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PATENT SPECIFICATION 1,111,933

DRAWINGS ATTACHED.

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1,111,933

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Int. Cl.:—C 02 b 1/12.

COMPLETE SPECIFICATION.

Improvements in or relating to Desalination.

We, UNITED KINGDOM ATOMIC ENERGY AUTHORITY, London, a British Authority, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The present invention relates to desalination by freezing, that is to say by a process in which the brine is cooled to such a low temperature that solid particles of "ice" are formed. It should be explained that this ice may be true ice or may be a hydrate, for example, formed between the water and the refrigerant fluid.

One convenient way of forming the ice is to pass liquid refrigerant such as, for example, butane into a stirred tank of brine and allow the refrigerant to vapourise by extracting the vapour from above the surface of the brine. The latent heat of vapourisation of the refrigerant will be withdrawn from the brine which will thereby be cooled to form ice particles. Depending upon the nature of the refrigerant and the conditions of temperature and pressure, a true ice or a solid hydrate with the refrigerant will be formed. Thus, if liquid propane is used as the refrigerant, the hydrate is liable to be formed as it is stable in pure water at pressures above 65 psig at a temperature of 42°F.

It is well known that the ice particles that form in such a freezing process are essentially free from brine and therefore the problem is to remove these ice particles from the freezer, remove any adhering brine and melt them to provide product fresh water of a quality suitable for drinking or agricultural purposes. However, unfortunately the adhering layer of brine tends to be very tenacious and the probyems encountered in its removal are extremely severe. It should be noted, for example, that simple draining will remove essentially no brine as the surface tension effects could be sufficient to maintain a column of brine some 70 cms high.

It is an object of the present invention to provide means for separating the brine from the crystals of ice.

According to the present invention there is provided a method of removing brine from ice crystals which comprises passing the ice crystals upwardly into a container to form a compacted mass of ice crystals therein, withdrawing brine from such compacted mass at spaced locations within the mass, passing substantially fresh wash water downwardly through the mass and withdrawing such wash water at spaced locations within the mass, and removing ice from the upper surface of such compacted mass to form product ice.

The product ice removed from the upper surface of the mass will of course carry with it adhering wash water and this ice is then melted and a proportion thereof is recirculated to form the wash water. Very conveniently the proportion recirculated is of the order of 5% of the net ice product together with all the adhering wash water so as to give a recirculation figure which is of the order of one half of the product mass (ice plus water removed). It is important to maintain the recirculation figure within very close limits for economic effectiveness and the order of control is in the region of ± 20% of the recirculated melted ice, which corresponds to a control of the order of ± 1% in the total wash flow. However, provided that the levels of the mass of ice crystals are maintained at their design location, this control can be effected by monitoring the salt concentration in the ice at some suitable location above the brine

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withdrawal locations. Thus, for example, the total flow of wash water may be controlled by monitoring the salt concentration in the removed ice product.

According to a further aspect of the present invention there is provided apparatus for separating brine from ice comprising a container adapted to contain a mass of ice crystals; a plurality of risers situated within such container, said risers having orifices adjacent their upper ends and being connected at their lower ends to manifolds; means to pass as slurry of ice and brine upwardly into such container, thereby to form a compacted mass of ice crystals which acts as a filter to remove ice particles from the slurry as the brine passes into the orifices of the said risers; means to pass wash water downwardly through the said mass and out of the same through the said orifices, and means to remove product ice from the upper surface of the said mass.

Very desirably the risers will terminate just short of the level at which the ice is removed. Very conveniently also, the risers will all be provided with their orifices at the same general level within the mass of ice crystals and the same orifices will serve for the outflow of brine and wash water, but if desired the orifices may be arranged at two levels, whereby one level of orifices acts primarily to withdraw the brine while the other level acts primarily to withdraw the wash water. The wall of the container may also be provided with orifices at the same general level.

In known fashion, the liquid withdrawn through the manifold device may be recirculated at least in part to the freezer.

In order that the invention may be more readily understood, one embodiment of the same will now be described by way of example and by reference to the drawings accompanying the Provisional Specification, wherein:

Figure 1 is a diagrammatic flow sheet,

Figure 2 is a schematic cross section through a portion of the apparatus of the present invention, and

Figure 3 is a plan view generally on the line III—III of Figure 2.

Referring now to the drawings, and to Figure 1 in particular, fresh brine at a temperature of approximately 70°F is supplied through a pipe 1 to a double heat exchanger 2 and passes thence by a pipe 3 to a freezer 6. Freezing is effected in the freezer 6 by passing into it a stream of liquid butane through a pipe 7 and withdrawing gaseous butane through a pipe 8 by means of a compressor 9.

The degree of freezing is controlled so as to give a slurry containing approximately 15—20% of ice which is passed by a pipe 10 to the base of an ice-water separator 11. From this separator 11, brine is withdrawn through a pipe 12 and recirculated through a pipe 13 to the freezer 6, a portion of this recirculated brine being rejected through a pipe 14 to the heat exchanger 2 and thence as reject brine through a pipe 15.

From the ice-water separator 11, a fresh ice product is withdrawn through a pipe 16, this ice product containing fresh water, and is passed to a melter 17 where it is melted and the fresh water so obtained is withdrawn through a pipe 18, a portion of this fresh water being recirculated as wash water through a pipe 19 to the ice-water separator 11 and the remainder being passed by a pipe 20 to the heat exchanger 2 and thence to a pipe 21 as product fresh water. The hot butane from the compressor 9 is passed by a pipe 22 to the melter 17 to melt the ice therein and the condensed liquid butane is returned from the melter 17 by the pipe 7 to the freezer 6.

It will be apparent that further heat exchange and extraction stages may be desirable in practice.

Referring now to Figures 2 and 3 of the drawings which show the ice-water separator 11 in greater detail, it will be seen that in general it comprises a square plan vessel with the pipe 10 communicating with its base. A plug of ice 30 is formed at an intermediate position in the vessel 11 and is supported by the hydrostatic pressure of the ice slurry in the portion 31 of the vessel acting as a friction force due to the flow of brine through the plug. A plurality of risers 32 extend vertically from manifolds 33 located in the space 31 and the plug of ice surrounds the upper portions of these risers, only one of which is shown in Figure 2.

At a suitable location each riser is provided with an orifice 34 which defines a boundary 35 between the filter and wash sections of the plug of ice. The orifices are of a sufficient size to permit the necessary liquid flow without an excessive pressure drop in the bed.

The mode of operation is that the slurry of ice and water pumped in through the pipe 10 supports the plug 30 which at the same time acts as a filter so that ice builds up continually upon the lower surface of the plug whilst the brine flows out though the orifices 34 and thence *via* the risers 32 and manifold 33 to the pipe 12. The pipe 19 communicates with spray means 37 located in the upper portion 36 of the vessel 11 and a spray of fresh wash water at a temperature very close to the freezing point is caused to flood over the upper surface of the plug 30. This wash water flows downwardly under gravity to displace the brine adhering to the ice and flows out through the orifices 34. It will be appreciated that as the plug 30 is being continually added to

at its lower surface, it will tend to rise within the vessel 11 and therefore means (not shown) are provided to remove the top surface at regular intervals so as to maintain this top surface just above the top of the risers 32. This scraped off ice, which is of course wet with wash water, forms the product ice that is removed through the pipe 16.

In a typical example, the intake through the pipe 1 can be considered as 200 parts and thus the input to the freezer 6 *via* the pipe 3 is again 200 parts. The input to the freezer 6 through the pipe 13 is 325 parts and the output from the freezer through the pipe 10 is therefore 525 parts of which 105 are ice and the remainder brine. It will be appreciated that it may be desirable to recirculate some or all of the flow in the pipe 13 directly to the pipe 10 to avoid overloading the freezer 6. The ice addition to the base of the plug 30 is therefore 105 parts and it follows that the ice removal through the pipe 16 is also 105 parts, but this will have 105 parts of water adhering thereto so that the total flow in the pipe 18 is 210 parts which is split to give 100 parts in the pipes 20 and 21 and 110 parts in the pipe 19. It follows that the outflow through the pipe 12 is 425 parts, of which 325 parts flow to the recycle pipe 13 and 100 parts are rejected through the pipes 14 and 15.

In order to maintain product quality it is important to stabilise the top of the bed of ice and this is readily effected by control of ice removal (which sets the length of the wash section). With these parameters fixed, quality control is effected by ensuring a small positive net wash rate. This is conveniently effected by controlling the proportion of wash water flowing in the pipe 19. To overcome the difficulty of holding this to 110 parts ± 1 part, the brine content of the ice is conveniently monitored and the wash rate controlled thereby. Thus the brine content may be measured at any suitable location above the line 35 or in the pipe 16.

WHAT WE CLAIM IS:—

1. A method of removing brine from ice crystals which comprises passing the ice crystals upwardly into a container to form a compacted mass of ice crystals therein, withdrawing brine from such compacted mass at spaced locations within the mass, passing substantially fresh wash water downwardly through the mass and withdrawing such wash water at spaced locations within the mass and removing ice from the upper surface of such compacted mass to form product ice.

2. A method according to claim 1, wherein the brine and wash water are withdrawn at the same locations.

3. A method according to claim 1 or 2, wherein approximately 50% of the product mass of ice and adherent water is recirculated as wash water.

4. Apparatus for separating brine from ice comprising a container adapted to contain a mass of ice crystals; a plurality of risers situated within such container, said risers having orifices adjacent their upper ends and being connected at their lower ends to manifolds; means to pass a slurry of ice and brine upwardly into such container, thereby to form a compacted mass of ice crystals which acts as a filter to remove ice particles from the slurry as the brine passes into the orifices of the said risers; means to pass wash water downwardly through said mass and out of the same through the said orifices, and means to remove product ice from the upper surface of the said mass.

5. Apparatus according to claim 4, wherein the risers terminate at a level just below the level at which the ice is removed.

6. Apparatus according to claim 4 or 5, wherein the risers all have their orifices at the same general level and the container is also provided with orifices at this general level.

7. Apparatus according to any of claims 4 to 6, including means to re-circulate at least a part of the liquid withdrawn from the risers to a freezer.

8. Apparatus according to any of claims 4 to 7, including means to pass a portion of the product ice and adherent water to a melter and means to recirculate a proportion of the fresh water from the melter as wash water.

9. A method of removing brine from ice crystals substantially as hereinbefore described with reference to the drawings accompanying the Provisional Specification.

10. Apparatus for removing brine from ice crystals substantially as hereinbefore described with reference to and as shown in the drawings accompanying the Provisional Specification.

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WHAT WE CLAIM IS:—

1. A method of removing brine from ice crystals which comprises passing the ice crystals upwardly into a container to form a compacted mass of ice crystals therein, withdrawing brine from such compacted mass at spaced locations within the mass, passing substantially fresh wash water downwardly through the mass and withdrawing such wash water at spaced locations within the mass and removing ice from the upper surface of such compacted mass to form product ice.

2. A method according to claim 1, wherein the brine and wash water are withdrawn at the same locations.

3. A method according to claim 1 or 2, wherein approximately 50% of the product mass of ice and adherent water is recirculated as wash water.

4. Apparatus for separating brine from ice comprising a container adapted to contain a mass of ice crystals; a plurality of risers situated within such container, said risers having orifices adjacent their upper ends and being connected at their lower ends to manifolds; means to pass a slurry of ice and brine upwardly into such container, thereby to form a compacted mass of ice crystals which acts as a filter to remove ice particles from the slurry as the brine passes into the orifices of the said risers; means to pass wash water downwardly through said mass and out of the same through the said orifices, and means to remove product ice from the upper surface of the said mass.

5. Apparatus according to claim 4, wherein the risers terminate at a level just below the level at which the ice is removed.

6. Apparatus according to claim 4 or 5, wherein the risers all have their orifices at the same general level and the container is also provided with orifices at this general level.

7. Apparatus according to any of claims 4 to 6, including means to re-circulate at least a part of the liquid withdrawn from the risers to a freezer.

8. Apparatus according to any of claims 4 to 7, including means to pass a portion of the product ice and adherent water to a melter and means to recirculate a proportion of the fresh water from the melter as wash water.

9. A method of removing brine from ice crystals substantially as hereinbefore described with reference to the drawings accompanying the Provisional Specification.

10. Apparatus for removing brine from ice crystals substantially as hereinbefore described with reference to and as shown in the drawings accompanying the Provisional Specification.

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