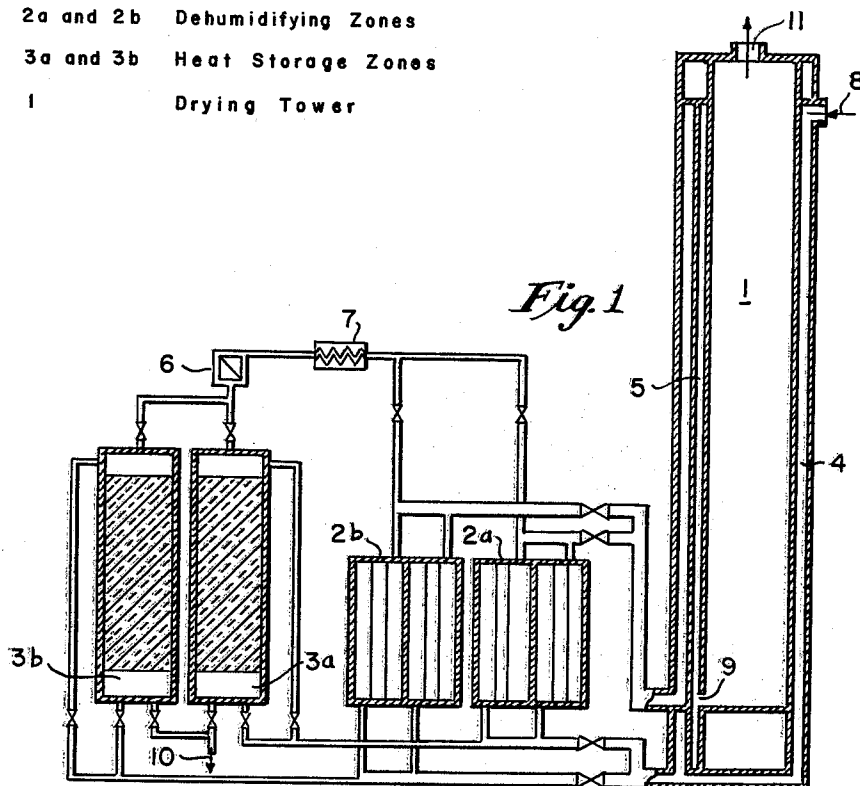
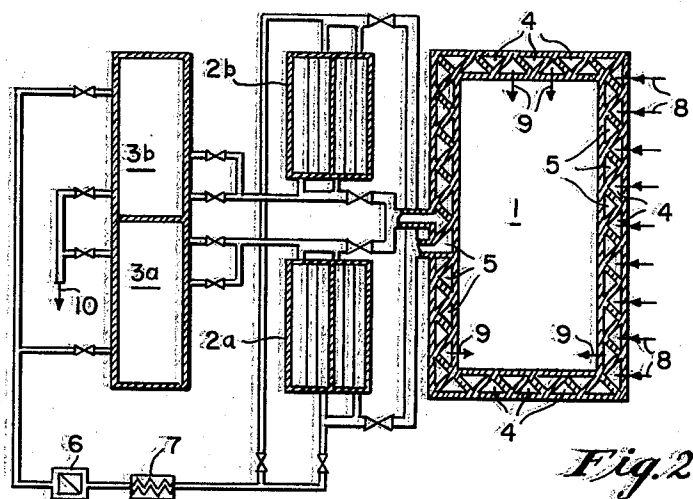


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METHOD AND APPARATUS FOR THE SPRAY DRYING OF HEAT
SENSITIVE LIQUIFORM MATERIALS
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3,190,343

2a and 2b Dehumidifying Zones
3a and 3b Heat Storage Zones
1 Drying Tower



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3,190,343

METHOD AND APPARATUS FOR THE SPRAY DRYING OF HEAT SENSITIVE LIQUIFORM MATERIALS

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The present invention relates to improvements in a method and apparatus for drying particulate solid materials, such as dehydrating aqueous dispersions, suspensions or solutions of solids. More particularly, it is concerned with improvements in the dehydrating procedures disclosed in my copending applications Serial No. 735,299, filed May 14, 1958, for "Dehydration Process and Apparatus Therefor," now abandoned, and Serial No. 87,808, filed February 8, 1961, for "Dehydration Process, Product Obtained Thereby, and Apparatus for Carrying Out Said Process."

With the procedures disclosed and claimed in these applications, it first became possible to obtain "instant" powders merely by drying. The instant powders obtained by these procedures have all the properties of the solids contained in the starting material. They are not denatured and, in the case of food products, they show no change of taste. They may be considered as "instant" products because the powders will instantly dissolve without leaving a residue, even in cold water, if they are colloiddally soluble or, if they are only dispersible, they will be instantly dispersed or wetted, while swelling.

In this previously disclosed method, the material to be dried is dispersed in the upper region of a high tower in the form of a dense umbrella of droplets descending in the tower through a counter-currently flowing stream of relatively cool or cold drying air, the air being introduced in the lower region of the tower in a highly dehumidified state, for instance, with a water content of 0.35 g./cu. m., at a temperature not exceeding about 60° C. In view of the low temperature of the drying gas, the residence time of the material in the tower must be relatively long and the volume of drying gas must be accordingly large.

It is one of the primary objects of the present invention to increase the residence time of the material to be dried in the countercurrently flowing drying gas without increasing the height of the drying tower.

It is another object of this invention to operate the drying apparatus with a minimum of heat requirements.

It is still another object of the invention to handle the dried material so that it sustains substantially no damage due to denaturing or abrasion until it is packaged in impermeable containers.

It is a further object to improve the quality of the dried material further and to control the apparent density of the instant powder.

The above and other objects and advantages may be obtained according to the present invention due to a singular property of the instant powders obtained by my "cool air" drying method. I have found that these instant powders consist of fully spherical granules with holes reaching deeply into the interior of the spheres even when they still contain about 5% to 20% water, depending on the type of material. Once the material has reached this spherical structure, the powder may be conveyed by air streams or mechanically without destroying the spherical granules or appreciably abrading the same. Furthermore, an air stream may upwardly pass through a layer of spherical granules of this type and having a thickness up to about 20 cm. without causing turbulence in the layer.

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In one aspect of this invention, special means is provided to prevent undue turbulence in such dried goods which should remain as little disturbed as possible until they are packed and to convey them from the drying tower to the packing zone in the shortest possible path. If the dried powder is of the type which tolerates stirring, the invention provides special means for removing the powder from the drying tower and for conveying it in the shortest possible path to the packing station which may be, if desired, any conventional vacuum-packing system.

If the starting material is particularly hygroscopic, such as tomato concentrate which may still contain tomato peels and which tends to stick to the bottom of the drying tower, brushing means must be placed there to avoid the formation of a solid material layer on the tower bottom. In the various embodiments of this aspect of the invention, the brushes serve partially not only for conveying the dried material but also for imparting turbulence thereto.

Different types of apparatus will be used for different materials, depending on their characteristics, the method and apparatus of the invention being adapted for use with any starting material which may be dried to form a powder. Types of useful apparatus include

(1) A drying tower with a flat or substantially flat perforated bottom through which the drying gas flows upwardly into the tower, the sieve-like bottom taking a variety of forms.

(2) A drying tower with a conically converging impermeable or perforated bottom having the material outlet at its apex, with or without brushes.

(3) A drying tower with a flat or substantially flat impermeable bottom with brushes for imparting turbulence to the powder.

(4) A drying tower with a partitioned jacket to obtain a temperature equilibrium between the day and night air used as drying gas, on the one hand, and the air dried chemically, for instance, by silica gel or molecular sieves, so as to store heat and simplify the servicing of the tower.

(5) A drying tower with a special material distribution arrangement for controlling the bulk density of the powder.

If desired, the drying tower may be combined with other driers, for instance, freeze driers for very sensitive materials. Also, aromatic substances may be admixed with the drying gas because the porous granular structure of the dried powder obtained according to my method makes it possible for the powder effectively to adsorb aromas.

The above and other objects, advantages and features of the present invention will become more apparent in the following detailed description of certain preferred embodiments thereof, taken in conjunction with the accompanying schematic drawing wherein

In all embodiments of the present invention, use is made of a drying tower according to my above mentioned copending applications, wherein the throughput of the material to be dried, its droplet size and distribution, the drying gas velocity and temperature are so correlated that the material falling through the dehumidified and upwardly streaming drying gas reaches the tower bottom in the form of porous and fully spherical granules which remain on the bottom without collapsing or adhering to each other. This novel granular structure of the dried material makes it possible to introduce the gaseous drying agent into the tower through the bottom, even if it carries a layer of dried powder up to 20 cm. thick and without imparting turbulence to the powder layer. The powder remains lying on the tower bottom until it has reached the desired degree of dehydration and is then

conveyed on the shortest possible path to the vacuum packing station (which does not form part of the present invention). Alternatively, the powder may be removed from the bottom of the tower as soon as it may be mechanically or pneumatically conveyed to a sieve-like support on which it is additionally dried to the desired degree of dehydration without turbulence.

The drying tower used in the invention may be provided with a false bottom which is a horizontal porous, sieve-like support. The false bottom defines a space with the tower bottom and an inlet pipe supplies a gaseous drying medium to the tower. The liquid material to be dried in the tower is introduced therein through a supply conduit leading to a material distributing system having a plurality of jets for producing an umbrella-like curtain of droplets over almost the entire horizontal cross section of the tower. The used drying medium, which carries most or all of the water from the liquid material dried in the tower, may escape into the atmosphere through a flue or it may be recovered in a pipe leading to a gas dehumidifying plant so that the drying medium may be returned to the drying tower in a closed cycle after it has been dehumidified. Adjustable valves may be mounted in gas outlets to regulate the draft of the drying medium according to requirements.

The granular powder is collected on the false bottom until it has reached a desired layer thickness and after it has reached a predetermined degree of dehydration. A scraper, which is rotatable about the axis of the tower, is turned to push the dried material through a radial slot arranged in the false bottom. The screw conveyor is mounted in a housing which has an upper opening facing the radial slot so that the dried material will fall through the slot into the housing and will be transported out of the housing and the tower by the screw conveyor directly into a vacuum packing device without contacting the atmosphere.

If the scraper has brushes for pushing the dried material, it may be useful intermittently to blow a dried gas through inlet pipe to remove material adhering to the brush bristles. Adjustable valve means are mounted in inlet pipe to control the gas stream therethrough.

In another embodiment of the invention, the dried material is not removed from false bottom by a mechanical scraper but by a pneumatic conveyor. The pneumatic conveyor comprises a radially extending pipe arranged for rotation about the axis of the tower to sweep over false bottom with a suction slot facing the false bottom. The radially extending pipe is in communication with an axially extending tube whose output is connected to the interior of a container which is under sub-atmospheric pressure. The tube is rotated through a gear train by a power source.

If desired, the mechanical and pneumatic conveyors may be so combined that the mechanical scraper pushes the dried material towards the circumference of the tower while the pneumatic conveyor has suction slots only at the outer end or ends of the radial pipe to pick up the powder at the tower circumference and transport it pneumatically to the packing station.

In another embodiment of the invention, two spaced and superposed sieve-like false bottoms may be arranged in the tower. Each of the false bottoms is constituted by a plurality of sector-shaped sieve boxes. The boxes may be turned about their axes.

The brushes are also rotatable about their axes by suitable motors and sweep the undersides of the sieve boxes. In this manner, the dried spherical granules fall first on the upper false bottom, pass through its sieve boxes, are swept off their undersides, fall on the underlying false bottom, pass through the latter's sieve boxes, are swept off their undersides and drop to the bottom of the tower where they are swept by a rotating scraper or brush into a central outlet opening through

which the dried powder is immediately gravity-fed into packing station without contacting the atmosphere.

The dehumidified drying gas may be introduced into the bottom of the drying tower a pipe and a baffle plate may be mounted over the outlet of the pipe to distribute the drying gas over the entire cross section of the tower so that it will rise from the bottom in a column.

The sieve boxes may be bounded by two generally horizontally extending perforated or sieve-like walls and one of these walls may have placed thereover a fine-mesh web. The sieve boxes may be turned about their axes.

The introduction of drying gas is preferably initiated only shortly after the sieve boxes have been turned so that the fine-mesh sheet is fully dried before another layer of dried material is formed thereon.

In another embodiment of the tower used in the invention, there are mounted two false sieve bottoms in horizontally rectangular cross section.

The two false bottoms are spaced apart and each bottom consists of a plurality of adjacently mounted sieve boxes bounded by horizontally extending sieves covered by fine-mesh sheets. A support extends horizontally below each false bottom and carries as brushing device for movement thereon so as to sweep the underside of each false bottom. Another scraping or brushing device is movably mounted on a support above the tower bottom for sweeping the bottom or floor of the tower and convey the dried material to an outlet opening.

While two superposed false bottoms may be used, a single false sieve bottom will suffice for materials which may be dried easily. Also, the lower false bottom may consist of a single sieve instead of the illustrated sieve boxes. In many instances, the scraping or brushing device may be omitted at the lower sieve bottom because all the dried powder will drop off the sieve boxes when the same are turned.

In another embodiment of the tower used in the invention, the tower may have a false sieve bottom constituted by a perforated conveyor band. The bottom of this tower extends laterally to form an after-drying chamber whose length is about twice the diameter of the tower. The conveyor is about twice the diameter of the tower. The conveyor band extends into the after-drying chamber and transports the dried material from the tower, through the after-drying chamber to the packing station without contact with the atmosphere. The gaseous drying medium is introduced into the tower through inlet opening. In another variant of the tower, there may be mounted three superposed perforated conveyor bands in superposed relationship to form three false bottoms. Adjacent bands move in opposite directions so that the dried material is moved from one band to the other before the last band conveys the material to the packing station.

In another embodiment of the tower of the invention, a false sieve bottom is rotatably mounted about the axis of the tower. The drying gas enters the tower through inlet opening in the bottom of the tower and a radially extending baffle plate extends from the center of the tower to the material outlet. If desired, a screw conveyor may be mounted under the baffle plate to transport the dried material out of the tower to the packing station. Alternatively, a dried gas may be used to blow the dried material into material outlet, to which suction may be applied if needed or desired. A scraping or brushing device is arranged above the baffle plate to sweep dried material off the plate and onto the sieve bottom. In another drying tower in accordance with the invention a false sieve bottom may be yieldingly mounted on the tower wall by means of spring supports. The spring supports may be excited by an oscillating device so that the spring-suspended bottom is oscillated and dried material is passed therethrough to the bottom of the tower. The underside of the sieve bottom is swept by a scraping or brushing device rotatable about the axis of the tower. A similar rotating scraping or brushing device sweeps over the bot-

tom or floor of the tower and conveys the dried material to outlet opening.

Another embodiment of the tower of the invention may have a conical bottom converging towards a central outlet opening leading to an after-drying chamber where- in three perforated conveyor bands are mounted one above the other.

In another embodiment, the tower may be fitted with an imperforate and almost flat false bottom. This embodiment is particularly useful for very hygroscopic materials or materials of different components, such as tomato concentrate containing tomato peels. The peels dry more slowly than the remainder of the concentrate and tend to clog any sieve after extended operation. Therefore, it is necessary to dry such a material to a large extent on an imperforate support before drying is completed on a sieve.

An imperforate false bottom may have the configuration of an annular trough with only slightly inclined side walls.

In accordance with the invention, the dehumidified drying gas is blown into the tower through an inlet pipe whose vertically extending portion surrounds a drive shaft and leads to a baffle plate which deflects the drying gas in the direction of the rotating brushes. A brushing device is mounted above the baffle plate to sweep the same and remove therefrom any dried material and drop it to a false bottom.

A stirrer may be rotated by a motor to move the dried material through a sieve in the after-drying chamber. If the dried material is not too sensitive to abrasion, the sieve in the after-drying chamber may be oscillated for more rapid removal of dried material therefrom. Useful operating conditions of this embodiment of the invention include a speed of two to ten rotations per minute of the brush elements about the tower axis while they are rotated about their own axes at such high speeds as 300 to 1400 r.p.m. In this manner, the brushes serve not only for the mechanical conveyance of the dried material from the false bottom of the tower but also keeps the material from adhering to the false bottom and maintains it in a turbulent state. In view of the high rotational speed of the brushes, it is preferred to use nylon bristles or strips. Like synthetic resins may be used instead of nylon.

In another embodiment the drying tower may have a slightly conical imperforate false bottom converging toward central material outlet opening. The false bottom is swept by a brushing device which conveys the dried material into an opening. An inlet pipe for a dry gas containing a suitable aromatic substance leads to a radially extending pipe adjacent each brush and having a downwardly open outlet slot. In this manner, the porous spherical granules on the bottom will be impinged directly by the aroma-containing gas and will adsorb the aroma. The drying gas proper may be introduced into the tower by an inlet conduit whose vertical portion coaxially surrounds a pipe and leads to a baffle plate which deflects the drying gas and distributes it uniformly about the false bottom of the tower. A funnel is rotatably mounted on the pipe inlet and leads from the outlet opening to a selected one of three after-drying chambers. The three after-drying chambers may be so operated that one is continuously filled with dried material coming from the tower while the second one is used for after-drying and the third one is emptied. In such an operation, the drying gas is first introduced into the chamber used for after-drying whence it is led into the chamber filled with the material from the tower and from there into the tower itself. In such an operation, no material losses are encountered because any fines are returned to the tower by the drying gas and are removed from the upwardly streaming drying gas by the liquid material sprayed into the top of the tower.

Enrichment of the dried material with an aromatic

substance has been particularly useful in the production of instant coffee. With the use of different aromatic substances, coffee of different quality may be obtained in this manner. For instance, enrichment of the coffee aroma may be obtained with the gas obtained from the end phase of the coffee roasting just at the beginning of point at which the coffee beans turn brown. Alternatively, the gases following the cooling of the coffee beans after roasting may be used for this purpose or a gas conducted through the coffee while it is ground. Finally, use may be made of the gases evolving during any stage of extraction. In each instance, the instant coffee will have a different aroma.

Since the drying method of the invention with relatively cool air of the invention requires drying towers of large volume and correspondingly large volumes of drying gas, the present invention also provides for operation of the drying tower with as little heat requirement as possible and with a maximum recovery of the required heat. For this purpose, the drying tower is connected with a special air conditioning plant.

Drying towers useful for the practice of this invention must have a height in the range of 50 m. to 200 m., tower heights of about 70 m. having been found most useful for most purposes.

In accordance with the present invention, a minimum of structural units are used for the heat recovery and the dehumidification of the air and these units for conditioning the drying air are part and parcel of the drying tower. By placing the dehumidification housing into the drying air and heating cycle, the invention maintains a constant temperature of the drying air entering into the tower over each cycle of dehumidification and regeneration of the drying medium, with no, or a minimum of heating or cooling of the drying air. This temperature equilibrium is obtained inside the drying housing in multiple steps. If desired, the drying air may be additionally heated in the drying tower from the walls of the tower so that the air keeps its entry temperature while streaming upwardly in the tower and thus maintains its drying power almost until it reaches the region where the liquid material is released.

The dehumidification of the drying air is effected with the aid of adsorption media, such as silica gel or molecular sieves and experience has shown that a packing of such adsorption media may remove water from the air passed therethrough for about 5 to 6 hours. This must then be followed by a regeneration cycle of about equal duration during which hot air of constant temperature is passed through the adsorption medium packing, the temperature of the regenerating air ranging between about 150° C. and 300° C., depending on the adsorption medium.

The cold or cool air drying of the present invention requires a constant supply of dehumidified air of a temperature of about 25° C. to 30° C., for instance, for introduction into the drying tower and of about 160° C. for regenerating the dehumidifying packing if silica gel is used for this purpose, for instance. Thus, the invention provides improved means for conditioning the air in this manner with a minimum of servicing.

This is accomplished in accordance with the invention by passing the fresh air through a chamber defined by the outer wall of the drying tower and a heat-storing intermediate wall between the outer and inner walls of the tower, while the dehumidified fresh air is passed through the chamber defined by the inner tower wall and the intermediate wall, which has an inwardly facing heat-insulating lining, after it has been conducted through the dehumidifying adsorption medium and before it is introduced into the drying tower. If additional cooling is required, fresh air for regenerating the adsorption medium may also be passed through the first-named chamber on its way to the adsorption medium and/or through a heat-storage device in the regenerating cycle.

To obtain a drying air of constant temperature over a period of 24 hours, use is made of two facts, i.e. the temperature difference of the atmospheric air between night and day time, on the one hand, and the rise of the temperature of the adsorption medium during the 5 to 6 hours dehumidifying cycle from about 15 to 20° C. to about 40 to 50° C. When the fresh air is passed through the outer chamber of the double wall or jacket of the drying tower during the night, the heat-storing intermediate wall in the jacket will be cooled, together with the heat-storing outer wall of tower, to such a degree that the fresh air conducted to the adsorption medium will never exceed a maximum temperature of about 20° C. during the entire day. The lower the temperature of the air passing through the adsorption medium packing, the higher the dehumidification efficiency of the packing. In the initial time period of dehumidification, the dried air leaves the packing with an average temperature of about 25° C. In the preceding cycle corresponding to the final time period of dehumidification, the dried air left the adsorption medium at a temperature of about 50° C. and caused the inner wall of the drying tower jacket to be heated to an average temperature of 45° C., as the said air is passed through the inner jacket chamber before introduction into the drying tower. Heat exchange accordingly causes the initially dehumidified air to be heated to 35° C. during its passage through the inner jacket chamber on its way to the drying tower, at which temperature it then enters the interior of the tower. In the second period of dehumidification, the dried air leaves the packing with an average temperature of about 35° C. and this rises to 45° C. or so in the final dehumidification period. The warmer air raises the temperature of the previously cooled tower wall so that heat exchange continues to keep the temperature of the dehumidified air entering the drying tower at about 35° C. This cycle is repeated as additional fresh air is passed through a second adsorption medium packing which has, meanwhile, been regenerated.

Temperature control may be obtained by imparting a zigzag configuration to the intermediate wall in the drying tower jacket, which increases its heat-storage capacity and also sub-divides the space between the outer and inner tower walls into individual cells. The heat exchange may then be controlled by suitable control of the passage and amount of air streams into the individual cells. Thus, a variety of drying air temperatures may be obtained independently of the temperature of the atmospheric air, in addition to the temperature of 35° C. given hereinabove by way of example. In case of extreme climatic conditions or specially low drying air temperatures required for certain materials, for instance, 18° C. for drying butter, special heat exchangers for cooling or heating the fresh air may be positioned in the fresh air conduits ahead of the adsorption medium or the inlet into the drying tower. In most instances, however, it is possible to dispense with such special heat exchangers or to operate the same only for short periods of time at certain points of the cycle.

Since the temperature of the dehumidification packing rises at the end of the dehumidification and regeneration cycles, suitable thermocouples may be used for automatically switching the packings from the dehumidification to the regeneration cycle, and vice versa. If desired, the entry temperature of the drying gas into the drying tower may be used to initiate this switching a little sooner, particularly if the latter temperature is also used to direct the drying air suitably through the individual jacket cells and to control its throughput to obtain the desired drying gas temperature. If a thermostat indicates this desired temperature to be exceeded, it may then automatically switch the gas stream through a freshly regenerated adsorption medium while causing regeneration of the exhausted medium. The entire air circulation through the drying plant may be effected by fans mounted in the fresh air inlet openings of the outer wall of the drying tower.

FIGS. 1 and 2 illustrate a structural embodiment of the plant for conditioning the drying air in the indicated manner, FIG. 1 being a vertical section of the tower and FIG. 2 showing a horizontal section thereof. To facilitate a schematic showing of the conduits, the elements 2a, 2b, and 3a, 3b are shown in FIG. 1 one behind the other, while they are illustrated adjacent one another in FIG. 2. In practice, they are arranged only at one of the two locations. Elements 6 and 7 also are positioned at the same location.

The drying air enters the drying tower at inlet opening 9 and passes upwardly to outlet opening 11. The liquid material distributing means (not shown) is mounted in the tower below the drying gas outlet opening. The tower, which may have circular or rectangular walls, is surrounded by a jacket formed by an inner and outer tower wall defining a space therebetween. This space is divided into outer cells 4 and inner cells 5 by an intermediate zigzag wall which has a heat-insulating lining facing the interior of the tower. It is preferred to make all the walls of cement which has a considerable heat-storing capacity. A drying plant designed to dry about 5000 liters of liquid starting material per hour in a drying tower of 70 m. height, about 5000 to 6000 tons of cement will be needed to build the jacket walls with its dividing wall.

The fresh air for drying as well as for regeneration of the adsorption medium is passed into the plant from the atmosphere through the outer cells 4 of the tower jacket. If desired, the air may be led up and down the cells several times before leaving the jackets. For instance, it may be blown into the cells 4 of one side wall of the tower by eight fans mounted in front of suitable inlet openings in the wall. It may then be directed, for instance from the lower cells of the one wall into the outer cells 4 of the two adjacent walls, passing upwardly through these cells and being conducted by suitable conduits from the upper cells into the outer cells of the adjacent wall opposite to the first-named wall, whence the air is led through openings in the lower portion of the latter wall into a header.

As shown in FIG. 1, the header is sub-divided into two branch conduits. In one of the operating cycles, the fresh air, which has been pre-heated by passage through jacket cells 4, is led through the upper branch conduit into a regenerated adsorption medium packing 2a consisting of two vertical packings arranged in parallel. The other portion of the pre-heated fresh air is conducted into a heat storage device 3a. The entry valve of the lower branch conduit then remains closed. In the following operating cycle, a portion of the fresh air coming from cells 4 is conducted by the lower branch conduit to adsorption medium packing 2b which is similar in structure to packing 2a. The other portion of the fresh air is then led from the lower branch conduit to heat storage device 3b. At this cycle, the entry valve of the upper branch circuit remains closed.

Depending on the cycle, the dehumidified air coming from packing 2a or 2b is conducted to the inner cells 5 of the tower jacket and is led up and down these cells in a manner similar to that described in connection with the passage of the fresh air through cells 4. Finally, the dehumidified and conditioned drying air is introduced into the tower through opening 9.

The fresh air further heated in heat storage devices 3a or 3b is led through the flue of the heating element of another heat exchanger 6, where it is additionally heated, and is finally directed into a heat exchanger 7 where it is brought to the required regeneration temperature. This hot air is then directed to the adsorption medium packing requiring regeneration, whence it is passed into one of heat storage devices 3a or 3b to heat the same. The regenerating air then passes from the heat storage devices into the atmosphere through flue 10. The inlet openings for cells 4, which admit the fresh air thereto, and for cells 5, admitting the dehumidified and conditioned drying air, are provided with suitable filters.

If the temperature of the adsorption packing used for dehumidifying the air exceeds a predetermined value, for instance 50° C., a thermosensitive relay may automatically operate suitable valves in the air conduits to direct the fresh air to a previously regenerated adsorption packing and to direct the regenerating air to the exhausted packing. The control of the next cycle may then be taken over by a thermostat in the regenerated packing. However, the cycle control may also be effected in an obvious manner by a thermostat in the conduit directing the conditioned air to cells 5.

By using a tower wall jacket as heat storage and balancing device, it is possible to equalize the air temperatures so as to obtain a drying air of nearly constant temperature throughout the operation of the tower. Since the atmospheric air is first led through outer jacket cells 4, its temperature may be raised sufficiently on its way to the adsorption packing so that the conditioned and dehumidified air will never drop below a given temperature, for instance 25 to 30° C., at its entrance into the tower. Temperature control may be achieved by creating zones of different temperatures in the tower jacket. For instance, the fresh air supply fans, which may be eight or nine in number, for instance, may each supply a separate air conduit leading to the header so that, depending on the fan speed and the corresponding air throughput of each fan, the air entering the adsorption packing from each conduit has a different temperature. In a similar manner, the drying air may be prevented from reaching a temperature higher than desired by conducting the air on its way to the tower through more or fewer cooled cells 5. Excess air temperature toward the end of the dehumidifying cycle may also be avoided by switching prematurely to the subsequent cycle as soon as the temperature reaches a certain point if it would be impossible to change the air path through the jacket cells. This switch may be automatically effected by a thermostat at inlet opening 9.

Since the time period during which drying air is introduced into the tower at a temperature substantially exceeding the desired temperature level is relatively short in each cycle, the inner wall of the tower jacket will be maintained at substantially constant temperature. This may be accomplished by suitable dimensioning the wall thicknesses. Furthermore, additional control may be obtained, if desired, by lining the outwardly facing surface of the intermediate jacket wall with an insulating layer in some of the jacket cells. Heat storage is effected primarily in the zigzag intermediate wall in the tower jacket. It is also possible to make the volume of cells 4 and 5 different, for instance to make the cells 5 larger than cells 4. The amount of air passing through cells 4 may be one and a half or two times that passing through cells 5, depending on the ratio of drying air to regenerating air, so that the cool night air may be used to an increased extent for cooling the heat exchangers.

As indicated hereinabove, the adsorption medium regenerating air is not led through cells 5 but is passed into the atmosphere at 10. The rising drying air tends to decrease in temperature from the bottom to the top of the tower and if desired, the jacket space may be subdivided by horizontal partition walls so that the inner wall of the tower jacket will be kept at different temperatures at different levels.

Some water will be removed from the fresh air by condensation as it passes through outer jacket cells and a suitable water outlet is provided at the bottom of cells 4 in the jacket.

While the invention has been described in connection with certain now preferred embodiments, it will be clearly understood that many variations and modifications may occur to be skilled in the art, particularly after benefitting from the present teaching, without departing from the spirit and scope of the present invention as defined in the appended claims.

I claim:

1. The method of supplying air into a drying tower having a jacket formed by an inner and an outer tower wall defining a space therebetween, said space being divided into a first and a second region by an intermediate wall and the walls of the first region having been preconditioned by heat-exchange with atmospheric air at one temperature, which comprises subsequently

passing atmospheric air having another temperature through the first region to exchange heat with the walls of the first region; then

dehumidifying the air after it has left the first region by feeding it through a dehumidifying zone; then

passing the dehumidified air through the second region to exchange heat with the walls of the second region; and then

feeding the dehumidified air having a temperature not exceeding about 60° C. into the drying tower continuously for at least one diurnal period.

2. The process of claim 1 in which the temperature of the dehumidified air which is fed into the tower does not exceed 30° C.

3. The process of claim 1 in which the dehumidifying zone has a temperature in the range of 15° to 50° C.

4. The process of claim 1 in which the dehumidified zone has a temperature in the range of 20° to 40° C.

5. The method of supplying air into a drying tower having a jacket formed by an inner and an outer tower wall defining a space therebetween, said space being divided into a first and a second region divided by an intermediate wall and the walls of the first region having been preconditioned by heat-exchange with atmospheric air at one temperature, which comprises

cooling atmospheric air having a higher temperature in the first region by releasing heat to the walls of the first region; then

dehumidifying the cooled air by feeding it through a dehumidifying zone; then

passing the dehumidifying air through the second region to exchange heat with the walls thereof; and

feeding the dehumidified air having a temperature not exceeding 60° C. into the drying tower.

6. The method of supplying air into a drying tower having a jacket formed by an inner and an outer tower wall defining a space therebetween, said space being divided into a first and a second region by an intermediate wall and the walls of the first region being preconditioned by heat-exchange with atmospheric air at one temperature, which comprises

heating atmospheric air having a lower temperature in the first region by absorbing heat from the walls of the first region; then

dehumidifying the heated air by conducting it through a dehumidifying zone; then

passing the dehumidified air through the second region to exchange heat with the walls thereof; and

feeding the dehumidified air having a temperature not exceeding 60° C. into the drying tower.

7. The method of supplying air into a drying tower having a jacket formed by an inner and an outer tower wall defining a space therebetween, said space being divided into a first and a second region by an intermediate wall and the walls of the first region having been preconditioned by heat-exchange with atmospheric air at one temperature, which comprises

heating atmospheric air having a lower temperature in the first region by absorbing heat from the walls of the first region; then

dehumidifying the heated air by conducting it through a dehumidifying zone;

heating the dehumidified air by absorbing heat from the walls of the second region;

feeding the heated dehumidified air having a temperature not exceeding about 60° C. into the drying

tower, then cooling the dehumidified air by releasing its heat to the walls of the second region and feeding the dehumidified air having a temperature not exceeding about 60° C. into the drying tower.

8. The method of supplying air into a drying tower having a jacket formed by an inner and an outer tower wall defining a space therebetween, said space being divided into a first and a second region by an intermediate wall and the walls of the first region having been preconditioned by heat-exchange with atmospheric air at one temperature, which comprises

cooling atmospheric air having a higher temperature in the first region by releasing heat to the walls of the first region; then

dehumidifying the cooled air by feeding it through a dehumidifying zone; then

cooling the dehumidified air by releasing heat to the walls of the second region;

feeding the cooled dehumidified air having a temperature not exceeding 60° C. into the drying tower, then heating the dehumidified air by absorbing heat from the walls of the second region and feeding the dehumidified air having a temperature not exceeding about 60° C. into the drying tower.

9. The method of supplying air continuously for at least one diurnal period at a temperature in the range not exceeding about 60° C. into a drying tower having a jacket formed by an inner and an outer tower wall defining a space therebetween, said space being divided into a first second region by an intermediate wall and the walls of the first region being preconditioned by heat-exchange with atmospheric air at one temperature, which comprises

cooling atmospheric day air having a higher temperature in the first region by releasing its heat to the walls of the first region; then

dehumidifying the cooled air by conducting it through a dehumidifying zone; then

passing the dehumidified air through the second region to exchange heat with the walls of the second region; then

feeding the dehumidified air having a temperature not exceeding about 60° C. into the drying tower;

heating atmospheric nocturnal air in the first region by absorbing heat from the walls of the first region; then

dehumidifying the warmed air by conducting it through a dehumidifying zone; then

passing the dehumidified air through the second region to exchange heat with the walls of the second region; and then

feeding the dehumidified air having a temperature not exceeding about 60° C. into the drying tower.

10. The method of supplying air into a drying tower having a jacket formed by an inner and an outer tower wall defining a space therebetween, said space being divided into a first and a second region by an intermediate wall and the walls of the first region being preconditioned by heat-exchange with atmospheric air at one temperature, which comprises

passing atmospheric air having another temperature through the first region to exchange heat with the walls of the first region; then

dehumidifying the air by feeding it through a dehumidifying zone which has a dehumidifying and a regeneration cycle;

passing the dehumidified air through the second region to exchange heat with the walls thereof; and

feeding the dehumidified air at a temperature substantially constant and not exceeding about 60° C. during each cycle of the dehumidifying apparatus continuously into the drying tower for at least one diurnal period.

11. The method of supplying, for at least one diurnal period, a continuous supply of air into a drying tower having a jacket formed by an inner and an outer tower wall

defining a space therebetween, said space being divided into a first and a second region by an intermediate wall and the walls of the first region being preconditioned by heat-exchange with atmospheric air at one temperature, which comprises

(a) during the day

cooling atmospheric air having a higher temperature in the first region by releasing its heat to the walls of the first region; then

dehumidifying the air by feeding it through a dehumidifying zone; then

passing the dehumidified air through the second region to exchange heat with the walls thereof, and then

feeding the dehumidified air having a temperature not exceeding about 60° C. into the drying tower continuously, and

(b) during the night

heating atmospheric air having a lower temperature in the first region by absorbing heat from the walls of the first region; then

dehumidifying the air by feeding it through a dehumidifying zone; then

passing the dehumidified air through the second region to exchange heat with the walls thereof; and

feeding the dehumidified air having a temperature not exceeding about 60° C. into the drying tower continuously.

12. The method of supplying air into a drying tower having a jacket formed by an inner and an outer tower wall defining a space therebetween, said space being divided into a first and a second region by an intermediate wall and the walls of the first region being preconditioned by heat-exchange with atmospheric air at one temperature, which comprises

passing atmospheric air having another temperature through the first region to exchange heat with the walls of the first region;

dehumidifying the air after it has left the first region by feeding it through a dehumidifying zone; then

subjecting the dehumidified air to an alternating heating and cooling cycle during which heating cycle, the dehumidified air is heated by absorbing heat from the walls of the second region and during which cooling cycle, the dehumidified air is cooled by releasing heat to the walls of the second region; and then

feeding dehumidified air having a temperature not exceeding about 60° C. into the drying tower.

13. The process of claim 12 in which the air which is fed into the drying tower is essentially kept at a constant temperature not exceeding about 60° C.

14. The method of supplying air continuously for at least one diurnal period at a temperature not exceeding about 60° C. into a drying tower in which material to be dried is descending from the upper region of the tower as a dense umbrella of droplets and is accumulating as a layer of dried material on the bottom of the tower, said drying tower having a jacket formed by an inner and an outer tower wall defining a space therebetween; said space being divided into a first and a second region by an intermediate wall and the walls of the first region being preconditioned by heat-exchange with atmospheric air at one temperature, which comprises

passing atmospheric air having another temperature through the first region to exchange heat with the walls of the first region;

dehumidifying the air after it has left the first region by feeding it through a dehumidifying zone; then

passing the dehumidified air through the second region to exchange heat with the walls of the second region; and then

feeding the dehumidified air having a temperature not exceeding about 60° C. into the drying tower; and

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feeding the air upwardly within the drying tower for at least one diurnal period.

15. The process of claim 14 which comprises feeding the dehumidified air into the bottom of the tower and then upwardly through the layer of pre-dried material accumulated at the bottom of the tower.

16. The process of claim 14 which comprises feeding the dehumidified air upwardly through a layer of pre-dried material accumulated at the bottom of the drying tower, then upwardly as an airstream countercurrently and through the umbrella of droplets of material to be dried descending in the tower.

17. The tower of claim 15 which has air-conduct means interconnecting a plurality of the cells.

18. The method of supplying air into a drying tower having a jacket formed by an inner and an outer tower wall defining a space therebetween, said space being divided into a first and a second region by an intermediate wall which comprises

preconditioning by heat-exchange the walls of the first region with atmospheric air at one temperature, passing atmospheric air having another temperature through the first region to exchange heat with the walls of the first region;

dehumidifying the air after it has left the first region by feeding it through a dehumidifying zone; then passing the dehumidified air through the second region to exchange heat with the walls of the second region; and then

feeding the dehumidified air having a temperature not exceeding about 60° C. into the drying tower continuously for at least one diurnal period.

19. A drying tower using dehumidified atmospheric air as a drying medium, said tower comprising

a heat-exchange jacket surrounding the tower, said jacket being defined by an outer and an inner wall of heat-exchanging material, an intermediate wall of heat-exchanging material in said jacket, said intermediate wall dividing the jacket into two chambers adjacent the outer and inner wall, respectively.

20. The drying tower of claim 19 in which the thickness of the intermediate wall exceeds that of the inner and of the outer tower walls, respectively.

21. The tower of claim 19 which has a heat-insulating layer on the intermediate wall on the side facing the outer tower wall.

22. The tower of claim 19 which has a heat-insulating layer on the intermediate wall on the side facing the inner tower wall.

23. The tower of claim 19 in which the intermediate wall divides each chamber into a plurality of cells extending along said walls.

24. The tower of claim 23 in which the intermediate wall has a zigzag configuration.

25. The tower of claim 19 in which the two chambers have a different volume.

26. The tower of claim 25 in which the volume of the inner chamber exceeds that of the outer chamber.

27. A drying tower using dehumidified atmospheric air as a drying medium, said tower comprising

a heat-exchange jacket surrounding the tower, said jacket being defined by an outer and an inner wall of heat-exchanging material, an intermediate heat-insulating wall of heat-exchanging material in said

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jacket, said intermediate wall dividing the jacket into two chambers adjacent the outer and inner wall, respectively.

28. A system which comprises a drying tower using dehumidified atmospheric air as a drying medium, said tower comprising

a heat-exchanging jacket surrounding the tower, said jacket being defined by an outer and an inner wall of heat-exchanging material, an intermediate wall of heat-exchanging material in said jacket, said intermediate wall dividing the jacket into a first chamber adjacent the outer wall and a second chamber adjacent the inner wall and dehumidifying means, the two chambers, the dehumidifying means and the tower being so operatively connected that during operation of the tower atmospheric air passes through the first chamber, then through the dehumidifying means, then the second chamber and then into the bottom part of the tower at a temperature not substantially exceeding 60° C.

29. The system of claim 28 in which the dehumidifying means comprise two zones, one for dehumidifying the air as it passes from the first to the second chamber, and a second zone that undergoes regeneration as the first zone dehumidifies the air.

30. A system which comprises a drying tower using dehumidified atmospheric air as a drying medium, said tower comprising

a heat-exchanging jacket surrounding the tower, said jacket being defined by an outer and an inner wall of heat-exchanging material, an intermediate heat-insulating wall of heat-exchanging material in said jacket, said intermediate wall dividing the jacket into a first chamber adjacent the outer wall and a second chamber adjacent the inner wall and dehumidifying means, the two chambers, the dehumidifying means and the tower being so operatively connected that during operation of the tower atmospheric air passes through the first chamber, then through the dehumidifying means, then the second chamber and then into the bottom part of the tower at a temperature not substantially exceeding 60° C.

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