

July 31, 1951

J. J. MOJONNIER
SPRAY DRYING APPARATUS

2,562,473

Filed May 7, 1945

5 Sheets-Sheet 1

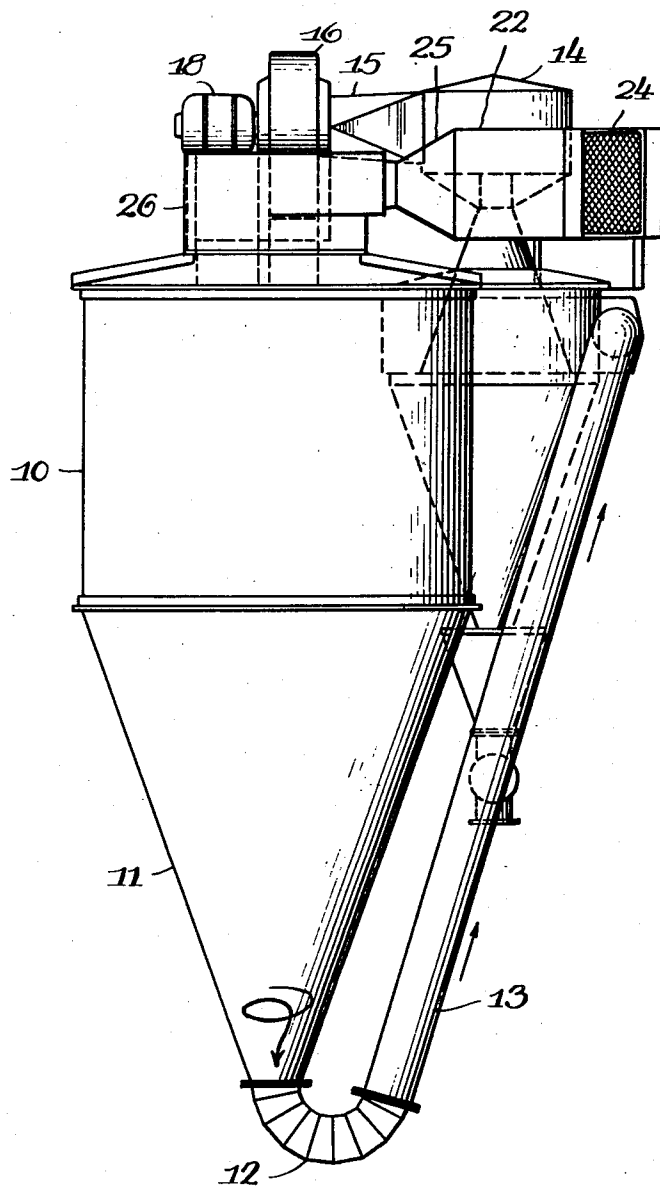


Fig. 1

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Fig. 2

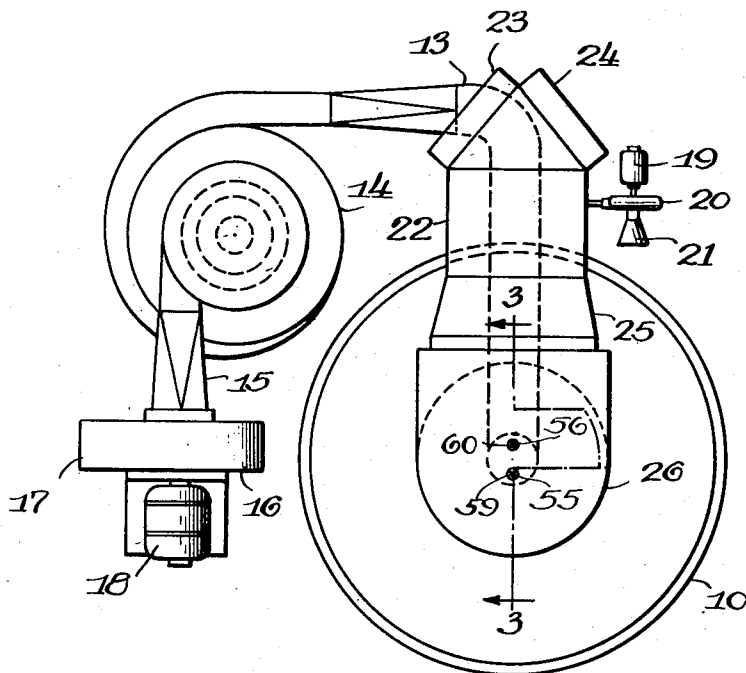
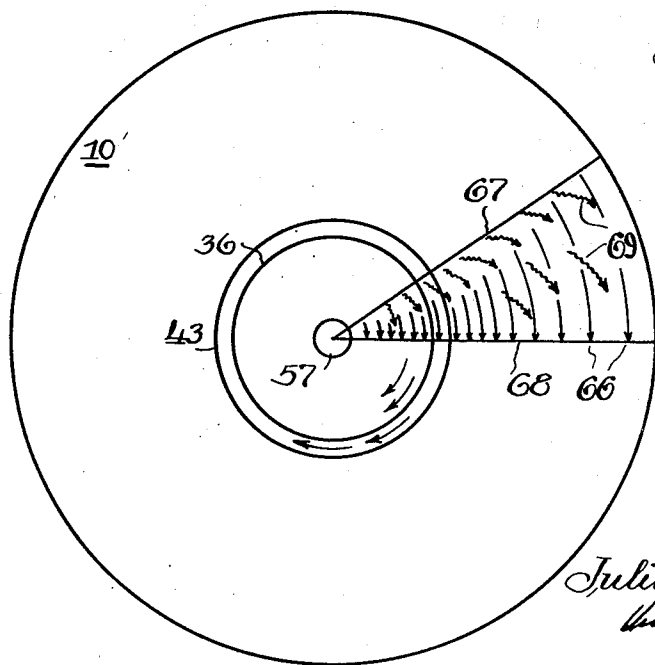


Fig. 9



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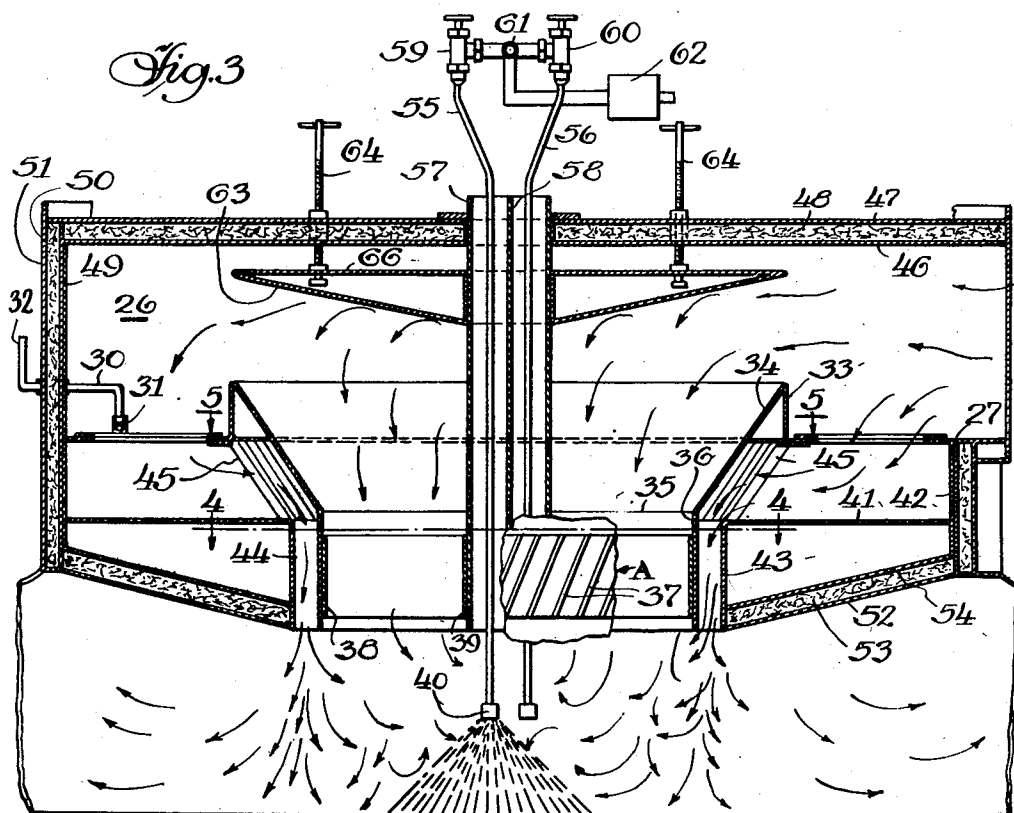
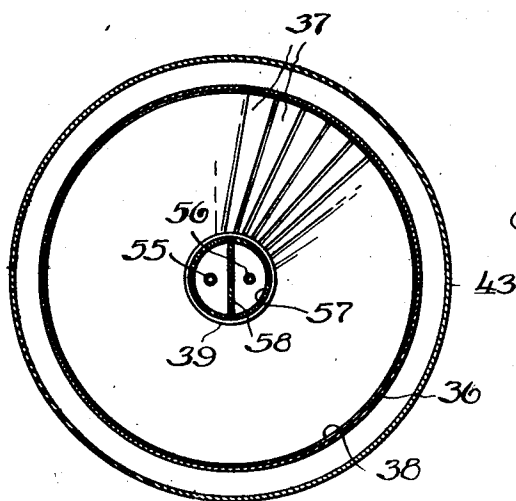
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Filed May 7, 1945

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Fig. 5

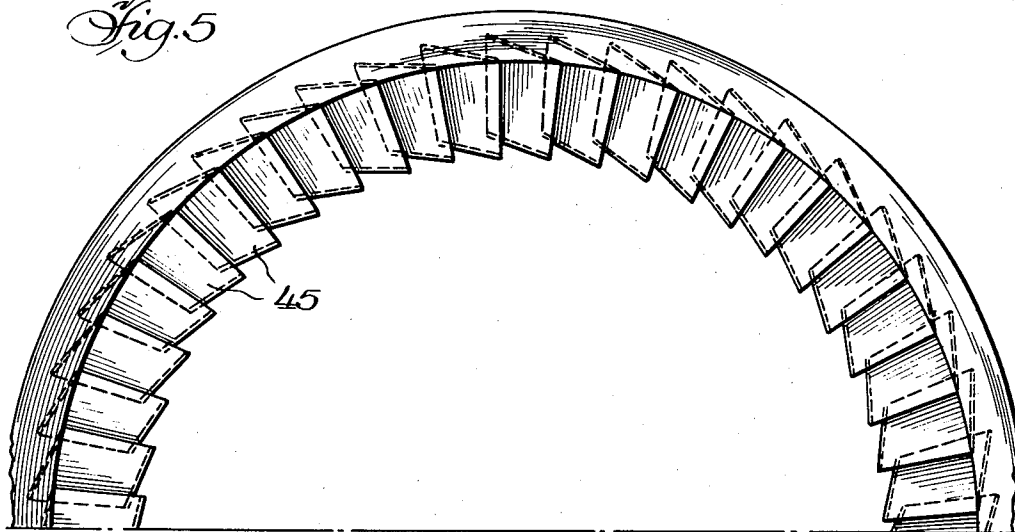
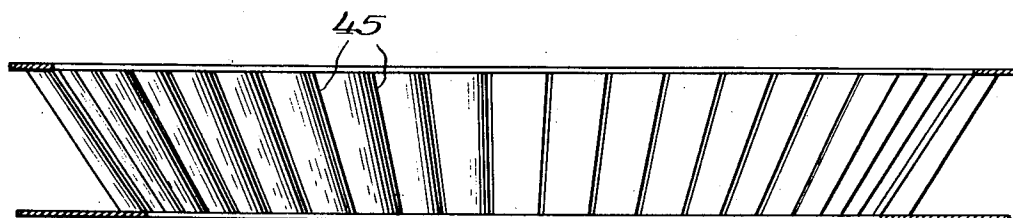
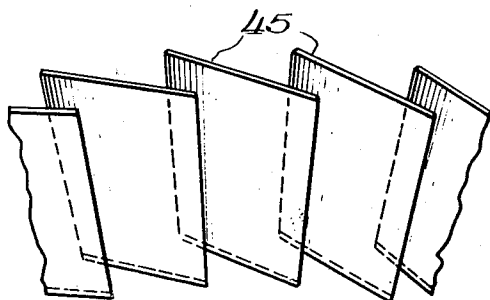


Fig. 6

Fig. 7



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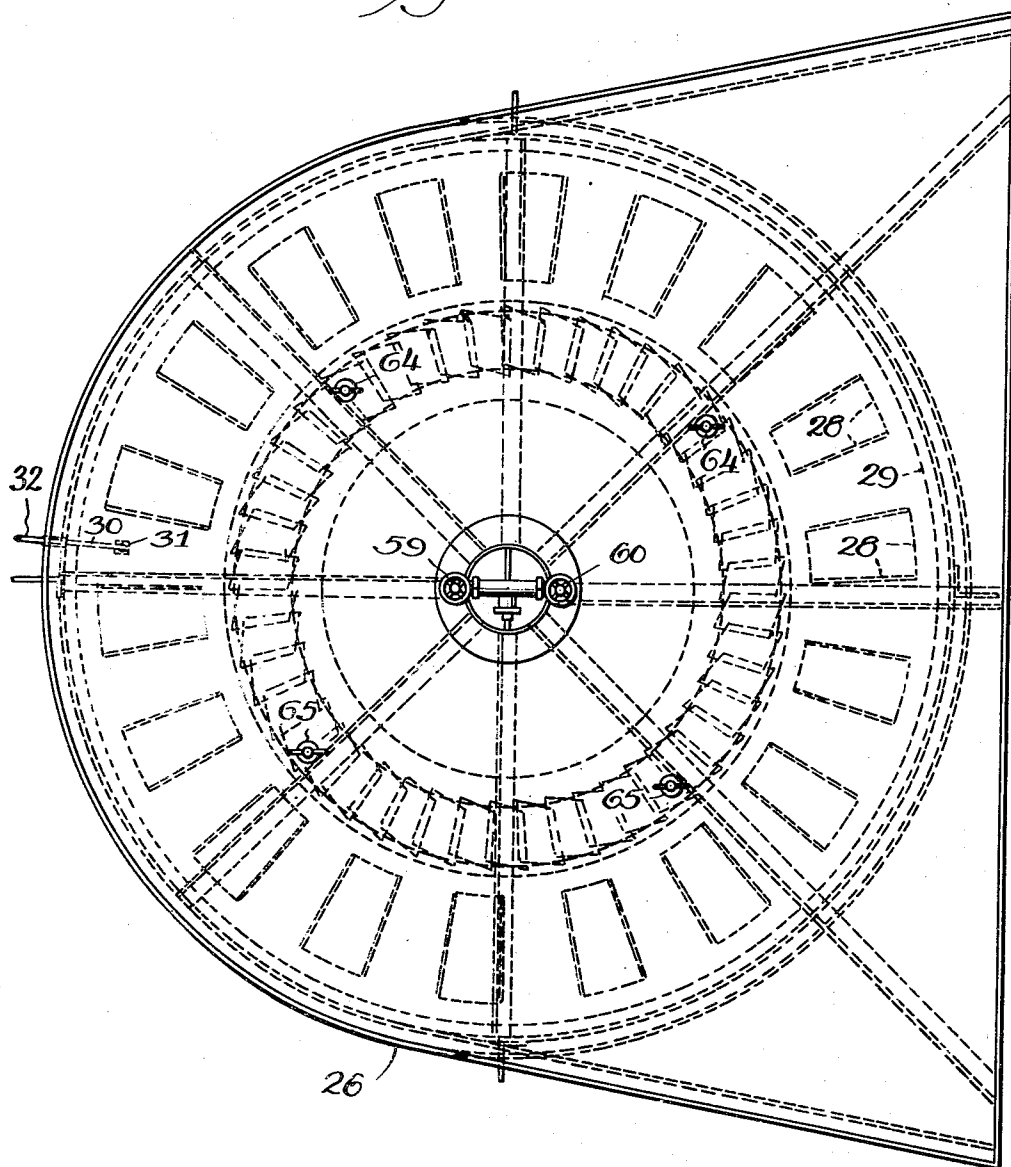
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Fig. 8



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UNITED STATES PATENT OFFICE

2,562,473

SPRAY DRYING APPARATUS

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Application May 7, 1945, Serial No. 592,466

5 Claims. (Cl. 159-4)

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This invention relates to improvements in spray drying methods and apparatus, and more particularly to the type in which the liquid product to be desiccated is sprayed into a heated atmosphere and dried to powdery form while in suspension in that atmosphere.

Heretofore, when efforts have been made to reduce sprayed material to a dry free flowing powder while still in suspension in the drying medium, large scale production on an economical basis has not been attained because of the rapid accumulation of tacky material on the drying chamber walls, and the contamination of the final product by large percentages of scorched particles. The necessity for scraping of the walls has always diminished production and caused frequent shut downs. The presence of scorched particles has meant inferior products and led to decreased production in an effort to minimize contamination.

My invention provides a new method and apparatus for handling the sprayed particles to attain the desired drying efficiently while eliminating scorching of the product.

One of the objects of my invention is to provide a new method and apparatus for uniformly controlling the temperature to which the sprayed particles are subjected to avoid the harmful effects of localized overheating or overheating of a portion of the product.

Another object of the invention is to provide a new method of spray drying wherein the suspension of the product in the drying medium is controlled in such a manner as to accomplish efficiently a thorough and uniform dehydration and to prevent adherence of the sprayed particles to the apparatus surfaces.

Another object of the invention is to conduct the drying operations in such a manner as to avoid scorching and discoloring any portion of the final dried product due to any and all causes.

Another object of the invention is to maintain the sprayed particles in suspension in an atmosphere of drying gases until dried and to maintain the dried particles in suspension in the gases during their evacuation from the desiccation chamber.

Another object is to spray the liquid material into an atmosphere of drying gas maintained under such conditions of temperature, pressure, relative humidity, and agitation that instantaneous evaporation of moisture uniformly from all of the solids occurs, without injury to the solids, and without depositing solids on the drying chamber walls.

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Further objects and advantages of the invention will be apparent from the following specification and the accompanying drawings, wherein a preferred embodiment of the invention has been shown and described.

In the drawings:

Figure 1 is a side elevation of one form of an apparatus embodying my invention;

Figure 2 is a top plan view of the same device omitting the fuel gas blower;

Figure 3 is a vertical sectional view through a portion of the drying gas intake at the top of the apparatus along the broken line 3-3 of Figure 2;

Figure 4 is a horizontal sectional view taken at the level of line 4-4 in Figure 3;

Figure 5 is a plan view at line 5-5 of Figure 3 limited to showing half of the baffles admitting hot gases to the underside of the central cone;

Figure 6 is a view in elevation of the same baffles of Figure 5;

Figure 7 is an enlarged detail of some of the baffles of Figure 5;

Figure 8 is a top plan view of the drying gas inlet of the apparatus;

Figure 9 is a diagrammatic illustration of the air flow in the zone below the spray nozzle.

Referring now to Figures 1 to 9 of the drawings, the apparatus includes a desiccating chamber consisting of a large cylinder 10 to the bottom of which is secured a conical chamber 11. At the lower end of the cone 11 is an elbow pipe 12 connected to a riser pipe 13 through which the dried powdery material, such as milk powder, for example, and the drying gas and vapor are exhausted.

This form of my invention employs an exhaust fan to exhaust the drying chamber, causing heated air to be drawn by suction into the drying chamber in a novel controlled manner, yielding new results and advantages in spray drying technique.

Accordingly, the pipe 13 is connected to a separator, generally designated as 14, into which the powder and gases are drawn and in which the dried material is separated in any appropriate manner from the drying gases and vapor, while the gaseous material is then exhausted through conduit 15 to atmosphere by a blower 16, having an exhaust port 17 and a motor 18.

The details of construction of the separator 14 do not constitute a part of the present invention, hence the details thereof are not shown. The separator may be of the centrifugal or "cyclone" type, or it may be any other type suitable

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for a process of this character. In the drawings I have indicated a structure having an outline suggesting a cyclone separator, which will suffice to indicate the nature of the device.

Air for drying of the sprayed material may be heated prior to its admission to the drying chamber by any suitable means, such as steam coils, electrical heating elements, coils containing hot liquids or gases, or, as I have indicated in the drawings, the air may be heated by direct injection of burning fuel oil or gases. In Figure 2 the drawing shows a motor 19 driving a blower 20 to which is connected an air intake filter 21 for supplying air for the products of combustion. Gas such as ordinary city gas may be introduced and mixed in any suitable manner with this air by the blower 20 and the burning products injected into the chamber 22.

The air to be heated is drawn by suction through a pair of filters 23 and 24 into the chamber 22 where it becomes mixed with the burning gases.

By controlling the proportion and temperature of the products of combustion admixed with the air at this point, any desired and suitable temperature of the drying gases for spray drying may be obtained. For the spray drying of milk, to form a milk powder of exceptionally low moisture content I have found that if the total mixture of air and gases has an average temperature of 350° F. excellent results may be obtained.

The air thus heated, admixed with the products of combustion is then drawn by suction through the duct 25 into a distributing chamber 26, from which the major portion of the air is conducted to the central portion of the drying chamber while the remainder of the heated air is drawn into the drying chamber through an annular aperture, surrounding the main stream. To obtain this controlled admission and distribution of the air the following structure is provided.

A deck 27 (see Fig. 3) extends across the chamber 26, sealing the bottom of it, except where perforated by a central opening and by a plurality of ports such as 28 equally spaced about the deck, as shown in Figure 8. An annular rotatable valve plate is disposed upon the deck and is provided with an equal number of apertures of the same size as to ports 28. In an obvious manner this valve plate may be rotated to fully uncover all of the ports simultaneously, or to partially close all of them to any extent that may be desired, and even to close all of them completely. This valve plate is generally indicated as 29 and may be rotated by a hand operated lever 30 having its inner lower end extending into a socket 31 secured upon the valve plate and having its horizontal portion extending outwardly from the chamber 26 and thence bent to form a handle 32.

As seen in Figure 3, the deck 27 has a large central aperture from the margin of which rises a vertical annular wall 33 which is joined at its upper edge to a cone 34, the cone terminating at its lower edge 35 where it joins with a central air inlet wall 36.

As it is an object of the invention to impart to the entering heated air a vigorous whirling movement, I have provided an arrangement of inclined baffle plates such as 37 supported between an outer collar 38 and an inner collar 39, positioned as shown in the central well 36. These baffles are fixed in the well as shown and may be inclined to impart to the air either a swirling

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clockwise or counterclockwise motion. I have shown them arranged to impart a clockwise motion to the entering air as viewed from above. The air emerging from these baffles therefore enters the top of the drying chamber under vigorous agitation and all whirling in one general direction, such as clockwise. As indicated in Figure 3, this swirling heated air immediately encounters a finely divided spray of the liquid material being sprayed under pressure from one or more nozzles such as 40. Several of these nozzles may be employed, and in some instances where it is desired to obtain a spray dried mixture derived from two different liquids, one or more of the nozzles may be employed to spray the second liquid.

Below the deck 27 I have arranged another deck 41 extending from the peripheral wall 42 and with it forming a chamber beneath the deck 27. A cylindrical wall 43 located as shown and joined to the deck 41 provides an annular passage 44 through which a second stream of heated drying gases may be admitted to the drying chamber.

In order to impart a swirling motion to this second stream of heated air, I arrange, as shown in Figure 3, a plurality of inclined baffle plates such as 45 which are preferably so disposed and spaced apart as to permit air entering from the ports 28 to pass between these baffle plates and to be set in whirling or circular motion by the baffle plates before the air passes into the annular passage 44. Both streams, as they enter the drying chamber, will have the same general direction of rotary travel, that is, both clockwise, or both counterclockwise.

The second stream of air therefore enters the drying chamber in the form of an annular ring rapidly revolving in the same direction as the main stream and engaging and mixing with the latter at a substantial distance from the center of the main air stream. The functions and various purposes of this secondary air stream will be more fully described hereinafter.

In order to conserve heat the use of a certain amount of insulation in the passages for the heated air is desirable. For example, the chamber 26 is provided with a ceiling 46, above which is located another wall 47 and between them a layer 48 of insulation may be provided. The peripheral wall 49 of the chamber 26 may also be separated by a layer 50 of insulation from an exterior wall 51.

Also the ceiling of the drying chamber immediately surrounding the air inlet may be formed by a wall 52 above which is a layer of insulation 53, covered by another partition 54.

As indicated, the one or several pipes such as 55 and 56 for conducting the liquid material to the spray heads may be led into the drying chamber through a central duct 57, which may, if desired, have a central vertical partition 58. Means for regulating the flow and the pressure of the liquid material to be sprayed, or its pre-heating, if desired, do not constitute a part of this invention, hence details relating thereto will not be here described. I have indicated that valves such as 59 and 60 may be provided. If two spray heads are to be connected to one delivery pipe, such a pipe may be attached at 61 and cross connected to both valves. Pump mechanism for pumping the liquid, not being involved in the present invention, will not be particularly illustrated, but will be suggested by the unit 62 which may be considered to represent a pump for sup-

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plying liquid under pressure to the spray head 40.

In Figure 3, a deflecting cone 63 is shown slidably mounted about the central tube 57 for vertical movement by means of threaded rods 64 and 65 rotatably connected to the horizontal plate 66. Where needed this deflecting baffle may be employed both for deflecting and for partially controlling the proportioning of air flow between the main stream through the well 36 and the auxiliary stream through the channel 44.

To explain the operation of the device, the drying of whole milk in the apparatus will be described as an example. Air admitted under suction through the air filters 23 and 24, induced by the action of the exhaust fan 16 will pass through the chamber 22 where it becomes mixed with products of combustion from the burning of ordinary cooking gas or fuel oil, or some other suitable fuel. The heated air then flows into the chamber 26 (Figure 3). The major portion of the air stream enters the top of the cone 34, passing downwardly thereafter through the baffles 37 which impart to it a rapid swirling motion in a clockwise direction. This air immediately encounters the spray of milk emerging from the spray nozzles 40, and being heated to a suitable temperature such as 350° F., for example, it causes instantaneous evaporation of the finely sprayed milk. It is apparent that due to the violent agitation of the main air stream an intimate and thorough mixture of the sprayed particles and the air will take place. This will result in flash evaporation of the milk, which will produce an instantaneous temperature drop and a consequent partial vacuum around each sprayed particle. I have found that as a result of the above described effect the spray drying of the milk will usually take place at a wet bulb temperature ranging from about 105° F. to 115° F. It is apparent that these low temperatures will not injure either the flavor or the ingredients of the milk.

Upon viewing Figures 1, 3 and 9, it will be apparent that the main air stream, having a whirling motion, in a clockwise direction, for example, as it encounters the finely divided spray of milk, will gradually expand radially outwardly while continuing its circular motion. The effect obtained is that the spray of liquid particles or droplets is expanded or torn apart by the main air stream, and thoroughly mingled with the air.

In the meantime, as the main stream of air is whirling and expanding toward the periphery of the cylindrical chamber 10, its velocity in a peripheral direction is decreasing. Likewise, the rapid temperature drop resulting from flash evaporation of the milk droplets is found to reduce the temperature of this drying gas very sharply, for example, from 350° F. (dry bulb temperature) down to about 185° F. (dry bulb temperature) or 105° F. (wet bulb temperature) in the immediate vicinity of each evaporated drop.

The secondary stream of air flows down into the chamber for admixture with the air already present and encounters the main body of air at the annular zone indicated in Figures 3 and 9, in an area generally surrounding the spraying zone, thereby imparting a substantial temperature increase to the mass of swirling air, and at the same time sustaining and accelerating the rotary motion of the main stream of air.

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This increase of the average temperature of the main stream of vapor-bearing gases will lower their relative humidity, which increases their ability to absorb further moisture from any particles of milk powder which have not yet been adequately dried. Also the secondary stream of whirling gases, positively imparting increased rotary movement to the entire body of gas about a vertical axis, thereby insures more thorough mixing of the milk particles and the drying medium, greatly increases the length of travel of the solids in the air suspension, and prevents any tendency for stratification of vapor or of gases of unequal temperatures.

The rotating main stream of heated air entering the drying chamber at and near its top central portion applies a rotative force to the spray and the drying gases already present, applying this force to the top center of the entire mass, inducing it both to spin and expand. The main stream, entering centrally, mixes with and to a large extent evaporates the spray, but loses both in temperature and rotary velocity. The secondary stream restores some of this temperature, and engaging the main body as indicated, positively imparts to it a rapid rotary motion.

The combined action of the two streams of heated air is such that while the drying gases are intensely agitated in and about the spraying zone, the motion is principally rotary about the central vertical axis of the chamber. The sprayed particles, while still moist or sticky, are held down out of contact with the ceiling of the chamber and held out of contact with the side walls. The rotary motion of the gases also serves to sweep the walls clean of any particles which may strike them, and as the whole mass moves downwardly into the conical portion of the drying chamber, the generally horizontal rotary movement as well as the downward rate of travel of the gases and the suspended particles will be accelerated, thus aiding effectively the complete withdrawal of all of the dried material.

Under the action of the exhaust fan the dried particles and the gases will be exhausted through the elbow 12, the riser pipe 13, and in the separator 14, the dried powdery material will be separated from the gases, after which the gases will be discharged through the port 17. The various parts, including the elbow and riser, are so proportioned and employed that no extra blower or mechanical conveyor are needed for evacuating the powdery product.

In Figure 9, I have indicated that there are in general several types of motions of the gases and non-gaseous particles in the drying chamber, particularly in the cylindrical portion anywhere above the conical chamber 11 and below the spray nozzle. The arrows such as 66 indicate the generally horizontal rotary motion in an illustrative segment of the chamber defined by the radius lines 67 and 68. The short arrows indicate higher velocities, while the longer arrows indicate lower velocities. The arrows 69 formed of wavy lines indicate that in addition to the rotary motion there is a gradual movement of the gases and of the solid particles from the center outwardly. Of course, no attempt is made to indicate accurately the relative velocities or directions, as these are not readily capable of accurate determination or illustration.

I have found that by conducting the drying of whole milk in the manner here described it is easily possible to obtain at the separator a milk

powder with a moisture content of 2.25% and even lower, and unimpaired in color or flavor. Milk powder thus dried is suitable for packaging and storage, and may later be mixed with water to yield a fluid milk scarcely distinguishable from fresh milk.

The wet particles of sprayed milk are appropriately brought into contact with the hottest air, while the dried particles are maintained in contact with air at lower temperatures.

It is apparent that by rotating the perforated valve plate 29 it is readily possible to proportion the amount of heated drying gases admitted to the chamber in the auxiliary stream, and this will be done in order to modify the conditions within the drying chamber to obtain a most complete desiccation of the product under temperature conditions most favorable to the product. While the invention is not limited to any one relative proportion between the main and auxiliary streams I have found that for spray drying of whole milk an auxiliary stream comprising 25% and a main stream comprising 75% of the total air intake gives excellent results.

Liquid materials other than whole milk may be spray dried in this apparatus and according to the method of this invention. The quantity sprayed per hour, the amount of air flow and the temperatures of the air and of the liquids sprayed may all be varied to yield rapid desiccation to desirable final moisture contents, without clogging of the apparatus, or scorching of the product.

While I have shown and described herein preferred forms of the invention, it should be understood that considerable further modification of the method and apparatus may be employed and that such modifications are contemplated, without departing from the spirit and scope of the appended claims.

I claim as my invention:

1. In a spray drying apparatus in combination with an elongated vertically extending chamber of circular horizontal cross section, means for projecting a spray of liquid material into the upper central portion of the chamber, a central duct opening downwardly into the top central portion of the chamber, radially extending inclined baffles positioned in said duct arranged to impart a downward spiraling rotation to air flowing therethrough and to deliver downwardly into the chamber at positions closely spaced angularly about the central vertical axis of the chamber a plurality of air streams flowing obliquely with respect to a horizontal plane immediately below said duct, an annular duct surrounding the first duct having an annular bottom outlet surrounding the opening of the first duct, and means for delivering an air stream into the second duct imparting thereto a circular motion having the same rotative direction with respect to the chamber axis as said oblique air streams, the second duct discharging its rotating stream downwardly into said oblique streams.

2. In a spray drying apparatus in combination with an elongated vertically extending chamber of circular horizontal cross section, means for projecting a spray of liquid material into the upper central portion of the chamber, a central duct opening downwardly into the top central portion of the chamber, radially extending inclined baffles positioned in said duct arranged to impart a downward spiraling rotation to air flowing therethrough and to deliver downwardly into the chamber at positions closely spaced angularly about the central vertical axis of the chamber a

plurality of air streams flowing obliquely with respect to a horizontal plane immediately below said duct, an annular duct surrounding the first duct having an annular bottom outlet surrounding the opening of the first duct, baffles in the second duct positioned for imparting to an entering air stream a circular motion within the duct about its axis in the same rotative direction as said oblique air streams, the second duct discharging its air stream as an annular rotating column downwardly into said oblique streams.

3. In a spray drying apparatus in combination with an elongated vertically extending chamber of circular horizontal cross section, means for projecting a spray of liquid material into the upper central portion of the chamber, a central duct opening downwardly into the top central portion of the chamber, radially extending inclined baffles positioned in said duct arranged to impart a downward spiraling rotation to air flowing therethrough and to deliver downwardly into the chamber at positions closely spaced angularly about the central vertical axis of the chamber a plurality of air streams flowing obliquely with respect to a horizontal plane immediately below said duct, a downwardly restricted funnel shaped channel connected with the top of said duct for delivering air thereinto, an annular duct surrounding said first duct and said channel, said annular duct having baffles in its upper portion surrounding said channel for imparting to an air stream flowing through the second duct a circular motion having the same rotative direction as said oblique air streams, the second duct having an annular bottom outlet surrounding the outlet opening of the first duct for delivering said air stream as an annular rotating column downwardly into said oblique streams.

4. In a spray drying apparatus in combination with an elongated vertically extending chamber of circular horizontal cross section, means for projecting a spray of liquid material into the upper central portion of the chamber, a central duct having a portion defined by an outer cylindrical vertical wall, said duct having a bottom outlet opening downwardly into the upper central portion of the chamber, radially extending inclined baffles positioned in said duct arranged to impart a downward spiraling rotation to air flowing therethrough and to deliver downwardly into the chamber at positions closely spaced angularly about the central vertical axis of the chamber a plurality of air streams flowing obliquely with respect to a horizontal plane immediately below said duct, an annular duct surrounding the cylindrical wall of the first duct defining therewith a vertically extending annular passage, and means for delivering an air stream into the second duct imparting thereto a circular motion having the same rotative direction with respect to the chamber axis as said oblique air streams, the second duct discharging its rotating stream downwardly into said oblique streams.

5. In a spray drying apparatus in combination with an elongated vertically extending chamber of circular horizontal cross section, means for projecting a spray of liquid material into the upper central portion of the chamber, a central duct having a portion defined by an outer cylindrical vertical wall, said duct having a bottom outlet opening downwardly into the upper central portion of the chamber, radially extending inclined baffles positioned in said duct arranged to impart a downward spiraling rotation to air

flowing therethrough and to deliver downwardly into the chamber at positions closely spaced angularly about the central vertical axis of the chamber a plurality of air streams flowing obliquely with respect to a horizontal plane immediately below said duct, a downwardly restricted funnel shaped channel connected with the top of said duct for delivering air thereinto, an annular duct surrounding said first duct and said channel, said annular duct having baffles in its upper portion surrounding said channel for imparting to an air stream flowing through the second duct a circular motion having the same rotative direction as said oblique air streams, the second duct having an annular bottom outlet surrounding the outlet opening of the first duct for delivering said air stream as an annular rotating column downwardly into said oblique streams.

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