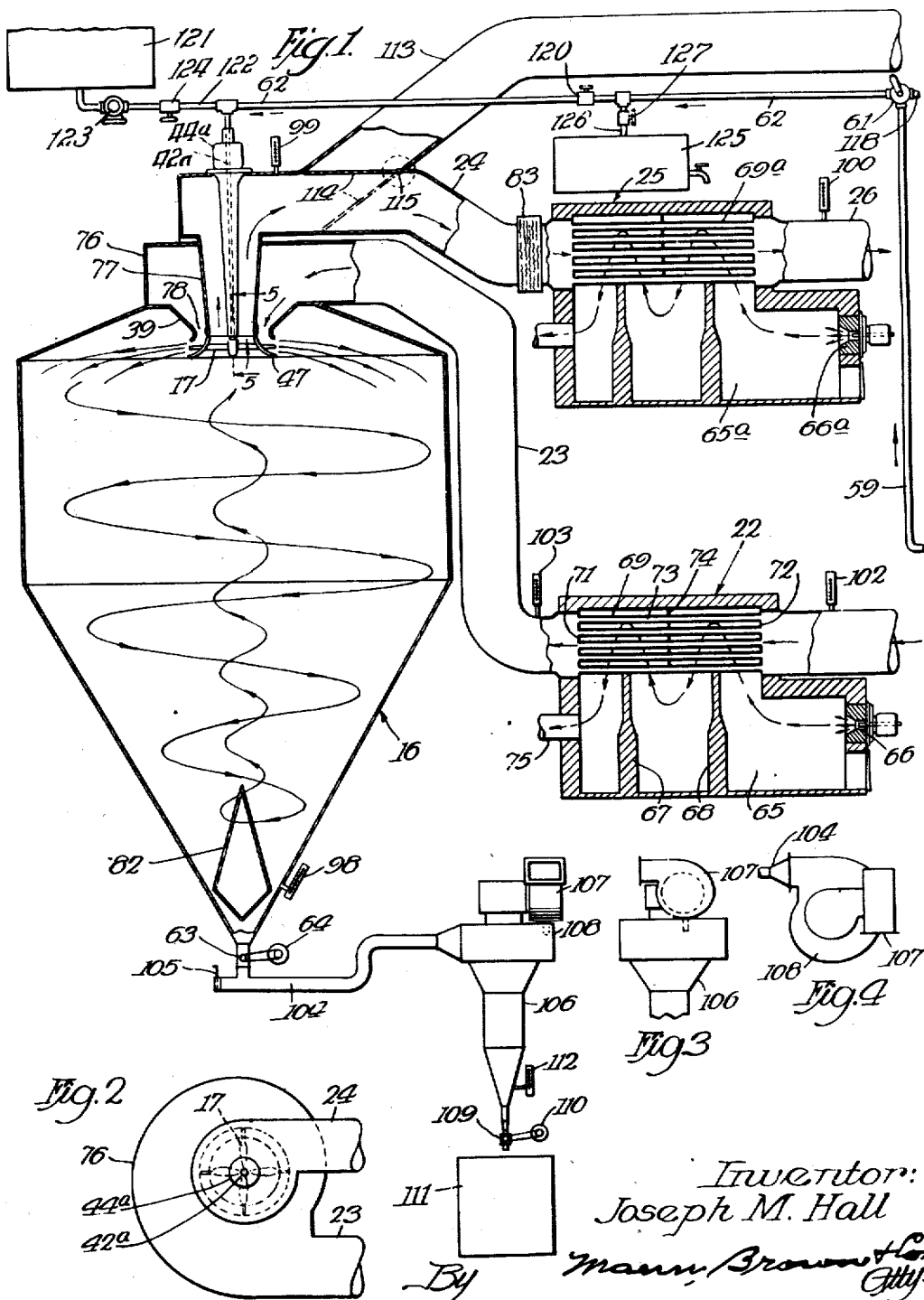


May 14, 1946.

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METHOD OF AND APPARATUS FOR CONCENTRATING
AND DEHYDRATING LIQUID PRODUCTS
Filed July 29, 1942

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2 Sheets-Sheet 1



Inventor:
Joseph M. Hall
By *Mann, Brown & Co.*
Attys.

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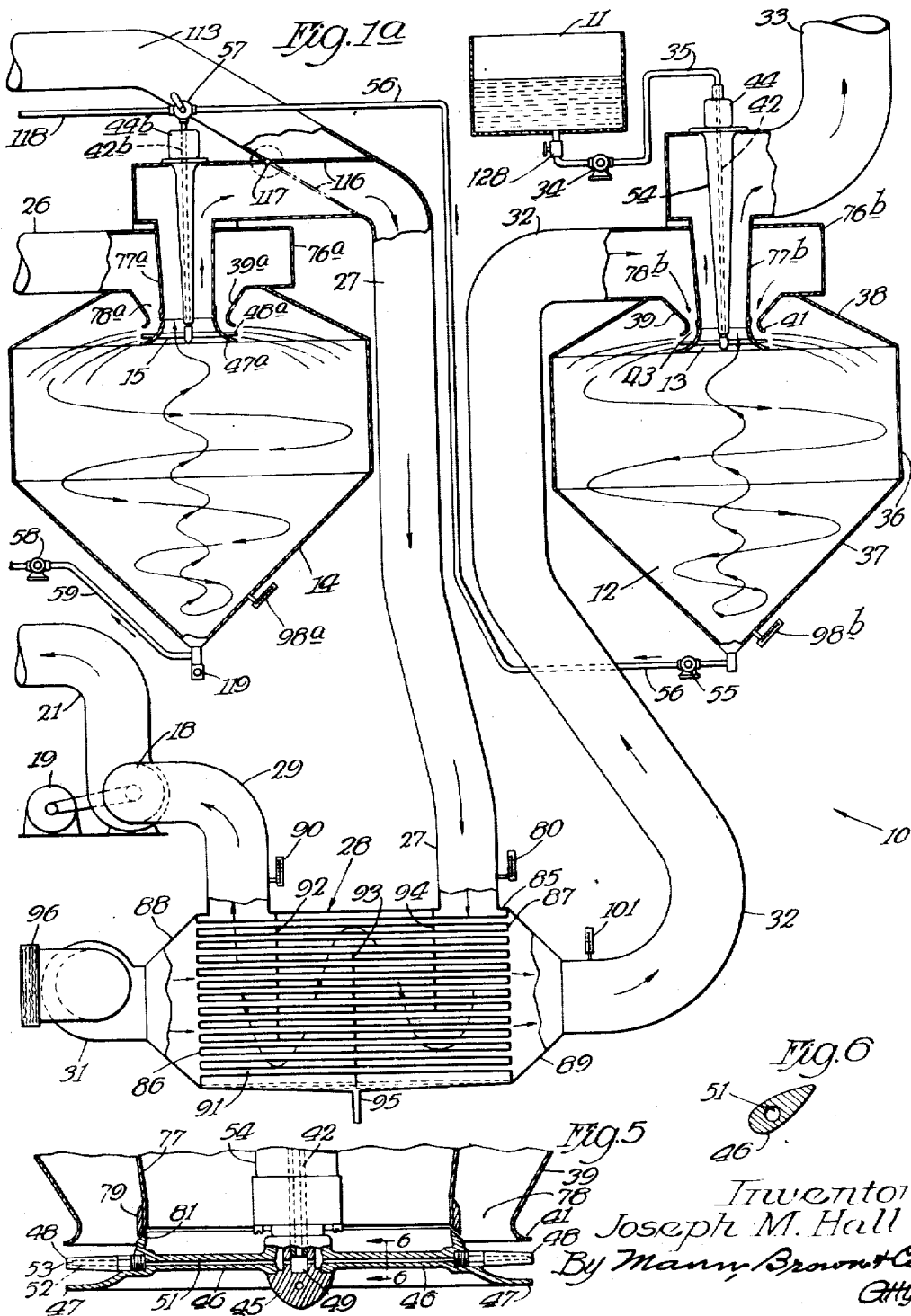


Fig. 5

Fig. 6

Inventor:
Joseph M. Hall
By Manny Brown & Co.
Attys.

UNITED STATES PATENT OFFICE

2,400,459

METHOD OF AND APPARATUS FOR CONCENTRATING AND DEHYDRATING LIQUID PRODUCTS

Joseph M. Hall, Chicago, Ill., assignor to Drying & Concentrating Company, a corporation of Delaware

Application July 29, 1942, Serial No. 452,690

23 Claims. (Cl. 159—17)

This invention relates to the method of and apparatus for dehydrating liquid products, and one of the principal objects of the invention is the provision of a new and improved apparatus for this purpose that may be readily and easily cleaned with a minimum of time and labor.

Another object of the invention is the provision of a new and improved method of concentrating and dehydrating or desiccating liquid products in an economical and efficient manner.

A further object of the invention is the provision of a series of cyclone separators within which the liquid product is treated by currents of air circulated through these separators without the use of vacuum pans or chambers operating at reduced pressure.

Another object of the invention is the provision of a new and improved apparatus for concentrating by circulating the liquid product through the apparatus in one direction and simultaneously circulating a heating medium through the apparatus in the opposite direction, whereby the same medium may be used over and over again.

A further object of the invention is the provision of a new and improved apparatus having means for preconcentrating the liquid product before it is introduced into the evaporator or for introducing the liquid product directly into the evaporator, as desired.

A still further object of the invention is the provision of a new and improved apparatus for simultaneously concentrating and dehydrating a liquid product or for simultaneously concentrating one liquid product and dehydrating another, or for mixing a liquid product with another liquid product in concentrated form and then dehydrating the mixture.

Another object of the invention is the provision of a new and improved apparatus for concentrating and desiccating liquid products that may be manufactured and installed at a reasonable cost, that is economical to operate, and easily cleaned and inspected.

Another object of the invention is the provision of a new and improved apparatus for concentrating and dehydrating liquid products that is adjustable within wide limits to meet various conditions of operation, and to compensate for the different characteristics of the various liquid products from which moisture may be extracted.

Other and further objects and advantages of the invention will appear from the following description, taken in connection with the accompanying drawings, in which

Figs. 1 and 1^a are a side elevation of the apparatus, with parts broken away and parts in section, and showing the entire system more or less diagrammatically;

Fig. 2 is a plan view of the desiccator chamber, with parts broken away and parts omitted for the sake of clearness;

Fig. 3 is a side elevation of the combined cooler and separator device;

Fig. 4 is a top plan view of the structure shown in Fig. 3, turned through an angle of 90°;

Fig. 5 is a section on the line 5—5 of Fig. 1 or of Fig. 1^a, with parts broken away and parts omitted for the sake of clearness; and

Fig. 6 is a section on the line 6—6 of Fig. 5.

In the use of desiccating systems it is necessary, in dehydrating or concentrating certain liquid products, to thoroughly clean the operating mechanism that contacts the product frequently, and in concentrating and desiccating milk this must be done at least once in each twenty-four hours due to the fact that the conditions of heat and moisture in the system are favorable to a rapid growth of bacteria.

The present invention seeks to provide mechanism that may be readily cleaned with a minimum of time and labor.

Referring now to the drawings, the reference character 10 designates the entire apparatus or system, which comprises a reservoir 11 for the liquid product; an evaporator or first stage evaporator chamber 12, having a spray head 13 therein for discharging the liquid product into the evaporator in the form of a spray for removing a part of the moisture therefrom; an evaporator or second stage evaporator chamber 14, having a spray head 15 for receiving the liquid product from the first stage evaporating chamber 12 and discharging the same into the second stage evaporating chamber 14 into the form of a spray for concentrating the same; and an evaporator or third-stage evaporator chamber 16, having a spray head 17 for receiving the concentrate from the evaporator 14 and discharging the same for desiccating the product. The third-stage evaporator 16 may be termed a desiccator, dehydrator or dehydrator chamber.

In the operation, the first stage of evaporation occurs in the evaporator 12, where the liquid has a portion of its moisture removed; the second stage occurs within the evaporator 14, where the liquid is concentrated; and the third stage of evaporation occurs within the dehydrator or desiccator 16, where the product is reduced to a dry powder. As will hereinafter be described, in

desiccating certain types of material, or where it is desired to concentrate the product only, the second stage may be eliminated either partially or entirely.

The apparatus or system also includes mechanism for circulating heated air through at least some of the evaporating chambers in a closed circuit for removing moisture from the product. This mechanism comprises a fan or blower 18, operated by a motor 19 for discharging air into a conduit 21, which in turn conducts the air through a heater or heat exchange element 22. From the heater or heat exchange element the heated air flows through a conduit 23, which delivers the air across the head 17 for desiccating the product, as will presently appear.

The system is provided with a conduit 24, which conducts the air from the dehydrator or desiccator 16 through a heater or heat exchange element, which may be termed a super-heater, 25, and conduit 26 over into the evaporator 14 for removing moisture from the liquid product discharged from the spray head 15. The air is discharged from the evaporator 14 through a conduit 27 and a condenser or heat exchange device 28 for removing moisture from the air and then through a conduit 29 back to the fan 18. The temperature of the air is lowered and the moisture removed therefrom in the heat exchange device 28 by fresh air that is forced through the heat exchange device by the fan 31. In cooling the circulating air, the fresh air becomes heated and is conducted through a conduit 32 and discharged across the spray head 13 in the evaporator 12, and exhausted from the evaporator through the pipe or conduit 33. Since the liquid product is conducted through the system in a direction counter to the flow of air, the apparatus for treating the liquid will first be described.

The liquid product is contained in the reservoir 11 located in any convenient place, and from which it is conducted by a pump or the like, 34, and conduit 35 to the evaporator 12. The evaporator 12 is similar to the conventional cyclone separator, and comprises a cylindrical central portion 36, a tapered portion 37, and an upper section 38 tapered upwardly. The upper section 38 is provided with an axial opening in which is secured an air deflector member 39, which tapers downwardly and has its lower edge 41 curved outwardly, as clearly shown on the drawings.

The liquid product from the conduit 35 passes through a vertical spindle 42 extending downwardly and axially through the opening 43 formed in the air deflecting member 39. The spindle 42 is adapted to be rotated by a suitable motor 44 mounted on the top of the apparatus. Attached to the lower end of the spindle 42 is a spray head 45 (see Fig. 5), having the arms 46 extending radially therefrom. Mounted on the outer end of the arms 46 is an annular deflector 47 which is concave in cross-section, as shown in said figure. Nozzles 48 extend through the deflector 47, and are threaded in the outer ends of the arms 46 for discharging the liquid product in the form of a spray outwardly of the deflector 47. The head 45 is provided with a recess 49, which is in alignment and in communication with the hollow spindle 42 for receiving the liquid product from said spindle. The arms 46 are provided with bores 51, which are in alignment with the corresponding bores 52 in the nozzles 48. The bores 52 are reduced in diameter at their outer ends, as shown at 53, to form a nozzle opening for discharging the liquid

product therefrom in the form of a spray as the head is rotated.

The spindle 42 is hollow and is rotatably mounted in, and surrounded by, a casing 54, which secures the spindle and operating motor in position on the evaporator. The liquid product, after it is sprayed into the evaporator 12 and acted upon by the heated air, as will presently appear, is collected as a partially concentrated liquid in the bottom of the evaporator and forced by the pump 55 through the conduit 56 and valve 57 over into the evaporator chamber 14. Since the evaporator chamber 14 is similar in construction to the evaporator chamber 12, it is not thought necessary to repeat the description. The spray heads 13, 15 and 17 are identical in construction, and Fig. 5 shows one of them, the head 13, 15 or 17, in vertical section.

The liquid product is discharged by the spray head 15 into the evaporator 14, where it is concentrated by the treatment of heated air as will presently appear. Since the spray head 15 and the mechanism for operating the same is substantially like that already described, it is not believed necessary to repeat the description in detail.

The concentrated liquid product flows to the bottom of the evaporator 14 and is removed therefrom by a pump 58 through the pipe 59, valve 61, and conduit 62, through the hollow spindle 42^a, to the spray head 17 by means of which it is sprayed into the dehydrator chamber 16. In this chamber the concentrate is desiccated by the heated air discharged into said chamber, as will presently appear.

The desiccated product in the form of a dry powder is collected in the lower portion of the dehydrator chamber 16, and may be removed therefrom by gravity through a valve 63 operated by a motor 64.

Suitable means are provided for conducting the heating medium through the apparatus in a direction counter to the movement of the liquid product. In the form of the construction disclosed, air is used as the heating medium for evaporating the moisture, and this air is confined to a closed circuit through the dehydrator 16 and evaporator 14 and is reduced in temperature for removing the moisture after each cycle of circulation, as will now be described.

Beginning in the heating medium cycle at the fan 18, the air is discharged into the conduit 21 where it is conducted through the heat exchange or heater 22. The heater may be of the conventional furnace type having the fire-box 65, which is adapted to be heated by the combustion of liquid fuel supplied by the nozzle 66 which discharges into the forward end of the fire-box 65. A pair of baffles 67 and 68 extend upwardly in spaced relation from the bottom of the fire-box for changing the direction of the heated gases as they pass through the furnace of the heater or heat exchange element. The heat exchange device 69, comprising the flue sheets or partitions 71 and 72, is mounted above the fire-box 65. A plurality of tubes 73 is rigidly mounted in the sheets 71 and 72, and a baffle 74 extends downwardly from the roof of the heat exchange in a vertical plane substantially midway between the baffles 67 and 68 so that the heated gases passing through the heat exchange will be caused to take a sinuous path, as indicated by the arrows in Fig. 1. The heated gases of combustion, after passing through the furnace, are discharged

through a suitable passage or discharge pipe 75 leading to the exterior of the building.

The heated air discharged from the fan 18, in passing through the heater or heat exchange element, has its temperature very greatly increased. The heated air passes from the heater or heat exchange element into conduit 23, which conducts the same to a snail 76 mounted on the dehydrator chamber 16. The snail gives the air a rotary movement, which causes it to rotate about a downwardly tapered shield member 77, see Fig. 5. The shield 77 and air deflector 47 deflect the air downwardly across the nozzles 48 through an annular passage 78 formed between the shield member 77 and downwardly extending projection 39 on the upper portion of the dehydrator chamber, see Fig. 5. The shield 77 may, if desired, be provided with an annular sleeve corresponding to the sleeve 79, shown in detail in Fig. 5, which is rigidly secured to the lower end of said shield and is provided with a beveled lower edge which overlaps a corresponding beveled upper surface 81, Fig. 5, of the deflector 47, thereby directing the air in the passage 78 downwardly across the joint between the rotating deflector and shield, Fig. 5.

The snail 76 causes the air to rotate, and it continues to rotate after it enters the dehydrator 16, and this rotation causes the heavier particles of the liquid product to be thrown against the walls of the desiccator and the desiccated particles will move down the wall to the lower part of the chamber. The air will continue to move downward and then will be forced upwardly in a spiral of smaller diameter, passing out through the interior of the shield 77 which is arranged axially of the desiccator chamber.

A double cone-shaped member 82 is mounted in the lower part of the dehydrator chamber and the air will rotate about the upper portion of this member. The air will be discharged from the desiccator by the arms 46 through the interior of the shield 77 into the conduit 24. The arms 46 are shaped to function as an exhaust fan, as shown in Fig. 6, for withdrawing the air from the dehydrator chamber and discharging the same into the conduit 24 secured to the upper end of the shield 77, Fig. 1. The air, in passing through the dehydrator chamber, will absorb a considerable amount of moisture. In order that this air may be used to advantage in the evaporator 14 for removing moisture from the particles of the liquid product introduced therein, it is necessary that the air be heated to a higher temperature than was done in the heater 22. In order that the air may be heated, a second heater or superheater 25 is employed for this purpose.

The air is substantially free of the desiccated particles of liquid product, but some of the particles may be carried over and into the evaporator 14 and become caramelized, thereby discoloring and impairing the flavor of the milk therein, and for that reason a filter 83 is provided in the conduit 24 for removing all solid matter before the air reaches the superheater 25. The superheater 25 is substantially like the heater 22, and comprises the heat exchange section 69^a, the furnace or firebox portion 65^a, and the burner 66^a. The heated air passing from the second heater or superheater 25 at a very greatly increased temperature will be discharged into the evaporator 14 through the passage 28, and through a snail 76^a rigidly mounted on the evaporator 14 and integral with the deflector 39^a. This

snail will impart a rotary movement to the air passing down into the dehydrator around the shield 77^a through the passage 78^a. The air, in passing across the spray head 15, will evaporate a considerable portion of the moisture from the liquid product, and in its rotation the heavier particles of the liquid product will be thrown by centrifugal action outwardly against the wall of the container and will be collected in the lower part thereof in a more or less concentrated liquid, from where it may be removed by the pump 58. The air will be withdrawn from the evaporator 14 and be discharged by the blades of the spray head 15 through the shield 77^a into the conduit 27, which will conduct the air down to the condenser 28.

The condenser 28 comprises an outer casing 85 having the flue sheets 86 and 87 extending across each end thereof. The ends may taper outwardly, as shown at 88 and 89, to form headers. The header 89 is in communication with the conduit 32, and the header 88 is in communication with the discharge side of the fan 31. Suitable tubes 91 have their ends rigidly secured in the flue sheets 86 and 87 and form passages for the air from the fan 31. Suitable baffles 92, 93 and 94 are provided for causing the air from the passage 27 to take a sinuous path through the heat exchange device or condenser. The baffles 92 and 94 extend downward from the upper wall of the device, and the baffle 93 extends upwardly from the bottom wall between the baffles 92 and 94. The upper wall of the condenser 28 has the lower end of the conduit 27 secured therein at one end, and the conduit 29 secured in the top wall at the other end of said device.

Air, in passing along the conduit 27, will be conducted through the heat exchange device 28 in one direction, and the cool air from the fan 31 will be conducted in the opposite direction through the tubes 91, thus effecting a heat exchange which will lower the temperature of the air in the closed circuit flowing through the conduit 27 to such an extent that considerable moisture will be precipitated, and this moisture may be discharged from the heat exchange device through the discharge pipe 95.

The air for the fan 31 enters the fan through a suitable filter 96, and, in passing through the device 28, will have its temperature considerably increased, and this air passes along the passage 32 and downwardly through the annular passage 78^b which surrounds the shield 77^b. The passage 32 is also provided with a snail 76^b, which will cause the air to rotate about the vertical axis of the evaporator 12 as it flows across the nozzles of the head 13. Since the head 13 is a duplicate of that shown at 17, it is not thought necessary to duplicate the description.

The air, in passing across the nozzles, will be brought into intimate contact with the finely divided particles of the liquid product, and a certain amount of the moisture contained in the product will be absorbed by the heated air. Centrifugal force will throw the particles radially outwardly against the side walls of the evaporator chamber 12, and the liquid will be collected in the lower part of the chamber to be removed therefrom by the pump 55 through the conduit 56. The air will be withdrawn from the evaporator by the spray head, as in the previous construction, and will be discharged through the interior of the shield 77^b into a discharge pipe

33, where it may be discharged either into the building or exteriorly thereof.

The three evaporator chambers may be provided with individual thermometers 98, 98^a and 98^b for indicating the temperature of the liquid product within the chambers. Thermometers may also be mounted on the conduit 24, as at 99, on the conduit 26, as at 100, on the conduit 32, as at 101, on the conduit 21, as at 102, on the conduit 27, as at 80, on the conduit 29, as at 90, and on the conduit 23, as at 103, for indicating the temperature of the air at those points.

The temperature of the desiccated product, when it leaves the dehydrator chamber, is too high for storing the product, and for that reason suitable means may be provided for cooling the product preparatory to packaging the same. In the form of the construction shown, the desiccated product is adapted to be discharged into a cooling conduit 104, having a valve or gate 105 for admitting fresh air into the conduit. The conduit 104 conducts the dry material to a cooler and centrifugal air separator device 106. This device is provided with an exhaust fan 107, which causes the air to flow along the conduit 104 and around the snail 108 and into the separator 106. Since the air separator is of the conventional type, it is not thought necessary to describe the same in detail. The dry material is separated in the separator 106, and the air escapes axially of the separator into the fan 107 and is discharged therefrom, as is common in such constructions.

The lower end of the separator 106 is provided with a valve 109, which is adapted to be operated by a motor 110 for discharging the desiccated particles of the liquid product into a suitable container 111. If desired, a thermometer 112 may be mounted in the lower portion of the separator 106 for indicating the temperature of the powder. If the powder is too warm to be collected in bulk, the valve 109 is opened further to admit a greater volume of fresh air.

Certain classes of liquid products are more readily evaporated or desiccated than others, and for that reason it may not be necessary to employ the intermediate or second stage evaporator 14 for further concentrating the product before desiccating it. It may be desired to concentrate the product only without desiccating the same. In either event, the evaporator 14 may not be necessary.

Suitable means are provided for shunting both the heating medium and the liquid product around the evaporator 14. Any suitable means may be employed for this purpose. In the form of the construction shown, a shunt by-pass or auxiliary conduit 113 is provided for shunting the heating medium around the furnace or heat exchange device 25 and the evaporator 14. This passage is attached to the conduit 24 adjacent to the motor 44^a, and its other end is in communication with the conduit 27 adjacent to the motor 44^b, which operates the spray head 16 of the desiccator 14. As shown, a valve or closure 114, hinged as at 115 to the upper wall of the conduit 24, is provided for directing the heating medium into the shunt 113 when desired. The hinge 115 is a friction hinge which will hold the closure in adjusted position. The valve 114 is adapted to be turned to the position shown in dotted lines at the left of Fig. 1, and may be held in any adjusted position, as desired, by the friction hinge 115.

When it is desired that all of the air shall pass through the shunt or auxiliary conduit 113, the valve 114 is moved to its lowermost position, as shown in dotted lines in Fig. 1. When it is desired that all of the air shall pass through the conduit 24 and the heating furnace 25, the valve is moved to the closed position, as shown in full lines in Fig. 1.

The opposite end of the shunt or auxiliary conduit 113 is likewise provided with a valve or closure 116, hinged, as at 117, by a friction hinge which is adapted to hold the closure in any adjusted position. The closure 116, in the full line position shown, assists in closing off the shunt or by-pass 113, and when moved to the dotted line position it assists in closing off the passage leading to the evaporator 14 and the furnace 25.

When it is desired to include the evaporator 14 and the heating furnace 25 in the operation of the system, the valves 114 and 116 are moved to the position shown in full lines in the drawings, and the valves 57 and 61 are likewise moved to the position indicated. The valves 57 and 61 are three-way valves, so that when moved into the position shown the liquid product will pass upwardly through the pipe or conduit 56 and down through the hollow spindle 42^b, but when it is desired to cut out the operation of the evaporator 14 the valve is moved to position to close the passage through the spindle 42^b and permit the liquid product to pass along the conduit 118 over to the valve 61, which has been moved to position to close the pipe 59 whereby the fluid will pass into the pipe 62 and be delivered to the passage in the spindle 42^a. The closures 114 and 116, in the meantime, have been moved to the dotted line position, so that neither the air nor the liquid product will be delivered to the evaporator 14.

In the type of liquid product that may be desiccated without treating the same in the evaporator 14, it may be desired to simultaneously concentrate and desiccate different portions of the liquid product. This may be readily done by adjusting the valves 57 and 61, and the closures to partially open position and close the valve 58. The portion of the liquid product that has been concentrated in the evaporator 14 may then be removed from the evaporator through a valve 119 in the bottom thereof, while the portion that has been desiccated may be removed through the valve 63 as described above.

There are times when it is desirable to concentrate or dehydrate two liquid products simultaneously, or to concentrate one liquid product and simultaneously dehydrate another. At other times it may be desirable to produce a dehydrated mixture of two different liquid products, such, for instance, as milk and eggs. In order that the dehydrating apparatus may perform these functions it is provided with additional cooperating mechanism, as will now be described.

A reservoir 121 for containing a liquid product is provided, as shown in Fig. 1. A conduit 122 conducts the liquid product from the reservoir 121 to the conduit 62 leading to the spray head 17. The conduit 122 is provided with a pump 123, which may be of the rotary type, for forcing the liquid product along the conduit 122. This conduit is also provided with a valve 124, which may be adjusted for controlling the flow of the liquid product along the conduit 122.

A container 125 is provided for receiving a concentrate from either the chambers 12 or 14, as will presently appear. A conduit 126 is pro-

vided between the conduit 62 and the container 125. A valve 120 in the conduit 62 beyond the conduit 126, and another valve 127 in the conduit 126, may be adjusted to control the flow of the concentrate through the conduits 62 and 126. By closing the valve 120 and opening valve 127 all of the concentrate flowing along the conduit 62 will flow into the reservoir or container 125. By closing valve 127 and opening valve 120 all of the concentrate will flow over to the dehydrator chamber 16. Furthermore, by partially opening both valves 120 and 127 the flow of concentrated liquid product will be divided, part flowing into the container 125 and part over into the chamber 16.

In the operation of the device, when it is desired to concentrate one liquid product and simultaneously dehydrate another, one liquid product is placed in the reservoir 11 and the other liquid product in the reservoir 121, the valves 120 and 127 being adjusted so that the liquid concentrate flowing along the conduit 62 will be directed into the container 125. If it is desired to concentrate this liquid by passing it only through the chamber 12, the valves 51 and 61 are so adjusted that the liquid from the chamber 12 will pass directly along the conduits 56 and 62 into the container 125 from the chamber 12. The closures 114 and 116 are lowered to the dotted line position in Fig. 1, so that the heated air from the dehydrator chamber 16 will by-pass the chamber 14 and flow along the conduit 113 directly into the heat exchanger 28, and from the heat exchanger through the heater 22 back to the dehydrator chamber 16 to complete the circuit. The valve 124 is also opened and the pump 123 started, which will pump the liquid in the reservoir 121 into the spray head 17, which in turn will discharge into the dehydrator chamber 16 for dehydrating the product, or for concentrating it, as may be desired, depending on the nature of the liquid product; the adjustment of the valve 124; and the temperature of the drying medium. In event a concentrate is desired from the chamber 16, the conduit 104 is removed and the container 111 placed beneath the valve 63 for receiving the concentrated liquid product from the chamber 16.

It may be desired to dehydrate a mixture of two liquid products where one of the products is more volatile than the other, or where one contains more moisture than the other. The one that is more volatile, or that containing the less percentage of moisture, may be placed in the reservoir 121, and the one containing the greater percentage of moisture in the reservoir 11. The valves may be arranged so that the liquid product in the reservoir 11 passes first through the evaporating chamber 12, and then the concentrate through the evaporating chamber 14, or the chamber 14 may be by-passed. The product containing a less percentage of moisture is placed in the reservoir 121 and is fed simultaneously with the concentrate to the spray head 17, which, in spraying the mixed liquids, will thoroughly mix the same so that the dehydrated product may be mixed in any proportion desired. In order to vary the proportions of the mixed product the conduit 35 is provided with a valve 128 so as to control the amount of liquid passing through the conduit 35. The valve 124 may also be adjusted to control the amount of liquid flowing through the conduit 122. In this way the mixture of the two products may be varied within a wide range. Furthermore, it may be desired to obtain a

concentrate of one liquid product and a dehydrated mixture of this and another liquid product. This may be accomplished by placing one liquid product in the reservoir 11 and the other in the reservoir 121 and properly adjusting the various valves. The relative amount of concentrate may be varied by adjusting the valves 120 and 127. If both valves are partially open the liquid product from the reservoir 11 will be divided, part deposited in the container 125 as a concentrate and the remainder in the chamber 16 as part of the dehydrated mixture.

In the first stage of evaporation the system uses a large volume of air at comparatively low temperature, so that the condenser within which this air condenses the moisture contained in the recirculated air may operate efficiently for this purpose and at the same time be heated sufficiently to evaporate moisture from the product within the first stage evaporator 12. In event air at high temperature is employed as the drying medium and the evaporating chamber 14 is by-passed, the fresh air, in passing through the heat exchanger 28, will have its temperature considerably increased. The condenser 28 is provided with a large conducting surface whereby it is an efficient heat exchange apparatus.

While the different units comprising the apparatus may be varied in size, shape or form, which would vary the operating conditions, the following was found to give satisfactory results:

In an apparatus producing fifteen pounds of desiccated milk per minute from 170 lbs. of skim milk per minute, the fan 18 circulated 8500 cubic feet of air per minute through the system. The air leaving the condenser at around 125° F. had its temperature raised to around 400° F. in passing through the heater 22. Its temperature was lowered to around 200° F. in the dehydrating chamber. This is some 40° to 60° above the saturation point of the air. The air then flows through the second heater 25, where its temperature is raised to around 540° F. and introduced into the evaporator 14, where its temperature is reduced to around 150° F. About 48,000 cubic feet of air per minute at, say, 70° F. is forced by the fan 31 through the heat exchange 28, where its temperature is raised to around 140° F. This air escapes from the evaporator 12 at around 80° F. There is not such a large reduction in the temperature of the air discharged from the evaporator 12, but it will be noted that the volume is very large and consequently a large number of heat units are utilized for evaporating moisture from the liquid particles.

It will thus be seen that the entire apparatus may be easily cleaned because the product is treated only in large chambers which are easily accessible through doors, not shown, which may be provided in the side walls of the different cyclone evaporator chambers. By the use of these large chambers there is not the necessity for the use of so-called vacuum chambers or pans with their attendant maze of tubes that must be cleaned at frequent intervals.

This application is a continuation in part of my application filed May 26, 1939, Serial No. 275,934, for Method of and apparatus for concentrating and dehydrating liquid products.

It is thought from the foregoing, taken in connection with the accompanying drawings, that the construction and operation of my device will be apparent to those skilled in the art, and that changes in size, shape, proportion or detail may

be made without departing from the spirit and scope of the appended claims.

I claim as my invention:

1. In a system for dehydrating liquid products, a first stage evaporator member, a second stage evaporator member, a dehydrator member, a condenser, each of said members comprising a chamber having a cylindrical upper portion and a tapered lower portion and each having a tangential inlet for the drying medium and an axial discharge opening for said medium, a fan in each of said discharge openings, nozzles carried by said fans for atomizing said product, a reservoir for a liquid product, means for conducting said product from said reservoir to said first stage evaporator member and from the first stage evaporator member to the remaining members in sequence, a primary heater, a second heater, means for causing a gaseous drying fluid to circulate in a closed circuit through said primary heater, dehydrator member, second heater, second stage evaporator member and condenser, said drying fluid entering said last-named member through said inlet and being discharged by said fan through said axial opening, and means for causing fresh air to flow through said condenser and then through said primary evaporator for initially concentrating said liquid product.

2. In a system for dehydrating liquid products with the aid of a gaseous drying medium, a first stage evaporator member, a second stage evaporator member, a dehydrator member, each of said members being in the form of the conventional cyclone separator having tangential inlets and axial outlets through its upper wall, for the drying medium, means for introducing the liquid product in the form of a spray into said evaporator and dehydrator members in series in the order named, means for causing a drying medium to recirculate through said dehydrator member and second stage evaporator member in series, means for conducting fresh air in heat exchange relation with said first-named air and conducting the same to the first stage evaporator member, and means for circulating said fresh air through said first stage evaporator member whereby moisture will be progressively removed from said product as it passes through said members.

3. A method of dehydrating liquid products which consists in discharging the product in the form of a spray into a plurality of enclosures in series, discharging heated air through said spray in the last two of said series of enclosures in series in a reverse order, circulating fresh air through the first of said series of enclosures, and heating all the air introduced into each enclosure just prior to its introduction thereto, the heating of the air for the next to the last enclosure being at the highest temperature.

4. A method of dehydrating liquid products which consists in discharging the product in the form of a spray successively into a series of enclosures, continually recycling air in a closed circuit through at least one of said enclosures, heating the air in said closed circuit and then heating a large amount of fresh air by transferring heat thereto from the air in said closed circuit and causing the heated fresh air to flow through a spray of the product in the first of said series of enclosures for initially concentrating said product.

5. A method of removing moisture from liquid products which comprises spraying the product into three enclosures in series, continuously circulating a first stream of drying medium through

the last two of said enclosures in said series in a closed circuit for evaporating moisture from the product sprayed therein, heating said stream just prior to its entry into each of the two enclosures, causing said stream to flow through a heat exchanger device, and causing a copious second stream of drying medium to flow through said device in heat exchange relation to said first stream for cooling said first stream and for heating said second stream and then discharging said second stream into the first of said enclosures for evaporating moisture from the product sprayed therein, and finally discharging said second stream from the last-named enclosure.

6. A method of desiccating a liquid product in a continuous process which comprises passing a gaseous drying medium through a heater to heat the medium, discharging the same into a third stage drying chamber causing the same to move downwardly in an outer spiral, then upwardly in an inner spiral within said chamber to a point of discharge, conducting said medium discharged from said chamber to a second stage drying chamber, passing the medium in transit between said chambers through a second heater to reheat the medium, causing the reheated medium to circulate through said second stage drying chamber in a manner similar to its movement through the first stage drying chamber, conducting said medium from said second stage chamber through a heat exchanger back to said first-named heater for completing its cycle of movement, simultaneously causing air to flow through said heat exchanger for heating the air from said medium and circulating said air through a first stage chamber, and spraying a liquid product into said chambers in series into the air entering said chambers beginning with said first stage chamber.

7. A method of desiccating a liquid product which comprises discharging air tangentially into at least a first, second and third enclosure for causing the air to form rotating columns in said enclosures, spraying the product into the rotating column of air in each of said enclosures in series from the first enclosure to the last and heating the air immediately before it is introduced into each of said enclosures, the air for the second enclosure being heated materially above that introduced into the remaining enclosures, and recirculating a portion only of said air through the second and third enclosures in a closed circuit.

8. A method of concentrating and dehydrating a liquid product which comprises discharging air tangentially into at least three internally unobstructed enclosures causing the air to form rotating columns in said enclosures, recirculating portions of said air through two of said enclosures in series, spraying the liquid product into the rotating columns of air in the enclosures in series, heating the air just prior to its introduction into said two enclosures, and utilizing a portion of the heat thus introduced into the last-named two enclosures to heat the air introduced into the remaining enclosure, said last-named air being in much greater volume than that supplied to either of the remaining enclosures.

9. In an apparatus for dehydrating a liquid product, a plurality of chambers including a dehydrating chamber, means for conducting said product from one of said chambers to another and for discharging said product in a spray into said chambers in series in a predetermined order ending with said dehydrating chamber, means for circulating a predetermined amount of drying

medium in a closed circuit through some of said chambers and across said sprays in series beginning with said dehydrating chamber, means for heating said medium immediately prior to its flow across each of said sprays, a condenser through which said medium is circulated in said closed circuit, and means for circulating a much greater amount of drying medium through said condenser and through the remainder of said chambers for evaporating moisture from said product.

10. In a system for concentrating and desiccating a liquid product in a continuous operation, a reservoir for said product, three cyclone separators arranged in series and constituting the sole spaces where moisture is removed from said product, the last one of said series constituting a dehydrator, means for conducting a liquid product from said reservoir to said separators in series ending in said dehydrator, means for discharging said product in the form of a spray into said separators in the same order, means for circulating a first stream of air through two of said separators, including said dehydrator, in a closed circuit in series beginning with said dehydrator, means for heating said air stream just prior to its introduction into each of said two separators, means for circulating a second stream of air through the third of said separators at high velocity for evaporating moisture from the particles sprayed therein, and a heat exchanger for transferring heat to said second air stream from said first air stream.

11. In an apparatus for desiccating a liquid product comprising a first stage evaporating chamber, a second stage evaporating chamber, a dehydrating chamber, means for conducting a liquid product to said chambers in series, ending with said dehydrating chamber, means for discharging said product into said chambers in the same order in the form of a spray, means for circulating heated air in a closed circuit through said second stage evaporating and dehydrating chambers in series, beginning with said dehydrating chamber, means for discharging said air across said sprays in a spiral movement, means for condensing moisture from said heated air by the use of a copious supply of fresh air for absorbing heat therefrom, and means for discharging said fresh air across the spray of said product in said first stage evaporator chamber for reducing the moisture content of said product.

12. In a system for dehydrating liquid products, a container for a liquid product, a plurality of chambers including an evaporating chamber and a dehydrating chamber, means connected with said container for spraying the liquid product into said chambers in series ending with said dehydrating chamber, means for circulating heated air in a closed circuit through at least one of said chambers other than said evaporating chamber, a heat exchanger in said circuit, means for circulating air in great volume through said exchanger and through said evaporator, and means for heating the air in said closed circuit.

13. A method of dehydrating liquid products which comprises discharging the product in the form of a spray successively into two enclosures, heating air and circulating the same in a closed circuit through one of said enclosures, and then heating a large amount of fresh air by transferring heat thereto from the air in said closed circuit and causing the heated fresh air to flow through a spray of the product in the other of

said enclosures for initially concentrating said product.

14. A method of mixing and dehydrating at least two liquid products in one continuous operation which comprises individually concentrating one of said products in a current of spirally moving heated air, discharging the concentrated product and the other liquid product from separate sources into a single spray head and then discharging the mass of liquids from said spray head into a spirally moving current of said heated air within an enclosure for mixing the liquids and for dehydrating the mixture, and removing the mixed dehydrated product from said enclosure.

15. An apparatus for concentrating and dehydrating a liquid product comprising a heater, a centrifugal dehydrating chamber, a heat exchanger, conduits for connecting said dehydrating chamber, heat exchanger and heater in a closed recycling circuit, means for causing a drying medium to flow around said circuit in a closed cycle with a spiral movement through said chamber, an evaporating chamber, means including a conduit for conducting fresh air through said heat exchanger for heating said air, and for causing said air to flow spirally down into and out of said evaporating chamber, means for spraying a liquid product into the spirally moving heated air within said second chamber for concentrating said product, and means for spraying the concentrate into the spirally moving drying medium within said first-named chamber for dehydrating said concentrate.

16. In a dehydrating apparatus, a heater, a dehydrating chamber, a heat exchanger, means for circulating a gaseous drying medium in a closed circuit through said heater, dehydrating chamber and heat exchanger, a reservoir, a spray head in said dehydrating chamber for spraying a liquid product into the drying medium entering said dehydrating chamber from said reservoir for dehydrating said product, an evaporating chamber, means for conducting air through said heat exchanger for heating said air, a second reservoir for containing a second liquid product, a spray head within said evaporating chamber for spraying said second liquid product into said air as it enters said evaporating chamber, a conduit for conducting said second liquid product to said last-named spray head, means for conducting a portion of the concentrate from said evaporator chamber to said first-named spray head, a receptacle, means for conducting the remaining portion of said concentrate to said receptacle, and valve means for varying the proportionate amounts of said liquid products delivered to said first-named spray head whereby the proportionate amounts of the dehydrated mixture may be varied while simultaneously collecting a concentrate of one of them.

17. In a system for dehydrating a mixture of liquid products, a dehydrating chamber, a heater, a heat exchanger, means for circulating a drying medium through said heater, dehydrator and heat exchanger in a closed circuit, a spray in said dehydrator for spraying a liquid product therein, a reservoir for containing a liquid product to be dehydrated, a first conducting means for conducting said liquid product to said spray from said reservoir, means for controlling the amount of liquid product flowing from said reservoir to said spray, an evaporator, means for causing a drying medium to flow through said exchanger and into and out of said evaporator,

a second reservoir for containing a liquid product, a spray for spraying said last-named liquid product into said last-named drying medium within said evaporator for concentrating the last-named liquid product, a second conducting means for conducting the concentrate from said evaporator to said first conducting means, and means for controlling the flow of concentrate through said second conducting means whereby the dried particles of said liquid products will be thoroughly mixed and the proportional amounts may be varied.

18. An apparatus for dehydrating a liquid product, comprising a first stage evaporator chamber, a second stage evaporator chamber, a third stage dehydrator chamber, a heat exchanger, a fan, a heater, an intake passage for conducting a drying medium from said fan to said third stage dehydrator chamber through said heater for discharging said medium in said last-named chamber, a principal discharge passage for conducting said medium from said third stage dehydrator to said second stage evaporator, a main passage for conducting said drying medium from said second stage evaporator to said fan through said heat exchanger, a shunt passage, valves in said shunt and principal passages for directing all or a portion of the drying medium through said shunt or principal passage, an air passage for conducting air through said heat exchanger and delivering the same into said first stage evaporator for concentrating a liquid product therein, a reservoir for a liquid product, a spray head for each chamber, conduit means for conducting said liquid product from said reservoir to said first stage evaporator and for conducting the concentrate selectively to either the second stage evaporator chamber or to the dehydrator chamber or to both, a receptacle for selectively receiving concentrate from said first stage or second stage chamber or from both, a second reservoir for containing a second liquid product, conduit means for delivering liquid from said second reservoir to said dehydrator, and valves in said conduit means for controlling the relative amounts of the liquid products flowing along said conduits.

19. An apparatus for simultaneously dehydrating and mixing a plurality of liquid products in one continuous operation, comprising an evaporating chamber, a dehydrating chamber, a heater, a heat exchanger, means for conducting a gaseous drying medium through said heater, said dehydrating chamber, said evaporating chamber, said heat exchanger, and back to said heater in a closed circuit, means for shunting a portion or all of said medium around said evaporating chamber, a reservoir for containing a liquid product, means including conduits for conveying said liquid product to said evaporating chamber and the concentrate from said evaporating chamber to said dehydrating chamber, means for spraying said products into said drying medium in said chambers, valve means in said conduits for directing a portion only or all of said product to said evaporating chamber, a receptacle for receiving all or only a part of the concentrate from said evaporating chamber, a second reservoir for containing a different liquid for mixing with said liquid supplied to said dehydrator chamber, and a valve for controlling the amount of liquid supplied from said second reservoir for varying the proportionate amount of the material in the resultant mixture.

20. In a dehydrating system for liquid prod-

ucts, a first stage evaporator chamber, a second stage evaporator chamber, a dehydrator chamber, means for spraying the liquid product into said chambers and for conducting the liquid product through said chambers in series in the order named, a heat exchange device, means for circulating a first stream of air through said heat exchange device, means for heating the air after its passage through said device, means for discharging this last-named air into said dehydrator chamber in a rotary movement and for conducting the same axially therefrom for dehydrating the sprayed liquid product therein, means for heating the air conducted from said dehydrator chamber above the temperature at which it was introduced into the dehydrator chamber, means for discharging the reheated air into said second stage evaporator in a rotary movement for reducing the moisture content of the liquid product therein, means for discharging the air axially from said second stage evaporator chamber and for conducting the same through said heat exchange device, means for circulating a second stream of relatively cool air through said device at high velocity for condensing the moisture in said stream of air and for heating said second stream of air, and means for conducting said second stream of air to said first stage evaporator chamber and for causing the same to move spirally therein and axially therefrom for evaporating moisture from the liquid product sprayed into said first stage evaporator chamber.

21. In a system for desiccating a liquid product, a plurality of large centrifugal chambers circular in cross-section, arranged in series, and each having a cylindrical upper portion and a tapered lower portion, the cylindrical portions of said chambers being internally unobstructed, each chamber having a spray head therein having arms provided with nozzles, said spray heads being alike in construction, means for rotating said heads for discharging a liquid product in the form of a spray into each of said chambers, means for supplying said liquid product to said heads in series, means providing a first stream of air for flow across the nozzles in some of said chambers including the last chamber in the series for removing moisture from said product, said chambers constituting the sole enclosures where moisture is evaporated from said product, said arms constituting fan blades for exhausting the air from said chambers, selective means for either conducting said air stream from the last of said series of chambers through the chamber second from the last of said series or for shunting the air stream in whole or in part around the chamber second from the last of said series, means for heating said air stream just prior to its introduction into said last chamber, means for circulating a second stream of air through the first chamber of said series for removing moisture from the fresh liquid product, and means for transferring the heat from said first stream of air to said second stream of air prior to discharge of said second stream into said first chamber.

22. A method of dehydrating material involving the use of two evaporators, said method including the steps of continuously recycling a drying medium in a closed circuit through the two evaporators in series, cooling the drying medium at a point in said closed circuit upstream from one of said evaporators to lower the vapor content of the drying medium by condensation, heating said stream of drying medium at a point between said one point and said evaporator to raise

the drying capacity of the stream, heating said medium to again raise the drying capacity thereof at a point downstream from said one evaporator and upstream from the other evaporator, and continually feeding said material to said two evaporators for dehydration by said stream.

23. A method of dehydrating material involving the use of two evaporators, said method including the steps of continuously recycling a first stream of drying medium through one of said evaporators, heating said stream at a point upstream from said one evaporator, bringing a

second stream of relatively cool drying medium into heat exchange relationship with said first stream at a point therein downstream from said one evaporator thereby cooling said first stream to lower the vapor content thereof by condensation and thereby releasing latent heat to raise the temperature of said second stream, introducing the heated second stream into the other evaporator and feeding said material to said two evaporators for drying action thereon by said two streams.

JOSEPH M. HALL.

Certificate of Correction

Patent No. 2,400,459.

May 14, 1946.

JOSEPH M. HALL

It is hereby certified that errors appear in the printed specification of the above numbered patent requiring correction as follows: Page 1, second column, line 40, for "chamber 14 into" read *chamber 14 in*; page 6, first column, line 19, claim 1, for "circular" read *circulate*; and that the said Letters Patent should be read with these corrections therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 23rd day of July, A. D. 1946.

[SEAL]

LESLIE FRAZER.

First Assistant Commissioner of Patents.

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