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DRYING METHOD AND APPARATUS

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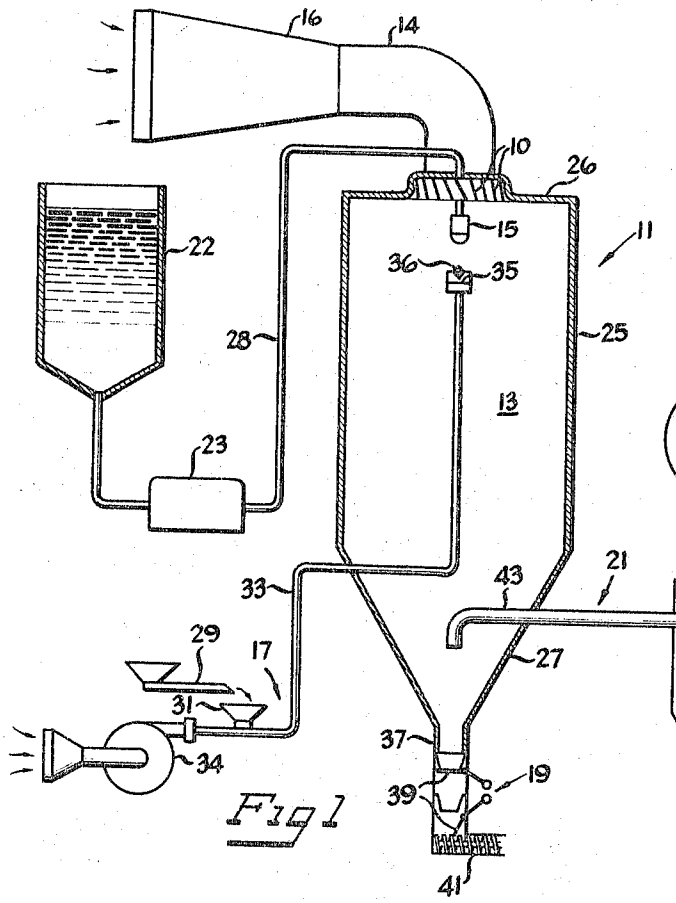

Fig 1

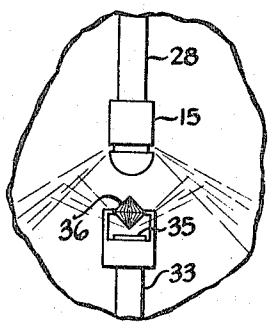

Fig 2

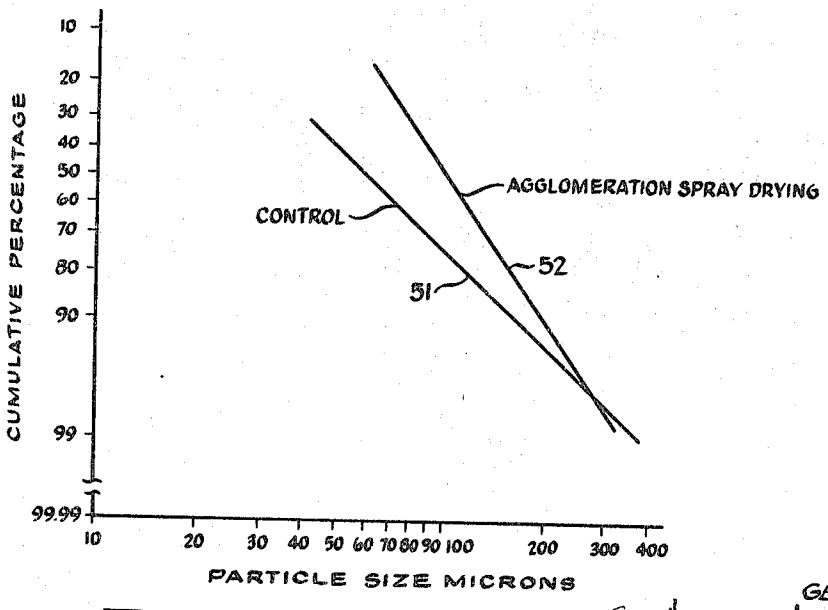

Fig 3

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DRYING METHOD AND APPARATUS

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The present invention relates generally to the removal of liquid from liquid dispersions such as solutions or suspensions. More specifically, it relates to the removal of liquid from liquid dispersions of heat-sensitive substances to provide a dry form of the substance to facilitate storage, handling, etc., and which dry form of the substance is readily liquid-dispersible to reconstitute the liquid dispersion in either its original form or a modified form.

For large-scale liquid removal operations, two methods of liquid removal or drying have often been utilized. In one method, a rotating drum or cylinder is utilized upon which the liquid dispersion is deposited in a film on the periphery of the rotating drum. The drum is maintained at a temperature above the boiling point of the liquid to be removed and the liquid is evaporated from the film, leaving a residue of dried substance which is then separated from the drum. A difficulty with this method is that it may not be practical where the dispersion from which liquid is to be removed is subject to damage or change at high temperatures, such as is the case with certain edible organic substances.

The other often utilized method of liquid removal is spray drying. This method is particularly useful in removing liquid from dispersion of heat-sensitive substances. In a conventional practice of this method, the liquid dispersion is conducted under pressure to a nozzle wherein it is atomized and propelled into a relatively large chamber through which heated air is also circulated. The small size of the droplets issuing from the nozzle promotes extremely rapid evaporation and transfer of liquid therefrom to the air. There are thereby obtained dried particles which fall to the bottom of the chamber, from which they are removed. It is in connection with the spray drying method that the present invention is utilized.

One of the disadvantages of spray drying is the difficulty with which some dried substances produced thereby are dispersible in liquid when it is desired to reconstitute the dispersion. It is known that dispersibility is functionally related, in part, to the size of the dried particles. In general, the smaller the particle size, the greater the resistance of the particles to passage of liquid therethrough, and the poorer the dispersibility.

In order to improve the dispersibility of dried substances made by spray drying, it is known to agglomerate the dried particles thereof into larger clusters. This has been effected in various ways, including rewetting the spray dried particles to a moisture content of about 15 percent or greater to render the particles cohesive. The particles are then afforded sufficient contact time with each other to build up the desired cluster diameter, following which the clusters are again dried to the desired final liquid content.

It is an object of the present invention to provide an improved method and apparatus for spray drying of liquid dispersions and agglomeration of the resultant dried particles. It is a further object of the present invention to provide an improved method and apparatus for spray drying of liquid dispersions of edible organic substances and agglomerating the resultant dried particles. It is a particular object of the present invention to provide a method and apparatus wherein spray drying of liquid dispersions of edible organic materials and agglomerating of the resultant dried particles are concurrently effected to provide a readily dispersible product. Other objects and advantages of the present invention will become apparent from the following description and drawings, in which:

FIGURE 1 is a schematic representation of an embodiment of apparatus suitable for the practice of the present invention;

FIGURE 2 is an enlarged view of a portion of FIGURE 1 and illustrating the path of particle travel schematically; and

FIGURE 3 is a graph depicting the improved particle size distribution obtained in accordance with the present invention.

Generally, and with particular reference to FIGURE 1 of the drawing, there is provided a dryer-agglomerator unit 11 enclosing a chamber 13, an air supply duct 14, a spray nozzle 15, an agglomerating powder entrainment assembly 17, product discharge means 19, and a fines separation system 21. In accordance with the present invention, drying of the liquid dispersion and agglomeration of the resultant dried particles are effected continuously and concurrently within the dryer-agglomerator unit 11 to provide substantial economies in equipment investment and in operating costs.

The dryer-agglomerator unit 11 comprises a generally cylindrical body portion 25, a circular cover 26 and frusto-conical lower portion 27, all joined at suitable places to define a chamber 13. The particular configuration of the unit 11 may be varied in accordance with conventional practice without departing from the scope of the present invention.

Unit 11 further includes an air supply duct 14 through which air is drawn into chamber 13 by means of a blower 12. The details of blower 12 and its associated ducts and apparatus will be explained subsequently. The air supply duct 14 opens into chamber 13 at the center of the circular cover 26. A heater 16 is provided in duct 14 whereby, during operation of the unit 11, a flow of hot, low-humidity air is continually discharged into the interior of the chamber 13. The deflector baffles 10 in duct 14 direct this air in a generally helical flow around the inner wall of body portion 25 and down through the chamber 13.

The liquid dispersion enters chamber 13 through a liquid dispersion feed conduit 28 which is disposed centrally in the circular cover 26 coincident with the axis of cylindrical body portion 25. The conduit 28 is in fluid communication with a reservoir 22 and a pump 23, by means of which there is continuously made available a pressurized supply of the liquid dispersion to be processed. A spray nozzle 15 is secured to the end of conduit 28 in chamber 13. The spray nozzle 15 may be of any conventional configuration, but preferably is constructed so as to provide a spray in a hollow cone-shaped pattern of atomized droplets of the liquid dispersion which fans outwardly toward the wall of the chamber 13.

In accordance with the invention, an agglomerating powder, entrained in a stream of air, is introduced into the chamber 13 to intersect the spray of liquid dispersion. To this end, an entrainment assembly is provided. The agglomerating powder entrainment assembly 17 comprises a feeder 29, a hopper 31, and a tubular conduit 33. The feeder 29 includes means (not illustrated) for vibrating the feeder and by which the rate of flow of a substantially dry powdered material can be regulated. The hopper 31 is connected with the tubular conduit 33. The agglomerating powder entrainment assembly 17 is adapted to controllably meter an agglomerating powder (subsequently described in particularity) from the vibrating feeder 29 into the hopper 31 and thence into the tubular conduit 33. Air from a blower 34 is supplied to the tubular conduit 33 so that the agglomerating powder from the feed hopper is entrained in the air stream in the conduit 33. The tubular conduit 33 extends through the wall of the chamber 13 into its interior and thence upward

coincident with the axis of cylindrical wall portion 25 to a terminus 35 which is below but adjacent the spray nozzle 15. A deflector 36 may be provided at terminus 35 to deflect the stream of air and entrained particles into a conical pattern. There is thereby provided means whereby a stream of air having agglomerating powder entrained therein may impinge upon the cone-shaped spray of droplets of liquid dispersion issuing from the spray nozzle 15 before such spray reaches the inner walls of the body portion 25.

The product discharge means 19 comprise a chute 37 which communicates with the frusto-conical portion 27 of the chamber 13. Discharge means 19 further comprise a pair of gates 39 which are slideably received in the chute 37, and a screw conveyor 41 through which the dried and agglomerated product is discharged for further processing, such as packaging (not illustrated). Gates 39 comprise a two-door dump port and are alternately opened and closed by a cam (not illustrated) to maintain a seal between conveyor 41 and the chamber 13. Such an expedient is well known in the art.

A fines separation system is provided for removing those dried particles which are below minimum size requirements. The fines separation system 21 includes a moist air duct 43 and a cyclone separator 45 in fluid communication therewith. The moist air duct 43 extends from the chamber 13 through the frusto-conical portion 27, and terminates at its connection to the cyclone separator 45. Moist air and finely divided dried dust suspended therein may thereby be conducted out of the chamber 13 and to the cyclone separator 45, wherein such dust is recovered from the air by centrifugal action. The cyclone separator 45 may be of a conventional design known to those skilled in the art, which includes a fines discharge port 47 through which the dust is recovered, and an exhaust port 48 connected to blower 12, and an exhaust port 49 through which moist exhaust air (depleted of dust) is discharged.

In accordance with the method of the present invention, a flow of hot, low-humidity air is established into the chamber 13 through the air supply duct 14. A stream of air which need not be heated is established through the tubular conduit 33, and a controlled flow of agglomerating powder is established from the vibrating feeder 29 and the hopper 31 into the tubular conduit 33.

A flow of the liquid dispersion to be dried is established through the spray nozzle 15 to provide a hollow cone-shaped spray of atomized droplets expanding outwardly to the walls of the chamber 13. In accordance with known spray drying technology, there is thereby obtained rapid evaporation of liquid from the droplets.

In accordance with the present invention, the resultant dried particles are concurrently agglomerated while within the chamber 13 to provide a readily dispersible product. Such agglomeration results from the provision of the stream of entrained agglomerating powder which is discharged from terminus 35 of conduit 33 and impinges upon the hollow cone-shaped spray. This may be more clearly understood by referring to the schematic representation of FIGURE 2. The terminus 35 of conduit 33 is disposed relatively close to the nozzle 15. Entrained dry particles are blown out of conduit 33 and fly into the stream of droplets. It may be observed that the path of the entrained dry particles intersects the stream of droplets at a relatively large obtuse angle. The dry particles and the droplets have substantial opposing components of velocity.

The agglomerating powder comprises a substantially dry non-cohesive powder which is compatible with the dried agglomerates of the final product. The agglomerating powder may, for example, comprise previously-dried material which is the same substance as the substance in the fluid dispersion. Alternatively, it may comprise a substance different from that of the fluid dispersion but whose presence in admixture therewith is desired. In the case of food products, therefore, the agglomerating powder might be, for example, sucrose, flour, etc. The particle size of the agglomerating powder is not critical in obtaining the benefits of the present invention. The moisture content of the agglomerating powder desirably is sufficiently low to enable it to be metered and fed into the tubular conduit 33 without bridging or balling. Of course, the lower the moisture content of the agglomerating powder, the less moisture which will have to be evaporated in the chamber 13, and the more efficient will be the operation.

While the mechanism through which the benefits of the present invention are achieved are not fully understood, and without intending to limit the scope of the present invention, it is believed that the impingement of the relatively dry agglomerating powder upon the droplets of fluid dispersion (as particularly illustrated in FIGURE 2) provides a cohesive base upon which agglomeration proceeds. Because of the high rate of evaporation of water from the droplets, a substantial portion of their contained water is evaporated shortly after emerging from the spray nozzle 15, and collision thereof with particles of the agglomerating powder at sufficient velocity results in cohesion therebetween. Further collisions result in further buildup of particle size until the resultant cluster of agglomerate loses moisture so that it no longer has a cohesive surface.

The resultant agglomerates of dried particles and agglomerating powder fall downwardly in the chamber 13 and into the chute 37 of the product discharge means 19. They are thereafter removed therefrom by the screw conveyor 41 for subsequent processing.

The air, containing vapor transferred to it from the fluid dispersion and finely divided dust or fines suspended therein, passes through the moist air duct 43 and into the cyclone separator 45. The dust or fines recovered from the air is discharged from the bottom of the cyclone separator 45 through the fines discharge port 47, and the moist air is discharged through the exhaust port 48.

In a particular mode of operation of the apparatus of the present invention, the fines recovered from the moist exhaust air in the cyclone separator 45 may be utilized as the agglomerating powder. Such recycling of the fines permits a closed-cycle operation, whereby the entire output of the dryer-agglomerator unit 11 comprises a dried product having desired dispersibility in liquid. In normal operation, the amount of fines which may be expected to be recovered in the cyclone separator 45 is about one-third of the weight of dry particles produced from the fluid dispersion fed to the spray nozzle 15. This amount of fines provides desirable operation when recycled through the agglomerating powder entrainment assembly 17.

The air entering chamber 13 through duct 14 is provided at such a velocity and angle as to cause the dried particles to be thrown to the inner wall of body portion 25 due to centrifugal force. The result is that the dried particles swirl around the inner wall of body portion 25 and form a moving wall of particles which abrade off the wall any sticky material that might adhere to the wall. The dried particles which swirl around the wall include the dry powder added through conduit 33 such that a very dense wall of moving particles is formed. This fact makes it possible to spray-dry products which have heretofore been impossible to spray-dry without the use of costly, specialized equipment.

A further advantage of the spray-drying and agglomerating techinque of the invention is that the dry powder added through conduit 33 need not be the same substance as the liquid suspension being sprayed. For example, in the preparation of a food product, one or more ingredients of the product, such as sucrose, flour, etc., may be added as the dry powder through conduit 33. The resulting agglomerated dried substance is therefore more

readily dispersed in liquid to form a reconstituted liquid dispersion which is modified from the original liquid dispersion sprayed into the chamber **13**.

A particular advantage of the technique of the invention over a conventional spray-drying technique may be observed from FIGURE 3. In FIGURE 3, the line **51** represents the particle size distribution for a food product which has been spray-dried by the conventional spray-drying technique previously described. It will be seen that at the 50 percent level, the particle size is about 60 microns. The improvement by utilizing the technique of the invention may be observed from the line **52** whereon, at the 50 percent level, the particle size exceeds 100 microns. This substantial improvement in particle size results over nearly the entire distribution range, and it will therefore be appreciated that a substantial improvement in the dispersibility of the final product in liquid is achieved.

It may therefore be seen that the invention provides an improved method and apparatus for spray-drying of fluid dispersions and agglomeration of the resultant dried particles. The technique of the invention has particular applicability to the spray-drying of fluid dispersions of edible, organic substances and for agglomerating the resultant dried particles. Spray-drying and agglomeration of the resultant dried particles are concurrently effected to provide a readily dispersible product in an economical manner.

Various modifications of the invention will be apparent from the foregoing description to those skilled in the art and such modifications are intended to fall within the scope of the appendant claims.

What is claimed is:

1. A method for removing liquid from a liquid dispersion and concurrently forming dried agglomerates, said method including the following steps: providing a drying chamber, introducing air to the chamber at predetermined speed, temperature and humidity, and circulating such air in the chamber, partially removing liquid from the liquid dispersion by spraying the liquid dispersion into the chamber from the center thereof in a pattern having the general shape of a hollow cone, providing a source, exteriorly of the chamber, of non-cohesive particles of a substance compatible with the dried agglomerates, and causing the non-cohesive particles to collide with and adhere to partially dried particles of the sprayed liquid dispersion to form agglomerates by ejecting a stream of gas having such non-cohesive particles entrained therein into the chamber from a position substantially aligned with the axis of the hollow cone pattern of the sprayed liquid dispersion, said path of entrained non-cohesive particles being in a direction to intersect the path of the sprayed liquid dispersion such that the sprayed liquid dispersion and the dried particles have substantial oppositely directed components of velocity.

2. The method of claim **1** wherein the step of providing a source of non-cohesive particles includes recovering the fines resulting from the drying of the liquid dispersion and utilizing such fines as at least a portion of the non-cohesive particles.

3. The method of claim **1** wherein the air introduced to the chamber is circulated in a generally helical flow and wherein the predetermined speed thereof is sufficient to urge the non-cohesive particles and the dried agglomerates to the limits of the chamber by centrifugal force.

4. The method of claim **1** wherein the gas entrained non-cohesive particles are ejected into the chamber in a generally hollow conical pattern having an axis substantially colinear with the axis of the hollow cone pattern of the sprayed liquid dispersion.

5. Apparatus for removing liquid from a liquid dispersion and concurrently forming dried agglomerates, said apparatus including in combination, means defining a drying chamber, means for introducing air to the chamber at predetermined speed, temperature, and humidity and for circulating such air in the chamber, means for partially removing liquid from the liquid dispersion by spraying the liquid dispersion into the chamber in a pattern having the general shape of a hollow cone, means exteriorly of the chamber for providing a source of non-cohesive particles of a substance compatible with the dried agglomerates, means for causing the non-cohesive particles to collide with and adhere to partially dried particles of the sprayed liquid dispersion to form agglomerates by ejecting a stream of gas having such non-cohesive particles entrained therein into the chamber from a position substantially aligned with the axis of the hollow cone pattern of the sprayed liquid dispersion, said ejecting means being directed so that the path of entrained non-cohesive particles intersects the path of the sprayed liquid dispersion such that the sprayed liquid dispersion and the non-cohesive particles have substantial oppositely directed components of velocity.

6. The combination of claim **5** wherein said means for providing a source of non-cohesive particles include means for recovering the fines resulting from the drying of the liquid dispersion and utilizing such fines as at least a portion of the non-cohesive particles.

7. The combination of claim **5** wherein said means for ejecting a stream of gas having such non-cohesive particles entrained therein comprise means for ejecting such non-cohesive particles in a generally hollow cone shaped pattern having an axis substantially colinear with the axis of the hollow cone pattern of the sprayed liquid dispersion.

8. The combination of claim **5** wherein said means for entraining such non-cohesive particles comprises a source of pressurized air.

9. The combination of claim **5** wherein said means for introducing air to the chamber comprises a blower and a duct providing a generally helical circulation of air in the chamber, said blower providing air of which the predetermined speed is sufficient to urge the non-cohesive particles and the dried agglomerates to the limits of the chamber by centrifugal force.

10. The method of claim **1** wherein the agglomerates formed by the collisions of the non-cohesive particles and the partially dried particles are subjected to further drying by the circulating air.

11. The combination of claim **5** wherein said chamber-defining means comprise a hollow cylinder having a substantially vertical axis and means closing each end of said hollow cylinder, wherein said spraying means comprise a first conduit having a first orifice disposed in the chamber substantially aligned with the axis of said cylinder proximate an end thereof and means for conducting the liquid-dispersion under pressure to said first conduit, and wherein said ejecting means comprise a second conduit having an orifice disposed adjacent and below said first orifice and substantially aligned with the axis of said cylinder.

12. The combination of claim **11** wherein said ejecting means include an agglomerating powder entrainment assembly disposed exteriorly of the chamber and comprising a blower in fluid communication with said second conduit and a hopper also in fluid communication with said second conduit for adding the non-cohesive particles, said blower providing air under pressure sufficient to expel such non-cohesive particles through said second orifice and into the path of the sprayed liquid dispersion.

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