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SPRAY DRYING APPARATUS

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3 Sheets-Sheet 2

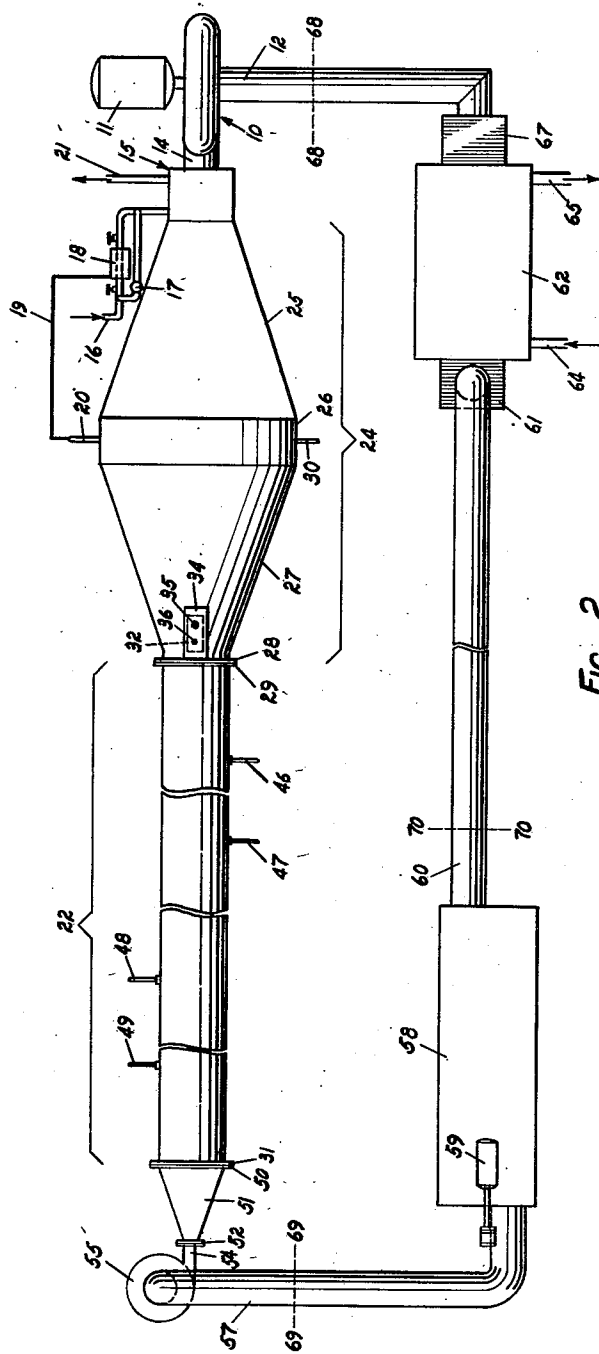


Fig. 2

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Fig. 3b

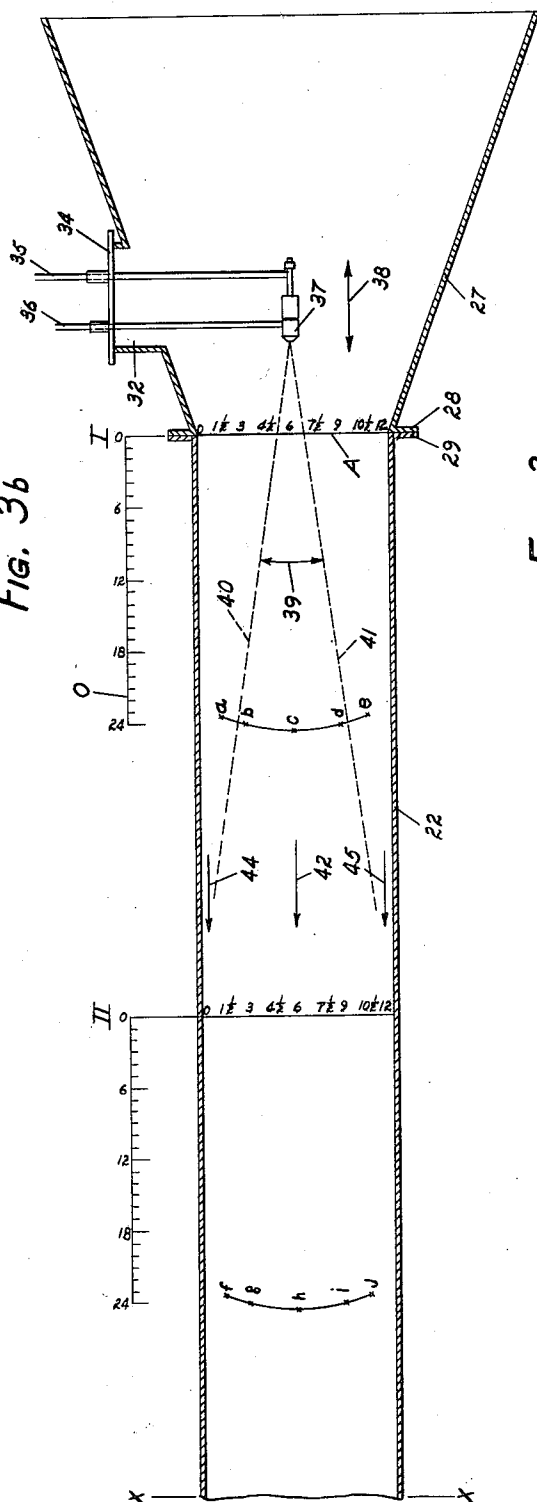
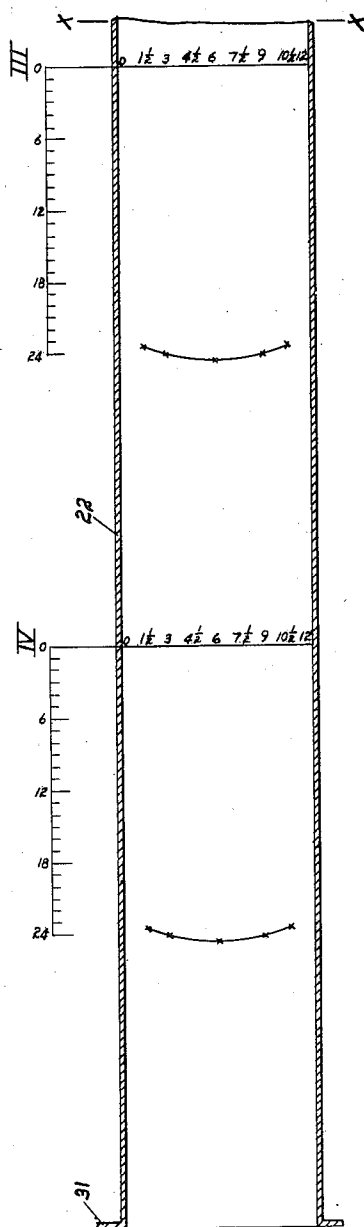


Fig. 3a



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SPRAY DRYING APPARATUS

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4 Claims. (Cl. 159—3)

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This invention relates to improvements in methods and apparatus for spray drying. The invention is particularly directed to improvements in spray driers that permit spray drying of foodstuffs. In the drying of, for example, milk, eggs, or milk products, there are two systems currently used for commercial production, both of which use exceedingly large volume drying chambers.

In one commonly used commercial spray drier the drying chamber is a large room-like chamber into which the material to be dried is sprayed concurrently with a flow of heated air through the room, the intent being to provide sufficient distance of fall for the sprayed particles so that by the time they reach the bottom chamber they will be dry. In this system a sufficient dimensional size of drying room is provided so that impingement of undried particles on the walls of the chamber is not encountered to any appreciable degree. The drying air flow through the chamber is not appreciably relied upon for control of the direction of movement of the sprayed particles.

In another system the drying chamber is cyclonic in type, the spraying being either concurrent or countercurrent as to the flow of drying air. In this system turbulence is sought, the thought being that turbulence of the drying air will achieve maximum drying rate.

These principal commercial systems, while the best now available and while used extensively, have certain limitations which prescribe their utility. In the first place, the volume of the drier in relation to the drier rate (pounds of dried material produced per hour) is large; consequently the housing of the drying unit is difficult and expensive. In addition, a large volume of drying air or gas is necessary to fill (or charge) the drying system, and this factor alone has prohibited the use of inert gases in the large volume driers presently available.

In addition, in present commercial systems the drying rate for a given particle is slow, consequently the maximum temperatures that have been utilizable with organic foods have had to be kept low. Thus, for the drying of milk and milk products, the maximum temperatures allowable in present commercial systems is about 320° F. Any higher temperatures have, due to the relatively long time periods of particle contact during drying, produced taste and flavor deterioration, due probably to partial degeneration of the organic material, particularly of proteinaceous constituents thereof. Any attempts to increase

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temperatures of drying media in present systems has also lowered the quality, particularly in respect to the reconstituting of the dry solid in that a greater percentage of the dried material remained permanently insoluble, i. e. the solubility index is increased.

It is an object of the present invention to overcome these difficulties of the present commercial systems and to provide improved methods and apparatus for drying in which the drying media temperatures and drying capacity per unit of volume of the drying unit are increased to levels heretofore thought impossible, and to provide a drier product, but without deleterious effect on the flavor or quality and without increase in the solubility index of the product.

It is also an object of the invention to provide drying apparatus of much smaller size for a given drying capacity than heretofore available, with consequent lowered costs of construction, maintenance and space requirements and which is easier to clean while in service.

It is a further object of the invention to provide an improved method and apparatus of wide adaptability, useful as a closed system wherein the drying media may be recirculated and may be other than air and in which pressures of the drying media may be lower or higher than atmospheric so as to facilitate the drying of particularly delicate or intractable materials.

Other objects of the invention include the provision of improved methods and apparatus wherein the drying is conducted in a tube wherein the flow of drying media is concurrent to that of the finely divided material undergoing drying and in which the flow of drying material is at a substantially uniform velocity throughout the drying duct cross-sectional area.

Other and further objects of the invention are those inherent in the apparatus herein illustrated, described and claimed.

The invention is illustrated with reference to the drawings in which

Figures 1 and 2 are, respectively, side elevational and plan views of a drying apparatus illustrative of the invention; and

Figures 3a and 3b, which should be considered as joined at the line X—X, are an enlarged schematic cross-sectional view of the drying duct and fluid spray station of the apparatus, including also a portion of the drying gas velocity unifying double cone.

Throughout the drawings corresponding numerals refer to the same parts.

Referring to the drawings, Figures 1 and 2,

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the invention is illustrated as of the recirculatory type in which the charge of drying gas is recirculated time and again out of contact with the outside atmosphere, but, as hereinafter explained, it will be understood that the apparatus need not be recirculatory. The drying apparatus and method of the invention include a blower generally designated 10 which is preferably motor-driven by the motor 11. The blower has an inlet 12 and an outlet 14 which is connected to a heating unit generally designated 15 having a heating fluid inlet 16, a manual control valve 17 and an automatic control valve 18 which is regulated by the thermally responsive element 20 through the lead 19. The element 20 is positioned in the heated stream of drying gas so as to be responsive to the temperature thereof and thereby control the amount of heat delivered by the heater 15. The drying gas is heated to temperatures as high as 350° F. and even higher temperatures, such as 400° F. The return line for the heater 15 is shown at 21.

Under the bracket there is shown the tubular drying chamber 22 which has a length preferably not less than three times its maximum transverse dimension. The tubular drying chamber 22 may be arranged either horizontally, as shown, or may be placed vertically or at an angle since the orientation is not a critical factor in the operation. In accordance with the present invention the drying is accomplished in the tubular chamber which has an unobstructed interior. Also, in accordance with the present invention there is provided means upstream from the tubular drying chamber to substantially unify the velocity of the drying gas across the full cross section of the tubular drying chamber. In the illustrated embodiment of the invention, this means 24 consists of a gradually expanding conical section 25 which is joined to a short cylindrical section 26, the latter in turn being joined to a gradually decreasing conical section 27 which terminates at the flange 28. Flange 28 is connected to the flange 29 in the tubular drying chamber. The double cone velocity unifying section 24 has no obstructions on its interior save only that the cylindrical portion 26 is apertured to permit a thermometer 30 to be inserted and is apertured to receive the thermally responsive element in the same section. Neither the thermometer nor element 20 offer any appreciable impediment to the gas flow. Otherwise, the interior of the double cone 24 is free from obstructions. The effect of this contrivance is to pattern the flow of air therethrough in such a manner that the air delivered to and flowing through the tubular drying chamber 22 under conditions of air flow only and without spray from nozzle 37, has a nearly constant velocity, regardless of where the velocity measurement is made across any transverse section through the drying chamber up to about 12 diameters measured axially from the inlet end of the tubular drying chamber. It may be stated that no reliable method is available for measuring air flow under conditions when liquids or solids-containing fluids are sprayed from nozzle 37. This is due to the fact that moisture and/or solids impingement upon measuring instruments renders them unreliable. The air flow through tube 22 is best explained in Figures 3a and 3b which, taken together, show a portion of the conical section 27, flanges 28, 29 and the tubular drying chamber 22 which terminates at its own flange 31. It will be understood that Fig-

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ures 3a and 3b should be considered as assembled end to end at the breaking line X—X.

On Figures 3a and 3b there are illustrated graphs showing the air velocities at several stations along the tube. Thus, at station I the ordinate 0 is a scale of velocities in feet per second, whereas the abscissa A is a scale of dimensions across the tube. Thus, measurements of the velocities were made at positions 1½", 3", 6", 9" and 10½" from one of the tube walls. The scale of velocities at station I is shown by the curve a, b, c, d, e. The plotted velocity readings are actual velocities as measured in the tube and as shown by the scale 0 they are all within the range of 23 to 25 feet per second in the particular run under consideration and hence are of substantially constant value across the tube. Similarly, at station II the curve f, g, h, i, j which likewise shows actually velocity measurements within the interior of the tube that are the same as those at station I, the same being true at station III and station IV along the tube. In each instance the velocities were within the range 23 to 25, hence substantially constant across a transverse section of the tubular drying chamber 22 and substantially constant at all stations along the tube. The aforesaid velocity measurements were made when air only was flowing through the tubular drying chamber 22, because of the impossibility of making reliable velocity measurements when liquids or solids-containing liquids are entrained in the air stream, as heretofore explained.

Referring again to Figures 1 and 2, the conical portion 27 is provided with an opening 32 having a cover plate 34 thereon through which an air inlet pipe 35 and a liquid inlet pipe 36 pass and extend to the spray nozzle 37 located centrally along the axis of the conical portion 27 which is coincidental with the axis of the drying chamber 22. The spray mounting is shown enlarged in Figure 3b and may be constructed so that the plate 34 can be moved axially in respect to the conical section 27 so as to position the nozzle 37 at various positions along the axis, as illustrated by the double arrow 38, thus allowing adjustment in the spraying position while still maintaining the axial alignment of the nozzle with the axis of the drying chamber. The nozzle 37 may be positioned a considerable distance back along the axis of cone 27 from flanges 28—29 without danger of side wall impingement due to the maintenance of air velocity along the walls of cone 27 and tube 22 and the narrow angle of the spray cone. The material being dried may be sprayed by any other suitable means. Thus, for example, the material may be sprayed under high pressure without the use of air or other gas under pressure for the spraying operation.

The nozzle 37 is constructed so that the liquid sprayed therefrom is projected within the narrow spray cone of relatively low angularity indicated by angle 39, the outer limits of the spray cone being illustrated by the dotted lines 40 and 41. The drying fluid moves down the tube 22 in the direction of arrow 42, and is of substantially constant velocity even near the boundaries defined by the walls of tube 22. The effect of this is to hold the sprayed particles within the narrow cone between lines 40 and 41. The relatively high velocities adjacent the inner surface of the tube 22 as compared with the velocities near chamber walls in prior art devices, as indicated by the arrows 44 and 45, has the effect of propelling

particles rapidly down the tube, thus impelling them forwardly through the tube rather than permitting them to impinge on the tube walls as would otherwise be the case if the drying gas velocity near the boundaries of the tube 22 were, as is usually the case, very much lower than at the central portion. Actual tests have shown that when the velocity unifying section 24 is used upstream in respect to the drying tube 22, that impingement of undried particles on the tube walls is reduced to a negligible extent. Where built in accordance with our discovery, the tube 22 may be made very much smaller in cross-sectional dimension and total volume without danger of having undried particles impinged upon the walls thereof than is the case when the drying gas within the tube does not have a substantially constant velocity throughout the extent of cross section area herein disclosed, and the volume of the drying gas required to charge the system is, therefore, very much less for a given amount of material treated than in prior systems. However, in building a drier in accordance with our discovery the diameter of the double cone at its point of maximum diameter should be not less than three times the diameter of the tube 22, and the length of the tube 22 should be not substantially less than three times its diameter.

The drying tube 22 shown in Figure 2 is illustrated as having a plurality of test stations at 46, 47, 48 and 49 at which temperature and drying gas velocity readings may be made for purposes of adjustment and experimentation. It will be understood, of course, that these may be eliminated in any apparatus which is designed for one specific installation but are useful in apparatus that is used for various drying procedures and for experimental work.

The flange 31 of the drying chamber 22 is coupled to flange 50 of a conical reducing section 51 which is in turn coupled by means of its flange 52 to the inlet 54 of a cyclone separator 55 which serves to remove the major portion of the solids produced in the tube 22. The solids collect in the bottom portion 56 of the cyclone separator which is best shown in Figure 1. While the drying gas passes out of the tube 57 and enters a bag house type separator 58 which is optionally

The drying gas leaves the bag house by way of tube 60, it being understood that at this time the drying gas is moisture laden, due to the water removed from the liquid sprayed at the spray nozzle 37 and the temperature is lowered due to cooling by evaporation of the liquid. Tube 60 connects to the inlet 61 of a cooling chamber 62 which is provided with a finned tube cooler supplied with cooling water or refrigerant via inlet pipe 64. The outlet pipe from the cooler is shown at 65. The cooling water may be refrigerated, if desired, or the coolant may be the gas used in the refrigeration machine. The outlet 67 of the cooler constitutes a water trap in which the moisture which is condensed (upon cooling the drying gas) is collected and the cooled, drying gas is then returned by pipe 12 to the inlet of the blower 10 for recirculation. Other methods of cooling or drying (with or without incidental cooling of the gas) may be used. Thus, the drying air or gas of the system may be dried by using suitable desiccants, such as silica gel without necessarily removing the contained heat thereof. If desired, the apparatus may be broken at line 68—68 and fresh air may be drawn into the blower, used once for drying and thence discharged at break 69—69 in pipe 57 which constitutes the air outlet from the cyclone separator, or, if desired, the air outlet may be made by breaking pipe 60 as indicated at 70—70 which then serves as the discharge. In such case the drying gas is air and is used only once and then exhausted. The advantages of the system, however, are by no means diminished by such usage since the decreased space requirements are still to be had and the advantages of high temperature drying are obtained. When a closed circuit system is used the entire system may be operated at sub-atmospheric pressure or super-atmospheric pressure in order that the drying may take place at any desired temperature which is thereby imposed upon the sprayed material which is undergoing drying. The drying gas may be air or some non-oxidizing gas, such as nitrogen, helium, carbon dioxide or the like.

By way of further illustration of the invention but without any limitation thereon, reference is made to the following examples which are tabulated for comparison:

Run.....	I	II	III	IV	V	VI
Material.....	Milk	Casein	Milk	Milk	Ice Cream Mix	Salt
Per Cent Solids.....per cent.	40	6.2	40	40	35	27
Feed rate.....lb./min.	1/2	3/4	3/4	1/2	1/2	1/2
Drying gas:						
Inlet Temperature:						
Dry bulb.....° F.	60	60	63	62	60	70
Wet bulb.....° F.	58	58	61	60	58	68
Relative Humidity.....per cent.	88.8	88.8	89.3	90	89.8	90.3
Weight of Drying Gas (Dry basis).....lb./min.	35.3	35.3	34.8	49.5	35.3	45.2
Drying Tube Gas:						
Velocity.....ft./sec.	10.5	10.5	10.5	14.9	10.5	13.6
Inlet Temp.....° F.	265	275	275	265	275	275
Drying Gas:						
Exit Temperature:						
Dry Bulb.....° F.	190	200	182	198	194	196
Wet Bulb.....° F.	96	101	94	98	98	102
Relative Humidity.....per cent.	4.2	7	3.7	3.7	3.7	5.2
Moisture Content of Powder.....do.	.94	2.2	1.4	.96	.5	.05
Solubility Index (Standard Dairy Solubility Test).....	.1	—	.1	.1	—	—

provided with a shaker mechanism 59. The house 58 may be provided with tubular filter cloths so as to strain out any residual solids and may be eliminated, if desired. Or the cyclonic separator 55 may be eliminated and a bag house at 58 or any other suitable gas-solid separator, such as an electrostatic precipitator, may be relied upon entirely to remove the solids from the stream of drying gas.

In the foregoing runs the "feed rate in pounds per minute" was the weight of the liquid sprayed through the nozzle 37. The drying gas inlet temperatures were measured in pipe 12 leading to the inlet to the blower 10. The relative humidity of the drying gas was high at this point, but due to the low temperature of the inlet gas the total water content of the drying gas was small. The weight of the drying gas, dry basis,

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was calculated on the basis of the velocity of gases passing through the drying tube 22. The drying tube gas velocities were actual measurements taken in the drying tube and the drying tube gas inlet temperature was the temperature of the gas measured at thermometer 30 just before entering the drying tube. The drying gas exit temperature measurements were made at the conical reducer 51. The moisture content of the powder was determined by actual test of the dried powders produced, as was also the solubility index which is a standard dairy product solubility test made in accordance with the methods prescribed by the American Dry Milk Institute "The Grading of Dry Milk Solids."

As many apparently widely different embodiments of this invention may be made without departing from the spirit and scope thereof, it is to be understood that we do not limit ourselves to the specific embodiments herein except as defined by the appended claims.

What we claim is:

1. A spray drying apparatus comprising a long tubular drying duct having an inlet and discharge end, spray means adjacent the inlet end of said duct positioned axially therein for spraying a narrow cone of liquid particles in the duct from the inlet toward the outlet end, an air heater and blower means for moving a current of heated air through said duct from the inlet to the outlet thereof, and double conical means connected to the inlet end of the duct and through which said heated air moves, including a first conical duct section having a cross section equal to that of the duct at the inlet end, connected to said inlet end, said conical section being diverged outwardly to a larger cross sectional area and connected to a second conical section having the same cross-sectional area at the point of connection, said second conical section being then gradually reduced in cross sectional area in the up-stream direction.

2. A drying apparatus comprising a long tubular drying duct having an inlet end and a discharge end, means for spraying material to be dried into the inlet end of said duct and axially thereof, a generally frusto-conical member having its bases parallel to each other and per-

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pendicular to the axis of said conical member and having its smaller diameter the same as the diameter of said duct, said conical member being attached to said duct at its smaller diameter, and a blower for introducing a flow of gas into said conical member at the larger base thereof and in predominantly parallel flow with respect to the axis of said conical member, thereby regulating the flow of gas to such inlet end as to maintain a substantially uniform rate of flow of gas across the cross section of said duct.

3. A drying apparatus as set forth in claim 2 characterized in that the diameter of the larger base of said generally frusto-conical member is not less than three times the diameter of the smaller base of said conical member.

4. A drying apparatus as set forth in claim 2 characterized in that the length of said tubular drying duct is not less than three times its diameter.

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