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[54] **METHOD FOR CONSTRUCTING ICE ISLANDS IN COLD REGIONS**

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[51] **Int. Cl.** **E02b 3/00,** F25c 1/02

[58] **Field of Search** ..... 61/46, 36 A, 1 R; 166/DIG. 1

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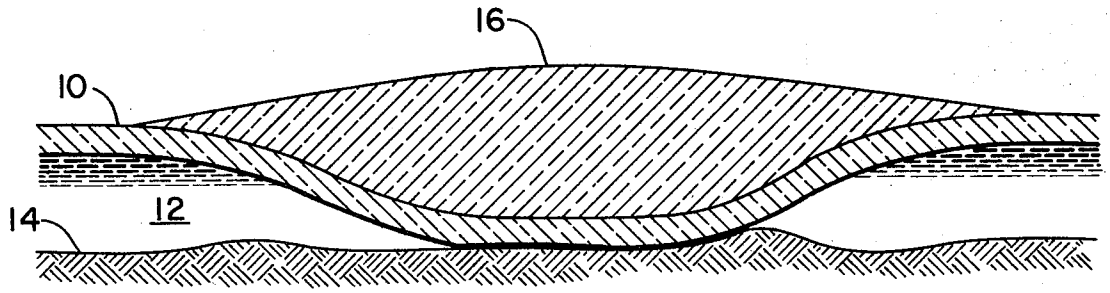
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[57] **ABSTRACT**

A method for constructing ice islands in cold regions in which water is placed on the surface of a floating sheet of natural ice and allowed to freeze to form an ice body having a mass such that its draft is greater than the water depth, whereby the ice island is permanently grounded.

10 Claims, 3 Drawing Figures



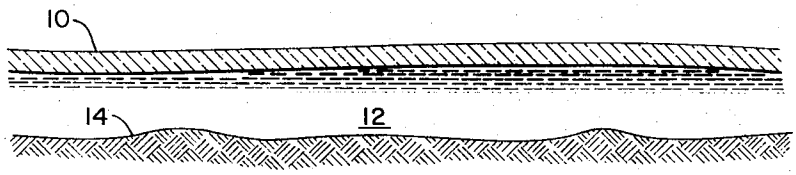


FIG 1

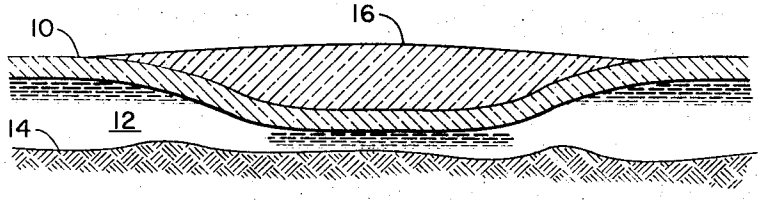


FIG 2

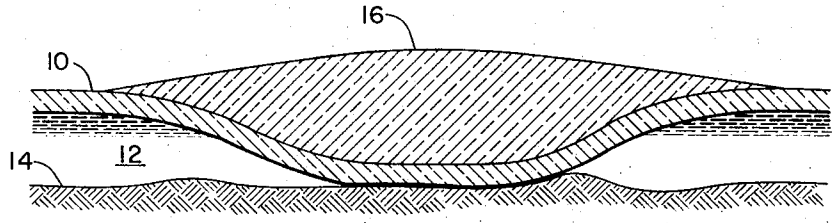


FIG 3

METHOD FOR CONSTRUCTING ICE ISLANDS IN COLD REGIONS

This invention relates to the construction of ice islands, and more particularly to a method for forming artificial ice islands in cold regions to serve as a base for operations.

Because of the increased activity in cold areas, such as the polar regions, and especially in the Arctic, and the lack of land masses in much of the area, need exists for suitable bases from which exploratory drilling, petroleum recovery, supply, tanker berthing and scientific operations can be conducted. Some of these operations have been successfully carried out from floating pack ice or from fast ice along the shore. The ice pack, which accounts for almost all of the ice cover in the Arctic ocean, is a conglomeration of very young ice and ice several years old. However, because of the low strength of the relatively thin, e.g., 2 to 4-foot thick sheet ice, and the vigorous forces and pressures that exist within the pack ice that tend to keep it in a continual state of fracture, the pack ice is highly unreliable as an operation site. The use of fast ice along the shore as a base for operations is often unsatisfactory since the desired operational site may not be frozen over, and often operations must be deferred until late in the season to obtain ice of sufficient thickness to support the intended operation.

Natural ice islands, formed by calving from a land ice mass, are occasionally found adrift in the ice pack. Because of their substantial size and thickness, these floating blocks are found to be excellent platforms from which certain operations can be conducted. However, often these natural ice islands can not be found at the desired location, and because they are usually adrift, they cannot be employed in a fixed location, unless the island happens to be grounded. Furthermore, even if a natural ice island is found grounded at the desired location, experience has shown that changes in the wind, currents, or forces exerted by surrounding pack ice can cause the ice island to break up or to be set adrift.

Attempts have been made to thicken sheets of natural sea ice by placing sea water on the surface of the ice and allowing the water to freeze. In this manner the sheet ice is thickened to provide additional strength. While these attempts have been somewhat successful in providing a base for certain light operations, at least on an experimental basis, because of the relatively low strength and mobile nature of the sheet ice, the technique does not provide a suitable base for heavy duty operations in a fixed location. Thus, need exists for a method for constructing artificial ice islands to provide both temporary and permanent fixed bases from which various operations can be conducted.

Accordingly, it is a principal object of this invention to provide a method for constructing relatively high strength, fixed location, ice islands.

Another object of the invention is to provide a method for constructing a relatively high strength ice island in a fixed location from which various operations can be conducted.

Still another object of the invention is to provide a method for constructing an artificial ice island useful as an offshore drilling platform.

A still further object of the invention is to provide a method for thickening natural sheet ice to provide a bottom-supported, fixed location, ice island.

Other objects and advantages of the invention will be apparent from the following description and accompanying drawings, in which:

FIG. 1 is a cross-sectional view schematically illustrating a typical sheet of natural ice floating on a water body;

FIG. 2 is a cross-sectional view schematically illustrating an ice island during construction and prior to grounding on the bottom of the water body; and

FIG. 3 is a cross-sectional view schematically illustrating an ice island constructed in accordance with the method of this invention.

Briefly, this invention contemplates a method for constructing ice islands in cold regions in which water is placed on the surface of a floating sheet of natural ice and allowed to freeze to form an ice body having a mass such that its draft is greater than the water depth whereby the ice island is permanently grounded.

Artificial ice islands can be constructed by the method of this invention in any geographic region having average ambient temperatures during the construction period sufficiently low to freeze water. As a practical matter, it is preferred that the method be practiced in a region exhibiting average ambient temperatures below about 25° F. during the construction period, and most preferably below about 10° F. Average ambient temperatures within these ranges are encountered in both the Arctic and Antarctic during a substantial portion of the year.

FIG. 1 illustrates a typical natural floating ice sheet wherein a substantially uniform sheet of ice **10** is floating on a water body **12** overlying a bottom **14.** Ice sheet **10** can be part of the polar ice pack or fast ice attached to the shore. Water body **12** can be a marine body such as an ocean, sea, bay, or the like, or a fresh water lake. Preferably, the construction site is selected at a location and construction commenced at a season of the year during which the construction site is covered with a layer of ice of substantially uniform thickness and having a relatively fracture-free, smooth surface. Although the sheet of ice need only have sufficient thickness to support the weight of the men and equipment employed in the construction operation, and can have an initial thickness of one foot, or less, thicker initial ice coverage is preferred. Oftentimes the initial ice sheet will be up to 6 feet in thickness, with coverages of 2 to 3 feet being typically encountered.

Construction of the ice island is commenced by depositing water directly onto the surface of ice sheet **10** at the desired location of the ice island, or at a preselected location such that drift during the construction operation will place the island over the desired location at the time of grounding. Sea water can be used to form the ice island, however, fresh water is preferred, if available, since fresh water forms higher strength ice upon freezing. Water is placed upon the ice sheet either by flooding with water pumped onto the surface of the ice, or by spraying water onto its surface. Either confined flooding or free-flooding can be employed. In the confined flooding technique, a system of dikes having the desired shape are formed to contain the water during the freezing operation. In the free-flooding technique, the water is placed on the surface and allowed to disperse in all directions from the point of discharge. The water is discharged onto the surface of the natural ice at the center of the portion to be thickened, and an oval or circular pattern having its thickest portion at

the middle and tapering outwardly to the edges is usually obtained. The size and shape of the ice island will depend on the initial thickness of ice sheet **10**, the water discharge rate and application technique, and the air temperature. If a large ice island is to be formed, water can be discharged at several points. The location of the discharge points relative to each other will affect the shape of the resulting ice island. With either the confined or free-flooding techniques, it is usually not necessary to remove snow from the surface of the ice or to otherwise prepare the surface. However, the snow can be leveled to knock down the drifts, which will also pack the snow and produce better spreading of the initial floodings.

The water can be applied to the surface of the natural sheet ice continuously at a rate such that freezing prevents accumulation of excessive depths of water or, alternatively, the ice can be flooded intermittently to a shallow depth and allowed to freeze to form successive layers of ice. The depth of each layer should be about 2 to 6 inches, measured at its deepest part, the optimum depth for individual flooded layers being about 4 inches. The depth of the water and the ultimate thickness of each layer of ice is greatest at the center of the body, and less towards the edges to produce the tapering configuration.

As schematically illustrated in FIG. **2**, the weight of the added layers of ice **16** applied by free-flooding causes relaxation or plastic deformation of the natural ice sheet **10** until a new point of buoyancy equilibrium is established, resulting in a buildup of a convexo-plane shape with the convex surface laying at the interface of the original ice surface. Of course, the pattern obtained by confined flooding will be different since the ice buildup will conform to the shape of the dike. This less tapered configuration often causes more severe stresses in the ice sheet **10** at the edge of and adjacent to the ice buildup. The elevation of the surface of ice **16** will be somewhat higher than the surrounding sheet ice since the larger ice mass will float higher in the water than the thinner sheet ice.

The application of water to the surface of the ice body is continued until the mass of the ice body is such that its draft is greater than the depth of water body **12**, whereupon the ice body becomes grounded and anchored in place. As illustrated in FIG. **3**, ice layers applied to the surface subsequent to grounding can no longer cause the body to sink to a lower point of buoyancy equilibrium, thus the ice builds up above the surface of the surrounding ice as additional layers are applied. Flooding is continued until the mass of the ice island is sufficient to securely anchor the island to the marine bottom, and to obtain an elevated working platform. It is preferred that additional ice layers be applied until the surface of the ice body is at least about **3** feet above its maximum free-floating elevation to assure grounding. Ice islands having surface elevations up to 40 feet higher than the surrounding sheet ice can be constructed, and surface elevations as much as 10 to 30 feet above the surrounding sheet ice are readily attainable.

The method of this invention can be used to construct ice islands in waters having depths of less than about 50 feet, and is especially suited for construction of ice islands in water up to about 30 feet in depth, and particularly in relatively shallow water having a depth of 10 feet or less.

Also, if desired, piles or other supportive members can be frozen into ice **16** during the construction process to provide an integral support system for a drilling rig or other equipment to be placed upon the artificial ice island.

This invention is further illustrated by the following example which is illustrative of a specific mode of practicing the invention and is not intended as limiting the scope of the invention as defined by the appended claims.

This example illustrates the practice of the invention in a cold region having an average ambient temperature below the freezing point of water. The ice island is constructed in a marine body having a depth of about 15 feet at mean low tide. The construction site is covered by a sheet of floating natural ice that is relatively smooth and free of fractures. Snow drifts are leveled and the loose snow cover compacted. A pump is set and sea water pumped through a single discharge hose onto the surface of the ice sheet to a depth of about 4 inches. Pumping is discontinued and the water allowed to freeze. This alternate pumping and freezing operation is continued until the resulting ice body has a draft greater than the water depth so that the artificial ice island is grounded and the surface of the ice island has an elevation at its highest point about **5** feet above the surrounding floating ice. The completed ice island is of generally circular configuration and has a contour that tapers from the center to the edges.

Various embodiments and modifications of this invention have been described in the foregoing description and example, and further modifications will be apparent to those skilled in the art. Such modifications are included within the scope of this invention as defined by the following claims.

Having now described the invention, I claim:

1. A method for constructing an artificial ice island in a water body covered by a floating sheet of ice, which comprises placing water on the surface of a selected portion of the floating sheet of ice, said selected portion being substantially less than the whole of said ice sheet and being surrounded by a remaining contiguous portion of said ice sheet, and said water being placed on said selected portion under ambient conditions such that the water is frozen on said selected portion to form an ice body having a central thickened portion and tapering in thickness from said central portion outwardly to the edge of said selected portion, said ice body having a mass sufficiently large that the sheet of ice is deformed downwardly so as to define one continuous sheet of ice having three portions: (1) a grounded portion centrally located within said selected portion, which is grounded on the bottom underlying said water body; (2) an intermediate portion contiguous with said grounded portion and with an exterior portion of said ice sheet, said intermediate portion tapering in thickness from said grounded portion to said exterior portion; and (3) said exterior portion being undeformed and floating on said water body; and thereafter placing additional water on the upper surface of the ice island so that additional ice is formed to raise the elevation of the ice island above that of the surrounding floating ice.

2. The method defined in claim **1** wherein said water is intermittently placed on said selected portion and allowed to freeze between placements.

3. The method defined in claim 2 wherein said water is intermittently placed on said selected portion to a depth of 2 to 6 inches at each placement.

4. The method defined in claim 1 wherein said water placed upon the surface of said selected portion freely floods said surface.

5. The method defined in claim 1 wherein said water body has a depth of less than about 50 feet.

6. The method defined in claim 1 wherein said water is placed on the surface of said selected portion and frozen until the elevation of said artificial ice island is raised to at least about 3 feet above its maximum free-floating elevation.

7. The method defined in claim 1 wherein said water body is a marine body and the water placed on said selected portion is sea water.

8. The method defined in claim 1 wherein said water placed on the surface of said selected portion is fresh water.

9. A method for constructing an artificial ice island in a water body covered by a floating sheet of ice, which comprises:

placing water on the surface of a selected portion of said floating sheet of ice to freely flood the surface of the selected portion to a maximum depth of about 2 to 6 inches, said selected portion being substantially less than the whole of said ice sheet and being surrounded by a remaining contiguous portion of said ice sheet, and said water being placed on said selected portion under average ambient temperatures below the freezing point of water;

allowing the water placed on said selected portion to freeze;

repeating the alternate flooding and freezing steps to form an ice body having a central thickened portion and tapering in thickness from said central portion outwardly to the edge of said selected portion, said ice body having a mass sufficiently large that the sheet of ice is deformed downwardly so as to define one continuous sheet of ice having three portions: (1) a grounded portion centrally located within said selected portion, which is grounded on the bottom underlying said water body; (2) an intermediate portion contiguous with said grounded portion and with an exterior portion of said ice sheet, said intermediate portion tapering in thickness from said grounded portion to said exterior portion; and (3) said exterior portion being undeformed and floating on said water body; and

continuing the alternate flooding and freezing steps until the elevation of the ice island is at least about 3 feet above its maximum free-floating elevation.

10. A method for constructing an artificial ice island in a marine body covered by a floating sheet of ice, which comprises:

intermittently placing sea water on the surface of a selected portion of said floating sheet of ice to freely flood the surface of the selected portion to a maximum depth of about 2 to 6 inches, said selected portion being substantially less than the whole of said ice sheet and being surrounded by a remaining contiguous portion of said ice sheet, and said water being placed on said selected portion under average ambient temperatures below the freezing point of water;

allowing the water placed on the selected portion of said ice to freeze;

repeating the alternate flooding and freezing steps to form an ice body having a central thickened portion and tapering in thickness from said central portion outwardly to the edge of said selected portion, said ice body having a mass sufficiently large that the sheet of ice is deformed downwardly so as to define one continuous sheet of ice having three portions: (1) a grounded portion centrally located within said selected portion, which is grounded on the bottom underlying said water body; (2) an intermediate portion contiguous with said grounded portion and with an exterior portion of said ice sheet, said intermediate portion tapering in thickness from said grounded portion to said exterior portion; and (3) said exterior portion being undeformed and floating on said water body; and

continuing the alternate flooding and freezing steps until the elevation of the ice island is at least about 3 feet above its maximum free-floating elevation.

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