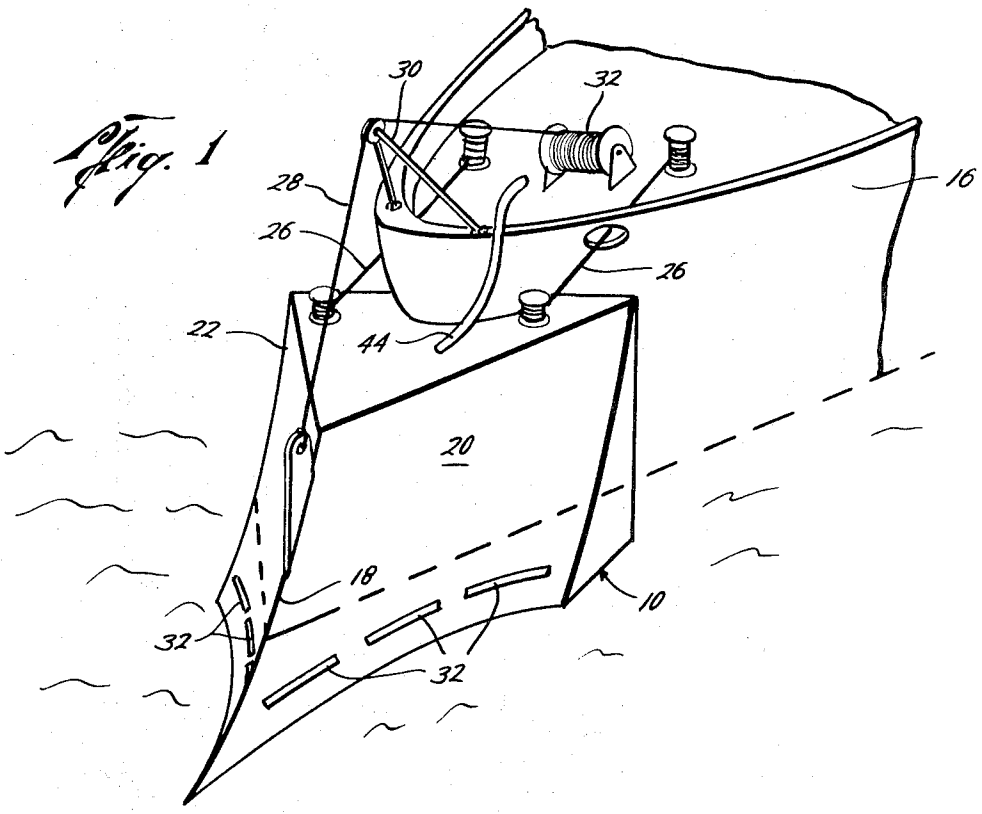
March 23, 1971 C. D. WOOD 3,572,273

APPARATUS FOR BREAKING A LAYER OF ICE ON A BODY OF WATER BY REPETITIVE COMBUSTIVE EXPLOSIONS

Filed Aug. 6, 1969 2 Sheets-Sheet 1

Fig. 1



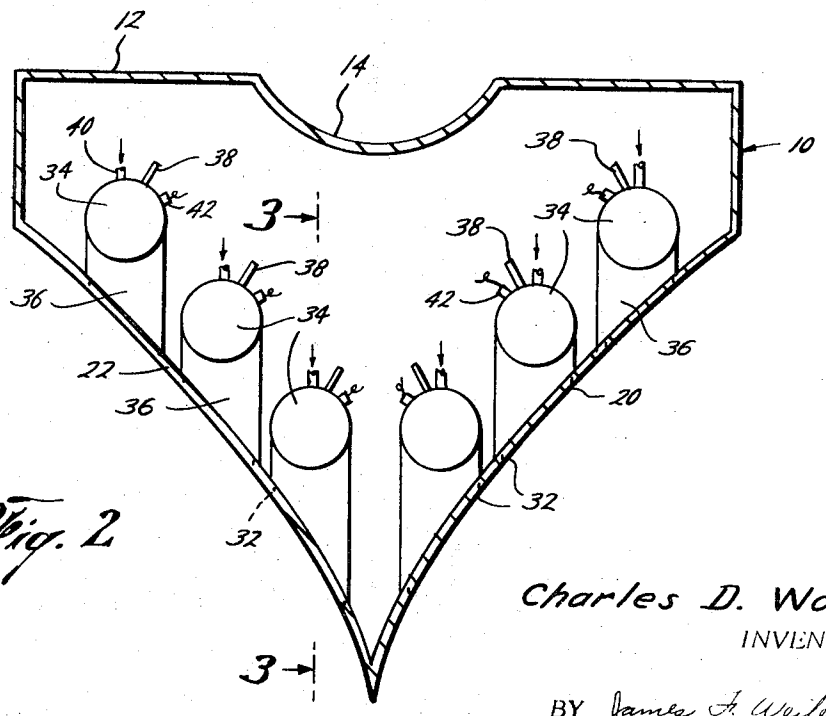


Fig. 2

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Fig. 3

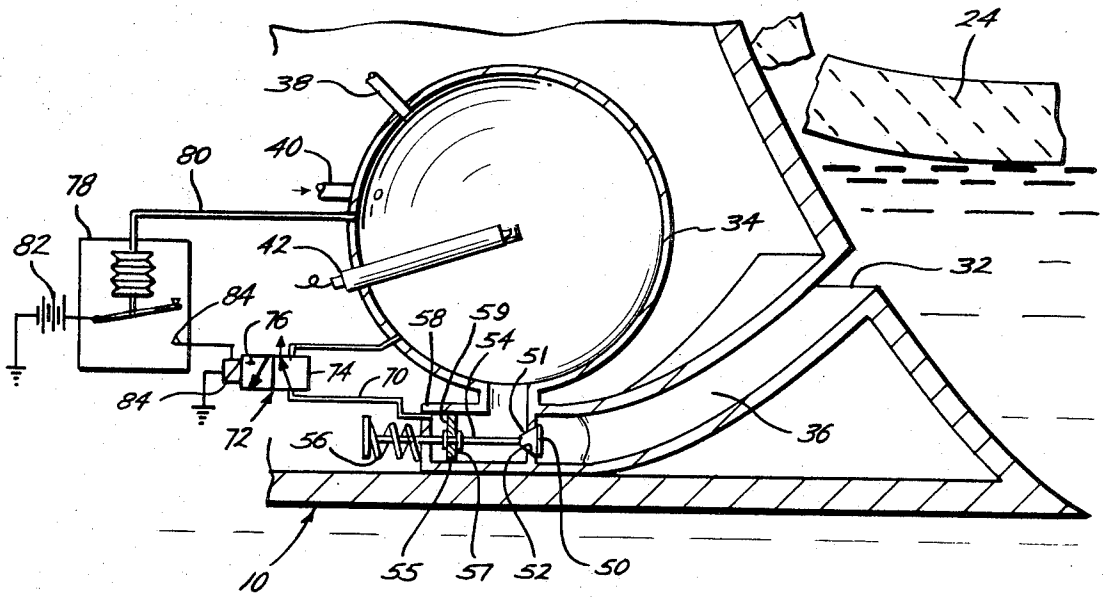
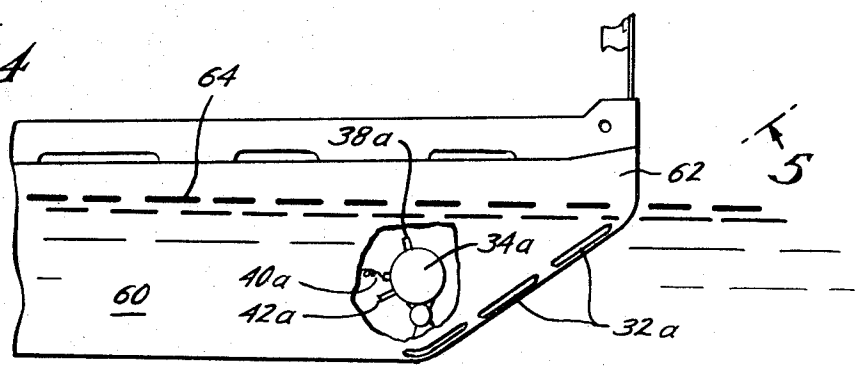


Fig. 4



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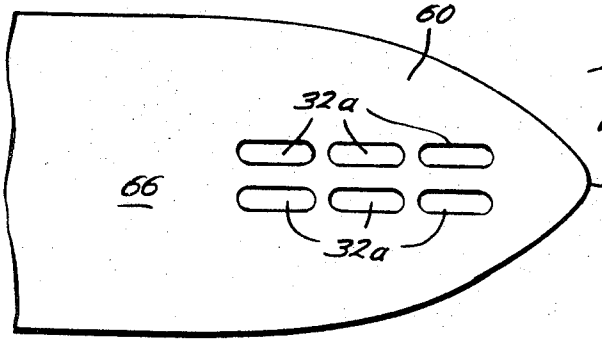

Fig. 5

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APPARATUS FOR BREAKING A LAYER OF ICE ON A BODY OF WATER BY REPETITIVE COMBUSTIVE EXPLOSIONS

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Int. Cl. B63b 35/08
U.S. Cl. 114—40 13 Claims

ABSTRACT OF THE DISCLOSURE

An apparatus to break the ice on bodies of water to allow passage of vessels by providing a movable buoyant body having a face for contact with the ice and a plurality of exhaust openings in the face and positioned below the waterline of the body with each exhaust opening connected to a combustion chamber for applying the combustion energy from a hydrocarbon fuel directly to the ice for breaking and melting the ice. A plurality of exhaust openings in the hull of an ice-breaker adjacent the bow with a normally closed combustion chamber connected to each opening. A buoyant pontoon non-rigidly attached to the bow of a ship and having a front face extending downwardly and outwardly to slide under layers of ice with a plurality of exhaust openings for providing a combustive explosion directed against the ice and having valve means normally closing the combustion chamber for preventing water entering therein but opening on a predetermined pressure buildup in the chamber.

BACKGROUND OF THE INVENTION

Generally, the discovery of natural resources in the Arctic Sea has created a problem of increasing transportation through the sea even when it is frozen over. However, the only practical way to break up the ice has been by icebreakers. The present invention provides an apparatus which can assist an icebreaker or can be utilized with other types of vessels as an icebreaker.

SUMMARY

The present invention is directed to applying the principle of displacing materials by applying the combustion energy from a hydrocarbon fuel as disclosed in copending patent application Ser. No. 514,057, dated Dec. 15, 1965, now Pat. No. 3,461,577 and entitled Method of and Apparatus for Displacing Materials, and applying this concept to breaking ice from bodies of water by using the explosive force and heat energy of the combustion of hydrocarbon fuel and air as a source of energy.

The present invention is directed to providing a movable buoyant body adapted to float in the water and having a face on the front for contact with the ice with a plurality of exhaust openings in the front face positioned below the waterline of the body for being positioned against the ice with each exhaust opening attached to a combustion chamber having a supply of hydrocarbon fuel and air connected thereto with igniting means for repetitively providing an explosive force against the ice.

In one embodiment the exhaust openings from the combustion chamber are connected directly to the hull of an icebreaker hull adjacent the bow and directed downwardly below the waterline whereby the icebreaker may ride upon thick layers of ice for breaking and exploding an opening through the ice.

In another embodiment a buoyant pontoon is attached, preferably non-rigidly to the bow of a suitable ship, and is moved through the water with a face extending forwardly and downwardly to slide under a layer of ice with exhaust openings in the face of the pontoon for positioning adjacent the ice whereupon the exhaust gas produces an impact load upon the ice and causes melting of the ice which provides a layer of water between the ice and pontoon that is effective as a lubricant.

Other features and advantages will be apparent from the following description of the invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a fragmentary perspective view illustrating the use of the invention in connection with the pontoon adapted to be connected to and moved by a ship,

FIG. 2 is a cross-sectional view of the pontoon of FIG. 1,

FIG. 3 is a cross-sectional view taken along the line 3—3 of FIG. 2 and includes a schematic control of the valves,

FIG. 4 is a fragmentary elevational view, partly in cross section, illustrating another embodiment of the present invention connected directly to the bow of an ice-breaker, and

FIG. 5 is a cross-sectional view taken along the line 5—5 of FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring now to the drawings, and particularly to FIGS. 1, 2 and 3, the reference numeral **10** generally indicates a buoyant pontoon having a rear side **12** including a surface **14** contoured to coact with a bow of any suitable ship such as a tanker **16** so that the pontoon **10** may be moved through the water. Preferably, the front face of the pontoon includes a leading edge **18** and faces **20** and **22** directed downwardly and outwardly but behind edge **18** so as to, as best seen in FIG. 3, slide under an ice layer **24** and apply an upward force on the ice **24** due to the buoyancy of the pontoon **10**. While the pontoon **10** could be rigidly connected to the ship **16**, it is desirable to allow the pontoon **10** to contact and follow the contours of the lower surface of the ice sheet **24** and tend to be pushed downwardly into the water by such contact. In the preferred embodiment of the present invention, it is desirable that the pontoon **20** be connected to the ship **16** by connecting means which allow relative movement between the ship **16** and pontoon **10**. For example, the pontoon may be connected to the ship **16** by steel cables **26** and relative movement may thus be provided between the pontoon **10** and the ship **16** by trimming or easing the cables **26** with suitable winches. A third cable **28** may be attached to the center line of the pontoon and lead over a boom **30** to a winch **32** and can be used to help control the pitch of the pontoon and by means of a slipping brake on the winch can also absorb some of the recoil force which will be described hereinafter.

A plurality of exhaust openings **32** are provided in the front faces **20** and **22** of the pontoon directed upwardly and outwardly from the pontoon so that the combustive forces from the openings **32** are directed toward the lower surface of the ice layer **24** when the face of the pontoon is in contact with the ice. A combustion chamber, and preferably a separate combustion chamber **34** for each opening **32**, which are positioned inside of the pontoon, are connected to each of the exhaust openings **32** through an exhaust duct **36**. The combustion chambers **34** are charged with a suitable combustion mixture for creating an explosion therein, and preferably the chambers **34** are charged with an air/fuel mixture, the air being provided by any suitable and conventional means as described in the above mentioned patent application such as a compressor (not shown) through an air inlet **38** and the fuel is provided by any suitable and conventional fuel supply means such as a fuel injection nozzle **40** to provide an air/fuel mixture at the desired pressure and air/fuel mix-

ture ratio. Combustion may be initiated in the mixture by any suitable ignition means such as an ignition source **42** preferably extending to the center of the combustion chamber. Chamber **34** may also be of a spherical shape to provide the shortest possible flame travel and thus the maximum rate of pressure rise in the combustion chamber. While it is preferable that the combustion chambers **34** be located in the pontoon **10**, the fuel lines **40**, air lines **38** and ignition source **42** lines are preferably bundled together through a flexible hose **44** leading to the ship **16** for connection thereto to a suitable air supply, fuel supply and ignition control means. Any suitable manually operated or automatic control and timing means may be utilized to suitably control the admission of fuel, air and timing of the explosions in the chamber **34**.

The combustion chambers **34** are preferably closed while they are being charged with fuel and air to the desired initial pressure prior to ignition. One type of structure that may be provided to close the chambers **34** and also prevent water in the ducts **36** from entering the combustion chambers **34** is to provide suitable valve means such as poppet valve **50** (FIG. 3) having a valve seat **52** and a valve stem **54** which is acted upon by a spring **56** against a stop **58** tending to close the valve **50**. A piston **55** is connected to valve stem **54** and has a first side **57** directly exposed to pressure in the combustion chamber **34**. The cross-sectional area of the piston side **54** is larger than the cross-sectional area **51** of the valve **50** that is exposed to pressure in the combustion chamber **34**. Gas may reach or leave the second side **59** of the piston **55** through a line **70** and through actuating valve **72** which has two positions. When position **74**, as shown, is placed in the line **70**, the gas pressure on the side **59** of the piston is vented to atmosphere. Thus when the valve **72** is in position **74** and pressure is increased in the combustion chamber **34**, the poppet valve **50** is held in the closed position since the area of side **57** of the piston **55** exceeds the area of side **51** of valve **50**. Therefore, the chamber **34** can be charged and fired and the valve **50** will remain closed. However, when the control valve **72** is actuated to move position **76** into line **70**, the pressure in the chamber **34** will be in communication with side **59** of the piston through line **70**. Thus the pressure forces from chamber **34** are acting on both sides **57** and **59** of pistons **55** and are balanced and the force acting on side **51** of valve **50** opens valve **50** releasing the combustive forces into the ducts **36**. The spring **56** is sized so that after combustion it closes valve **50** while the pressure in the combustion chamber **34** exceeds the outside water pressure by a small amount thus preventing water flow into the combustion chamber **34**.

The actuating valve **72** may be controlled by any suitable means such as a pressure actuated switch **78** which is responsive to the pressure in the combustion chamber **34** through line **80**. Switch **78** is connected to a battery **82** and switch contact **84** energizes solenoid **84** connected to valve **72**. Thus when the pressure in chamber **34** reaches a preset level, switch **78** moves to contact **84** energizing solenoid **84** moving valve **72** into position **76** to open valve **50**. Of course, other types of valve means such as disclosed in the above mentioned co-pending patent application may be used.

The terminal combustion pressures and temperature can also be varied as desired. For example, with an air/fuel mixture of 12.5/1, an initial air pressure charge of 200 p.s.i. will result in combustion that produces a peak pressure of approximately 1000 p.s.i. and a temperature of approximately 4660° F. By increasing the initial air pressure charge to 425 p.s.i., the resulting combustion from the explosive mixture would produce a pressure of approximately 1625 p.s.i. and a temperature of approximately 4790° F. The resulting high pressures and high temperature gases are exhausted through the rapidly opening exhaust valve **50** to provide an explosive release of energy which acting against the ice sheet **24** and combined with the buoyant force of the pontoon **10** produces an impact load on the ice sheet **24** which causes failure of the ice. In addition, the hot exhaust gases passing up the forward face of the pontoon **10** between the broken ice and pontoon cause melting of the ice which provides a layer of water between the ice and the metal pontoon that is effective as a lubricant, thus reducing the frictional resistance to the forward motion of the pontoon **10**. When the valves **50** are open the chamber pressure in the combustion chambers **34** greatly exceeds the water pressure in the exhaust ducts **36** so that the gas flows from the chamber pushing the water ahead of the gas. When the chamber pressure begins to approach the surrounding water pressure but while it still exceeds the surrounding water pressure, the valves **50** are closed by the springs **58** and prevent the water re-entering the ducts **36** from reaching the combustion chambers **34**.

And as previously mentioned, the third cable **28** can be used to help control the pitch of the pontoon and absorb some of the recoil forces as the buoyant pontoon **10** may be pushed downwardly by the recoil force of the explosions.

Thus, the pontoon allows any vessel which is not normally equipped for ice breaking duties, such as an oil tanker, to act as an icebreaker by attaching the ice breaking pontoon **10** to the bow of the vessel and the pontoon will absorb the recoil of the explosion by the downward motion of the pontoon without transmission of undesirable recoil forces into the ship **16**. Additionally, the pontoon **10** will follow the bottom ice contour through the freedom of its leading edge **18** to move upwardly and downwardly.

However, the pontoon **10** has its limitations. For instance, for very heavy ice sheets **24**, the skin of the pontoon **10** must be made thicker to withstand the ice impact forces and thus the buoyancy of the pontoon for creating an upward force on the bottom of the ice may become marginal. And in areas where the ice sheets **24** are extremely thick with the bottom of the sheets extending to great depths in the water, it is not feasible to make the pontoon with a sufficient draft to extend under the ice. Under such conditions, the embodiment illustrated in FIGS. 4 and 5 can be provided to assist in breaking up the ice to provide passage for a vessel. For convenience of reference, the suffix *a* is applied to parts corresponding to those in FIGS. 1–3. Thus a conventional icebreaker hull **60** is provided with a plurality of exhaust openings **32***a* in its hull and positioned adjacent the bow **62** and directed downwardly and outwardly from the hull below the waterline **64**. Preferably, some of the openings are positioned on one side of keel **66** and other openings being on the second side of the keel **66**. A combustion chamber **34***a*, air supply **38***a*, fuel supply **40***a* and ignition means **42***a* similar to that previously described in connection with the embodiments of FIGS. 1–3 are connected, preferably to each exhaust opening **32***a* and operate in a similar manner. The ice breaking hull **60** differs in that it will ride upon an ice layer as is conventional and when one or more of the combustion chamber **34***a* are fired, the exhaust gas will be directed through the openings **32***a* against the ice. The resulting force of the weight of the ship **60** plus the pressure and heat forces of the exhaust gases, provide impact blows as well as a constant pressure on the ice. By means of the repetitive combustion explosions the icebreaker is able to break heavier ice than is possible without the combustion devices.

In operation, the pontoon **10** of the embodiment of FIGS. 1–3 or the icebreaker **60** of the embodiment of FIGS. 4 and 5 is conventionally moved through the water to place the exhaust openings **32** or **32***a* against the ice so that the high impact pressures and temperatures may be positioned as close as possible to the ice. High pressure air is supplied to the combustion chamber, fuel is injected into the combustion chamber through fuel injec-

tion means **40**, and conventional ignition means may be used to ignite the mixture. As the flame propagates through the air/fuel mixture charge, pressure is rapidly developed within the combustion chambers **34** and **34***a* and builds up causing predetermined release pressure to be reached thus causing the valve **50** to open and the force of the explosion is expelled through the ducts **36** and openings **32**. After the combustion gases have exhausted down to a predetermined level, the valve **50** is closed to reseal the chamber and prevent water from entering therein and the exhaust openings **32** are again moved into proximity of the unbroken ice to repeat the cycle.

The present invention, therefore, is well adapted to carry out the objects and attain the ends and advantages mentioned as well as others inherent therein.

What is claimed is:

1. An apparatus for breaking a layer of ice on a body of water by repetitive combustive explosions comprising,
- a buoyant body adapted to float on the water,
- means for moving the body in the water and against the ice,
- said body having a face on the front for contact with the ice,
- at least one combustion chamber in the body,
- a plurality of exhaust openings in the front face and positioned below the waterline of the body for being positioned adjacent the ice, each opening being connected to a combustion chamber,
- means connected to the chamber for admitting air under pressure into the chamber,
- means connected to the chamber for admitting fuel under pressure in the chamber thus forming a pressurized mixture of air and fuel,
- igniting means in said chamber for igniting said pressurized mixture of air and fuel,
- control means for repetitively controlling the admission of fuel, air and ignition of the mixture, and
- valve means normally closing said combustion chamber for allowing buildup of pressure in the chamber and preventing entrance of water thereto, but opening upon combustion of the mixture upon a predetermined pressure buildup in said chamber.

2. In combination with an icebreaker hull, an apparatus for breaking ice by repetitive combustive explosions comprising,
- at least one combustion chamber connected to said hull,
- a plurality of exhaust openings in the hull adjacent the bow and directed downwardly and outwardly below the waterline, each opening being connected to a combustion chamber,
- means connected to the chamber for admitting hydrocarbon fuel under pressure into the chamber,
- means connected to the chamber for admitting air under pressure into the chamber,
- igniting means in said chamber for igniting said pressurized mixture of air and fuel, and
- valve means normally closing said combustion chamber for containing the pressurized mixture in the chamber prior to ignition and preventing the entrance of water therein, but opening upon combustion of the mixture and upon a predetermined pressure buildup in said chamber.

3. In combination with an icebreaker hull, an apparatus for breaking ice by repetitive combustive explosions comprising,
- a plurality of combustion chambers connected to said hull,
- a plurality of exhaust openings in the hull, each of which is connected to a combustion chamber and positioned adjacent the bow and directed downwardly and outwardly from the hull below the waterline, at least one opening being on one side of the keel and at least another opening being on the second side of the keel,

- means connected to the chamber for admitting hydrocarbon fuel under pressure into the chamber,
- means connected to the chamber for admitting air under pressure into the chamber,
- igniting means in said chamber for igniting said pressurized mixture of air and fuel, and
- valve means normally closing said combustion chamber, but opening upon combustion of the mixture upon a predetermined pressure buildup in said chamber.

4. The apparatus of claim **3** wherein a separate combustion chamber is connected to each exhaust opening.

5. The apparatus of claim **4** wherein the combustion chambers are spherical.

6. Apparatus for breaking a layer of ice on a body of water comprising,
- a buoyant pontoon, the rear of the pontoon being contoured to coact with a ship's bow so that the pontoon may be moved in the water,
- the buoyant pontoon having a front face extending downwardly and outwardly for allowing the face to slide under a layer of ice,
- connecting means attached to the pontoon adapted to be connected to a ship,
- at least one combustion chamber carried by the pontoon,
- a plurality of exhaust openings in the front face of the pontoon, each of which is connected to a combustion chamber,
- means connected to the chamber for admitting hydrocarbon fuel under pressure into the chamber,
- means connected to the chamber for admitting air under pressure into the chamber,
- igniting means in said chamber for igniting said pressurized mixture of air and fuel, and
- valve means normally closing said combustion chamber, but opening upon combustion of the mixture upon a predetermined pressure buildup in said chamber.

7. The apparatus of claim **6** wherein a separate combustion chamber is connected to each exhaust opening.

8. The apparatus of claim **7** wherein the combustion chambers are spherical.

9. The apparatus of claim **6** wherein the connecting means is a non-rigid connection allowing vertical movement between the pontoon and the ship.

10. The apparatus of claim **6** wherein the connecting means includes cables and winches for lengthening or shortening the connection between the ship and the pontoon as the pontoon follows the contour of the lower surface of the ice.

11. The apparatus of claim **6** wherein the exhaust openings are below the waterline of the pontoon and are directed forwardly and upwardly.

12. The apparatus of claim **6** wherein,
- the front face of the pontoon includes a leading edge extending downwardly and outwardly for sliding under a layer of ice, and
- a face on either side leading downwardly and outwardly behind the leading edge.

13. The apparatus of claim **12** wherein the connecting means includes cables and winches for lengthening or shortening the connection between the ship and the pontoon including cables controlling the vertical movement leading edge of the pontoon.

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