United States Patent [19]

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[54] **PROTECTING A STRUCTURE IN WATER COVERED WITH SHEET ICE**

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[52] **U.S. Cl.** **61/1,** 61/46.5, 114/.5, 175/7

[51] **Int. Cl.** **E02b 3/00,** E02b 15/02

[58] **Field of Search** ..... 61/1, 36 A, 46.5; 114/.5, 5 F, 40, 41, 42

[56] **References Cited**

UNITED STATES PATENTS

3,129,565	4/1964	Bellamy	61/1
3,289,425	12/1966	Shrier	61/.5
2,449,963	9/1948	Ward	61/1

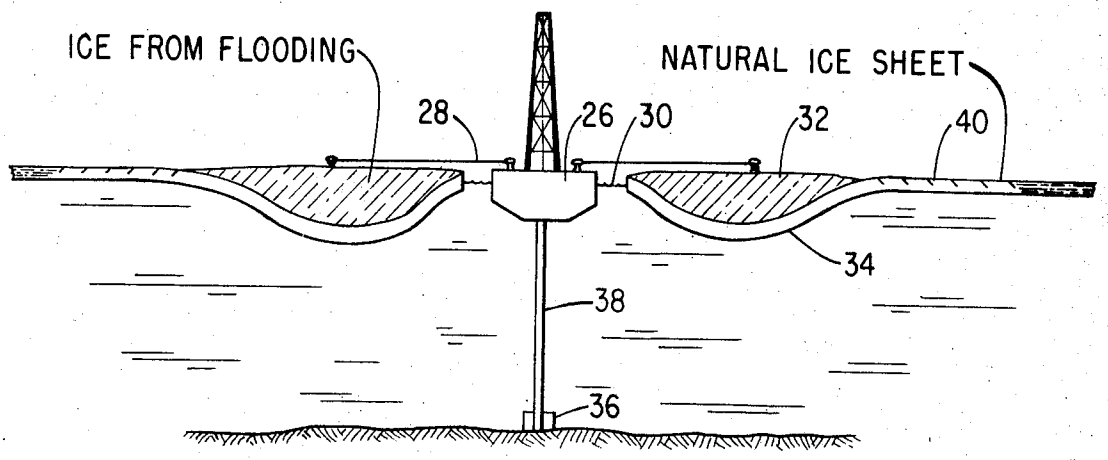
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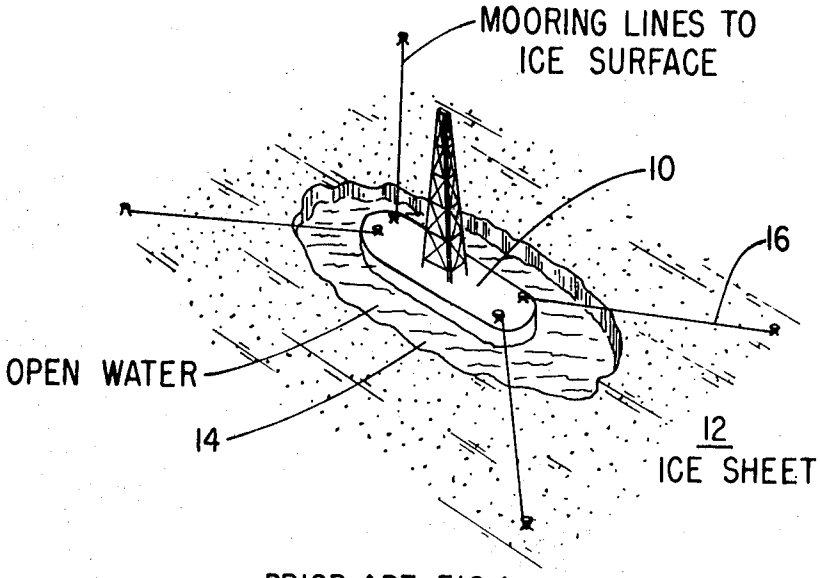
[57] **ABSTRACT**

This invention relates to a method of protecting a structure such as a vessel or platform located in water covered with an ice sheet. It especially relates to those areas in which pressure ridges (a region of built up ice rubble formed by thrusting action of two sheets of ice.) occur in the ice such as in the Arctic regions. In a preferred embodiment, a thickened or strengthened section of ice is formed around at least a part of the structure and open water is maintained between the strengthened section of ice and the structure. Just outside the strengthened section of ice is a buffer zone in which the sheet of ice has been weakened such as by cutting trenches partly through the ice. When a pressure ridge occurs in the area of the structure being protected, it is directed through the weakened section of ice around the strengthened section of ice. The pressure ridge should form in the weakened section away from the structure being protected.

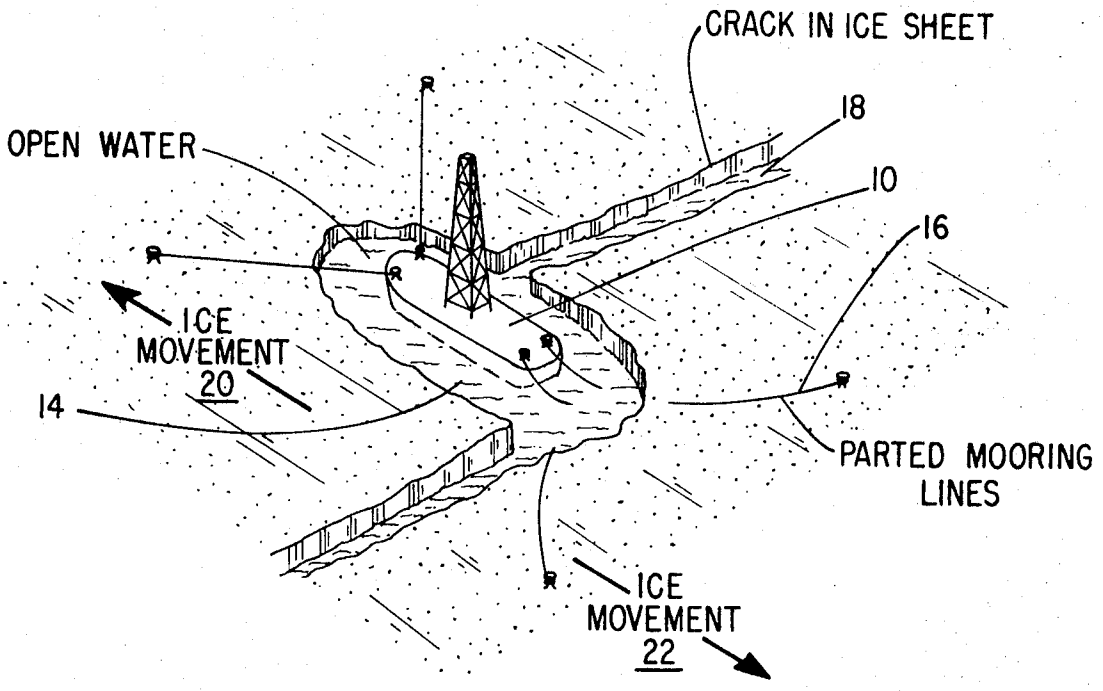
If a crack should occur between the legs of a temporary structure, it could damage such structure by pulling the legs apart. Here a weakened section of ice is provided away from the structure to cause the path of the crack to be away from the structure. Ways of strengthening the ice and making the weakened buffer zone are disclosed.

9 Claims, 9 Drawing Figures



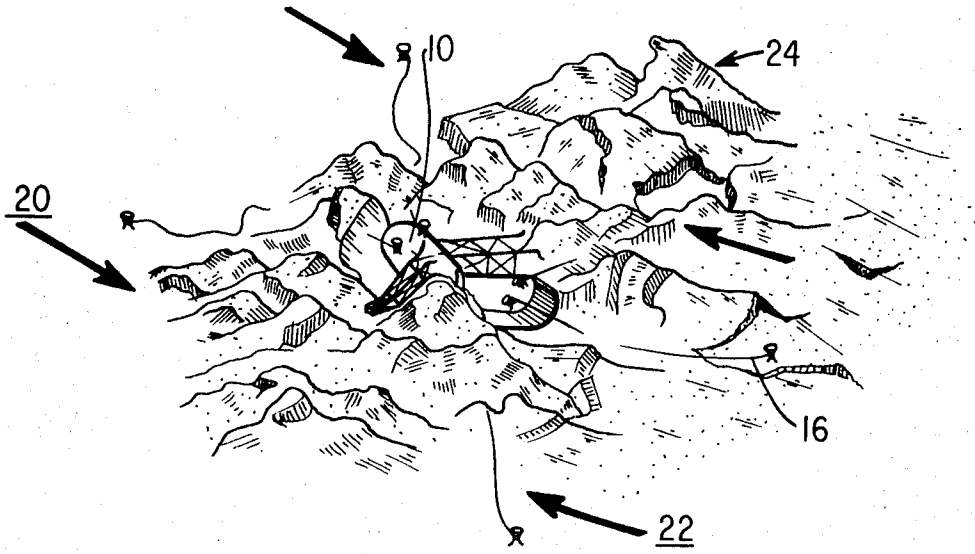


PRIOR ART FIG. 1



PRIOR ART FIG. 2

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PRIOR ART FIG. 3

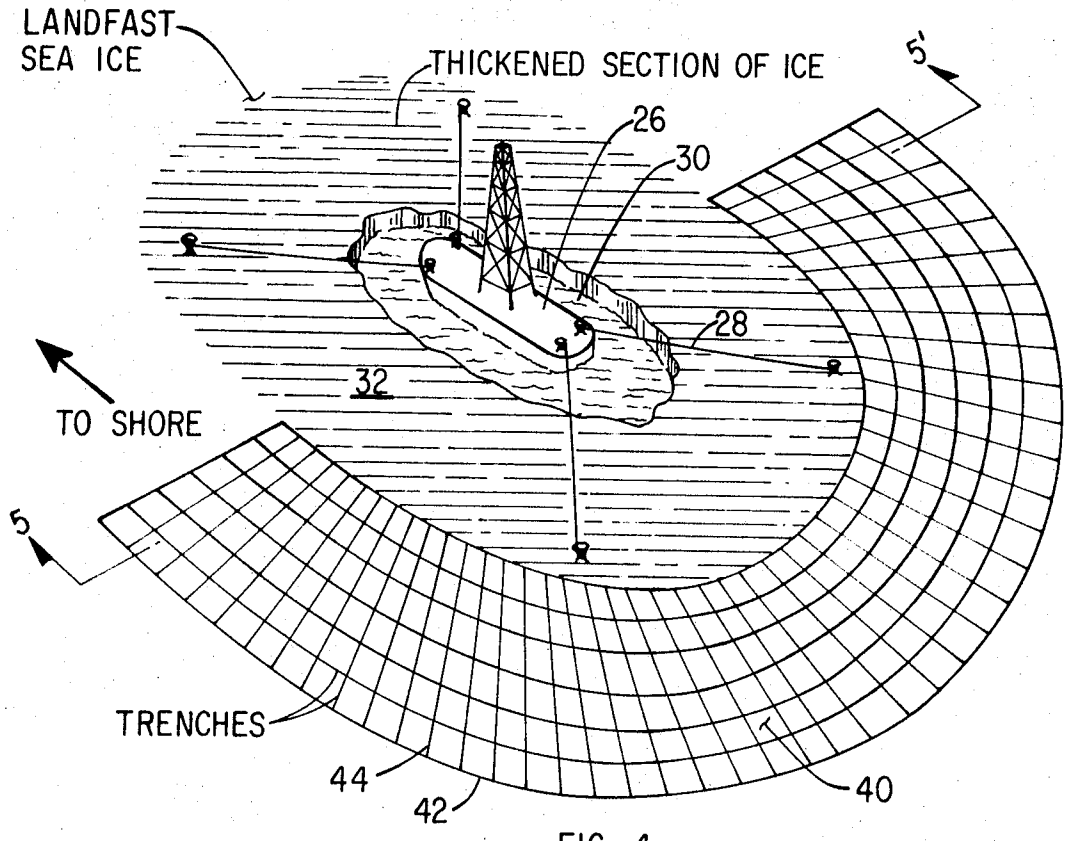


FIG. 4

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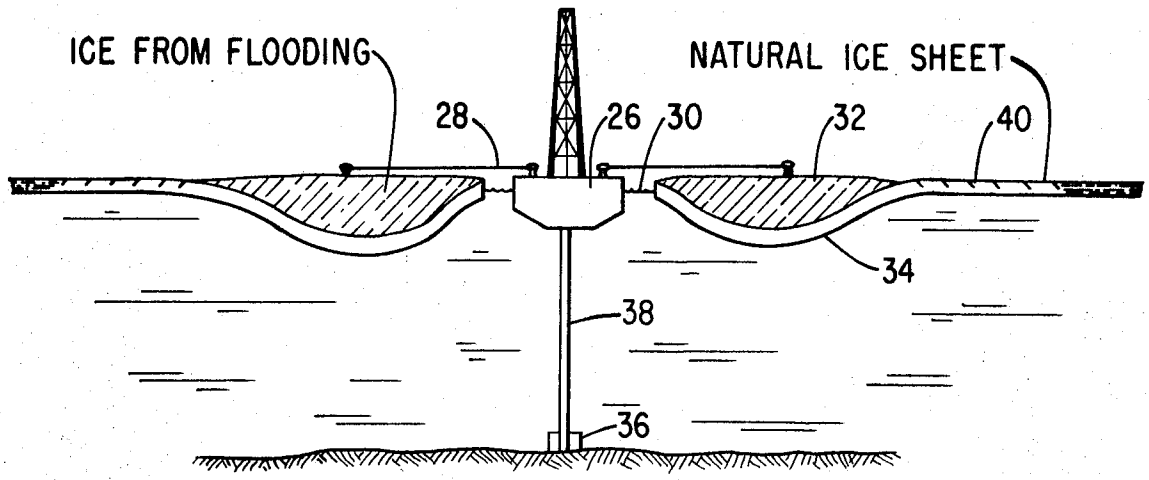


FIG. 5

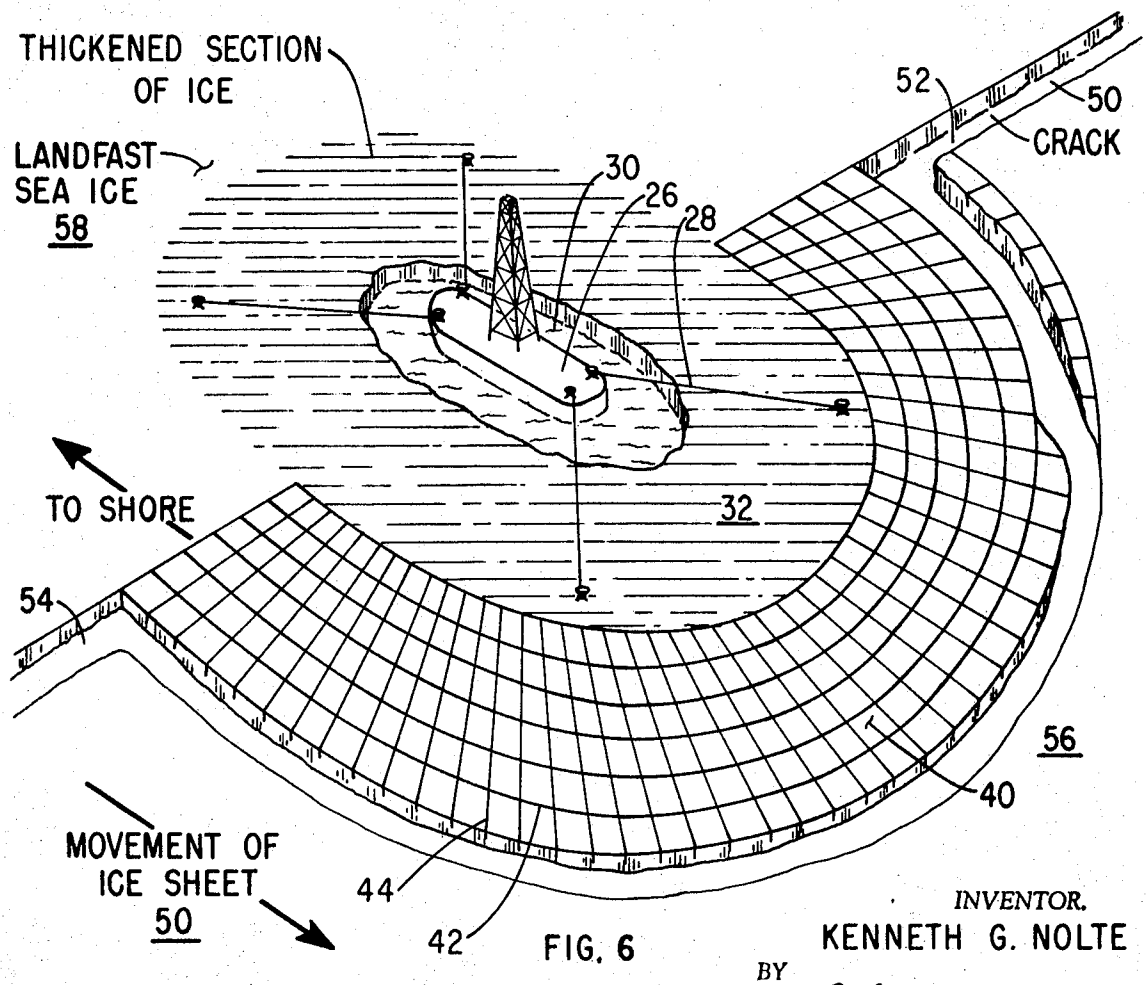


FIG. 6

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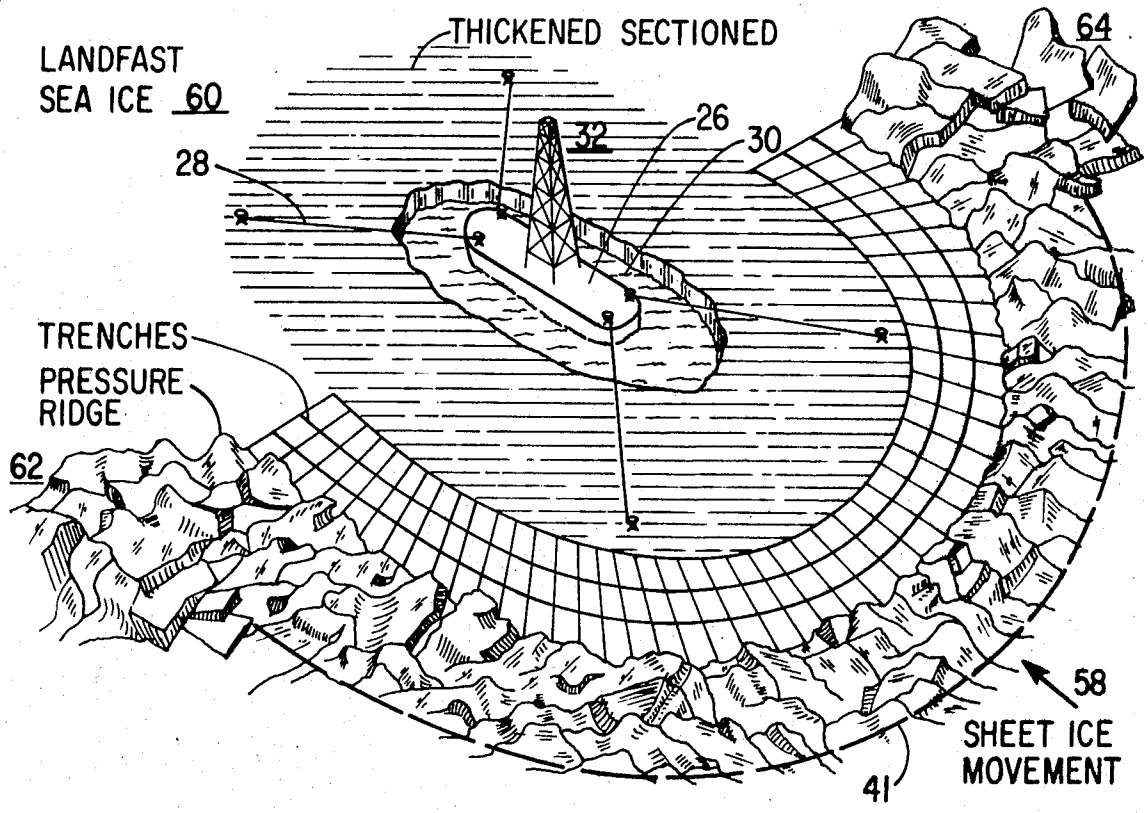


FIG. 7

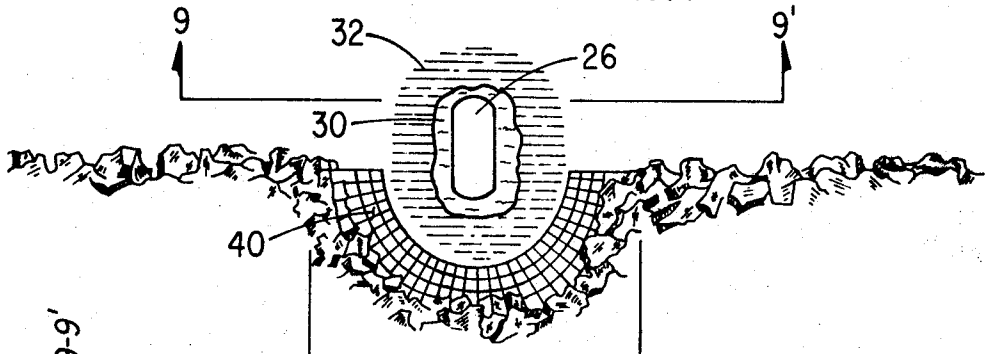


FIG. 8

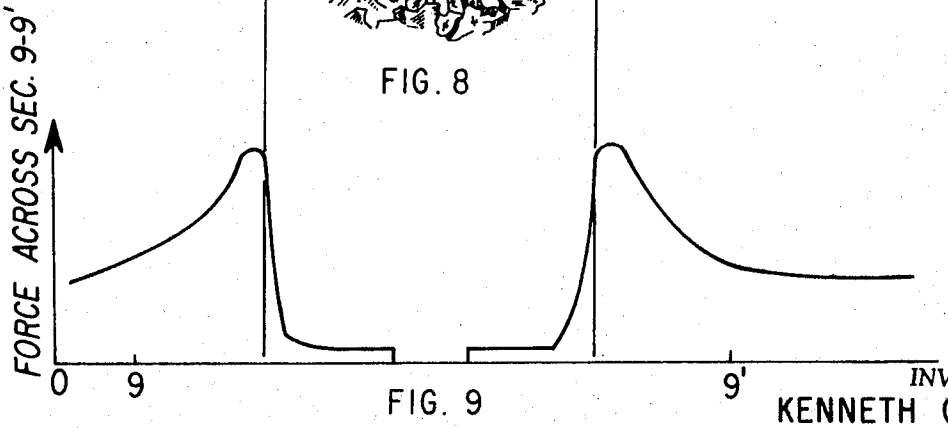


FIG. 9

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PROTECTING A STRUCTURE IN WATER COVERED WITH SHEET ICE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a method of protecting a vessel or other structure set in water which is covered by sheet ice. It relates especially to a method of protecting the vessel in those areas in which the sheet ice is subject either to pressure ridges or opening of cracks in the ice sheet. It particularly concerns a system in which either the pressure ridge or the opening of the cracks is diverted from forming near the structure or vessel being protected.

2. Setting of the Invention

Some areas of the ocean are covered with sheet ice for a good part of the year. One such area is the Arctic. There, the surface of the ice sheet is characterized by extreme irregularities resulting from deformation of the sheet of ice. One form of the ice pack irregularity is called a pressure ridge. A pressure ridge is normally a long narrow section of ice which has been built up to be many times thicker than the thickness of the ice sheet. Sometimes the pressure ridge extends 15 feet or more above the regular surface of the ice and this part is called the sail of the ridge. That part of the pressure ridges which extends below the regular surface is called the keel. The keel sometimes extends 50 feet or more below the ice sheet. The pressure ridge can be many miles long, e.g. 10–15 miles or more.

Pressure ridging ordinarily occurs when a sheet of ice is cracked into two portions and the two portions subsequently move toward each other. As the two ice sheets approach each other and collide their boundary forms a pile of debris (ice blocks plus snow). The overthrusting and crushing of the two interacting ice sheets causes pressure ridges. Sometimes, the two interacting ice sheets are of different thicknesses and this results in the pressure ridge to be composed mostly from debris from the thinner of the two sheets. However, if a pressure ridge is formed through the location of a vessel or structure frozen in the ice, the force of the pressure ridge is sufficiently great to cause severe damage to most vessels or structures. One way to protect vessels or structures from pressure ridges is to build them sufficiently strong to withstand the forces of the pressure ridge. However, this is very costly and may not be economically feasible for temporary, exploratory locations. Therefore, it is preferred to find other ways of protection against such forces of the pressure ridges. This present invention discloses such an improved method.

BRIEF SUMMARY OF THE INVENTION

Broadly speaking, this is a method of protecting a vessel or other structure in water covered with an ice sheet which could have pressure ridges, especially when the ice sheet is weakened by the presence of the structure. The term structure includes a floating vessel or an installation such as a platform having a deck supported by lugs or piles supported by the bottom of the body of water. In a preferred embodiment, a section of ice, spaced from the structure, is strengthened in a configuration which preferably encircles the structure to be protected. Open water may be maintained between the structure and the strengthened section of ice. The section of ice can be strengthened in a number of ways.

For example, one method is to apply water to the top of the ice sheet and letting it freeze into a thicker section of ice than the thickness of the normal ice sheet. The military uses this technique to strength sea ice for use as airstrips. The ice sheet surrounding the strengthened area of ice is then preferably weakened to form a buffer zone. One way of weakening this section is by cutting circumferential and radial trenches part way through the ice sheet. Experience has shown that trenches can be constructed in Arctic ice by ditch digging equipment or chain saws. If there is a tendency for a pressure ridge to form in the vicinity of the structure being protected, the presence of the structure will increase the chances that the pressure ridge will form through the location of the structure. However, by following the method of my invention, the path (direction and location) of the ridge formed will be altered to miss the structure being protected. If a crack or pressure ridge in the ice sheet occurs in the vicinity of the structure being protected, it will occur in the area of least strength. I have provided an area of lesser strength at a distance spaced from the structure to be protected. This area of lesser strength is adjacent to an area of ice of increased strength. The crack or pressure ridge will be formed at the area of least strength. Thus, in this case it will be formed through the path of the weakened buffer zone of ice. If this zone is spaced a certain distance from the structure, that structure should be protected from damage from the pressure ridge.

BRIEF DESCRIPTION OF THE DRAWINGS

A better understanding of the invention and various modifications and objects thereof can be made with the following description taken in conjunction with the drawings.

FIG. 1 illustrates a vessel floating in open water surrounded by an ice sheet.

FIG. 2 illustrates the same vessel as shown in FIG. 1 but having a crack in the ice sheet through the location of the vessel caused by different directional movement of the ice sheet.

FIG. 3 illustrates the same vessel as shown in FIG. 1 but having a pressure ridge formed through the location of the vessel.

FIG. 4 illustrates a method of protecting the vessel of FIG. 1 by strengthening the ice surrounding the open water and forming a buffer zone outside the strengthened section of ice.

FIG. 5 is a cross section taken along the line 5—5 of FIG. 4.

FIG. 6 illustrates what happens when a crack occurs in the vicinity of a vessel protected as shown in FIG. 4.

FIG. 7 illustrates the location of a path of a pressure ridge in the vicinity of a vessel protected as shown by the method of FIG. 4.

FIG. 8 is a plan view of a vessel protected in accordance with my invention in which the path of the pressure ridge is directed away from the protected vessel.

FIG. 9 illustrates in a qualitative way the lateral force exerted along the ice sheet along the line 9—9 of FIG. 8.

DETAILED DESCRIPTION OF THE INVENTION

Attention is first directed to FIG. 1 which illustrates one method considered by the prior art to protect a vessel from moving ice. Shown thereon is a floating vessel 10 which is supported by a body of water which has

ice sheet **12** on the top thereof. Open water **14** is provided all around vessel **10.** The vessel is shown as being anchored to the ice sheet by mooring lines **16** although it sometimes may not be anchored to the ice. The vessel may be anchored to the bottom of the body of water. The setting of the arrangement of FIG. **1** is in the ice infested Arctic waters where along the coastal regions a stable ice sheet is maintained for approximately 8 months of the year. This stable ice is termed land-fast ice and is characterized by a horizontal movement of the order of 100 feet or less during an 8-month period. Many such areas have land-fast ice and are to be explored for subsequent drilling of wells for oil and gas in such areas. One approach being considered by some for exploratory drilling is to insert a vessel in the land-fast ice. The permitted relative movement of the vessel with respect to a subsea well site is limited by current drilling techniques. For the shallow waters along the Arctic coast where land-fast ice occurs, the permitted movement may be limited to 10 to 15 feet before the drill pipe (extending between the vessel and the subsea well site) would break. Because possible movement of the land-fast ice can exceed the permitted movement of the vessel, it has been suggested by some that an open water area be maintained around the vessel which will permit the ice to move a given amount before the ice contacts the vessel and forces the vessel to move with the ice. This is the situation illustrated in FIG. **1.**

The use of an open water area will permit the ice sheet to move a given distance before the ice contacts the vessel or the structure being protected, however, the open water will create a stress concentration in the ice sheet. A well known result from the theory of elasticity is that a hole in a stressed plate raises the stress around the hole by a factor of 3. Because the open water region around the drilling site such as open water **14** will cause a stress concentration in the ice sheet, it is probable that a crack or pressure ridge which would naturally form in the vicinity of the site will form at the site and endanger the vessel or platform. It is noted that the insertion of a vessel or structure in the ice will also cause a stress concentration without the open water. In FIG. **2** a crack **18** is shown going through the open water area **14.** Here, we have one section of ice **20** and another section **22** which has relative movement in opposite directions. The most severe damage that this would likely cause is the parting of the anchor lines **16.** A much more serious situation is illustrated in FIG. **3.** There, we have the formation of a pressure ridge. There, the sections of ice **20** and **22** have moved toward each other forming the pressure ridge **24.** These pressure ridges can develop sufficient forces to severely damage most vessels. Vessel **10** is shown as being destroyed by the pressure ridge. It should be noted here that cracks and pressure ridges may occur in land-fast ice even without open water **14.** However, the open water **14** weakens the area around the vessel to be protected and encourages cracks or pressure ridges to be formed in that area. Thus open water alone is not the answer to the problem.

FIG. **4** illustrates a method whereby the path of any crack or of any pressure ridge that is formed in the vicinity of the vessel to be protected is diverted around that vessel. My method of course will not stop the formation of either cracks or pressure ridges, but it will control their path to prevent damage to the drilling vessel. Shown in FIG. **4** is vessel **26** which is anchored to the ice sheet by anchor lines **28.** An open water area **30** is maintained between the vessel **26** and the ice. The ice immediately surrounding open area **30** is a section **32** which has been strengthened. This strengthened section is created in one embodiment by increasing the ice thickness. A suitable technique includes flooding the surface of the area of ice to be strengthened with several inches of sea water and then allowing the flood water to freeze. This process is repeated until the desired thickness is obtained. The thickened section of ice is shown clearly in the cross section of FIG. **5.** There, the ice formed, designated by the numeral **32,** is shown above the natural sheet **34.** If vessel **26** is a drilling vessel as illustrated, the flooding technique of freezing of ice section **32** is rather simple, as the drilling vessel would have a pumping system and power plant available. As also shown in FIG. **5,** vessel **26** is above wellhead **36** and is connected thereto by a riser system **38** in a well-known manner.

It is seen that I have now provided a strengthened section of ice around vessel **26.** However, I wish to be sure than any cracks in the ice sheet or any pressure ridges which may be formed will occur outside the thickened section **32.** I therefore form a buffer zone **40** around the thickened section **32.** I weaken this buffer zone **40** by cutting a checkerboard pattern of trenches which include circumferential trenches **42** and radial trenches **44.** To further facilitate the failure of the area of trenches to thrusting actions (which is what occurs in the formation of pressure ridges) I cut the circumferential trenches at an angle (for example 45°). This permits adjacent blocks to easily ride up over each other. The trenches should not be completely cut through the ice sheet. As shown in FIG. **4,** the thickened section **32** is preferably formed completely around vessel **26.** However, the buffer zone **40** should preferably only partly encircle the thickened section **32.** It should encircle that section on the side of the land fast ice away from the shore. As a result, the pressure ridge will not form between shore and the vessel site and hence will not obstruct transportation across the ice from shore to the site.

FIG. **6** is essentially the same as FIG. **4** except that a crack **50** has been formed in the vicinity of vessel **26.** The two ends **52** and **54** of crack **50** illustrate a crack that ordinarily would have been directed through the open water space **30** except for strengthened zone **32** and buffer zone **40.** As buffer zone **40** is weaker than strengthened zone **32** the crack follows the weakened zone. Here, anchor lines **28** have survived the crack and have not been parted thereby. In FIG. **6** the movement of the section of ice **56** is towards the sea and the land-fast ice section **58** has moved very little. Thus, the occurrence of crack **50.**

If the crack **50** forms through the checkerboard weakened section, sea water will flow into the gridwork of trenches and freeze to restrengthen the buffer zone. This flowing of water into the trenches away from the crack can be prevented by not connecting all of the trenches when cut, for example the radial trenches would not be continuous but have uncut ice left in each radial path to form dams. Another way is to place snow in the trenches to form dams to prevent water from flowing from the crack into all the trenches.

Attention is next directed to FIG. **7** which is similar to FIG. **4** except that here a pressure ridge is shown as having occurred in the vicinity of vessel **26.** Here again,

I have not stopped the movement of the ice, but I have directed the path of the pressure ridge. Here, the movement of the ice of sheet **58** is toward the sheet of landfast ice **60.** The main thrust is illustrated as occurring along the line from **62** to **64.** However, I have reinforced section **32** so that it is more resistant to a compressive force than is buffer zone **40.** Thus, the crumbling of the formation of the pressure ridge is diverted into a path which follows the buffer zone **40.** The outer limit of the previously formed buffer zone is indicated by dotted line **41.** The pressure ridge then has had its path diverted around vessel **26.**

FIG. **8** is a top view of the vessel of FIG. **7** and shown vessel **26,** open water **30,** reinforced area **32** and buffer zone **40.** Directly beneath FIG. **8** is FIG. **9** which shows, in a qualitative manner only, the lateral force caused by this pressure ridge along the line **9–9'** of FIG. **8.** There it is shown that the force exerted on the ice surrounding vessel **26** and the strengthened section **32** is quite low compared to the force exerted on the ice outside the buffer zone **40.** The cause of this reduced force is buffer zone **40** which has absorbed the bulk of the energy caused by the movement of the ice sheet in this area.

I have taught one method of strengthening section **32.** Another way of strengthening this section is to lay a steel net or steel cables and freeze the net or cables into the ice—thus giving it reinforcement. The procedures outlined herein to protect a vessel or structure from cracks and pressure ridges in the ice have a higher degree of success if the strengthened and buffered zones are used to compliment each other, creating either zone by itself would increase the safety of the vessel or structure over that which would exist if no special preparation of the area were made.

While the above description of the various embodiments for creating the strengthened or buffer zones has been made in specific detail, various modifications can be made thereto, without departing from the spirit or the scope of the invention. For example, the buffer zone could be formed by placing insulation over the ice to retard the growth of its thickness. However, to place the insulation the ice must have previously reached a sizeable thickness to permit man and machine to safely work on the ice. The buffer zone could also be created by agitating the sea water by an air bubbler system under the water. However, this system would require an expensive installation prior to the beginning of the ice freezing process.

I claim:

1. A method of protecting a structure in water supporting an ice sheet secured to land such that movement of the ice sheet is restricted which comprises: constructing a thickened section of ice around at least a part of said structure, said thickened section being spaced from said structure, and during the time the structure is to be protected providing a buffer zone on the side of said thickened section away from said land which includes cutting circumferential trenches in said ice sheet, said trenches not extending through said ice sheet.

2. A method as defined in claim **1** which includes cutting radial trenches in said ice across said circumferential trenches and with such trenches radiating from said structure.

3. A method as defined in claim **2** in which said circumferential trenches are cut at an angle to vertical.

4. A method as defined in claim **1** in which the thickness of the thickened section of ice is increased by a factor of 3 over the thickness of the normal ice sheet.

5. A method as defined in claim **1** where said structure is a vessel floating on said water and anchoring said vessel to the bottom of said body of water.

6. A method so defined in claim **1** including the step of maintaining open water between the vessel and the thickened section of ice.

7. A method of protecting a structure in water covered with an ice sheet which comprises reinforcing a section of the ice in a pattern which at least partially encircles said structure, weakening the ice sheet on the side of the reinforced section away from said structure, and maintaining the portion of the ice thus weakened in its weakened condition during the time which the structure is to be protected.

8. A method as defined in claim **7** including the step of maintaining open water between said structure and the reinforced section of ice.

9. A method of protecting a structure in water supporting an ice sheet in which said ice sheet is secured to land which comprises providing a weakened zone in said ice sheet in a pattern spaced from said structure on the seaward side of said structure and only partly surrounding such structure, such weakened zone being maintained during the time which the structure is to be protected, and providing a strengthened section of ice between said structure and said weakened zone.

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