feet in thickness, it is not unusual to encounter ridges in the ice where the ice may suddenly extend to 20 or 30 feet below the water level. When such ridges are encountered, a barrier to air flow is encountered and the loss of buoyancy required to break the ice is insufficient to obtain the desired results. It is therefore desirable to combine the arrangement of FIGS. 1 and 2 with some means for augmenting the icebreaking with a mechanical capability when ridges of extra thick ice are encountered.

One such arrangement is shown in FIGS. 3 and 4 in which the pressurizing structure 22 is integrated with an icebreaking ship indicated generally at 24. The ship 24 is preferably of a type described in detail in copending application Ser. No. 183,466, filed Sept. 24, 1971, and assigned to the same assignee as the present invention. The ship 24 includes a hull 26 of generally conventional configuration, but with the bow portion being designed with a portion 30 of high positive rake and which is reversely curved to merge into a portion 32 of high negative rake at the waterline. As described in detail in the above-identified application Ser. No. 183,466, the ship 24 is provided with apparatus for inducing a pitching motion of the ship by shifting the center of buoyancy in a fore and aft direction at a controllable frequency. This is accomplished pneumatically by providing a forward pitching chamber 34 and an aft pitching chamber 36 that are rapidly and alternately filled with water and air. This air is forced into the chamber 34 by a pump 38 through an inlet duct 40, while air is ducted out of the chamber 34 through an exhaust duct 42 through a valve 44. Air in the rear chamber 36 is similarly controlled, all in the manner

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described in detail in the above-identified copending application.

The structure 22 includes an air-tight horizontal frame 46 which is wider than the ship's beam and which is mounted adjacent the bow of the ship so as to project outwardly on either side and in front of the bow structure. The frame 46 is preferably hinged to the deck of the ship 24 along the back edge, as indicated at 48. The frame supports a flexible skirt 50 which extends around the perimeter of the frame 46 and terminates against the sides of the ship's hull.

The skirt 50, which is constructed in the same manner as the skirt 16 described above in connection with FIGS. 1 and 2, provides a confined space surrounding the bow of the ship which can be maintained at substantially increased pressure. To this end, a fan 52 mounted in the hull of the ship 24 is connected by suitable ducts extending outside the hull into the space beneath the frame 46. By hinging the frame 46 to the deck of the ship 24, when extra high ridges of ice are encountered or when not in use, the frame 46 can be tipped upwardly, as by means of a cable 56 extending through a pulley on a mast 58 to a deck winch 59. Frame 46 is weighted by ballast water or other means, or may be mechanically locked into position to the ship to provide sufficient resistance to the upward force produced by the pressurized air reacting against the frame 46 within the skirt 50.

In the arrangement shown in FIGS. 3 and 4, the flexibility and vertical extent of the skirt 50 is such that it does not interfere with the induced pitching motion of the ship. The increased air pressure applied to the surface of the water surrounding the bow of the ship depresses the water level below the bottom of the ice reducing the buoyancy support of the ice in the same manner as described above in connection with FIGS. 1 and 2. Thus the unsupported weight of the ice makes a significant contribution to the forces applied to the ice causing failure and breaking up of the ice in front of the ship. At the same time, the air under pressure extends outwardly underneath the ice causing lifting and buckling of the ice a substantial distance in front of the ship, further weakening the ice, in the manner described above. The air also produces the effect of pushing the broken sections of ice outwardly away from the hull, thus reducing the drag forces encountered in pushing the ship through the channel of broken ice and water.

A further modification is shown in FIG. 3A in which the outlet duct from the fan 52 is provided with a butterfly or similar type of valve 54 by which the flow of air from the fan into the space in front of the bow may be modulated at a controlled frequency, as by a valve control mechanism 57. By modulating the pressure, it is possible to set up vibrations within the unsupported ledge of ice extending into the pressurized space below the frame 46. Since the ice is not floating on the surface of the water in this region, the damping of such vibrations is greatly reduced and it is therefore easier to induce resonant effects at the natural frequency of the ice structure, which can produce extremely high stress and failure of ice.

A further modification of the present invention is shown in the arrangement in FIGS. 5 and 6 in which the icebreaker unit, instead of being pulled across the surface of the ice, as described above in connection with FIGS. 1 and 2, can be pushed ahead of a conventional ship for opening a channel in front of the ship through the ice. Such an arrangement is useful, for example, in

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combination with ore boats or other types of vessels operating on the Great Lakes during the winter months. The icebreaking unit consists of a hull 60 having a segmented skirt 62 extending downwardly around the periphery. The space enclosed by the skirt 62 is pressurized by a pair of fans 64 and 66 mounted on the deck of the hull 60. The icebreaking unit supports itself on a cushion of air. It is moved along in front of the bow of the ship, indicated generally at 68, by a pair of retractable frames 70 and 72 which extend out from the rear of the icebreaking unit and are hingedly attached to the hull 60 by a suitable hinge structure, as indicated at 74 and 76, respectively. The frames 70 and 72 rotatably support a pair of rollers 78 and 80 which are positioned to engage the sides of the ship on either side of the bow. A pair of lines 82 and 84 are secured around cleats 86 on the deck of the hull 60 and are held under tension by winches (not shown) on the deck of the ship 68.

The hull 60 is provided with a plurality of ballast tanks, indicated at 88, by which the weight of the icebreaking unit can be varied depending upon the required air-pressure to depress the water surface below the hull 60 to a depth below the bottom of the ice. The thicker the ice, the greater the pressure required to depress the water level and accordingly the greater the counteracting weight of the icebreaking unit must be. The icebreaking unit may also be provided with deflector plates 90 suitably mounted below the hull 60 and positioned to deflect the particles of broken ice laterally outwardly beneath the unbroken ice sheet.

By making the icebreaking unit self-contained with its own source of power, it can be operated independently of the ship 68 if required. To this end, the icebreaking unit is provided with its own retractable propeller drive system. Two such propeller drives are indicated at 91 and 92, the propeller drives being hingedly supported at the rear of the hull 60.

Because of its greater stability, the twin-hulled or catamaran-type of craft has developed increasing interest in the oil-drilling field, for example. However, such type of craft has not been practical for use in areas where ice is encountered. An arrangement adapted to a catamaran design is shown in FIGS. 7, 8 and 9. As shown in these figures, the vessel includes two deep-draft hulls for large cargo capacity, as indicated at 100 and 102, respectively. The two hulls share a common deck 104 which extends across and closes the space between the two hulls. A hinged platform 106 extends outwardly in front of the bows of the two hulls in similar fashion to the frame 46 of FIGS. 3 and 4. The platform 106 is provided with a downwardly projecting flexible skirt 110 extending around the perimeter and terminating at the outer sides of the two hulls. An additional skirt 108 extends downwardly from the deck 104 in the space between the two hulls at a point near the stern of the vessel. Thus the space between the two hulls combines with the space defined by the front skirt 110 and the rear skirt 108 to form an enclosed region into which air is forced under pressure by a suitable fan (not shown). By this arrangement, the level of the water in front and between the two hulls can be depressed below the bottom of the surrounding ice sheet. By hinging the platform 106, the air-cushion system can be retracted out of the way so that any ridges can be rammed by the vessel without damage to the air-cushion system.

In order to reduce the drag of the broken pieces of ice to the movement of the ship, a portion of the air directed into the space between the two hulls may be released along the outer sides of the two hulls. As shown in FIG. 9, this may be done by providing ducts 112 which extend through the two hulls, bubbling air below the water line on the outer sides of the two hulls. The air is released along the length of the two hulls on the outboard sides of the vessel. The air may also be released along the keel, but a separate source of air at higher pressure than the air in the plenum formed by the skirts is then required.

What is claimed is:

1. An icebreaking vessel for use in ice-covered waters comprising:

a hull adapted to float in water at a characteristic load waterline with a draft determined by the weight of the vessel and its contents, the hull having a bow portion extending above and below the waterline,

a platform extending in front of the bow,

a flexible skirt extending around at least a portion of the perimeter of the platform and projecting downwardly from the platform, the platform and skirt being joined in substantially air-tight relation to form with the top surface of the ice-covered water a substantially enclosed plenum, the bottom of the skirt being disposed below the waterline of the hull, means coupling the platform and the hull so that propulsion of the hull is effective to move the platform in advance of the hull, and

means for forcing air into the plenum under pressure sufficient to depress the level of the water below the plenum to below the waterline of the hull, the draft of the vessel being substantially constant whether or not air is supplied under said pressure to the plenum.

2. The apparatus of claim 1 wherein the air forcing means is operable to force air into the plenum under sufficient pressure to depress the water below the plenum to a level below the vessel waterline sufficient to cause a surrounding ice sheet to break from its own weight.

3. Apparatus of claim 1 wherein the coupling means is arranged for movably connecting the platform to the bow portion of the hull of the vessel to permit vertical movement of the platform relative to the hull in front of the bow.

4. Apparatus of claim 1 wherein the platform extends rearwardly over the bow, the platform extending laterally a distance greater than the beam of the vessel, and means coupling the platform to the deck of the vessel in substantially air-tight relationship, the bow extending into the plenum.

5. Apparatus of claim 1 further including means for rapidly shifting the center of buoyancy of the vessel in a fore and aft direction to induce pitching movement of the bow.

6. Apparatus of claim 4 wherein the coupling means includes hinge means joining the platform along its rear edge to the ship, and means for raising and lowering the front of the platform about said hinge means to lift the platform clear of obstructions.

7. Apparatus of claim 2 wherein the flexible skirt extends completely around the perimeter of the plat-

form, and said means for forcing air into the plenum includes fans mounted on the platform for forcing air into the space below the platform.

8. Apparatus of claim 7 wherein said means movably connecting the platform to the hull includes frame members connected to and extending rearwardly from the platform, and roller means rotatably connected to the frame members and positioned to engage the sides of the hull on either side of the bow, the rollers having their axes of rotation substantially parallel to the water, the axes converging at the same angle as the converging sides of the hull at the bow so that the bow wedges between the rollers, and cable means extending between the platform and the hull for pulling the platform frame members and rollers toward the bow of the hull.

9. An icebreaker comprising a vessel having a pair of fixedly spaced apart hulls adapted to float jointly in water at a characteristic waterline with a draft determined by the weight of the vessel and its contents, a platform supported by the hulls so as to move with the hulls in response to propelling the hulls. The platform being substantially horizontal and projecting in front of the bows of the hulls and extending laterally beyond the beam of the vessel, a flexible skirt extending downwardly from the platform and joined to the platform in substantially air-tight relation. The skirt extending around the perimeter of the platform and terminating at the outside surface of the hulls, a rear flexible skirt extending between the two hulls, air-tight means extending between the hulls from the platform to the rear skirt, the skirts having bottom edges disposed below the vessel waterline whereby a plenum is formed in front of and between the two hulls, and means for pressurizing the plenum with air to a pressure sufficient to depress the water below the plenum to a level sufficient to cause the surrounding ice sheet to break off from its own weight, the draft of the vessel being substantially constant whether or not air is supplied under said pressure to the plenum.

10. The apparatus of claim 9 wherein the rear skirt is positioned near the stern of the vessel.

11. The apparatus of claim 9 further including hinge means securing the platform to the two hulls, and means for swinging the front of the platform upwardly from a horizontal position about said hinge means.

12. Apparatus of claim 9 further including means for discharging air along the outboard sides of the hulls.

13. The apparatus of claim 9 further including means for directing air from the pressurized plenum to the outboard sides of the hulls, the air being discharged just below the vessel waterline.

14. Ice breaking apparatus for use with a vessel having a buoyant hull, a deck and a prow extending therefrom comprising: a surface effect structure mounted on and attached to the prow and extending in front of the vessel and including a platform with a large areal extent having a flexible material attached to and extending downwardly from the platform to a point adjacent a surface being traversed by the vessel, such flexible material extending downwardly substantially around the underside of the platform to enclose the underside periphery of the platform, said surface effect structure having means mounted in the platform for forcing air below the platform.

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