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Updegrove

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[54] **METHOD AND APPARATUS FOR DRYING PARTICULATE MATERIALS**

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[51] Int. Cl. **F26b 17/12**
[58] **Field of Search**..................... 34/166, 181, 182; 259/21, 40, 5

[56] **References Cited**

UNITED STATES PATENTS

2,668,764	2/1954	Nauta	259/40
2,345,063	3/1944	Nauta	259/40
3,618,070	10/1971	Loomans	259/40

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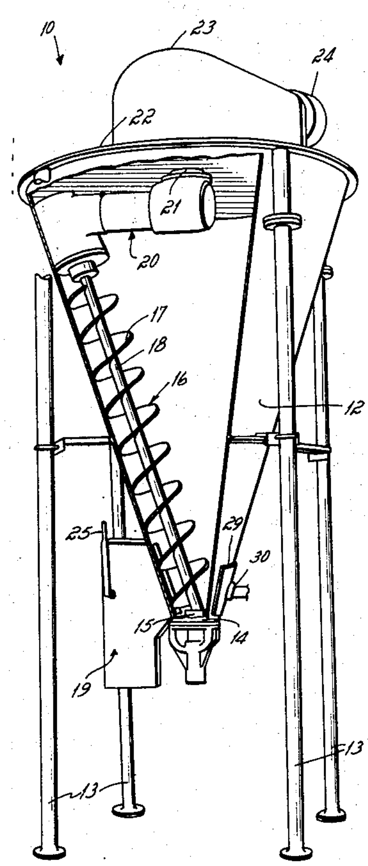
[57] **ABSTRACT**

A method and apparatus for drying a particulate material such as resin pellets, fine chemicals, pigments, cosmetic powders and the like. The method involves mechanically agitating the material while sweeping it with pre-dried, heated air. The preferred form of apparatus includes a frustoconical tank having an agitator screw which is rotated upon its own axis to lift material and is simultaneously orbited around the wall of the tank. Air or other gas which has been heated and dried is introduced at the bottom of the tank and flows upwardly through the material. The air, carrying with it moisture released by the material, is discharged at the top of the mixer. The material can be mixed, granulated and dried in a single operation.

14 Claims, 3 Drawing Figures



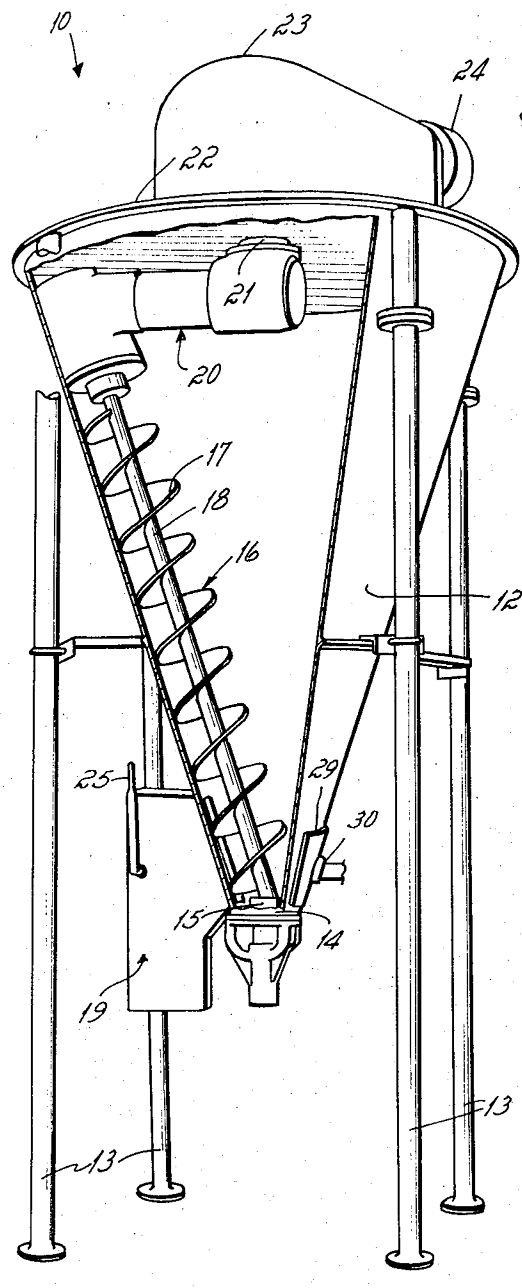

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Fig. 1

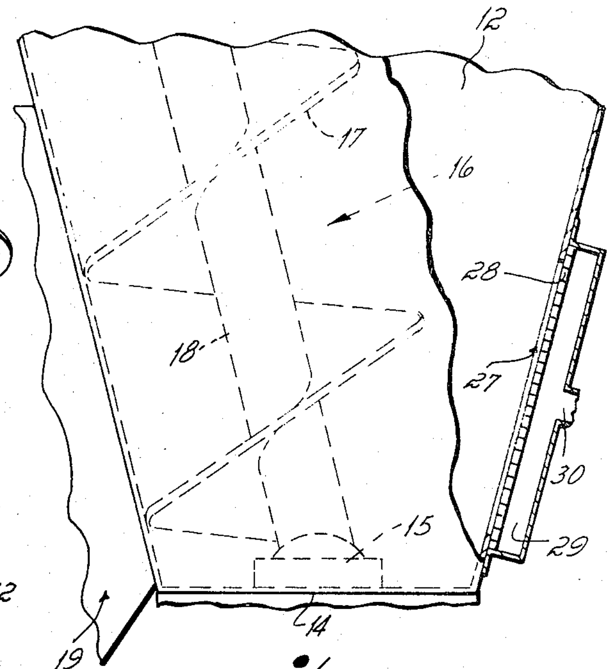
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Fig. 2

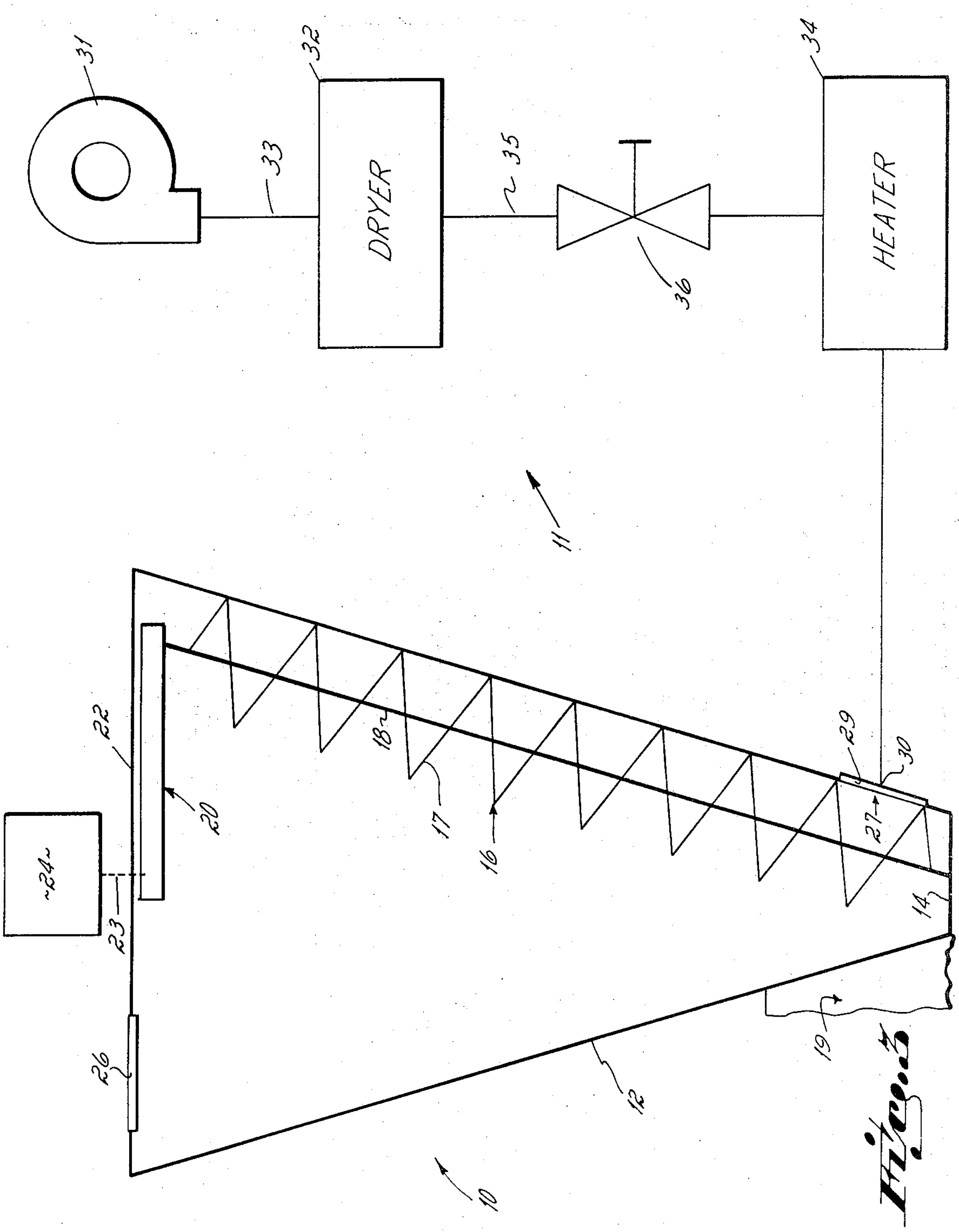

Fig. 3

METHOD AND APPARATUS FOR DRYING PARTICULATE MATERIALS

BACKGROUND OF THE INVENTION

This invention relates to a method of, and apparatus for, drying materials, such as textile resins, fine chemicals, pigments, pharmaceuticals, powdered metals and the like. In one important aspect, the invention is directed particularly to a method of drying materials to a very high degree of dryness, for example, to a final level of from 0.01 percent moisture content to 0.05 percent moisture content. A further important aspect is to provide a method and apparatus in which materials can be mixed, granulated and dried in a single operation.

In the past, many different types of apparatus have been proposed for drying particulate materials. Among such types of equipment are fluidized bed dryers, tunnel dryers and vacuum dryers. In handling materials which are to be dried to a high degree of dryness, vacuum dryers have in the past proven to be the most advantageous. In these dryers either bulk material is placed in a vessel or the material is placed on a carrier, such as a tray, which is in turn placed in an oven or the like. A hard vacuum is drawn and heat is supplied from a heated surface such as the vessel walls.

While dryers of this type have gone into large scale commercial use, they are subject to several well-recognized disadvantages. In the first place, vacuum equipment is inherently expensive to produce and expensive to operate and maintain. Moreover, it is extremely difficult at best and in most cases impossible to maintain close control of the product temperature in a vacuum dryer. Another disadvantage is that vacuum dryers require a relatively long time to bring material down to a high degree of dryness. For example, commercial vacuum dryers at the present time require from 8 to 12 hours to reduce the moisture of Nylon 6 resin pellets from 2 percent to 0.01 percent moisture. Other less efficient types of commercial drying equipment require as long as 36 hours to accomplish this drying operation.

The present invention is directed in part to a method of drying materials to a high degree of dryness in a substantially shorter period of time than has heretofore been possible. For example, the present method is effective to dry Nylon 6 resin pellets from 2 percent to 0.01 percent moisture content in 4 hours, which represents a time saving of from 50 percent to 66 percent as compared to the best vacuum dryers, and a time saving of some 89 percent compared to other forms of commercial drying equipment.

It is a further object of the present invention to provide a drying method which can be carried out in apparatus costing substantially less than vacuum drying apparatus. Moreover, the apparatus required to practice the present invention is not only less expensive to install, but also costs substantially less to operate and maintain.

More particularly, the present invention is predicated in part upon the concept of drying material by the combined action of mechanically agitating the material while sweeping it with a stream of hot pre-dried air or other gas. The material is preferably agitated so that it flows both transversely of the airstream and in counter-current relation to it.

The present drying method makes effective use of two driving forces. The first force is heat transferred from the air to the product which causes water vapor to evaporate from the product into the airstream by means of which it is carried from the vessel. The second driving force utilized is the imbalance between the vapor pressure of the airstream surrounding the product and the product itself. In accordance with the present invention, before the airstream is introduced into the mixer it is pre-dried to a dew point preferably in the range of from −10°F. to −40°F. This air has a very low vapor pressure as compared to the vapor pressure of the moisture in the material being dried.

When treating material in accordance with the present method, particularly in the preferred form of apparatus described below, optimum use is made of both of these driving forces. In the first place, the mechanical agitation of the material results in the airstream being continuously exposed to different material as the air passes from the inlet to the outlet. Thus, an optimum heat transfer is effected between the air and the material. All of the material being processed is kept at a uniform controlled temperature with no localized "hot spots."

As a result, the heat in the air is effectively utilized in vaporizing moisture from the product. This vaporization in turn rapidly lowers the temperature of the air. We have empirically determined that this combined action enables the use of air at a substantially higher temperature than would otherwise be possible without causing product deterioration. For example, if a product deteriorates in some manner, e.g., discolors, melts, reacts or the like, at a temperature of 120° F., I have determined that air temperature in the present method need not be limited to 120° F., but may be substantially higher, for example, as high as 270° F. The use of this higher temperature air accelerates vaporization and materially shortens the drying time. It will be appreciated that if the material is oxygen sensitive, other gases, such as carbon dioxide or nitrogen, can be used in place of air.

It is another aspect of the present invention to provide a method in which material can be effectively dried, granulated and mixed in a single operation. This aspect of the present invention is useful not only in drying material to a high degree of dryness, but also in drying material to a more moderate degree of dryness, for example, to a moisture content of from 0.1 percent to 2.0 percent.

Yet another aspect of the present invention is to provide novel apparatus for carrying out the present method. One preferred form of apparatus comprises a mixer having an inverted frustoconical tank. The tank encloses a screw agitator which is pivotally mounted at the bottom of the tank and is carried by a revolving arm adjacent to the upper end of the tank. The screw agitator extends in close proximity to the wall of the tank and orbits in such a manner that it sweeps the entire inner wall of the tank. At the same time, the agitator revolves on its own axis in such a manner as to lift the material from the bottom toward the top of the tank.

In accordance with the present invention, the tank is further provided with a porous air inlet connection adjacent to the lower portion of the tank wall. Air is supplied to this inlet from a system including a pump, or compressor, which forces air through a dryer and a heater. The air which is pre-dried to a low relative humidity enters the vessel at a temperature of from ambient temperature to 400° F. and at a pressure less than 25 psi. The air is preferably heated to a temperature close to the temperature at which it would heat the product to a point which would cause product deterioration. The air pressure is sufficiently high to force the air upwardly through the material at a flow rate below the flow rate at which the material would spout.

As the agitator moves through the material, it intermixes and granulates the material and continuously injects fresh material into the airstream. The mixer not only shifts the material in a transverse or horizontal plane, but also causes vertical displacement of the material, the material being carried upwardly by the screw and then flowing downwardly, countercurrent to the airstream. The hot, dry air transfers heat to the material in the tank, causing rapid evaporation which lowers the air temperature so that the air which has passed completely through the material and is discharged is moisture laden, relatively cool air at a temperature not substantially above the product temperature. For example, during a part of a typical operation, air is introduced at 270° F. and exits at 100° F. with product temperature being 97° F. and being substantially uniform throughout the tank. As will be appreciated, both air exit temperature and product temperature increase during the drying cycle.

One of the principal advantages of the present apparatus is that optimum heat and moisture transfer is effected between the airstream and material. The entering airstream is continuously brought into contact with fresh product so that no hot spot is developed. Moreover, the airstream passes through a relatively long path of product so it has ample contact to give up heat and pick up moisture. This again contributes to the overall efficiency of the operation resulting in the substantially decreased drying time required.

A further advantage of the present apparatus is that it is substantially less expensive than vacuum drying equipment not only from the point of view of initial investment, but is also much less expensive to operate and maintain.

Another advantage of the present apparatus is that it facilitates drying and granulation and mixing in a single operation.

A still further advantage of the present apparatus is that it can be utilized to dry materials which are originally in a paste condition or in which the particles are originally moist and sticky.

These and other objects and advantages of the present invention will be more readily apparent from the following detailed description of the drawings illustrating a preferred embodiment of the invention.

DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view, partially broken away, of a mixer constructed in accordance with the principles of the present invention.

FIG. **2** is an enlarged view, partially in section, of the lower portion of the mixer showing the air inlet plate.

FIG. **3** is a schematic view of the present drying system.

DESCRIPTION OF THE APPARATUS

A preferred form of mixer **10** embodying the present invention is shown in FIG. **1** and a drying system **11** utilizing such a mixer is shown in schematic form in FIG. **3**. As shown in FIG. **1**, mixer **10** comprises a vessel, or tank, **12** of generally inverted frustoconical configuration. The tank is supported in an upright, elevated position in any suitable manner, such as by means of legs **13**. The walls of tank **12** taper downwardly toward a flat bottom wall **14** which carries a universal joint **15**, ball and socket joint or the like, for supporting the lower end of a helical agitator screw **16**. Joint **15** is located on the vertical center line of the vessel. Agitator screw **16** includes a thin, helical plate **17** which is carried by an elongated shaft **18**.

The lower end of shaft **18** is carried by joint **15**, while the upper end of the shaft is journalled in a suitable bearing carried by the outer end of radial support arm **20**. The inner end of support arm **20** is rotatably supported as at **21** in the center of a cover member **22**. A drive **23** is interconnected with arm **20** and shaft **18**. This drive is effective to cause the arm **20** to revolve in a plane perpendicular to the axis of the tank at a relatively low speed, for example, two revolutions per minute. Drive **23** is also effective to rotate shaft **18** about its own axis, at a substantially higher speed, for example, a speed of 64 revolutions per minute.

It is to be understood that the mechanical details of the drive for arm **20** and screw **18** constitute no part of the present invention. Such mechanical drives are well known in the art. Moreover, while the drive is shown as including only a single motor **24** which is effective, through suitable gearing, to drive both radial arm **20** and agitator screw **16**, it is to be understood that if desired separate motors can be provided for driving the arm and screw.

Shaft **18** is mounted so that it intersects the vertical center line of tank **10** at an angle equal to half of the vertical angle of the cone defined by the walls of tank **12**. In operation, the support arm **20** revolves in a horizontal plane and causes the shaft **18** to orbit, or generate a conical shape, so that the agitator screw moves around the inside surface of wall **12** and deflects material away from the wall toward the center of the tank. At the same time, the agitator screw is revolved about its own axis, i.e., the axis of shaft **18** so that material within the tank is carried upwardly by the screw from the bottom toward the top of the tank.

In addition to the elements described above, mixer **10** includes a material discharge port adjacent to the lower end of the tank. This discharge port may be connected to a discharge chute, such as chute **19**, and the port may be opened or closed by a suitable valve, such as a sliding gate valve, rotating plug valve, or the like, the valve being operated by an actuator such as handle **25**. Additionally, the cover **22** is provided with openings (not shown) for introducing material into the mixer and with a suitable air discharge filter **26** (shown in FIG. **3**, but not shown in FIG. **1**). This filter, which discharges moisture-laden air from the mixer, can either be vented to atmosphere directly or through an air conduit if desired. It will be understood that if a gas, such as nitrogen, is employed, it can be recycled through the heater and dryer if desired.

In accordance with the present invention, a lower portiom of the wall of tank **12** is provided with an air inlet port **27**. This port is covered with a porous plate **28** or other member for defusing the air stream entering the mixer to prevent high pressure localized air jets which would cause the material to spout. One suitable form of plate is a sintered stainless steel plate. Such plates are manufactured by Pall-Trinity Micro Corporation and are designated porous type PSS plates Grades D and E. The sizes of the holes in these plates are 35 microns and 65 microns, respectively. The area surrounding air port **27** and plate **28** is enclosed by the walls of a duct-forming chamber **29**. This chamber is connected to an air inlet conduit **30**.

A complete drying system incorporating mixer **10** is shown diagrammatically in FIG. **3**. As there shown, the system includes in addition to mixer **10**, a blower **31**, a compressor or other source of pressurized air and a dryer **32**. The dryer is effective to remove moisture from the airstream and can be either of a desiccant type dryer or a refrigerant type dryer. Where very dry air, e.g., air having a –40° F. dew point is desired, a preferred form of dryer is a desiccant dryer of the type sold by McGraw-Edison under the trademark "Lectro-Dryer." Since the details of the construction of these dryers form no part of the present invention and since the construction is well known, it is considered unnecessary to describe the details of the dryer with particularity.

The inlet of dryer **32** is interconnected to compressor **31** by air conduit **33**. The dryer is also interconnected through conduit **35** and valve **36** to a heater **34**. Again, heater **34** can be of any conventional type such as an electrical air heater, gas heater, steam heater or the like. The outlet of heater **34** is connected to air inlet conduit **30** of the mixer.

This dryer system finds particular utility in the drying of materials in an "ultra high" degree of dryness. The term "ultra high degree of dryness" as used herein refers to materials dried to a very low moisture content of from, for example, 0.01 percent to 0.05 percent moisture. An example of such materials would be textile resin pellets such as Nylon pellets. Pellets of other resins, such as Dacron and polyester polymers, also fall in this category.

In drying Nylon pellets or other material to an "ultra high" condition the material is introduced into the mixer **10**. Drive **23** causes radial arm **20** to revolve slowly and causes agitator screw to rotate about its own axis at a higher speed. Thus the material is subjected to three distinct actions. In the first place, the screw agitator rotating on the axis of the shaft **18** lifts material from the bottom toward the top of the tank. Simultaneously, the agitator orbits around the wall of the tank as the upper end of the agitator is carried by radial arm **20**. This action tends to move material away from the wall of the tank deflecting it toward the center. In the third place, the material lifting upwardly by the screw gravitates downwardly intermixing with the material which is spiraled upwardly.

At the same time, the air supply provided by compressor or blower **31** is dried by dryer **32** to a very dry condition for example to a dew point of from –10°F. to –40°F., a preferred dryness being a dew point of –40°F. Air flows from the dryer to heater **34** where the temperature of the air is elevated to a temperature below that at which the air would raise the product temperature to a point causing deterioration of the material being processed. Depending upon this material the temperature may be from room temperature to approximately 400°F. For Nylon a preferred temperature is of the order of 200°F. In any event, this air temperature can be substantially above the critical maximum temperature for the material. Thus, we have determined empirically that if a material deteriorates at a temperature of 150°F. for example, the air temperature may be approximately 300°F.

This hot, dry air is introduced through chamber **29** and porous plate **28** into the bottom of the tank **12**. The air is preferably fed to the tank at a rate of from approximately one cubic foot of air per cubic foot of material to approximately 13 cubic feet of air per cubic foot of material per minute. The pressure of air in chamber **29** is relatively low, e.g., less than 25 psi, and is preferably less than 10 psi. The optimum pressure will vary with the size, density, etc., of the material being dried. In each case, however, the air pressure is large enough to force the air through the material, but the flow rate is below that at which spouting will occur within the material. The pressure does not create a fluidized bed in the material and may be from one to two magnitudes less than the pressure which would create such a bed.

As the hot dry air enters the tank, it is continuously brought into contact with different material. The hot air heats the material and causes evaporation of the water from the material. This evaporation in turn causes the air temperature to be lowered. As the air moves upwardly, it gives up heat and picks up moisture as it passes through an elongated conical "column" of material which is being thoroughly agitated. As a result, the air causes the temperature of the material to be raised in a very uniform fashion, i.e., there are not hot and cold spots, and no more than a nominal difference in temperature between different portions of the material. When the air reaches the top of the level of material, the air has given up much of its heat and has absorbed a considerable amount of moisture. For example, the air in the illustration given, exits through filter **25** at a temperature of approximately 100° F.

It is extremely important to the present process that the air is constantly being brought into contact with different portions of material so that the air temperature is effectively utilized in vaporizing moisture without locally heating the material being dried to a temperature which would result in deterioration of the product. In other words, the highly effective mixing action and air path provided in mixer **10** enables the use of air at a much higher temperature than the temperature at which the material deteriorates. As a result of the effective drying action provided by the present system, the Nylon can be dried to a 0.01 percent moisture content utilizing the present system in a substantially shorter length of time than that previously required; for example, in approximately 4 hours as opposed to the 8–12 hours required utilizing the best prior art vacuum equipment, and 36 hours utilizing other types of commercial equipment.

In addition to its utility in drying materials to an ultra high degree of dryness, the present equipment is also advantageous for use in drying materials to a somewhat higher moisture content, e.g., from 0.5 percent to 2 percent. One of the principal advantages of the present system in drying these materials (which advantage is also obtained when drying materials to an ultra dry condition) is that three operations are performed on the material simultaneously. Specifically, the materials are mixed, granulated and dried simultaneously in one operation within the mixer **10**. Materials which can be treated in this manner include fine chemicals, pigments and dye stuffs, cosmetic powders, various resins and the like.

In treating these materials, the materials are introduced into the tank **12** and the drive **23** started to cause support arm **20** to revolve and to rotate agitator screw **16** upon its own axis. Simultaneously, air at a temperature from room temperature to 400° F. and with a dew point of from −10° F. to −40° F. is introduced into the bottom of the tank through porous plate **28.** Again, the air pressure is high enough to force air through the material, but is less than that which would cause spouting of the material. The air temperature is less than the temperature which would elevate the material temperature high enough to cause deterioration of the product.

The degree of the dryness of the air supplied is dependent in part upon the ultimate dryness required of the product and in part upon the economics of the process. For material which is to be dried to a lesser degree of dryness, e.g., 0.5 percent air at −10° F. dew point can be employed. On the other hand, for some materials which are to be dried to a high degree of dryness, or which are inherently difficult to dry, it may be desirable to utilize air at −40° F. dew point. While air having a dew point below −40° F. could be used, it is not usually economically attractive using presently available equipment. As the air and materials are intermixed in the tank, the solid materials are mixed and granulated. At the same time, the hot, dry air which is constantly being brought into contact with different portions of the material effects an optimum heat transfer of the material to cause the moisture in the material to be vaporized and carried off by the swept air. The air and entrained moisture are discharged through filter **26.**

From the above disclosure of the general principles of the present invention and the above description of a preferred embodiment, those skilled in the art will readily comprehend various modifications to which the invention is susceptible. Thus, for example, the present method can be carried out utilizing different apparatus from the preferred form of apparatus shown. By way of example, such apparatus can include a tank having a conical bottom and cylindrical side walls of the type shown in Nauta U.S. Pat. No. 2,345,063. Alternatively, the mixer can include an agitator screw of conical configuration or can include twin agitators. Also, the upper end of the agitator screw can be shifted in a horizontal plane with a compound motion including a radial component as shown in Fox U.S. Pat. No. 3,338,562. Therefore, I desire to be limited only by the scope of the following claims.

Having described my invention, I claim:

1. A method of simultaneously mixing granulating and drying material, comprising the steps of:

placing said material in a vessel having conical walls sloping inwardly toward a bottom wall,

agitating said material by means of a screw agitator rotating upon its own axis and having its axis moved within the container, whereby said material is elevated and moved away from the container wall,

and simultaneously introducing into the lower portion of said container pre-dried, heated air at a flow rate less than the flow rate required to cause spouting of said material.

2. The method of claim **1** in which the air temperature is less than that required to raise the material to a temperature at which the material would degrade.

3. The method of claim **2** in which the air temperature is above the temperature at which the material would degrade.

4. The method of claim **1** in which the agitation is effective to maintain the entire quantity of material at a substantially uniform temperature.

5. The method of claim **4** in which the material is heated to a final temperature and the air emerges from contact with the material at a temperature not appreciably above the final material temperature.

6. The method of claim **1** in which air is swept over said material at a rate of from one to 13 cubic feet of air per cubic foot of material per minute.

7. A device for simultaneously granulating and drying material comprising:

a mixing vessel having a frustoconical side wall tapering inwardly toward a bottom wall,

an agitator screw,

means rotatably supporting the lower end of said agitator screw adjacent to the bottom wall,

a support arm disposed in the upper portion of the vessel,

means shifting said support arm in a plane transverse to the axis of the vessel, said support arm carrying the upper end of said agitator screw,

means for rotating said screw about its own axis,

means for introducing pre-dried, heated air under relatively low pressure to the lower portion of said vessel,

and means for discharging air from the upper portion of said vessel.

8. The apparatus of claim **7** in which the means for introducing air comprises a porous plate.

9. The apparatus of claim **7** in which said porous plate is disposed closely adjacent to the bottom wall of said mixer.

10. A system for drying materials, said system comprising:

a mixing vessel having a frustoconical side wall tapering inwardly toward a bottom wall,

an agitator screw,

means rotatably supporting the lower end of said agitator screw adjacent to the bottom wall,

a support arm disposed in the upper portion of the vessel,

means shifting said support arm in a plane transverse to the axis of the vessel, said support arm carrying the upper end of said agitator screw,

means for rotating said screw about its own axis,

an air inlet disposed adjacent to the lower portion of said vessel,

means for discharging air from the upper portion of said vessel,

an air dryer,

means for supplying air under pressure to said air dryer,

an air heater interconnected to said air dryer for heating said air,

and conduit means interconnecting said air heater and said air inlet.

11. The system of claim **10** in which said air inlet includes a porous plate.

12. The system of claim **10** in which said air dryer is effective to dry said air to a dew point of from −10° F. to −40° F.

13. The system of claim **10** in which said air is supplied to the vessel at a flow rate below the flow rate which would cause spouting of the material in the vessel.

14. The system of claim **10** in which air is supplied to the vessel at a rate of from one cubic foot of air to 13 cubic feet of air per cubic foot of material in the vessel per minute.

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