[54] METHODS AND PLANTS FOR DRYING MATERIAL IN LIQUID SOLID, SUSPENDED OR GRANULATED FORM, E.G. BLOOD-PLASMA, DIGESTED SLUDGE, FORAGE, FISH, CEREALS, ETC.

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[57] ABSTRACT

A method of drying material in liquid, solid, suspended or granulated form, e.g. blood-plasma, digested sludge, forage, fish, cereals, etc., wherein the material is fed batchwise, together with a large number of heated water-filled balls, into a drying tank which is set under subatmospheric pressure. A plant for performing the method comprises an upright drying tank including a closable inlet and outlet for simultaneously feeding and discharging, respectively, the material and the balls. A vacuum-pump connected to the drying tank sets said tank under subatmospheric pressure. A mixing tank and a separating tank are connected to said drying tank at the inlet and outlet thereof for mixing the material and balls before the materials and balls are fed into the drying tank and separated, after drying and discharge from the drying tank. An upright water heat exchanger is connected to the mixing and separating tanks for conveying said balls from the separating tank to the mixing tank during simultaneous heating of the balls.

23 Claims, 6 Drawing Figures
METHODS AND PLANTS FOR DRYING MATERIAL IN LIQUID SOLID, SUSPENDED OR GRANULATED FORM, E.G. BLOOD-PLASMA, DIGESTED SLUDGE, FORAGE, FISH, CEREALS, ETC.

This invention relates to a method of drying material in liquid, solid, suspended or granulated form, e.g. blood-plasma, digested sludge, forage, fish, cereals, etc., according to which the material is fed into a drying tank being set under subatmospheric pressure, and is dried with a drying medium which has a temperature higher than that of the material and therefore yields its heat to the material in order to boil away the moisture of the material at the subatmospheric pressure, whereby to expel this moisture from the material without injuriously raising its temperature, whereupon the moisture is condensed and removed from the drying tank and the material is discharged from the drying tank.

In conventional methods for the above-mentioned purpose the drying material is fed separately into the drying tank where it falls down and fills out the spaces between tubes arranged in the tank for circulating the drying medium. In order to avoid, for instance, bridge formation in the tank, these tubes must be spaced at intervals such that the total heat emitting surface of the tubes will be quite small relative to the quantity of material contained in the tank, whereby the drying process to secure homogeneous drying of the material will take a relatively long time. In order to reduce the time required it is not possible to increase the temperature of the drying medium very much since drying material of the above-mentioned or similar types in most cases does not stand such a temperature increase without being damaged.

The object of this invention is to provide a method whereby to obtain a substantial reduction of the time required for homogeneously drying the material and, consequently, a considerable increase of the efficiency of the drying process, by producing a larger heat-emitting surface than heretofore possible and without raising the temperature of the drying medium above what has so far been common practice.

This object of the invention is achieved by forming the drying medium of a large number of separate heating elements of high specific heat, feeding said elements into the drying tank simultaneously with the material, mixing said elements with said material, discharging said elements simultaneously with the material from the drying tank after drying of the material, and separating said elements from said material for using said elements for another drying cycle after reheating.

The invention also relates to a plant for carrying out this method, comprising a drying tank having a closable inlet and outlet for the material, a device for setting the drying tank under subatmospheric pressure, a circuit passing the drying tank, said circuit including a drying medium which has a temperature higher than that of the material and therefore is caused to yield its heat thereto in order to boil away the moisture of the material at the subatmospheric pressure, whereby to expel this moisture from the material without injuriously raising its temperature, and a device for condensing and leading off the expelled moisture, said drying medium being formed of a large number of separate heating elements of high specific heat, said elements being adapted to be fed into the drying tank together with the material and being adapted to be mixed therewith and to be discharged from the drying tank simultaneously therewith after drying of the material, and to be separated therefrom for being used for another drying cycle after reheating.

The invention will be described in more detail below with reference to the accompanying drawings, in which:

FIG. 1 is a schematic side view of a preferred embodiment of the plant according to the invention, and
FIGS. 2-5 are longitudinal sectional views showing in different stages the function of the plant according to FIG. 1, in which the major part of the ancillary equipment has been removed for greater clarity, and
FIG. 6 is a partially split view showing one of the various heating elements included in the plant.

The plant according to the invention, as shown schematically in FIG. 1 and FIGS. 2-5, comprises the following principal units: a drying tank 1, a primary tank 2, a secondary tank 3, an evacuating device 4, a heat exchanger 5, a heating device 6 and a cooling device 7. These principal units are equipped with various means, such as pipelines, valves, pumps, etc., which will be described as they come up in connection with their respective principal units.

The drying cylinder is in the form of an upright circular plate cylinder 8 having a conical bottom part 9. The tank 1 is supported by means of supports 10 on an intermediate framing of joists 11 in a building not shown which, in addition to the intermediate framing of joists 11, has a lower framing of joists 12 and an upper framing of joists 13. At the top the tank 1 is closed by means of a cover 14 and it comprises, on one hand, an inlet 15 which is connected, via a rubber sleeve type cut-off valve 16, to the outlet 17 of the primary tank 2 and, on the other hand, an outlet 18 which is connected, via a rubber sleeve type cut-off valve 19, to the inlet 20 of the secondary tank 3.

Also the primary tank 2 is in the form of an upright circular plate cylinder 21 having a conical bottom part 22 and a substantially flat cover 23. At the top said primary tank 2 has an inlet 24 for the material 25 to be dried, said inlet being connected, via a rubber sleeve type cut-off valve 26 and a pipe 27, to a magazine, not shown, for storing the material 25 which is not yet dried. By means of supporting beams 28 the primary tank 2 is mounted and supported on the drying tank 1 at the cover 14 thereof.

The secondary tank 3 is, like the drying tank 1 and the primary tank 2, in the form of an upright circular plate cylinder 29 having a conical bottom part 30 and a substantially flat cover 31. The secondary tank 3 includes in its bottom part 30 an outlet 32 for finally dried material 25 which is connected, via a rubber sleeve type cut-off valve 33 and a pipe 34, to a magazine, not shown, for storing the finally dried material. By means of supports, not shown, the secondary tank 3 is supported on the lower framing of joists 12.

As appears from the drawings, the drying tank 1, the primary tank 1, the primary tank 2 and the secondary tank 3 are vertically superposed with their inlets and outlets 15, 18, 17, 24, 20, 32, valves 16, 19, 26, 33 and pipes 27, 34 aligned with each other.

The evacuating device 4 comprises a vacuum pump 36 driven by means of a motor 35, said pump having its outlet 37 connected to the atmosphere via a conduit 38.
and having its inlet 39 connected to the primary tank 2, the drying tank 1 and the secondary tank 3, respectively, via a main conduit 40 with two branches 41, 42 in order to evacuate and keep evacuated said tanks at predetermined moments of the drying process to be described later on. For this purpose there are three rubber sleeve type cut-off valves 43, 44, 45 in the main conduit 40 and in the branches 41, 42. To equalize the pressure in the primary and secondary tanks 2, 3 at predetermined moments, also to be described later on, of the drying process, these tanks are provided with rubber sleeve type cut-off valves 46, 47 connected to the atmosphere in a suitable way.

The heat exchanger 5 is in the form of an upright circular plate column 48 and is generally of the same height as the total height of the primary tank, drying tank and the secondary tank 2, 1 and 3, respectively. By means of supports 49 the heat exchanger is supported on the same framing of joists 11 as the drying tank 1. Connected to the inlet 50 of the heat exchanger 5 is a pump 51 which, in turn, is connected, via a pipe 52 and a rubber sleeve type cut-off valve 53, to a further outlet 54 from the secondary tank 3. The pump 51 is adapted to convey heating elements 55, to be described in detail later on, through the heat exchanger and is of the type known under the term vortex pump. This pump type has the advantage that its impellers do not touch the elements 55 but these elements are conveyed under the action of the whirl of water caused by the impellers. At its upper end the heat exchanger 5 has a slightly conical container 56 which surrounds the heat exchanger and is adapted to receive the heating elements 55 conveyed upwardly through the heat exchanger and to transmit said elements at predetermined moments of the drying process to the primary tank 2 via a pipe 57 and a rubber sleeve type cut-off valve 58. The heating elements 55 are heated in the heat exchanger 5 while being conveyed upwardly through said exchanger by means of water which, in turn, is heated in the heating device 6. The hot water arrives at the upper part of the heat exchanger 5 via a supply conduit 59 in order to flow counter-currently with respect to the direction of transport of the heating elements 55 through the heat exchanger and to yield thereby its heat to said elements. The cooled water is led away from the heat exchanger to the heating device 6 via a conduit 60 which is connected to the heat exchanger at the lower part thereof, an intermediate container 61 and a conduit 62. A feed pump 63 for circulating the water is incorporated in the supply conduit 59.

The cooling device 7 is adapted to feed cold water via a pipeline 64 to nozzles 65 which are placed in a separate vessel 66 in the upper part of the drying tank 1. The object of the cold water leaving the nozzles 65 is to condense, in a manner to be described later on, moisture expelled from the drying material during the treatment in the drying tank. The mixture consisting of the condensate and the cooling water is discharged from the vessel 66 via a discharge conduit 67 which is connected to a container 68. From this container the excess of mixture is directly passed to an outlet 69 while the remainder of this mixture is passed back to the cooling device 7 via a pipeline 70. A feed pump 71 for circulating the cooling water is incorporated in the pipeline 70.

In the embodiment shown (see FIG. 6) the heating elements 55 consist of balls having a thin circumferential wall 72 of plastic material, e.g. polypropylene. These balls are filled with water to receive the highest possible degree of specific heat which, in the above-mentioned combination of plastic circumferential wall and water, amounts to about 0.9 cal/°C. The balls 55 has a diameter of about 40 mm and in the plant shown they amount to a number of about 300,000. 1,000 well filled balls have a weight of about 27 kg. At a temperature of 10° C these balls accumulate 27:10:0:9 = 243 kcal. The steam generation heat for water at a pressure of 10-15 dry = 585 kcal/kg. If assuming, for example, that 1,000 balls are heated from 35° to 70° C in the heat exchanger 5, this would correspond to an amount of heat of 3.5:243 = 850.5 kcal. As this amount of heat is transmitted to the moisture (water) in the drying material 25 at the treatment in the drying tank 1 during a calculated time of about 13 min, 850.5/585 = 1.45 kg H₂O evaporates by boiling at low pressure in the tank.

The plant described in the foregoing operates in the following way, reference being specifically made to FIGS. 2-5 which show different successive stages of function. Before the stage shown in FIG. 2, drying material and heated heating elements 55 have entered each into one part of the primary tank 2 via the pipe 27 and the pipe 57 respectively. In the stage shown in FIG. 2, the drying material 25 contained in the primary container 2 and heating elements 55 are fed to the drying tank 1 via the outlet 17, the open valve 16 and the inlet 15 and finally dried material and heating elements are discharged from the drying tank 1 to the secondary tank 3 via the outlet 18, the open valve 19 and the inlet 20. It should be noticed, and it is clearly apparent from the drawings, that the drying tank is of a volume about three times each of the primary and secondary tanks. The reason therefor is that it should be possible to run the plant batchwise, with a minor quantity in the primary and secondary tanks and a major quantity in the drying tank, thereby obtaining a more rapid and more efficient drying of the material. During the displacement of material shown in FIG. 2 all the three tanks 1, 2 and 3, are evacuated at a pressure of about 10 mm Hg and these tanks are kept evacuated by means of the vacuum pump 36. During this displacement the valves 43, 44, 45 are open while all the other valves, except valves 16, 19, are closed. When feeding the drying material 25 and the heating elements 55 into the drying tank 1, as described above, these are mixed with each other. In this connection it should be noticed that, in order to obtain an as efficient drying as possible and to facilitate the stepwise transport through the drying tank of the mixture consisting of drying material and elements, the heating elements should lie in contact with each other. The quantity of elements should therefore be kept constant while the quantity of drying material may be varied from a value corresponding to the volume of the free space between the elements when these are in contact with each other, and downwards within reasonable limits. When the primary tank 2 is evacuated and the drying and secondary tanks 1 and 3 are filled (see FIG. 3), the valves 16, 19 between the tanks and the valves 43, 45 of the vacuum pump are closed. While the valve 44 of this pump still is kept open and the valves 46, 47, which belong to the primary and secondary tanks 2, 3 and communicate with the atmo-
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sphere, are opened for pressure equalization in the primary and secondary tanks.

In the stage shown in FIG. 4, drying material 25 and heated elements 55 are fed, as already mentioned, into the primary tank via separate inlets from the magazine of material (not shown) and the conical container 56, respectively, on the upper part of the heat exchanger 5. During this stage, atmospheric pressure prevails in the tank. At the same time the dried material 25 is separated from the elements 55 in the secondary tank 3 by means of a vibrating screen 73 incorporated in this tank, while the dried material departs, via the open valve 33 and the pipe 34, to the magazine (not shown) for finally dried material 25, and the heating elements 55 are conveyed to the pump 51, via the outlet 54, the open valve 53 and the pipe 52, in order to be conveyed, during heating by means of the water from the heating device 6, upwards through the heat exchanger 5 and to successively attain the conical container 56. From this container the above elements are conveyed successively, as mentioned, further to the primary tank to be used for another drying cycle.

In the stage shown in FIG. 5 the primary and secondary tanks 2, 3 are evacuated to attain the same pressure as that prevailing in the drying tank 1, all the valves except valves 43 and 45 being closed.

In the stages shown in FIGS. 2-5, the drying tank 1 is evacuated, as mentioned, to attain a pressure of about 10 mm Hg and the drying of material therein takes place in the following way. Due to the low pressure prevailing in the drying tank and due to the fact that the elements transmit their heat to the material, the moisture therein begins boiling, while the expelled moisture arises through the material and enters the vessel 66 located at the upper part of the drying tank.

Since cold water passes out through the nozzles 66 placed in this vessel and this water hits the moisture coming from the material, this moisture is condensed and passes together with the cooling water down to the bottom of the vessel from which the mixture consisting of condensate and cooling water is removed via the outlet conduit 67 for discharge and recirculation. It should be pointed out again that three batches of drying material are at the same time in the drying tank, the batches having a gradually decreasing moisture content as counted from the top. When the lowermost batch is finally dried it is discharged from the drying tank in the manner shown in FIG. 2 and another batch of drying material is fed from the primary tank, while the intermediate batch of drying material now takes the place of the discharged finally dried batch in the drying tank.

The invention must not be considered confined to the embodiment described in the foregoing and shown in the drawings because it may be modified in various manners. The essential point of the invention is that as a drying medium for drying the material there is used a large number of separate heating elements which can be readily mixed with the drying material and contain the required heat for carrying out the drying process and have a large total heat-emitting surface so that the efficiency of the plant, and consequently its capacity, is substantially higher than in prior art plants for drying material of said type.

What we claim and desire to secure by Letters Patent is:

1. A method of drying material in liquid, solid, suspended or granulated form, such as blood-plasma, digested sludge, forage, fish, cereals, and the like, including the steps of feeding the material into a drying zone maintained under subatmospheric pressure, introducing into the zone a drying medium including a large number of separate elements of high specific heat at a temperature higher than that of the material, mixing said medium and said material to permit the drying medium to yield its heat to the material in order to boil away the the moisture of the material at the subatmospheric pressure to expel moisture from the material without injuriously raising its temperature, condensing the moisture and removing the condensed moisture from the drying zone and discharging simultaneously the drying medium and the material from the drying zone and separating said medium from said material.

2. A method as claimed in claim 1 wherein the drying medium elements are brought into contact with each other in the drying zone and the interspaces between the elements are completely or partly filled with the material.

3. A method as claimed in claim 1 wherein the drying medium and the material, before being fed into the drying zone are stored separately in a primary area which, while being filled with elements and material, is kept at atmospheric pressure and, before elements and material are fed into the drying zone, is set under the same pressure as this zone.

4. A method as claimed in claim 1 wherein the drying medium and the material, after drying of the material, are discharged from the drying zone and conveyed to a secondary area maintained under the same pressure as the drying zone until the discharge and conveying is completed and is then reduced to atmospheric pressure for separating of said medium and said material.

5. A method as claimed in claim 4 wherein the drying medium, after being separated from the material in the secondary area is pumped through a heated heat exchanger and the heated medium is then conveyed to the drying zone for reuse.

6. A method as claimed in claim 1 wherein the moisture expelled from the material is condensed by being cooled with water fed into a separate zone at the upper part of the drying zone, from which zone the cooling water and the condensate are removed.

7. A plant for drying material in liquid, solid, suspended, or granulated form such as blood-plasma, digested sludge, forage, fish, cereals and the like, said plant comprising a drying tank having a closeable material inlet and a closeable material outlet means for maintaining the drying tank under subatmospheric pressure, means connected to said tank for feeding a drying medium and material to be dried into said drying zone said drying medium having a temperature means for condensing and leading off the expelled moisture, said drying medium including a large number of separate heating elements of high specific heat.

8. A plant as claimed in claim 7 wherein the heating elements are each a volume element in the form of a ball, an ellipsoid and the like.

9. A plant as claimed in claim 8 wherein said heating elements each have a closed circumferential wall and the space inside said circumferential wall is completely or partly filled with a solid or liquid substance.

10. A plant as claimed in claim 9 wherein the circumferential wall consists of plastic.

11. A plant as claimed in claim 9 wherein the substance is water.
12. A plant as claimed in claim 8 wherein the heating elements are homogeneous.

13. A plant as claimed in claim 7 wherein the drying tank is in the form of an upright cylinder, a conical bottom on said tank, means connecting the inlet of the drying tank through a cut-off valve to a primary tank of substantially the same shape as the drying tank, and means connecting the outlet of the drying tank through a cut-off valve to a secondary tank of substantially the same shape as the drying tank.

14. A plant as claimed in claim 13 wherein the drying tank, the primary tank and the secondary tank are aligned in superposed relationship, with the primary tank uppermost and the secondary tank lowermost.

15. A plant as claimed in claim 14 wherein the primary tank includes a drying medium inlet which is connected via a cut-off valve to a drying medium magazine, and a heating element inlet which is connected via a cut-off valve to the outlet on a heat exchanger for heating the elements.

16. A plant as claimed in claim 14 wherein the secondary tank includes an outlet for material which is connected via a cut-off valve to a magazine for dried material, and a heating element outlet which is connected via a cut-off valve and a pump to the inlet on a heat exchanger for heating the elements.

17. A plant as claimed in claim 7 wherein the device for maintaining the drying tank under subatmospheric pressure includes a vacuum pump which is also connected to the primary tank and the secondary tank.

18. A plant as claimed in claim 17 wherein the vacuum pump is connected to the drying, primary and secondary tanks by means of conduits with built-in cut-off valves and the tanks are connected to the atmosphere by additional cut-off valves.

19. A plant as claimed in claim 18 wherein the cut-off valves are of rubber-sleeve type.

20. A plant as claimed in claim 19 wherein the means connected to said drying tank for feeding is also connected to said primary tank, said secondary tank and said heat exchanger, said heat exchanger having its inlet connected via the pump to the heating element outlet of the secondary tank and having its outlet connected to the heating element inlet of the primary tank.

21. A plant as claimed in claim 20 wherein the heat exchanger is in the form of an upright column of substantially the same height as the total height of the primary, drying and secondary tanks.

22. A plant as claimed in claim 21 wherein the heat exchanger contains water and is connected to a heating device for heating the water which, in turn, heats the heating elements conveyed by the pump through the heat exchanger from the inlet to the outlet thereof.

23. A plant as claimed in claim 7 wherein the means for condensing and leading off the moisture expelled from the material includes a vessel positioned in the upper part of the drying tank and into which nozzles open for injection of cooling water into the vessel for cooling down and condensing the moisture, and an outlet for leading off the condensed and the cooling water.