United States Patent

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[15] **3,675,430**

[45] **July 11, 1972**

[54] ARCTIC CONSTRUCTION AND DRILLING

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[22] Filed: **Feb. 5, 1970**

[21] Appl. No.: **8,898**

[52] **U.S. Cl.** **61/46,** 61/30, 61/35, 61/46.5, 61/50, 166/DIG. 1, 175/5

[51] **Int. Cl.** **E02d 21/00,** E02d 27/36

[58] **Field of Search** 61/46, 50, 52, 34, 30; 166/DIG. 1; 175/9, 57

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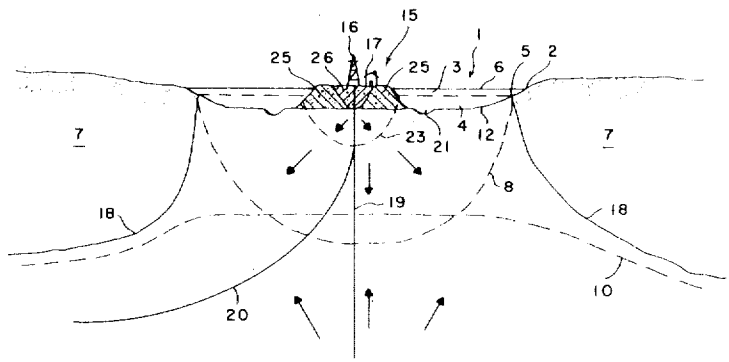
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[57] **ABSTRACT**

A method for constructing a working base in a permafrost area wherein the working base is located in bodies of water meeting certain requirements. A method for constructing a working base in a body of water and the working base itself.

23 Claims, 5 Drawing Figures



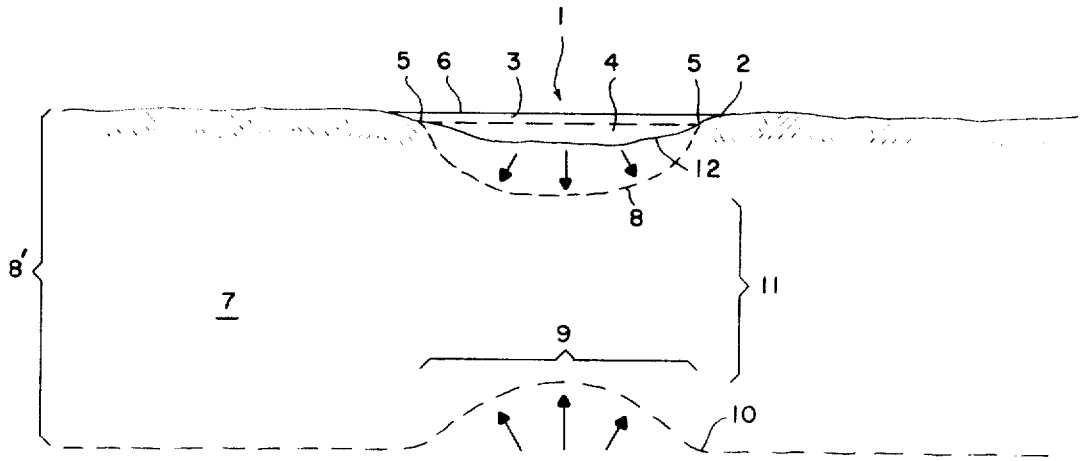


FIG. 1

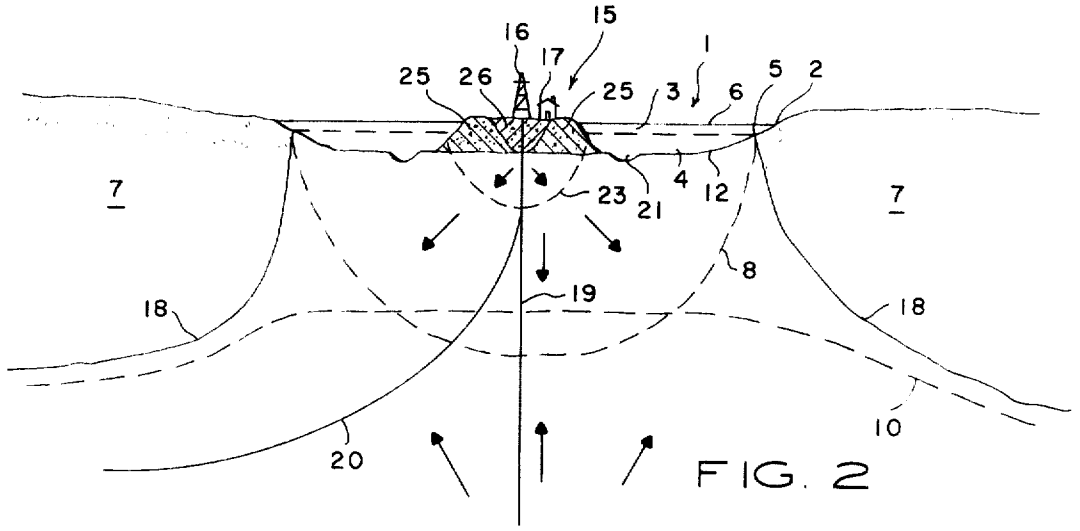


FIG. 2

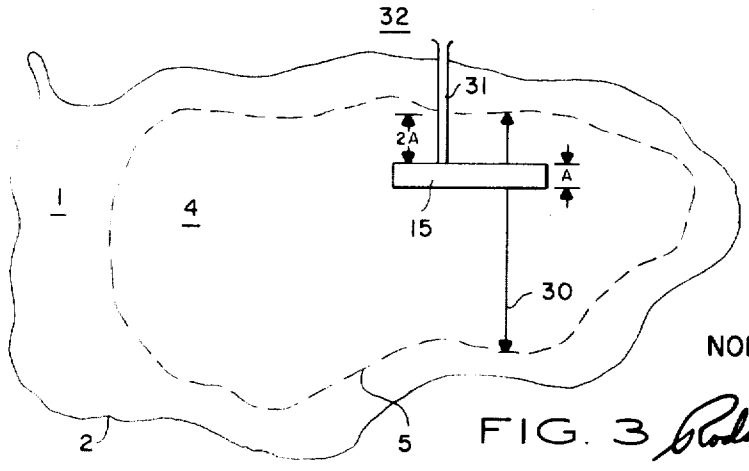


FIG. 3

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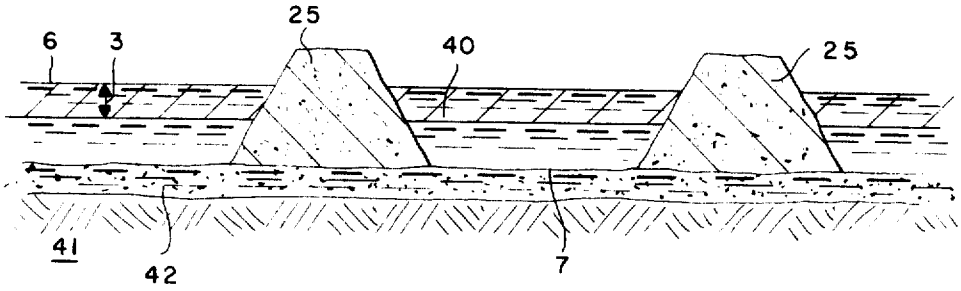


FIG. 4A

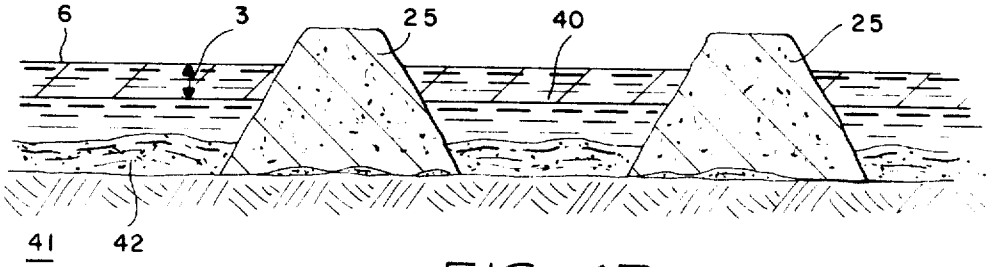


FIG. 4B

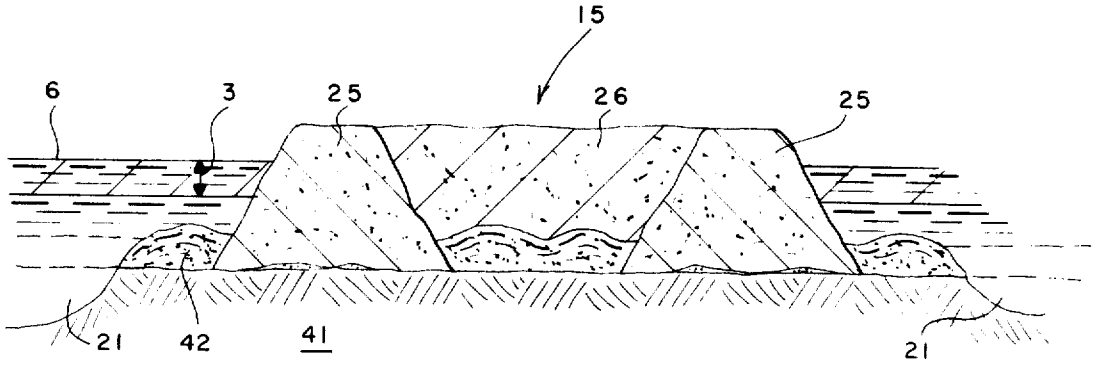


FIG. 4C

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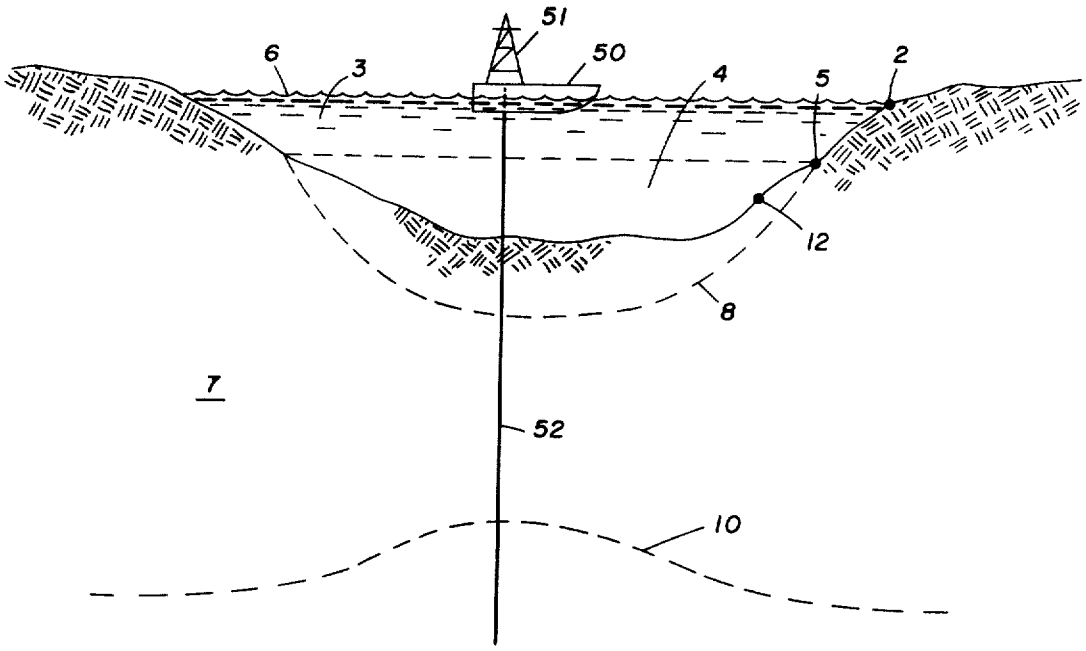


FIG. 5

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ARCTIC CONSTRUCTION AND DRILLING

BACKGROUND OF THE INVENTION

Permafrost is defined as a permanently frozen layer at variable depths below the earth's surface in frigid regions. The permafrost layer is composed of frozen soil and rocks that may extend from near the earth's surface to hundreds of feet therebelow. The upper portions of the permafrost contain intervals of free ice and/or ice lenses or veins. When the ice in the permafrost is melted, the free ice and ice lenses and veins can no longer support the soil and rock, thereby causing downward subsidence of the upper portion of the permafrost. In areas where the permafrost is thick, this upper portion is correspondingly thick and therefore the zone of subsidence on thawing of the permafrost is potentially large.

Depending on the particular region, the permafrost can be continuous, i.e., extending continuously throughout the area, or discontinuous, i.e., there being spaced apart portions of ground with no permafrost therein or spaced apart portions of permafrost itself. This invention applies to any permafrost area and, therefore, includes areas of both continuous permafrost and discontinuous permafrost of all types.

Permafrost is well known to be a major problem in Arctic construction and well drilling. The construction of a heated building on permafrost and the drilling and/or production of a well through permafrost can cause sufficient thawing of the permafrost and therefore vertical subsidence the ground supporting the building or well derrick to cause complete failure of the building or well. This failure necessitates abandonment of the project at that point and substantial economic loss.

Since a substantial portion of the Northern Country contains permafrost in varying thicknesses, it is highly desirable to operate in a manner which best avoids encountering the permafrost as much as possible rather than attempting to work against the permafrost and its inherent characteristics. In this manner one is using natural prevailing conditions to his advantage rather than working against these conditions.

SUMMARY OF THE INVENTION

In accordance with this invention, by locating a body of water in a permafrost area, the body of water meeting certain requirements as hereinafter defined in detail, one can substantially reduce, if not completely eliminate, the amount of permafrost encountered in drilling a well and carrying out other construction.

Accordingly, this invention relates to a method for constructing a working base such as a drilling pad or other construction support pad, a floating drilling barge, a jack-up drilling rig, and the like, in a permafrost area by locating a body of water in the permafrost area in which a portion of the water in that body of water remains continually unfrozen, i.e., remains in a liquid state through all seasons of the year. The working base is then located in the body of water and in the portion of that body of water which remains continually unfrozen (liquid). In this invention, the location of a working base in a body of water and in a continually liquid portion of water in that body of water includes locating the base on or under the normal top surface of the water, or both, the base further either floating on or in the water or resting on the bottom of the body of water or both.

A primary requirement of this invention is the location of a body of water in which a portion remains continually unfrozen and providing a working base in, on, or over the portion of the water which remains continually unfrozen. As will be described hereinafter, by following this requirement the amount of permafrost encountered below the working base will be substantially reduced, if not completely eliminated, thereby substantially reducing, if not completely eliminating, the problems normally encountered by constructing working bases over permafrost.

This invention also relates to a method for constructing a working base in a body of water by using a dam of material to outline the outer edge of the working base and leave the interior of the outline formed by the dam substantially unaffected, removing material from the bottom of the body of water around the outside perimeter of the outline dam to form a trench around the outside perimeter of the working base, and placing the removed bottom material in the interior of the outline formed by the dam to build the interior portion of the working base to a desired height. Material from outside the body of water can be used to form at least part of the dam and/or at least part of the fill for the interior of the outline formed by the dam if desired.

This invention also relates to a working base in a body of water wherein the outer periphery of the base is an outline dam and the interior of the outline formed by the dam is at least in part material from the bottom of the body of water, the working base also having a trench around at least part of the outer perimeter of the outline dam.

This invention is useful in all geographical areas in which at least some permafrost is present in the earth. It is particularly useful for locating and preparing sites for drilling and producing wells, particularly oil wells, wherein relatively warm liquid and/or gas will be passing up and/or down the well bore for extended period of time, and for providing working bases upon which to construct buildings and the like which are necessary as a habitat and for carrying on other cold weather operations such as mining, airports, and the like.

Accordingly, it is an object of this invention to provide a new and improved method for constructing a working base in a permafrost area. It is another object to provide a new and improved method for reducing the amount of permafrost encountered when working in northern regions. It is another object to provide a new and improved method for constructing a working base in a body of water. It is another object to provide a new and improved working base from which wells can be drilled and/or produced, buildings constructed, and the like.

Other aspects, objects, and advantages of this invention will be apparent to those skilled in the art from this disclosure and the appended claims.

DETAILED DESCRIPTION OF THE INVENTION

FIG. 1 shows a cross section of a body of water meeting the requirements of this invention and the state of the permafrost thereunder.

FIG. 2 shows the lake of FIG. 1 after the construction of a pad therein according to this invention.

FIG. 3 shows a top view of a body of water of FIG. 2.

FIGS. 4A through 4C show a method of constructing a pad according to this invention.

FIG. 5 shows the lake of FIG. 1 wherein the working base is one which floats in the water.

As part of the geologic chronology of the northern regions, the permafrost layer was formed and covered by an insulating layer known as tundra which kept the permafrost from melting. Lakes, rivers, and other bodies of water subsequently formed in various areas over the permafrost and tundra. Some of these bodies of water initially and/or eventually contained water to a depth sufficient that a portion of the water at the bottom of the body of water remained unfrozen throughout the winter. In other words, for a given location the maximum thickness of ice formed on the surface of a body of water will average a certain thickness and water below this maximum ice thickness will be continually unfrozen and liquid even in the severest winters.

This continual layer of unfrozen water provides a thermal blanket for the underlying permafrost and, therefore, prevents freezing of the permafrost to the earth's surface as it would if the layer of continually liquid water were not present. Also because of the thermal blanket effect of the continually liquid water layer, the vertical depth to which the permafrost zone extends will decrease because heat energy traveling from the interior of the earth toward the surface (geothermal effect) is sufficient to melt permafrost from the bottom up under the area affected by the thermal blanket of continually liquid water.

The above phenomena is described in FIG. 1 wherein there is shown a body of water 1 having a normal shoreline 2 to which the water extends when the body of water is unfrozen and to which the ice extends when the upper layer of the body of water is frozen. The body of water has a maximum ice thickness 3 below which water remains unfrozen and liquid year around. The continually or perpetually unfrozen portion 4 of water body 1 will have a continually unfrozen water shoreline 5 above which there is ice in the winter and below which there is liquid water in the winter. Water body 1 has a normal surface 6 which is liquid when thawed and ice when frozen.

Underlying the surface of the ground is, for example, a continuous layer of permafrost 7 which extends substantially from the surface of the earth to a finite distance below that surface as represented by reference numeral 8'. Thickness 8' represents the normal thickness of the permafrost when exposed to air and protected by the tundra. The tundra is not shown in the drawing for the sake of simplicity but will be a very small distance, e. g. up to 2 feet, on top of a very large, e.g. up to 2,000 feet, permafrost zone. Thus, in the normal equilibrium state the permafrost will have a thickness 8' and anyone attempting to operate from the earth's surface around water body 1, such as, for example, drilling a well, will have to contend with permafrost of thickness 8'.

However, due to the thermal blanket effect of portion 4 of water body 1, thawing of the permafrost will take place in two directions at the same time. Because of the heat sink effects of portion 4, thawing of the permafrost will extend downwardly from bottom 12 in a hemispherical manner as shown by dotted line 8 and the arrows therein. At the same time the geothermal effects described above will cause melting of the permafrost from the bottom upward in another hemispherical manner as shown by portion 9 of dotted line 10 and the arrows thereunder. Thus, there will be a substantial narrowing 11 of the depth of permafrost under water body 1 as compared to the normal depth 8' of permafrost under the earth's surface adjacent water body 1.

Accordingly, one operating in water body 1 and in portion 4 of water body 1 will have substantially less permafrost to contend with than if the same operation were carried out on the shore of water body 1.

Thus, at the very least, substantially less permafrost will have to be drilled through from water body 1 than from the shore of water body 1. In fact, depending upon the length of time water body 1 has been present and therefore the extent of thawing downwardly and upwardly as represented by dotted line 8 and portion 9 of dotted line 10, the permafrost under portion 4 of water body 1 can be nonexistent. This is so because the thawing can occur until portion 9 of dotted line 10 meets dotted line 8. In this situation, one drilling in the area of portion 4 of water body 1 would encounter no permafrost at all whereas the same operation carried out on the shore of water body 1 would encounter permafrost substantially of thickness 8'.

Thus, according to this invention operations carried out in portion 4 of water body 1 can substantially reduce, if not completely eliminate, the amount of permafrost that has to be dealt with and this is an exceedingly valuable advantage since the elimination or reduction of the permafrost encountered in carrying out an operation from the earth's surface gives an equivalent decrease or elimination of subsidence problems that could be encountered if the permafrost were thawed during and/or after the desired earth surface operation was carried out. By practicing this invention permafrost can be completely avoided in areas of otherwise continuous permafrost and this would be most helpful particularly in the drilling area since no precautions would have to be taken against permafrost subsidence due to thawing around the well bore. This in turn effects a substantial time and cost savings.

Generally, there will be some effective decrease in the depth of the permafrost zone where there is any continually unfrozen water portion 4 under water body 1. For exemplary purposes, however, the depth of water portion 4 at its deepest point when ice thickness 3 is at its maximum can be at least about 6 inches, preferably at least about 1 foot. The cross sectional area of portion 4 has no minimum or maximum other than that which is dictated by practical consideration such as weather. The desired operation can be carried out substantially within the horizontal area of portion 4. For example, in the situation where it is desired to drill one or more wells, the horizontal area of portion 4 should be sufficient to allow the drilling operation to be carried out therethrough. It is preferable that the horizontal area of portion 4 be greater than the working base from which the operation is to be carried out. As a further non-limiting example, the total depth of the water body, i.e., thickness 3 plus the maximum depth of portion 4, can be at least about 1 foot, preferably at least about 2 feet, in areas of discontinuous permafrost; and at least about 3 feet, preferably at least about 6 feet, in areas of continuous permafrost. For the maximum reduction of permafrost depth or even the elimination of permafrost, in addition to the above mentioned depth consideration, the shortest horizontal dimension (30 in FIG. 3) taken across portion 4 from one continually unfrozen shoreline 5 to the opposite continually unfrozen water shoreline 5 should be at least about two-thirds, preferably at least about two times, the depth of the permafrost 8' under land adjacent to water body 1.

The extent to which the permafrost depth is reduced below portion 4, including whether the permafrost is eliminated below that portion 4, will depend in part upon the age of the water body but will generally be at least about 5 percent less than the depth of the permafrost under the land adjacent water body 1.

The term "body of water" in this invention generally means an inland river, lake, pond, areas adjacent the shoreline of an ocean, and the like, but does not include the ocean as a whole because there is no permafrost under the ocean except for areas along a shoreline. Therefore, the ocean generally is not in a permafrost area. The permafrost area under the ocean and adjacent the shoreline thereof is most apparent where the shoreline is receding and/or the water level of the ocean is increasing. Thus, this invention is applicable to inland waters and offshore sea water adjacent the shoreline.

The working base is, according to this invention, located in water body 1 and in portion 4. By the term "in" in the foregoing sentence, it is meant to include the location or provision of one or more working bases on or under surface 6 or both and extending from surface 6 down any desired depth, including down to and below bottom 12. The working base can float in water body 1 or rest on bottom 12 or both. A floating working base can extend downwardly into portion 4 or not extend below depth 3 so that in the winter the working base is surrounded even on its lower end by ice.

The working base can be any type of supporting structure from a pad formed from earth, gravel, concrete, combinations thereof, and the like, metallic structures such as steel towers, offshore drilling jack-up rigs, and the like, floating barges, boats, and the like, so long as the desired operation is carried out on, in, or over portion 4 of water body 1. The operation can be one for drilling a well in the earth or merely constructing buildings or other facilities necessary to carry out other cold weather operations.

FIG. 2 shows water body 1 in which there has been constructed a working base 15 to support a drilling operation to be carried out by drilling rig 16 and also to support building construction represented by reference numeral 17. Pad 15 will be described hereinafter in detail.

For exemplary purposes, FIG. 2 has been drawn to show the state wherein the downward thawing of permafrost represented by dotted line 8 and the upward thawing of permafrost due to geothermal effects and represented by dotted line 10 has gone on to the extent that these two lines intersect one another, thereby substantially eliminating permafrost under portion 4. This is represented by solid lines 18 which show areas of permafrost 7 extending from continually unfrozen water shoreline 5 outward to normal shoreline 2 and

beyond. Thus, under portion 4 and between lines 18 there is substantially no permafrost so that a well borehole 19 drilled from rig 16 will encounter no permafrost and therefore no permafrost subsidence problems during drilling or production of the well.

Additionally, one or more directionally drilled well bores 20 can be drilled from rig 16 over to a point underneath solid land, thereby avoiding having to drill from the shore of water body 1. It is unique in the well drilling industry for it to be advantageous to deliberately locate a drilling site in a body of water and to directionally drill one or more well bores from the drill site in the body of water over to and under solid land on which no water is located and on which solid land a drilling rig would normally be located.

FIG. 2 shows a trench-like depression 21 on both sides of working base 15. This depression can extend partially or, preferably, completely around working base 15 as desired. The trench 21 can be functionally important to maintain working base 15 over unfrozen (no permafrost) earth. This is so because the upper portion of working base 15 is exposed to ambient air conditions and, therefore, freezing can occur through the depth of base 15 and downwardly in a hemispherical manner as represented by dotted line 23 and the arrows therein. Building 17 and other operations carried out on the surface of base 15 and which pass heat into base 15 can help avoid this freezing. Trench 21 can very materially aid in avoiding this freezing because it places a deeper and therefore larger thermal blanket around base 15 since more continually unfrozen water will be present around base 15 due to trench 21.

FIG. 2 shows base 15 to be composed of two spaced apart dam-like mounds of material 25, the spaced apart portion therebetween being filled by additional material 26. The construction of this base will be described in greater detail hereinafter.

FIG. 3 shows water body 1 with its normal shoreline 2 and its continually unfrozen water shoreline 5. There is also shown the shortest (minimum) horizontal dimension 30 across portion 4 between opposing points of shoreline 5.

Base 15 should be located somewhere in portion 4 and is preferably located so that the point of base 15 which is in closest approximation to shoreline 5 is at least about twice the narrowest horizontal dimension "A" of base 15. It is also preferred that the narrowest dimension "A" of base 15 be kept as narrow as possible without interfering with the operations to be carried out on the surface thereof so that heat from portion 4 can readily pass under the whole area of base 15 (heat will flow in from portion 4 most readily through the narrowest dimension of base 15).

Base 15 can be located by itself in water body 1 and access had thereto by water boat when the surface is unfrozen or ice boat or other vehicle when the surface is frozen. If desired, a roadway or bridge 31 can be constructed from the shore to base 15. If a roadway is constructed, it can be desirable to have a trench such as that shown by 21 in FIG. 2 along at least part of at least one of the sides of roadway 31 to thereby increase the thermal blanket adjacent the roadway and prevent freezing through the roadway down into the earth under portion 4. As a further example of a preferred method of practicing this invention, to minimize or even completely avoid encountering permafrost under portion 4, the minimum horizontal dimension 30 of portion 4 should be at least about two-thirds, preferably at least twice, the depth of the permafrost under the land 32 adjacent water body 1. Roadway or bridge 31 can meet base 15 at an angle to the long axis of base 15 as shown in FIG. 3 or parallel to that long axis if desired. By locating base 15 a substantial distance out into portion 4, should any refreezing similar to that shown by dotted line 23 in FIG. 2 occur, the refrozen portion will not extend to the permafrost line 18 (FIG. 2) under the shoreline 5. In this manner the location of base 15 helps prevent re-formation of permafrost under the body of water and consequently helps maintain the ground under the body of water permafrost free or at least in the reduced permafrost condition in which it was initially present before construction of base 15. Of course, any building or other operation on top of base 15 which puts heat into the base will also help prevent refreezing and maintenance of permafrost free condition under the base and the body of water in which the base is located.

As stated above, substantially any type base can be employed in accordance with this invention. A particularly desirable base and any roadway to that base can be constructed in the manner shown by FIGS. 4A through 4C.

FIG. 4A shows a pair of spaced apart dams which can be built for any length thereby defining the outer sides of the roadway or can be built in a closed configuration thereby outlining the outer perimeter of a base and leaving the interior portion 40 unfilled. The roadway can also be a single dam extending from shore to base 15. However, dam 25 can be employed as an outline dam to define the configuration desired for base 15. Thereafter, the interior 40 of the outline can be filled with material. Dam 25 can be built from and interior 40 can be filled with material from the bottom of water body 1 and/or material external to water body 1 as desired.

If the water body has a bottom composed of a firm sediment base 41 having an overlying soft sediment layer 42, it is desirable to allow dam 25 to settle through soft sediment 42 so that it rest on firm sediment 41 as shown in FIG. 4B, before filling interior 40.

Interior 40 can be filled to form a portion 26 of base 15 before, during, or after draining water from interior 40 and is preferably filled with material taken from the outer perimeter of outline dam 25 thereby forming trench 21 around at least a portion of the perimeter of base 15. In this manner fill material for interior 40 is obtained and at the same time the thermal blanket of water around base 15 is enlarged by way of trench 21. It is preferable that dam 25 and/or portion 26 of base 15 extend above water level 6 and at least 1 foot above water level 6 when at its maximum flood stage. However, if desired, either of dam 25 or fill 26 can be at or below water level 6.

FIG. 5 shows the lake of FIG. 1 with permafrost underlying same in which the working base is one which floats in water. More specifically, floating barge (working base) 50 carries on its surface deck a drilling rig 51 which drills conventional well borehole 52 through the underlying permafrost and into the earth below the permafrost.

Reasonable variations and modifications are possible within the scope of this disclosure without departing from the spirit and scope of this invention.

The embodiments of the invention in which an exclusive property or privilege is claimed are defined as follows:

1. In a method for constructing a working base in a permafrost area, the improvement comprising locating a body of water which lies over permafrost and in which a portion of the water remains continually unfrozen; and emplacing said working base in said body of water inwardly of the shoreline of said body of water, over said permafrost, and in said portion of water which remains continually unfrozen.

2. A method according to claim 1 wherein said body of water is a lake, river, or ocean areas adjacent the shoreline, the lower portion of which contains a substantial amount of water which remains in the liquid state through all seasons of the year, and said working base is provided on and/or under the normal surface of the body of water, said working base being one which floats in water, is supported by the bottom of said body of water, is supported by ice on the upper portion of said body of water, and combinations thereof.

3. A method according to claim 2 wherein said working base is one of (a) a pad supported on the bottom of said body of water in said portion of water which remains continually liquid and extending above the normal surface of said body of water and (b) a floating base which floats on said body of water when unfrozen and is surrounded by ice when an upper portion of said body of water is frozen.

4. A method according to claim 1 wherein said working base is employed for drilling and/or producing at least one well.

5. A method according to claim 4 wherein at least one well is directionally drilled from said working base under the ground adjacent said body of water.

6. A method according to claim 1 wherein the depth of the body of water at its deepest part is at least about 1 foot in areas of discontinuous permafrost and at least about three feet in areas of continuous permafrost.

7. A method according to claim 6 wherein the depth of the continually unfrozen water at its deepest part is at least about 6 inches.

8. A method according to claim 7 wherein the shortest horizontal dimension of the portion of continually unfrozen water is at least two-thirds the depth of the permafrost under the land adjacent said body of water.

9. A method according to claim 7 wherein the shortest horizontal dimension of the portion of continually unfrozen water is at least twice the depth of the permafrost under the land adjacent said body of water.

10. A method according to claim 1 wherein said working base is employed for supporting buildings.

11. A method for constructing a working base in a body of water in which a portion of the water remains continually unfrozen and which is surrounded by permafrost but which has no permafrost thereunder, the improvement comprising locating the desired working base in said body of water and in said portion of water which remains continually unfrozen, forming a dam of material around the outer periphery of the desired working base, thereby outlining the outer edge of the working base and leaving the interior of the outline formed by the dam substantially unaffected, removing material from the bottom of the body of water around the outside perimeter of the outline dam to form a trench around the outside perimeter of the working base, and placing the removed bottom material in said interior of the outline formed by the dam to build the interior to a desired height whereby said trench provides a larger thermal blanket of continually unfrozen water around said working base to prevent freezing of earth under said working base.

12. A method according to claim 11 wherein said bottom material is employed to form at least part of the dam.

13. A method according to claim 11 wherein material from outside the body of water is used to form at least part of the dam and/or at least part of the fill for the interior of the outline formed by the outline dam.

14. A method according to claim 11 wherein a roadway is constructed from shore to the working base by forming a single dam of material therebetween or by forming spaced apart dams of material and filling in the portion between the spaced apart dams to the desired height for the roadway.

15. A method according to claim 14 wherein the fill for the portion between the spaced apart dams is at least in part taken from along the outer edge of said dams to thereby form a trench in the bottom of the body of water along the outer edges of said roadway.

16. A method according to claim 11 wherein said outline dam extends from the bottom of the body of water to above the surface of the body of water.

17. A working base in a body of water in which a portion of the water remains continually unfrozen and which is surrounded by permafrost, but which has no permafrost thereunder, the improvement comprising the outer periphery of said base being an outline dam, the interior of the outline formed by said outline dam being at least in part material fro the bottom of the body of water, and a trench around at least part of the outer periphery of said outline dam, said working base being in said water and surrounded by said permafrost whereby said trench provides a larger thermal blanket of continually unfrozen water around said working base to prevent freezing of earth under said working base.

18. An apparatus according to claim 17 wherein at least one of the outline dam or the interior of the outline formed by the outline dam extend above the surface of the body of water.

19. An apparatus according to claim 17 wherein material from outside the body of water is used to form at least a part of said outline dam and/or at least a part of the interior of the outline formed by the outline dam, the remainder being substantially bottom material from said body of water.

20. An apparatus according to claim 17 wherein said working base additionally has a roadway extending from said working base to shore.

21. An apparatus according to claim 20 wherein said roadway comprises one of a single dam of material or a pair of spaced apart dams of material and fill material in the portion between the spaced apart dams, the fill material being to the desired height of the roadway.

22. An apparatus according to claim 20 wherein the fill for the portion between the spaced apart dams is at least in part taken from along the outer edge of said dams to thereby form a trench in the bottom of the body of water along the outer edges of said roadway.

23. An apparatus according to claim 17 wherein the point of closest approach of said base to the continually unfrozen shoreline of said water body is a distance from said shoreline of at least about twice the smallest horizontal dimension of said base.

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