

[54] DESALINATION PROCESS

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[56] References Cited

UNITED STATES PATENTS

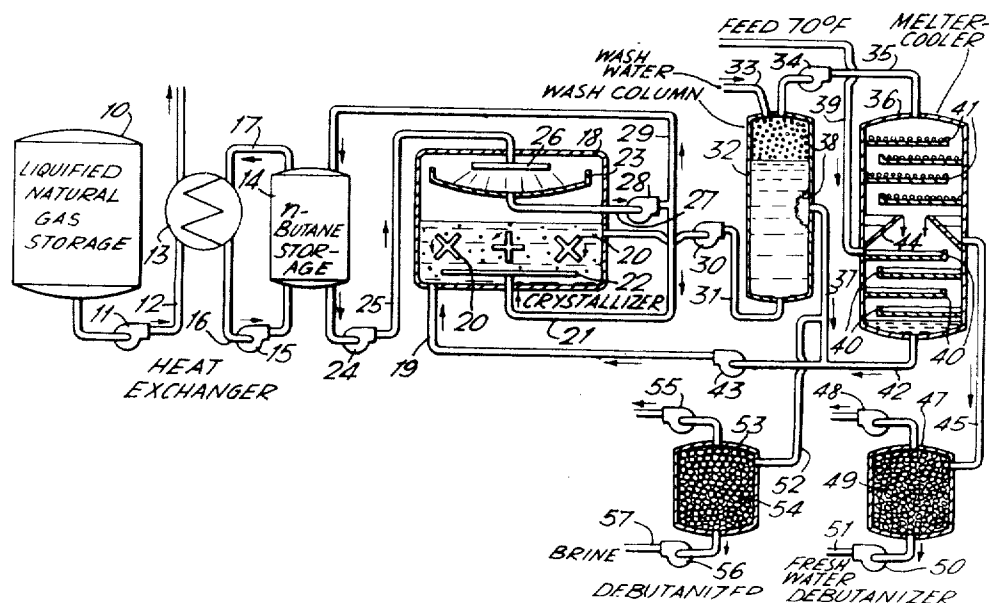
2,975,607	3/1961	Bodle.....	62/52
3,046,752	7/1962	Margiloff.....	62/58
3,070,969	1/1963	Ashley et al.	62/58
3,204,419	9/1965	Rose.....	62/58
3,240,024	3/1966	Ashley et al.	62/58
3,251,192	5/1966	Rich, Jr. et al.	62/58
3,478,531	11/1969	Karnofsky.....	62/58
3,535,210	10/1970	Linde et al.	62/52

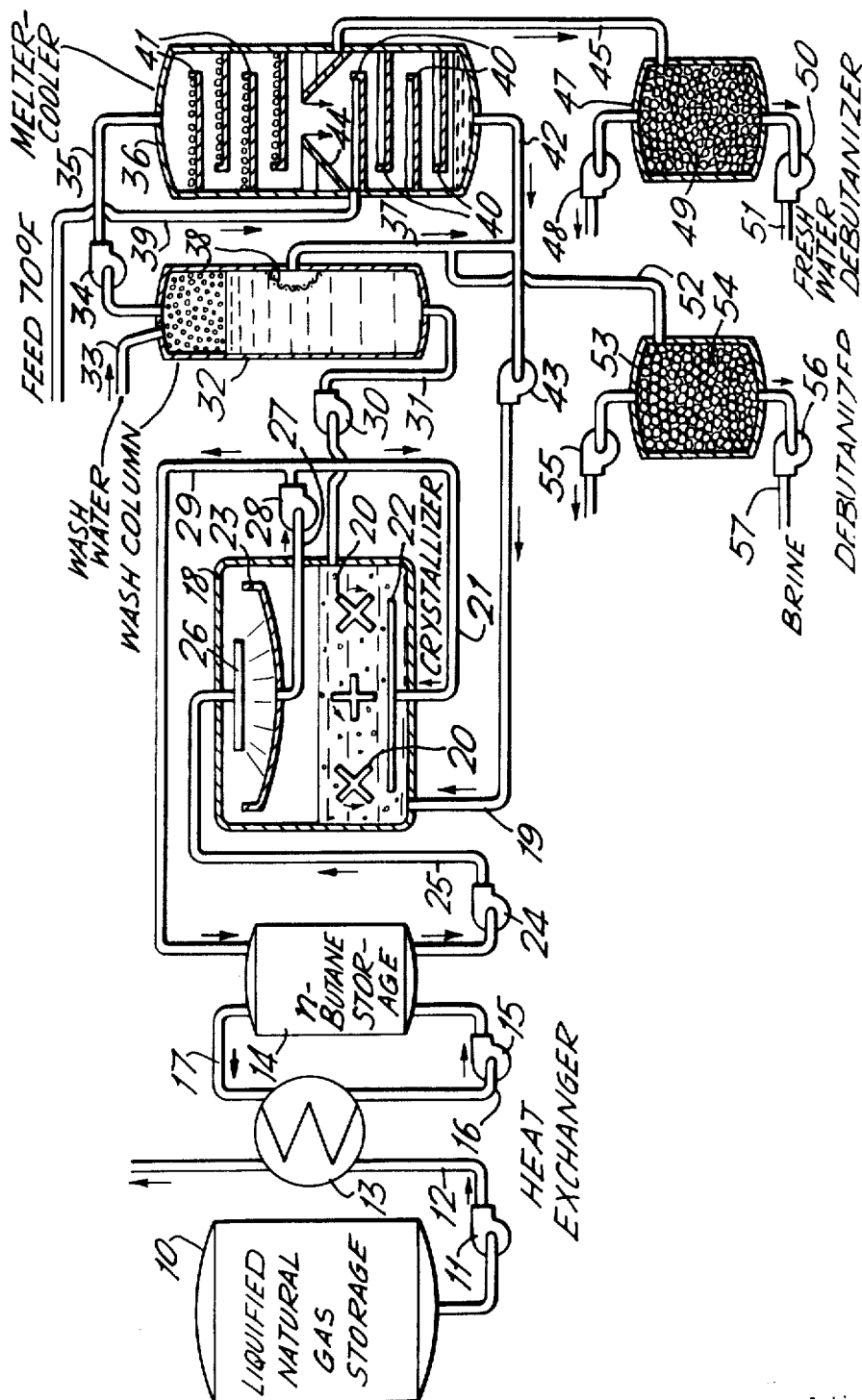
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[57] ABSTRACT

The freeze desalination of sea water is accomplished using the refrigeration potential released during the regassification of liquified natural gas. Sea water feed is cooled in an ice melter and feed cooler to near freezing, the feed is mixed with cold brine, and the feed is passed to a crystallizer wherein ice crystals are formed by direct contact with a refrigerant which has been cooled by the evaporation of the liquid natural gas. Ice crystals are separated from a slurry led from the crystallizer and the ice crystals are fed into the ice melter and feed cooler in which a refrigerant in a closed cycle condenses to melt ice and evaporates to cool feed. Fresh water is separated from condensed refrigerant in the ice melter and feed cooler. Refrigerant is stripped from the fresh water and brine passing from the system. In the crystallizer, gaseous refrigerant emerging from the feed is condensed by liquid refrigerant spraying into a tray suspended above the feed.

9 Claims, 1 Drawing Figure





DESALINATION PROCESS

BACKGROUND OF THE INVENTION

It is known to obtain water of high purity from sea water or similar salines by the freezing of the water in the solutions by direct contact with a volatile refrigerant and then separating and melting the ice crystals so formed. The refrigerant vapors leaving the crystallization zone are conventionally condensed by being compressed and brought back into a heat exchange relationship with the cold ice crystal product. Additional cooling for condensation of the refrigerant is usually provided by cooling water or sea water at ambient temperatures. After condensation, the liquid refrigerant is returned to the crystallization zone and the operation is repeated.

SUMMARY OF THE INVENTION

The main purpose of this invention is to provide a process for the freeze desalination of sea water or the like using the refrigeration potential of liquified natural gas when it is re vaporized for distribution. In the practice of this invention, liquified natural gas is passed through a heat exchanger to receive heat from a refrigerant such as n-butane which is stored in a reservoir and circulated through the heat exchanger. This re vaporizes the liquified natural gas for use.

In a novel crystallizer, the cold refrigerant is sprayed into a tray in the top of the crystallizer to condense refrigerant vapors in the tray. Some of the refrigerant drawn from the tray is returned to the refrigerant reservoir and some of the liquid refrigerant is introduced into a feed solution in the bottom of the crystallizer to vaporize therein and grow ice crystals. The feed introduced into the crystallizer is sea water which is cooled to about 36°F. in a combined melter-cooler unit. Cold brine is added to the feed which is then passed into the crystallizer.

A slurry of brine and ice crystals is drawn from the crystallizer and introduced into a wash column in which the ice crystals are separated from the brine. Some of the brine is passed through a debutanizer and out of the system and some of the brine is mixed with feed and introduced into the crystallizer as described. Ice from the wash column passes into the melter-cooler unit.

The melter-cooler unit is a closed unit having an upper and a lower portion. Ice is deposited on trays in the upper portion and melted by the condensation of n-butane rising from the lower portion. Melted ice and liquid n-butane are collected in the center of the unit and the water is drawn from below the liquid n-butane and passed from the system through a debutanizer. Liquid n-butane flows from the center of the unit onto trays in the lower half of the unit. Feed water is introduced into the trays in the bottom half of the unit to flow downward on the trays and become cooled to 36°F. as it vaporizes the n-butane which rises upward to become condensed in the upper half as described. Cold feed drawn from the bottom of the unit is passed to the crystallizer as described. Refrigerant need only be added to the melter-cooler unit to make up for any losses therefrom.

The particular freeze desalination process of this invention takes full advantage of the refrigeration potential of liquified natural gas so that it may produce fresh water at about \$0.50 per 1,000 gallons. Since the cost of building and operating a regassification facility are substantial, this invention offers the possibility of producing a useful product as well as regassifying the liquified natural gas. This will have a great economic advantage.

The particular process of this invention provides a desalination facility which requires no moving parts other than pumps. Maintenance will be reduced to a minimum and all the refrigeration potential will be used.

BRIEF DESCRIPTION OF THE DRAWING

The FIGURE of the drawing is a schematic diagram of the apparatus required to carry out the process of this invention with some of the elements of the apparatus shown in vertical section.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring to the drawing in detail, liquified natural gas is stored in a tank 10 or other suitable reservoir at substantially atmospheric pressure. The reservoir 10 would be of sufficient capacity to hold the discharge of one or more supertankers. The liquified natural gas would then be regassified continuously or as required. The liquified natural gas is pumped by pump 11 through line 12 to a heat exchanger 13.

A tank 14 is provided to store a refrigerant such as n-butane. A pump 15 circulates the n-butane through lines 16 and 17 between the heat exchanger 13 and tank 14. Thus, the liquified natural gas is regassified from a liquid at -260°F. to a gas approaching 20°F. in heat exchanger 13. The gas can be produced at any conventional desired pressure and may be allowed to further absorb heat to reach ambient temperatures if desired. The regassification is continuous as heat is constantly added in the heat exchanger 13 by the refrigerant. Heat exchanger 13 may be of any suitable type. The chilled refrigerant in tank 14 is used for the desalination of sea water in the following manner.

Crystallizer 18 has sea water feed mixed with brine at a temperature near the ice point introduced into it through pipe 19. The feed is mechanically agitated by agitator blades 20 as it is cooled below its freezing point (about 23°F.) by the direct contact evaporation of liquid n-butane introduced therein through pipe 21 and a perforated spreader 22. A tray 23 is disposed in the upper portion of crystallizer 18 above the feed level. Pump 24 passes cold refrigerant through pipe 25 to spray head 26 to spray into tray 23 and condense refrigerant vapors thereby in the vapor span of the crystallizer 18 to be collected in tray 23. The n-butane emerging from spray head 26 is at a temperature substantially lower than 20°F. so that it will readily condense vapors leaving the crystallization zone in the lower part of the crystallizer 18 at a temperature between 20°-26°F. Sprayed and condensed n-butane is drawn from tray 23 through pipe 27 by pump 28. Some of the n-butane from pipe 27 is passed through pipe 21 to vaporize in the crystallizer 18 and the rest of the n-butane is recycled to the tank 14 through pipe 29. Thus it may be seen that the heat of ice crystallization is continuously transferred to the n-butane in tank 14 and this heat is used to regassify liquified natural gas in heat exchanger 13.

As has been stated, cold sea water is mixed with brine to a 7 per cent salt content and introduced into crystallizer 18 through pipe 19. As ice crystals form in this feed, an ice-brine slurry is withdrawn by pump 30 through pipe 31. The slurry is introduced into wash column 32 in which the ice crystals float to the top to be washed with a water spray from pipe 33. Pump 34 removes the ice crystals through pipe 35 to introduce them into ice melter and feed cooler 36. A brine solution is removed from the wash column 32 through pipe 37. A screen 38 prevents any ice crystals from entering pipe 37.

Sea water at ambient temperatures enters the melter-cooler 36 through pipe 39. The feed flows downward in the lower half of the melter-cooler 36 on the staggered plates 40. In the upper half of the melter-cooler 36 an ice crystal and wash water slurry flows downward on the staggered plates 41. A given balance of n-butane is maintained in the melter-cooler 36 so that liquid n-butane is vaporized on the plates 40 by the feed from pipe 39 to cool the feed to about 36°F. by the time it is withdrawn through pipe 42 by pump 43. This cooled feed is mixed with brine withdrawn from wash column 32 by pipe 37. The feed and brine mixture is then introduced into crystallizer 18 by pipe 19 in the manner which has been described.

The center of melter-cooler 36 is defined by an upward facing baffle 44. Vaporized n-butane rises past baffle 44 to be condensed by the ice crystals on the plates 41 and melt them. The melted ice crystals flow as water from plates 41 to be trapped by baffle 44 and be withdrawn through pipe 45. Condensed n-butane floats on the water trapped by baffle 44 and overflows therefrom onto the plates 40 to be vaporized as described and cool incoming feed. Sufficient n-butane should be introduced into melter-cooler 36 to make up for any that

may be lost with the fresh water product and the brine flowing therefrom through pipes 45 and 42, respectively.

Product water from pipe 45 flows into a debutanizer 47 which is evacuated by pump 48 and packed with solid objects 49 to provide a large surface area. Pump 50 evacuates fresh product water through pipe 51 with a hydrocarbon content of less than 0.2 ppm with a vacuum in debutanizer 47 of 35 mm Hg.

Pipe 52 passes brine to debutanizer 53 packed with objects 54 and evacuated by pump 55. Pump 56 evacuates a debutanized brine through pipe 57.

The successful operation of the entire system depends on the design and operation of the crystallizer 18. Mechanical agitators 20 are provided to mix the feed with the ice-brine slurry. The sea water (3.5 per cent salt) is cooled to approximately 23°F. (60 per cent conversion) and ice crystals are formed and grown. The resulting brine has a salt content of 8.75 per cent. The heat of ice crystallization is removed by dispersing cold liquid n-butane in the bulk of the ice-brine slurry. The liquid n-butane is at a temperature lower than 23°F. This temperature difference between the liquid n-butane and the brine should be less than 5°F. and preferably about 2°F. By maintaining a pressure in the crystallizer equal to the equilibrium conditions, the liquid n-butane absorbs the heat of ice crystallization and evaporates. For example, at 21°F. the pressure is 12 psi. The n-butane vapors come in direct contact with the very cold n-butane spray above tray 23 in the upper part of the crystallizer 18. Here the n-butane vapors are condensed and recycled at 21°F. back to the crystallization zone.

The flow of cold n-butane is regulated to maintain a constant pressure in the crystallizer 18. Since the temperature in the upper part of the crystallizer 18 may fluctuate substantially, a cascade control loop (not shown) may be used to control the flow of cold n-butane from spray head 26. While the forementioned conditions for temperature and pressure are based on a 60 percent conversion, the crystallizer 18 can be operated at any desired conversion ratio or a multi-stage crystallization system could be used.

The percent of ice crystals in the crystallization zone is controlled by the brine recycle through pipe 37. A 20 percent ice brine slurry is satisfactory.

The ice melter and feed cooler 36 is operated at a pressure of 16 psia which is the equilibrium pressure at 34°F. for n-butane. As explained, the water and n-butane separate into two phases in the baffle section 44 so the water may be removed at 34°F. The liquid n-butane flows over the baffle 44 to come in direct contact with sea water at 75°F. As the sea water cools down to 36°F., the n-butane is evaporated to rise into the upper section and repeat the cycle. This melter-cooler 36 is less costly than a heat exchanger as no heat transfer surfaces are required.

Both the wash column 32, the debutanizers 47 and 53, and the heat exchanger 13 may be conventional pieces of apparatus. If desired, the novel melter-cooler 36 may be replaced with a conventional indirect contact heat exchanger so that heat required to melt the ice cools the feed.

Thus it may be seen that the process of this invention utilizes the refrigeration potential of liquified natural gas to produce low cost fresh water from sea water and other salines. While n-butane has been described as a preferred refrigerant, the system will operate with other hydrocarbon refrigerants, Freons, and the like.

What is claimed is:

1. In the process of desalination using the refrigeration potential of liquified natural gas during regassification, the steps of:

- a. passing the liquified natural gas through a heat exchanger to receive heat and become regassified thereby;
- b. circulating a liquid refrigerant through the heat exchanger to give up heat therein and become cooled;
- c. introducing a saline feed into a crystallizer providing a liquid crystallization zone and a vapor span thereabove;
- d. introducing cooled refrigerant into the liquid crystallization zone to rise and vaporize therein and form an ice-brine slurry;
- e. spraying and catching cooled liquid refrigerant in the vapor span of the crystallizer above the crystallization zone to condense vaporized refrigerant emerging from the slurry, control of the spraying of refrigerant maintaining temperature and pressure conditions in the vapor span of the crystallizer;
- f. recirculating at least some condensed and sprayed refrigerant for cooling in step (b);
- g. withdrawing the ice brine slurry from the crystallizer;
- h. separating the slurry into ice and brine; and
- i. melting the ice as a product.

2. The process according to claim 1 wherein in step (d) the feed is mechanically agitated for mixing with the slurry in the crystallization zone.

3. The process according to claim 1 with the additional step of storing liquid refrigerant, refrigerant from storage being recirculated through the heat exchanger in step (b) and refrigerant from storage being sprayed into the crystallizer in step (e), sprayed and condensed refrigerant withdrawn from the crystallizer being partly introduced into the crystallization zone and being partly recirculated for further cooling in step (f).

4. The process according to claim 3 wherein, in step (i) ice is melted to cool incoming feed used in step (c).

5. The process according to claim 4 wherein step (i) comprises the steps of (j) introducing the ice onto first plates in a closed container of a melter-cooler having a liquid refrigerant therein, (k) introducing feed onto second plates in the container, the liquid refrigerant vaporizing on contact with the feed on the second plates and condensing to melt ice on the first plates, and (l) decanting melted ice from liquid refrigerant and withdrawing the melted ice from the container, liquid refrigerant flowing in the container onto the second plates to contact and cool feed on vaporizing.

6. The combination according to claim 5 wherein in step (h) part of the brine is recycled by being mixed with feed in step (c), and the remainder of the brine is passed from the system.

7. The combination according to claim 6 wherein the melted ice in step (l) is stripped of refrigerant and the brine in step (h) is stripped of refrigerant.

8. The process according to claim 7 wherein the refrigerant of steps (b), (d), (e) and (f) is n-butane, the n-butane being sprayed into the vapor span of the crystallizer at a temperature below 20°F. in step (e), the temperature of the n-butane introduced into the crystallization zone being within 5°F. of the temperature of the feed.

9. The combination according to claim 8 wherein the refrigerant in the melter-cooler is n-butane, the melter-cooler at an equilibrium pressure and temperature of about 16 psia at 34°F.

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