

[54] ARCTIC ISLANDS

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[22] Filed: **July 13, 1973**

[21] Appl. No.: **379,139**

[52] U.S. Cl. **61/46, 61/36, 61/50**

[51] Int. Cl. **E02d 21/00**

[58] Field of Search **61/36 A, 36-46,**
61/50

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[57]

ABSTRACT

Artificial permafrost islands are constructed in Arctic sea waters to provide offshore sites from which oil and gas wells can be drilled. Sand and gravel are dredged from the floor of the sea and are redeposited at another location where an island is desired. The dredging and redepositing of sand and gravel are continued until a suitable insular shape and height are obtained. Subsequently, a slurry of silt in sea water, also obtained from the floor of the sea, is deposited on the heap of sand and gravel. A thickener, e.g., a gellant or a viscosifier, is incorporated into the slurry to effect consolidation of the ingredients so that they do not flow back into the sea after the slurry has been deposited on the island. The water of the thickened slurry eventually freezes upon exposure to the sub-zero temperatures of the environment, thereby converting the island into a permafrost structure which serves as a solid platform for a drilling rig, materials, equipment, housing, storage, etc.

38 Claims, No Drawings

ARCTIC ISLANDS

BACKGROUND OF THE INVENTION

The present invention pertains to man-made islands which can be used as offshore platforms in Arctic sea waters. More particularly, the present invention pertains to artificial permafrost islands which can be built and used in Arctic sea waters as operational sites for the search and production of oil and gas.

Geologists presently feel that offshore regions in Arctic waters show great promise as an oil and gas province. This hope is bolstered by gigantic gas and oil strikes recently made on land in the vicinity of the MacKenzie Delta and Prudhoe Bay, and by the fact that offshore areas are almost always more productive than adjacent land areas by a considerable margin.

Where offshore drilling operations can be conducted in a temperate zone, as off the coast of Texas, Louisiana, California, Australia, in the North Sea, etc., conventional shallow water drilling methods and production platforms can be employed. However, in view of the extreme cold and resulting harsh conditions which exist north of the Arctic Circle, neither the drilling nor the maintenance of offshore wells in the Arctic has been available or practical.

Naturally formed permafrost islands exist in the Arctic which, if they were properly located, would make good sites for the drilling of wells and subsequent production of oil and gas. These naturally occurring permafrost islands have withstood the ravages of the Arctic for centuries. They are composed of ordinary sand, gravel, clay and silt; the individual grains of these materials being tightly bound together by interstitial ice to depths of several hundred feet. The matrix of ice gives these islands great strength, and they are thus able to resist lateral forces exerted upon them by expansion and contraction of a recurring sheet of ice which forms around the islands during the colder months.

In an attempt to build artificial permafrost islands at selected locations for use as well drilling and producing sites, man has been making efforts to duplicate nature's feat. Shallow-water, high capacity dredges are employed to build up an island from sea floor materials during the months the waters are sufficiently free of ice. The blustering and freezing conditions of the Arctic winter are then relied upon to turn the island into a permafrost structure that can survive the hostile environment.

In accordance with prior methods, sand and gravel have been the preferred materials for building a permafrost island. The sand and gravel are dredged up from the sea floor, but a silt overburden which exists in abundance must first be removed to reach them. Heretofore, the silt has been little more than a detriment to the building of permafrost islands since it can only be cut and pumped off at a relatively slow rate, e.g., 20 percent of the capacity of the dredge for sand and gravel, and most of it flowed back into the sea when it was deposited on the island being built. It should be pointed out that it has not been previously possible to retain much of the silt on the island even when the sand and gravel were deposited in rings having an inner core and the silt was pumped into this inner core in a saturated state having the form of a soupy mush.

If it could be retained on the island being built until freezing into a permafrost structure occurs, silt would

be a desirable component of the structure since it can work its way into the interstices between the sand and gravel particles so that the structure is more nearly mineral in composition when freezing does take place.

The structure would hence be stronger and more resistant to attrition by heating and mechanical stress, i.e., it would be more akin to a natural permafrost island. In addition, silt would be the preferred material for placement in the inner core of a ring-shaped permafrost island. It would in fact be preferred over sand and gravel in this application provided it could be retained in the core until converted into permafrost. However, when untreated silt was previously used in the building of an island, large quantities of the solid drained back into the sea, e.g., 75-80 percent, even when the silt was deposited in an inner core of the island.

It is known that attempts have been made to devise means for dewatering silt so that it can be effectively employed in the building of permafrost islands. It is not known whether such dewatering means have as yet been fully developed, but in any event they are likely to be prohibitively costly and time consuming for the intended purpose.

Therefore, an object of the present invention is to provide an improved method of building a permafrost island whereby silt can be effectively employed as a material of construction.

Another object is to provide a method of consolidating silt with sand and gravel when building a permafrost island.

Still another object is to provide a method of retaining a slurry of silt in the inner core of a ring-shaped permafrost island being built until freezing of the silt slurry can occur.

Even another object of the present invention is to provide a method of effectively utilizing silt in the construction of a permafrost island without having to dewater the silt.

SUMMARY OF THE INVENTION

In the building of an artificial permafrost island in Arctic sea waters wherein sand and gravel are dredged from the floor of the sea and are redeposited on the sea floor at a location where an island is desired and until the height of the sand and gravel extends above the surface of the water, silt is consolidated with the sand and gravel of the island by mixing a thickener with a slurry of the silt in sea water, and the thickener-slurry mixture is then deposited on the island being built. The thickener can be a gellant or a viscosifier whereby the slurry becomes gelled or the viscosity thereof increased to a point where the flow of slurry ingredients back into the sea is at least substantially prevented, thus retaining the silt on the island until freezing into a permafrost structure can occur. Accordingly, it is not necessary to dewater the slurry in order to achieve a thickening thereof.

Various gellants and viscosifiers can be employed as thickeners, sodium silicate and xanthan gums being examples of thickeners which can be employed to advantage.

Where desired, the sand and gravel of the island can be shaped in the form of a ring having an inner core, and the core can be filled with the thickener-slurry mixture.

Man-made islands are thus formed which comprise a deposited mixture of sand, gravel, silt, sea water and a

thickener, and wherein the sea water becomes frozen by exposure to atmospheric conditions of the Arctic weather to form artificial permafrost islands.

DESCRIPTION OF PREFERRED EMBODIMENTS

The term "silt" as used herein is intended to mean silt per se, clay, clayey silt, and mixtures of such materials which usually exist in a layer on the sea floor over underlying deposits of sand and gravel. Silt can also be mixed with the sand and gravel in varying proportions.

In the practice of the present invention, sand and gravel can be dredged up from the sea floor and redeposited in a location where an island is desired and until the height of the sand and gravel extends above the surface of the water. This dredging and redepositing of the sand and gravel can be effected in accordance with practices and equipment which are already known and used by those skilled in the art. In addition, the dredging and pumping of silt can be accomplished by means of known apparatus and techniques.

Once enough sand and gravel have been heaped in building of the island to achieve a desired shape and a height which prevents the inundation of the island by waves and tides, depositing of silt in accordance with the present invention can then be commenced. As was previously indicated, the present invention involves thickening of a slurry of silt to prevent the draining or migration thereof from the island back into the sea. More specifically, a slurry thickener is mixed with the slurry of silt before the slurry is deposited on the island.

Thickeners which can be employed in the practice of the present invention include both gellants and viscosifiers. The term "gellant" as used herein is with reference to materials which form a semicrystalline structure by reaction with another material or by lowering of the temperature thereof while dissolved or colloiddally suspended in a liquid medium. More specifically, a gellant forms an extensive semicrystalline structure having interstices wherein a liquid in which the gellant was dissolved or suspended becomes encapsulated, hence forming a gel which comprises the semicrystallized gellant and the entrapped liquid. Examples of gellants include sodium and potassium silicates and mixtures thereof, certain polysaccharidic gums such as xanthan gums, and certain proteins such as gelatine.

Examples of gellants which form gels by reaction with another material include the aforementioned silicates and xanthan gums, the silicates being reactive with divalent cations such as calcium and magnesium sulfate to form gels, whereas xanthan gums form gels by reaction with trivalent cations such as aluminum and ferric sulfate.

Examples of gellants which result in formation of gels by lowering of temperature include gelatin and various other high molecular weight proteins.

The term "viscosifier" as used herein is with reference to a material which thickens a liquid within which it is dissolved or colloiddally suspended, by increasing the internal friction of the liquid and hence the viscosity of the mixture, without formation of a semicrystalline structure as occurs during gelation. However, some thickeners can function as either a gellant or a viscosifier, depending upon the concentration thereof in the liquid to be thickened, the temperature, or the presence or absence of gel-forming reactants. For instance,

xanthan gums function as a gellant when reacted with one or more of the aforementioned trivalent cationic salts, but function as a viscosifier in the absence of such a salt. In addition, gelatin functions as a gellant when the concentration thereof in water is sufficiently high and the temperature low enough, yet functions as a viscosifier at relatively lower concentrations and higher temperatures. Other viscosifiers which can be employed to advantage include methyl cellulose, carboxymethyl cellulose, mucilage, and various high molecular weight proteins such as globular proteins.

It will be appreciated that the amount of thickener which should be mixed with the silt slurry to achieve a desired increase in the viscosity or the gelling thereof is subject to considerable variation and depends, among other things, upon the particular type of thickener being used, the ultimate viscosity or degree of gelation desired, the concentration of silt solids in the slurry, temperature of the slurry, the pH, the salinity, and where influential, the type and concentration of divalent or trivalent cationic salts or polyelectrolyte incorporated into the slurry. When a gellant type of slurry thickener is employed, an amount should be used which will result in the solids of slurry having a settling rate of substantially zero, i.e., an amount of gellant should be used which provides a gelled slurry having sufficient gel strength whereby settling of solids in the gel is inhibited completely or else is inhibited to the point as to appear complete. When a viscosifier type of slurry thickener is employed, an amount should be added to the slurry which imparts an apparent viscosity thereto which is within the range of about 1 to about 80 poises, and advantageously about 10 to about 40 poises (Brookfield Model LVF, 30 RPM at 25°C.). It will be appreciated, however, that even higher viscosities can be imparted to the slurry by means of viscosifiers when such is preferably and practical. In any event, selection of the proper type and amount of gellant can be easily determined by one skilled in the art by using this disclosure as a guideline along with published information that is readily available.

Sodium silicate can be used to advantage as a gellant in the practice of the present invention, forming a gel when placed in sea water by reaction with naturally existing divalent cationic salts therein, e.g., calcium chloride and magnesium chloride.

Whereas various types of sodium silicate can be employed, including not only the liquid variety but also the dry type which can be reconstituted with fresh water, a preferred type is 40° Baume sodium silicate in liquid form which contains about 9% Na₂O and about 29% SiO₂. When practicing the present invention using a sodium silicate of this particular type, it can be mixed with the slurry of silt in a volume ratio of gellant to sea water in the slurry which is within the range of about 1/20 to about 1/1000, and a ratio of about 1/100 has been found to be satisfactory in most instances. It will be understood that where the gravity of the sodium silicate is higher or lower than 40° Baume, the ratio of gellant to sea water may have to be adjusted accordingly. With regard to using a sodium silicate having a Na₂O content of other than about 9 percent; it will be understood that such can be employed, but less solids form by precipitation when the Na₂O is less than about 9 percent, and the reaction with sea water can be faster than desired when greater than about 9 percent.

When sodium silicate is employed as a gellant, the efficiency of gelation can sometimes be improved by adding to the gellant-slurry mixture a salt containing a divalent cation, such as calcium sulfate or magnesium sulfate, in amounts beyond that at which they already exist in the sea water portion of the slurry. Mixtures of such ions can also be employed. Accordingly, the rate and degree of gelation can be adjusted, and in some cases the amount of gellant required to achieve a desired thickening can be reduced. Usually, the amount of divalent ions which can be introduced by means of a salt to facilitate gelation can range up to about 5 grams per liter of water in the slurry, advantageously up to about 3 grams per liter. Such cations can be thoroughly mixed into the slurry prior to addition of the gellant thereto by incorporation of a soluble calcium or magnesium salt, for in such a case the efficiency of gelation is greatly enhanced, thus resulting in lower chemical cost for the operation.

The aforementioned improved gelation of sodium silicate-containing slurries by means of a divalent cation can sometimes be further enhanced by incorporation into the slurry of one or more trivalent cations, such as aluminum or ferric ions, by addition of the sulfate salts, to provide efficiency of gelation beyond that which can be accomplished by means of divalent cations. When used in conjunction with added divalent ions in the previously indicated amount, trivalent ions can be added to a sodium silicate-containing slurry in amounts up to about 5 grams per liter of water in the slurry, advantageously up to about 3 grams per liter, although it will be understood that greater and smaller amounts of either a divalent or trivalent cations can be employed where preferable and practical.

As previously indicated, xanthan gums can be used as a gellant in the practice of the present invention by adding to the gellant-slurry mixture a trivalent cationic salt such as aluminum or ferric sulfate. When used as a gellant, xanthan gum can be added to the slurry in amounts which are within the range of about 0.1 to about 1.0 weight per cent based on the sea water content of the slurry, while also adding up to about 0.5 grams per liter of water of a trivalent cationic salt to the slurry, although greater or lesser amounts of xanthan gum or trivalent cationic salt can be used where preferable and practical. In such cases divalent ions are not required for gelation of xanthan gums, but the presence thereof does not hinder gelation.

In some instances a polyelectrolyte can be used in the practice of the present invention as a substitute for, or in mixture with a trivalent cationic salt, either for enhancing gelation of a silicate gellant or for effecting the gelation of a xanthan gum. Certain copolymers of acrylamide have been successfully employed in this manner as a polyelectrolyte, e.g., methylacryloyloxyethyltrimethyl ammonium methyl sulfate (MTMMS).

Xanthan gums which can be employed as a gellant or viscosifier in the present invention are polysaccharides, more specifically, biopolysaccharides which are produced by the action of certain bacteria such as the species *Xanthomonas campestris* on carbohydrates. Xanthan gums of this type are marketed under the trade name Kelzan by the Kelco Company. To particular advantage, xanthan gums having a molecular weight within the range of about 2,000,000 to about 50,000,000 can be employed. When used as viscosifiers instead of gellants, amounts within the range of about

0.1 to about 2.0 weight percent, based on the water content of slurry, can be employed although greater and lesser amounts can be used when preferable and practical.

Formation of the gellant-slurry mixture can be conveniently accomplished in various ways. In the dredging of silt, it can be brought up as a suspension in sea water which contains about 60 to 80 weight percent of solids. This suspension of silt in sea water, produced by dredging and pumping, thus constitutes a slurry which can be treated with a thickener without any necessity of dewatering the slurry beforehand. Thickener can be added to the slurry at any point in the pumping-piping system that is employed for conveying the slurry to the island being built and depositing it thereon provided, however, that the slurry is not rendered so viscous or gelatinous as to excessively hamper the delivery and the depositing thereof on the island. Usually, slurries having viscosities within the range of about 0.5 to 80 poises following thickening in accordance with the present invention can be pumped and conveyed without extreme difficulty, but the length of the piping run and the head pressure limits of the pump must be considered. As a consequence, the viscosity of a slurry being conveyed through a delivery pipe after thickening can, to advantage, have a viscosity within the range of about 10 to about 40 poises.

Following a somewhat different procedure, a gellant or a viscosifier can be mixed with the silt slurry just prior to the depositing thereof on the island being built, thus eliminating the difficulty of pumping the slurry after a large increase in the viscosity or formation of a gel. In accordance with this embodiment of the invention, the nozzle through which the silt slurry is discharged from the delivery line and deposited on the island can be provided with a jet through which an aqueous solution or suspension of the viscosifier or gellant thickener is fed to the nozzle and mixed with the slurry at the time it is being discharged from the nozzle and deposited on the island. A suction producing eductor can be used for this purpose, with the viscosifier or gellant being fed to the nozzle through the suction inlet of the eductor. Otherwise, other types of well-known mixing nozzles can be used for the purpose. Alternatively, the thickener can be injected into and mixed with a stream of the silt slurry as the stream leaves the discharge outlet of the delivery line.

Metering and feeding of the solution or suspension of the thickener to the slurry, and the divalent or trivalent cationic salts or polyelectrolytes when such is used, can be accomplished by conventional apparatus arrangements which are well known to those skilled in the art and which, therefore, do not have to be described in detail herein, and it will be understood that any one of these constituents can be fed to the slurry in the form of a suspension or solution in liquid when such is preferable and practical.

As was previously indicated, the gellant-slurry mixture is deposited on the island being built after sand and gravel have been piled to a satisfactory height above the surface of the water. Where preferred, the island can have the shape of a dome without an inner core, and in which case the slurry is directed over the entire surface of the exposed pile of sand and gravel so that it flows down through the interstices of these particles until they are filled by the slurry. Subsequently, pumping can be continued for coating of the slurry-

impregnated island. In other instances it is desirable to build the island in the shape of a ring and then fill the inner core with the gellant-slurry mixture so that upon freezing the core is filled with frozen silt instead of sand and gravel. The sand and gravel of an island, whether ring shaped or not, can also be impregnated and coated with the thickener-slurry mixture.

It should be pointed out that it is within the scope of this invention to deposit a thickener-slurry mixture on the island in several stages, each of which follows freezing of a previously applied deposit. Accordingly, in the building of a ring-shaped island the sand and gravel can be impregnated with slurry which is allowed to freeze before silt is deposited in the inner core and allowed to freeze.

After depositing of the thickener-slurry mixture on the island being built, the consolidated structure of sand, gravel and deposited silt can be protected from the effects of wind, water and sun until freezing occurs by laying on a protective coating of gravel and/or sand. Accordingly, the structure can be protected until the island is permanently frozen.

While the present invention has been described with reference to particular materials, condition, techniques and the like, it will nonetheless be understood that even other embodiments will become apparent which are within the spirit and scope of the invention defined in the following claims.

What is claimed is:

1. In a process for building an artificial permafrost island in Arctic sea waters wherein sand and gravel are dredged from the floor of the sea and are redeposited on the sea floor at a location where an island is desired and until the height of the sand and gravel extends above the surface of the water, the method of consolidating silt with the sand and gravel of the island being built which comprises mixing a slurry thickener with a slurry of silt in sea water, and depositing the resulting thickener-slurry mixture on the island being built.

2. A process as defined in claim 1 wherein the sand and gravel are redeposited on the floor of the sea substantially in the form of a ring having an inner core, and the silt slurry having the thickener added thereto is deposited in the inner core of the ring.

3. A process as defined in claim 1 wherein the thickener that is added to the slurry is a gellant.

4. A process as defined in claim 3 wherein the gellant is selected from the group consisting of sodium silicate, potassium silicate, and mixtures thereof.

5. A process as defined in claim 4 wherein the gellant is 40° Baume sodium silicate containing about 9% Na₂O and about 29% SiO₂.

6. A process as defined in claim 5 wherein the volume ratio of gellant to sea water in the slurry is about 1/20 to 1/1000.

7. A process as defined in claim 5 wherein the volume ratio of gellant to sea water in the slurry is about 1/100.

8. A process as defined in claim 1 wherein the content of silt in the slurry is within the range of about 60 to about 80 weight percent.

9. A process as defined in claim 4 wherein a divalent cationic salt is incorporated into the gellant-slurry mixture prior to the depositing thereof on the island being built.

10. A process as defined in claim 9 wherein said salt is selected from the group consisting of calcium sulfate magnesium sulfate and mixtures thereof.

11. A process as defined in claim 10 wherein said salt is incorporated into said gellant-slurry mixture in amounts up to about 5 grams per liter of water in the slurry.

12. A process as defined in claim 9 wherein said salt is thoroughly mixed with said slurry prior to the addition of said gellant thereto.

13. A process as defined in claim 3 wherein said gellant is mixed with said slurry immediately prior to depositing of the gellant-slurry mixture on the island being built.

14. A process as defined in claim 9 wherein a compound selected from the member of the group consisting of trivalent cationic salts, polyelectrolytes, and mixtures thereof is incorporated into the gellant-slurry mixture prior to the depositing thereof on the island being built.

15. A process as defined in claim 14 wherein said compound is selected from aluminum sulfate, ferric sulfate and mixtures thereof.

16. A process as defined in claim 14 wherein said compound is methylacryloyloxyethyltrimethyl ammonium methyl sulfate.

17. A process as defined in claim 15 wherein said compound is incorporated into said gellant-slurry mixture in amounts up to about 5 grams per liter of water in the slurry.

18. A process as defined in claim 3 wherein the gellant is reactive with a compound which is a member of the group consisting of trivalent cations, polyelectrolytes, and mixtures thereof.

19. A process as defined in claim 3 wherein the thickener is a xanthan gum.

20. A process as defined in claim 19 wherein a compound selected from the group consisting of trivalent cations, polyelectrolytes, and mixtures thereof is mixed with said gellant-slurry mixture prior to the depositing thereof on the island being built.

21. A process as defined in claim 20 wherein said compound is methylacryloyloxyethyltrimethyl ammonium methyl sulfate.

22. A process as defined in claim 20 wherein said compound is selected from aluminum sulfate, ferric sulfate and mixtures thereof, and said compound is incorporated into said gellant-slurry mixture in amounts up to about 0.5 grams per liter of water in the mixture.

23. A process as defined in claim 1 wherein the thickener is a viscosifier.

24. A process as defined in claim 23 wherein the viscosifier is a polysaccharide.

25. A process as defined in claim 24 wherein the polysaccharide is a xanthan gum.

26. A process as defined in claim 25 wherein the amount of xanthan gum mixed with said slurry is within the range of about 0.10 to about 2.0 weight percent based upon the water content of the slurry.

27. A process as defined in claim 25 wherein the molecular weight of the xanthan gum is within the range of about 2,000,000 to about 50,000,000.

28. A process as defined in claim 23 wherein the viscosifier is a cellulosic.

29. A process as defined in claim 23 wherein the viscosifier is a high molecular weight protein.

30. A process as defined in claim 1 wherein a said thickener-slurry mixture is deposited on the island being built and allowed to freeze, followed by another depositing of thickener-slurry mixture on said island and allowing the same to freeze.

31. A process as defined in claim 1 wherein a material selected from sand, gravel and mixtures thereof is deposited on the island being built after the depositing of the slurry-thickener mixture thereon.

32. A process as defined in claim 3 wherein the settling rate of solids in the thickener-slurry mixture is substantially zero.

33. A process as defined in claim 23 wherein the viscosity of the thickener-slurry mixture is within the range of about 0.5 to about 80 poises.

34. A process as defined in claim 23 wherein the vis-

cosity of the thickener-slurry mixture is within the range of about 10 to about 40 poises.

35. A man-made island in Arctic sea water comprising a deposit of sand and gravel which extends above the surface of the water, a slurry of silt and sea water consolidated with the deposit of sand and gravel, said slurry having a slurry thickener incorporated therein.

36. An island as defined in claim 32 wherein said thickener is a gellant.

37. An island as defined in claim 32 wherein said thickener is a viscosifier.

38. An island as defined in claim 32 wherein the sand and gravel are deposited in the form of a ring having an inner core and said slurry within said core.

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