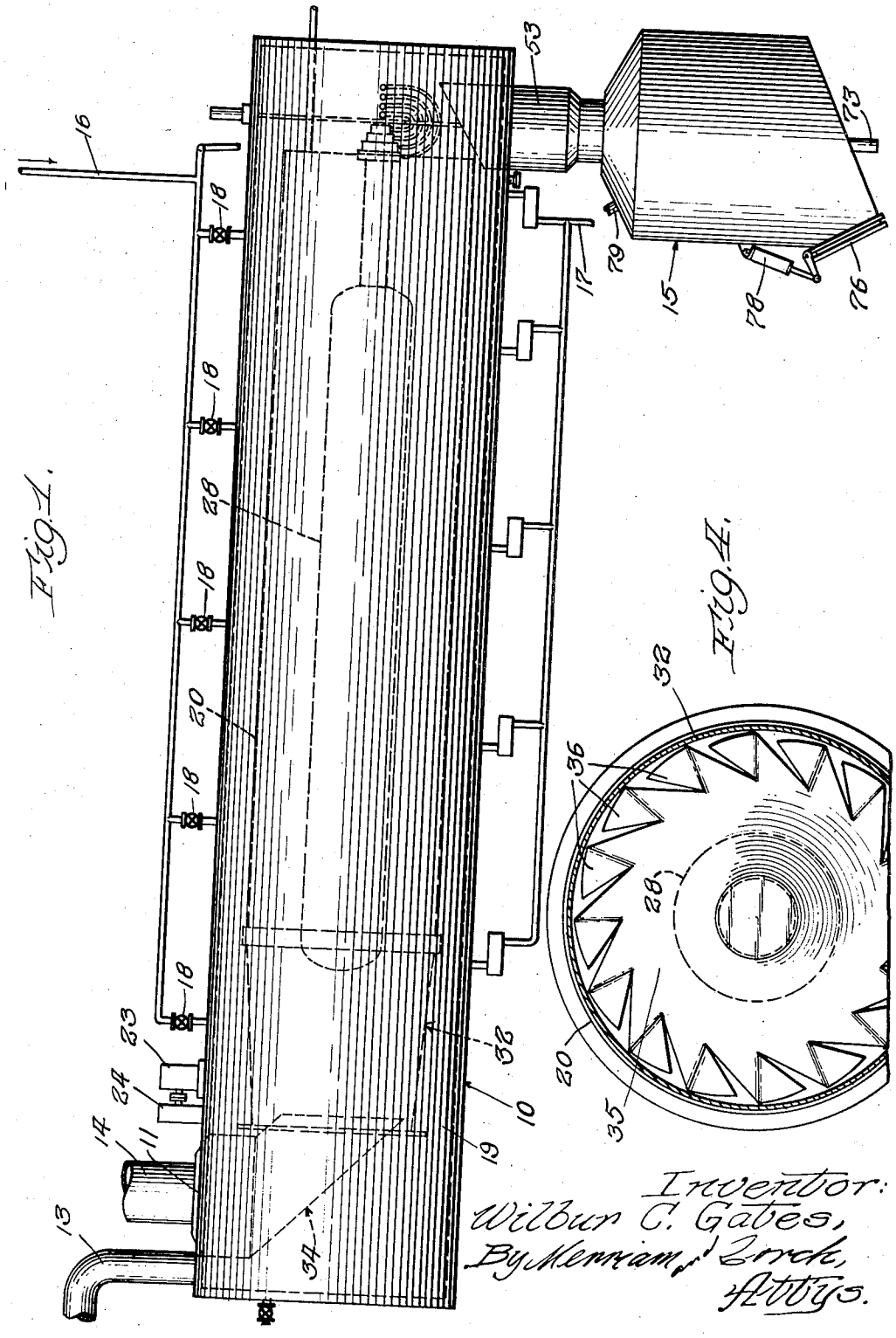
June 10, 1958 W. C. GATES 2,837,831

APPARATUS FOR VACUUM DRYING

Filed March 15, 1955 4 Sheets-Sheet 1



Inventor:
Wilbur C. Gates,
By Merriam, Smith & Lorch,
Attys.

June 10, 1958 W. C. GATES 2,837,831

APPARATUS FOR VACUUM DRYING

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Fig. 2A.

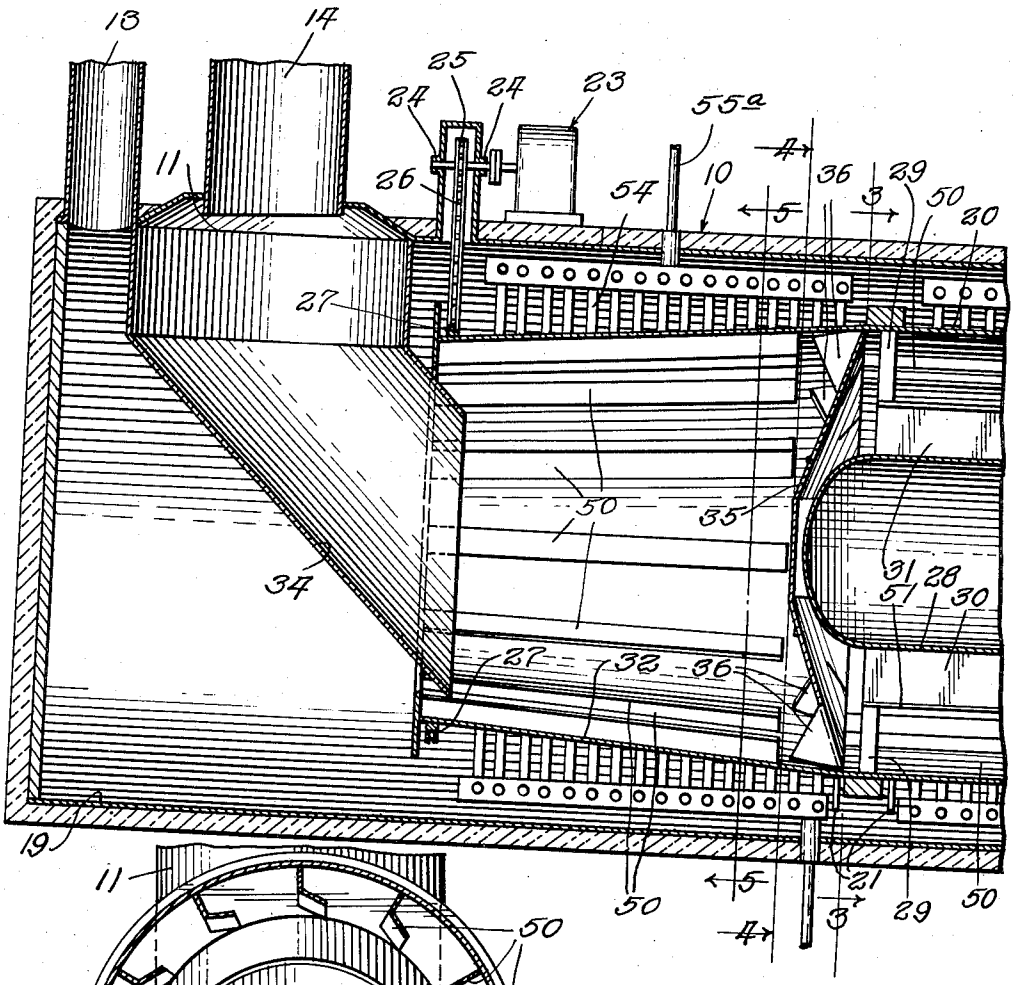


Fig. 5.

Inventor:
Wilbur C. Gates,
By Merriam, Zorch,
Attys.

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APPARATUS FOR VACUUM DRYING

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Fig. 2.

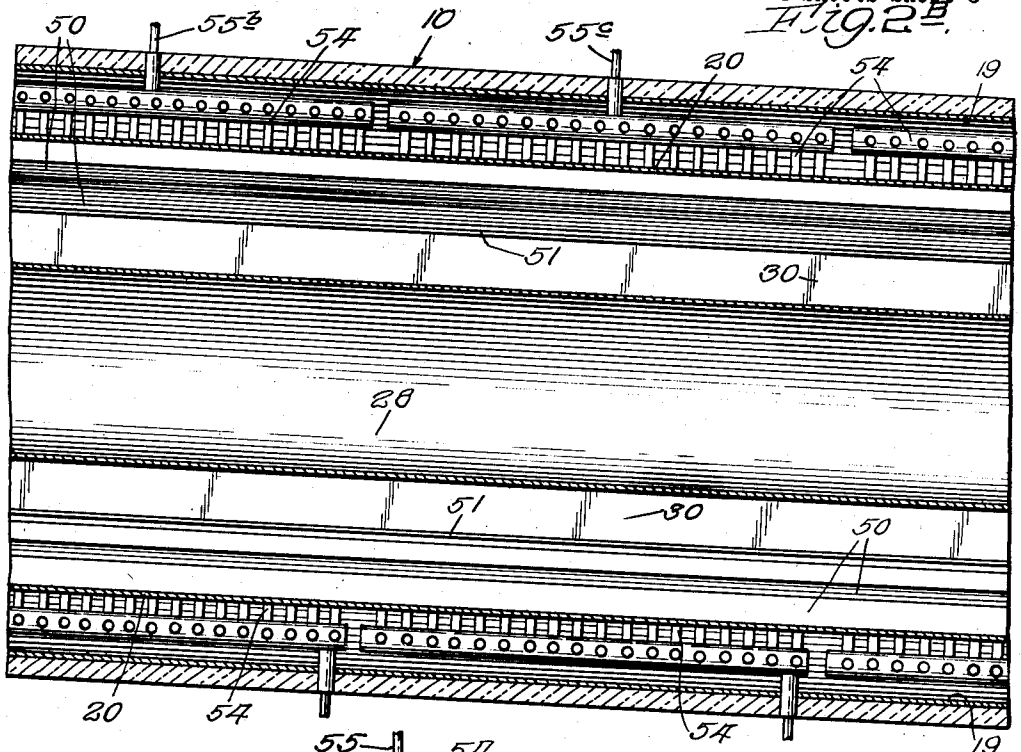
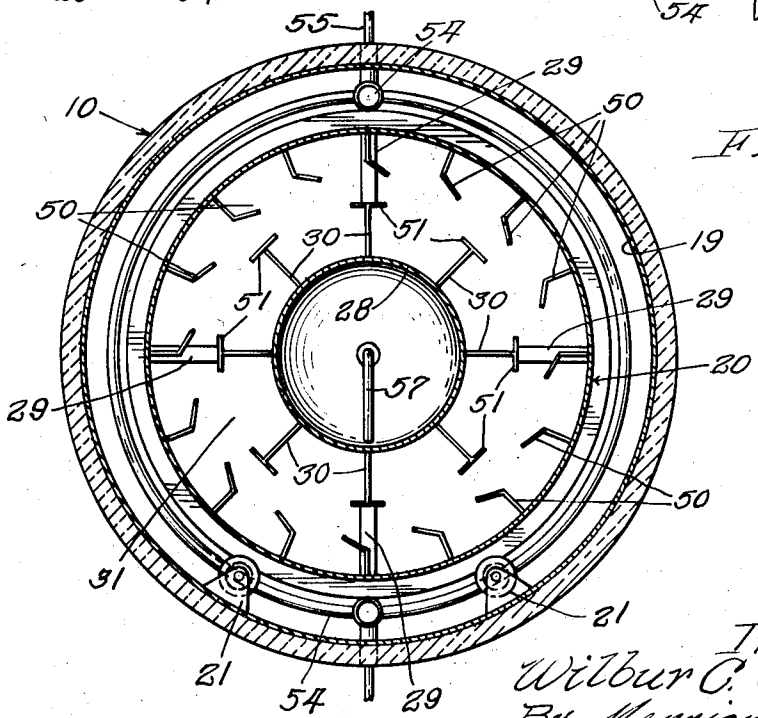


Fig. 3.



Inventor:
Wilbur C. Gates,
By Merriam, Lorch & Attys.

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APPARATUS FOR VACUUM DRYING

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Fig. 2c.

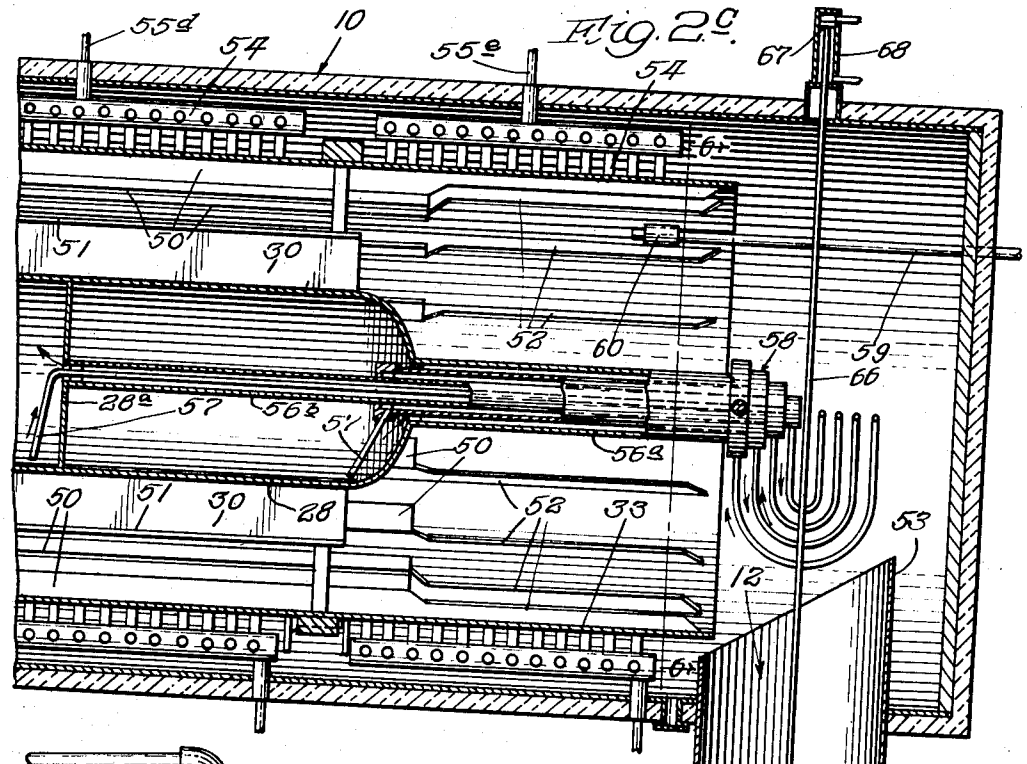
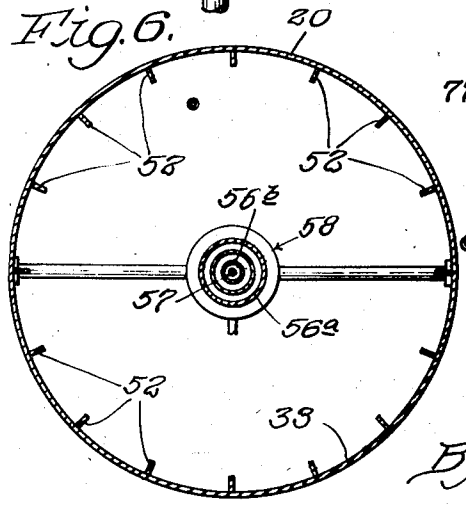


Fig. 6.



Inventor:
Wilbur C. Gates,
By Merriam, Zorck, Attys.

United States Patent Office 2,837,831 Patented June 10, 1958

2,837,831

APPARATUS FOR VACUUM DRYING

Wilbur C. Gates, Flossmoor, Ill., assignor, by direct and mesne assignments, of one-half to Chicago Bridge & Iron Company, Chicago, Ill., a corporation of Illinois, and one-half to Baerguard, Inc., Chicago, Ill., a corporation of Illinois

Application March 15, 1955, Serial No. 494,504

7 Claims. (Cl. 34—92)

This invention relates to apparatus for treating a flowable, liquid-absorbing solid material and more particularly to treating such material by moving it through a zone at a predetermined, controlled pressure condition.

The apparatus of this invention is particularly useful, for example, in the drying of a cereal such as wheat, rice, oats, and the like, particularly after such cereal has been vacuum puffed, in the drying of tobacco and in the drying of flour, powder, and the like.

As a result of the new apparatus of this invention, the following advantages are achieved when drying material: (1) matting or fusing of the moistened solids is greatly reduced; (2) scorching of the material is prevented; and (3) the rate of drying is increased as a result of tumbling of the material. If the tumbling is too violent or extreme, undesirable breakage of the product will occur. The apparatus and method of the present invention avoid such breakage.

Another advantage of the apparatus of this invention is that substantially uniform, desired "temper" or liquid content of the treated product is achieved. Careful heat profiling, i. e., regulation of the temperature of the regions through which the material passes, further aids in achieving the desired degree of substantially uniform temper.

All of these advantages are achieved by apparatus which can be operated continually without time-consuming shut downs for charging the machine with the material to be treated, removing the treated material, or any other similar step.

When the apparatus of this invention is employed for drying material, it is preferred that the controlled pressure be a vacuum. Under such condition, the following additional advantages are achieved: (1) because the vacuum condition increases the rate of evaporation, the temperature need not be raised to a high figure; and (2) the quantity of material that can be dried during a given period of time by equipment of a particular size is greatly increased; and, as a corollary, vacuum drying equipment with a particular output rate occupies very much less space than would equipment required for drying at a comparable temperature under, for example, atmospheric conditions.

Following is a detailed description of an embodiment of the apparatus of this invention which is directed to employment of the apparatus as a drier, and preferably as a vacuum drier. It is to be understood that the apparatus and method of this invention can also be employed to increase the liquid content of the material by a controlled, predetermined amount, whereby the "temper" of the treated material is substantially uniform.

The apparatus of this invention is illustrated in a preferred embodiment in the accompanying drawings and the method of this invention will be described by reference to the drawings, in which:

Figure 1 is a side elevational view of the apparatus of this invention;

Figures 2A, 2B and 2C are enlarged longitudinal sectional views of the input portion, middle portion and discharge portion, respectively, of the apparatus of Figure 1;

Figure 3 is a sectional view taken through the same apparatus along line 3—3 of Figure 2A;

Figure 4 is a sectional view taken substantially along line 4—4 of Figure 2A;

Figure 5 is a sectional view taken substantially along line 5—5 of Figure 2A; and

Figure 6 is a sectional view taken along line 6—6 of Figure 2C.

Material treating chamber

In the embodiment of the apparatus of this invention shown in Figure 1, material treating chamber 10, as here shown, is a drier and slopes downwardly slightly from input port 11 to discharge port 12. A line 13 leads from a pressure control source, as for example a vacuum pump (not shown), to the chamber 10. When a vacuum pump is employed, it is preferred that it be capable of maintaining a vacuum condition within the chamber 10 of as low as 0.1 inch of mercury absolute or lower.

The material to be dried, such as puffed rice, is introduced through input port 11 at the input end of the chamber 10 from a feed line 14, which is connected to the input port 11. In the event that a vacuum condition is maintained in the chamber 10 and the other end of the feed line 14 connects with a vacuum chamber of a vacuum puffing gun not shown in the drawings, introduction of the material will not impair the vacuum condition within chamber 10. However, if the other end of the feed line 14 is at atmospheric pressure, suitable lock means should be provided at the input port 11 to avoid any substantial impairment of the vacuum condition within the chamber 10.

Lock out chamber 15 is provided at discharge port 12 to permit removal of the dried material without any substantial change in the pressure condition within the chamber 10. The details of this lock out chamber 15 are explained in more detail below.

Various other parts of the apparatus, such as the means for achieving heat profiling within the rotatable outer drum 20 and inner drum 28, as shown in dotted lines in Figure 1, will be described in detail below.

Rotatable drums

Rotatable outer drum 20 is best seen in Figures 2A, 2B and 2C which collectively show this drum in longitudinal section rotatably mounted within chamber 10. As seen in Figure 3, outer cylindrically-shaped drum 20 is mounted within chamber 10 on four pairs of revolvable wheels 21, two pairs being positioned near one end of the outer drum 20 and the other two pairs, near the other end, as shown in Figures 2A and 2C. One wheel of each pair is located slightly to one side of the bottom of the outer drum 20.

Outer drum 20 is rotated on these wheel mountings by means of a motor 23, mounted on the top of chamber 10. The drive axle of the motor passes through hermetic rotary seals 24. Gear 25 drives chain 26, which in turn drives gear 27 attached to the rotatable outer drum 20.

Cylindrically-shaped inner drum 28 is rotatably mounted in spaced relation to and within the rotatable outer drum 20 by studs 29 which are fixedly attached to the inner drum 28 and the outer drum 20 at either end. As shown in Figure 3, inner drum 28 carries a group of tumbling vanes 30 (described in more detail below) some of which cooperate with studs 29 to aid in fixedly connecting the two drums.

The material to be dried passes through the annular space 31 between the two drums.

The slope of chamber 10 is determined by the desired slope of rotatable outer drum 20. This depends,

in turn, on the amount and type of material to be fed through the chamber **10**, rate of feed, the temperature in the chamber **10**, and the rate of rotation of the drums. When vacuum puffed rice is to be dried under a maintained vacuum condition in the chamber **10** of about 0.1 inch of mercury absolute, it is preferred that the angle of downward slope for the outer drum **20** be in the range of between one and four degrees.

Input end **32** of outer drum **20** is here shown as frustum-shaped to facilitate movement of the material to be dried into the annular space **31** between the two drums **20** and **28**. The additional downward slant assists in creating a constant rate of feed of material into annular space **31** between outer and inner drums **20** and **28**, respectively.

Output end **33** of outer drum **20** continues beyond the end of inner drum **28** with substantially the same cross sectional shape as in the first portion of the outer drum **20**.

Feed means

As previously stated, the material to be dried is introduced into the input port **11** from feed line **14**. From there it drops into an input chute **34**, through which it is fed directly into input end **32** of the rotatable drum.

As shown in Figs. 2A and 4, feed wheel **35** is provided. This wheel is fixedly attached to inner drum **28** at its input end. Blades **36** of this feed wheel are here shown as fan-shaped and assist in feeding material to be dried into annular space **31** at a uniform rate.

Tumbling vanes

Both outer drum **20** and inner drum **28** are equipped with tumbling vanes. Outer tumbling vanes **50** are mounted on the interior surface of outer drum **20**. It is preferred that the outer tumbling vanes **50** be scoop-shaped in cross section as shown in Figs. 3 and 5. As drum **20** rotates, outer tumbling vanes **50** pick up material lying on the bottom of the outer drum and carry it up into the upper portion of the annular space **31** enclosed by the inner and outer drums **28** and **20** respectively. The outer tumbling vanes in the embodiment shown run parallel to the longitudinal axis of outer drum **20**. However, they may be helical in arrangement if desired, or have any other suitable position so long as each vane runs lengthwise of outer drum **20**.

Inner tumbling vanes **30** are mounted on the outer surface of inner drum **28**. Like vanes **50**, they run lengthwise of the drum on which they are mounted. In the embodiment shown, vanes **30** are T-shaped in cross section, as best seen in Figure 3. They may, however, have a straight cross section or be of any other suitable shape, so long as they are spaced from vanes **50**.

Tumbling action

Referring to Figure 3, the flowable material carried up from the bottom of rotating outer drum **20** by outer tumbling vanes **50** will begin to spill out of these scoop-shaped vanes at some point in the side portion of annular space **31**. As any particular vane moves into the upper portion of the space enclosed by the two drums, it will spill out more and more of the material it holds. By the time an outer tumbling vane reaches the top, and starts down on the other side, all of the particles of material will have tumbled from the vane.

As the material tumbles out of vanes **50**, any portion of the material that tends to form clumps by matting or fusing of the moist solid material will tend to be separated upon falling onto the inner drum **28**. This will speed up the drying process by permitting more rapid evaporation from the smaller particles of the material than would be possible from larger clumps.

As best seen in Figure 5, outer, scoop-shaped tumbling vanes **50** extend into the input end **32** of outer drum **20**, a part of the drum into which the inner tumbling vanes **30** do not extend. Employment of these outer tumbling vanes **50** at the input end **32** of outer drum **20** results in more extreme tumbling of the material at the input end of the drier. Since the largest clumps of particles are more likely to form in this region because of the higher degree of moisture in the material at that stage and since the degree of moisture of the material is greatest, a great degree of tumbling in this region is preferred. These vanes, together with the frustum-shape of the input end **32**, also aid in achieving uniform feeding of the material into annular space **31**.

As shown in Figures 2C and 6, tumbling vanes **50** also extend into the output end of rotatable outer drum **20**. Instead of being scoop-shaped, it is preferred that these vanes be in the form of relatively low ridges **52** protruding from the inner surface of the outer drum **20**. As a result, a mild tumbling action is achieved at this end of the drum and assists in causing the dried material to empty at a uniform rate into a surge hopper **53**. This surge hopper is located immediately below the bottom of the output end of the outer drum **20**.

Limitation of maximum free fall of particles

If the tumbling produced by revolving vanes **50** and **30** is too extreme, undesirable breakage of the material being dried might result. To avoid this, it is preferred that tumbling vanes **50** be relatively closely spaced, as shown in Figure 3. Thus, even if not otherwise deflected, particles of material falling from vanes as high as position **50***a* or even position **50***b* in Figure 3 will have a fairly limited free fall before landing upon the next lower vane.

However, particles carried by vanes **50** into the extreme upper portion of the space enclosed by drum **20** would, unless otherwise deflected, have a free fall of substantially the full diameter of drum **20**. The arrangement of inner drum **28** and inner tumbling vanes **20** mounted thereon helps to avoid this by limiting the maximum free fall to which the material is subjected.

Any materials falling from outer tumbling vanes **50** after they have traveled beyond about position **50***b* will be caught by inner tumbling vanes **30** which have rotated into position **30***a* or beyond. Rotating inner drum **28** and inner tumbling vanes **30** carry this material around to the opposite side of annular space **31** and there permit it to drop to the bottom of the drum.

Cross bars **51** of each inner tumbling vane **30** helps to confine material which falls onto that vane as it rises on the ascending side. Further, it is seen that the opposite end of cross bar **51** operates on the descending side to restrain the material from sliding freely off tumbling vane **30** to drop to the bottom of the drum. Thus, tumbling produced by a drier carrying T-shaped inner tumbling vanes **30** is somewhat less active than if these vanes were simply straight members.

It is important to note that the distance between the inner surface of the outer drum and the outer surface of inner drum **28** may be varied, depending upon the type of material to be dried.

Outer tumbling vanes **50** and inner tumbling vanes **30** preferably are attached to their respective drums as by a continuous weld. This provides maximum heat transfer to the material to be dried. For the same reason, it is preferred to construct the tumbling vanes in solid form and of a metal having high heat conductance.

Heating elements

Referring to Figures 2A, 2B, and 2C, metal steam coils **54** are fixedly mounted within the chamber **10** and surround the rotatable outer drum **20**, being spaced therefrom. As here shown, these coils are arranged in separate banks surrounding different portions of outer drum **20**. Each bank is fed by a different one of lines **55***a*, **55***b*, **55***c*, **55***d*, and **55***e*, which, in turn, is connected to a steam input feed line **16** through valves **18**. Steam from a

source not shown flows through the steam input line 16, valves 18, into each bank of coils 54, and is then exhausted to the atmosphere through line 17, which is connected to the terminal of each of the bank of coils 54. Condensate formed in the coils 54 is removed through line 17, which vents to the atmosphere or a vacuum depending on the temperature conditions and pressure in the coils.

As a result, the amount of heat delivered to each bank and thus the temperature of each portion of the outer drum 20 surrounded by a bank of coils 54, may be separately controlled and profile heating of the drier achieved.

In order to achieve maximum drying rate, it is preferred to supply heat to inner drum 28. In the embodiment shown in Fig. 2C, inner drum 28 is divided into two compartments by a wall 28*a*. Each compartment is heated by means of input steam lines 56*a* and 56*b*, leading from a source of steam (not shown) through the end wall of the chamber 10, through a rotatable seal 58 (shown diagrammatically in Figure 2C) located at the closed end of the inner drum 28, and into the interior of inner drum 28. Steam line 56*b* passes through a hole in the wall 28*a* and terminates in the front compartment. Steam, flowing through input lines 56*a* and 56*b* empties into the two compartments of inner drum 28 and provides a separate source of heat to each compartment as well as to the inner vanes 30.

Spent steam and condensate formed in the interior of the inner drum 28 flows from the inner drum through an exhaust line 57, which leads from the closed end of each compartment of inner drum 28 through the rotatable seal 58 through the wall of the chamber 10 and to atmosphere or a vacuum depending on the temperature conditions and pressure in the compartments.

Within the limits imposed by the physical characteristics of the apparatus, the temperature of predetermined portions of the annular space 31 may be controlled by regulation of the amount of steam introduced into each bank of heating coils 54 and into the interior of each compartment of the inner drum 28.

Heated gas counterflow

Figure 2C shows another feature of the apparatus of this invention which may be used to greatly increase the rate of drying. This feature is the introduction into chamber 10 of a heated and/or dried gas flowing in the opposite direction from the flow of the material in the chamber 10, thus accelerating evaporation of absorbed liquid from the material to be dried.

As here shown, the gas is introduced through an input pipe 59 at the output end of chamber 10. This input pipe leads from a source of gas (not shown) through the wall of the chamber 10 at the output end and into the chamber. Nozzle 60 is attached to the end of the input pipe 59 and aids in directing the gas to flow in the annular space 31 in the opposite direction of the flow of tumbling material.

Output lock

As previously explained, the dried material flows from the output end 33 of outer drum 20 into the surge hopper 53. This hopper passes through discharge port 12 of chamber 10. The material accumulates here until it is passed through lockout chamber 15 for removal from the drier.

Bottom wall 63 of the surge hopper 53 is here shown as frustum-shaped. This forms an approach space through which the material must flow to reach the entrance to lock out chamber 15.

A metal shield member 64, here shown as conically-shaped, is so adapted that its circular edge fits snugly against walls 63. When so fitted, this shield stops the flow of material towards entrance port 65 of lock out chamber 15. The fit between shield 64 and wall 63 need be only sufficiently tight to prevent the smallest particle of the material being dried from sliding through.

Rod 66 is connected to the top of conically-shaped shield 64 and extends therefrom to a piston 67 at the upper end of the rod. This piston 67 is actuated by powered cylinder 68 and is adapted to move up and down to raise and lower shield 64.

Lock entrance port 65 is closed by a cover member 69, here shown as conical-shaped. A seal ring 70 is located about the circular entrance to lock out chamber 15. Conical-shaped cover 69 is so adapted that, when in an inverted position and pressed into the entrance to lock out chamber 15, the outer surface of the cover 69 forms a hermetically tight seal with seal ring 70. In order to open and close the entrance port 65, cover 69 is mounted on a rod 71 which terminates at a piston 72. This piston is actuated by a powered cylinder 73, and moves the cover up and down. The cover and sealing ring form a hermetic seal when the cover is in the up position.

Discharge opening 74 of lock out chamber 15 is provided with a movable cover 76 bearing against a seal ring about the opening when in closed position. Cover 76 can be opened and closed by means of movement of rod 77*a* connecting the cover 76 with piston 77, which, in turn, is actuated by a powered cylinder 78.

The same pressure condition as exists in the chamber 10 may be produced in lock out chamber 15 by means of a pressure control device (not shown) connected to the chamber by a line 79 leading from the lock out chamber 15 through T-joint 80 and valve 81 to the pressure control device. The branch of T-joint 80 opposite valve 81 is connected through valve 82 to the atmosphere.

Discharge of dried material

In operation, the desired amount of dried material is permitted to accumulate in surge hopper 53. During this period, lock out chamber 15 is connected to the pressure control source (not shown) so that the pressure within the lock out chamber is approximately the same order of magnitude as the pressure within chamber 10. Covers 69 and 76 are, of course, kept closed during this operation.

When the material is to be passed into the lock out chamber 15, cover 69 is opened, i. e., as here shown, moved downwardly, and shield member 64 is raised from its closed position of contact with approach wall 63. The dried material may then pass freely into the lock out chamber 15.

When the desired amount of material has accumulated in lock out chamber 15, shield member 64 is first returned to its closed position, cutting off the flow of the material through entrance port 65. Cover 69 is closed after shield member 64 is moved into its closed position. By so doing, no solid material can become entrapped between cover 69 and seal ring 70 when the cover is moved into its closed position.

When cover 69 is in closed position, valve 81 is then closed, shutting off the pressure control source and valve 82 is opened to the atmosphere. This brings lock out chamber 15 to atmospheric pressure. Cover 76 is then opened to permit the dried material to flow out. When lock out chamber 15 is empty, the cycle may be repeated.

Heat profiling

As explained above, different amounts of steam may be introduced through feed pipes 55*a*, 55*b*, 55*c*, 55*d*, and 55*e*. The amount of steam introduced determines the temperature of the respective banks of steam coils which in turn determines the temperature in predetermined portions of the annular space 31 enclosed between the outer drum 20 and inner drum 28. This makes possible accurate "heat profiling," i. e., regulation of the temperature of different zones within the annular space 31, because the

major heat transfer from steam coils **54** is effected through radiation of heat upon the wall of outer drum **20**.

At the input end of outer drum **20**, where the degree of moisture is the highest, it is preferred that the temperature be maintained at a higher level than in subsequent portions within annular space **31**. As the material to be dried moves through annular space **31** towards the output end of the chamber **10**, it becomes progressively less moist. To avoid overheating of a cereal towards the end of the drying process, it is preferred that the temperature of each successive zone within the annular space **31** be successively lower than the temperature of the preceding zone.

The apparatus of this invention may be used to produce a controlled rate of evaporation of moisture from the material being dried. The accuracy of this control of evaporation rate is enhanced by the combination of heat profiling with drying under vacuum conditions, the pressure control source being a vacuum pump. In the drying of cereals, and particularly vacuum puffed cereals, it is preferred to maintain a vacuum condition in the chamber **10**.

In turn, the carefully controlled evaporation rate permits control, to within quite narrow limits, of substantially uniform "temper" or moisture content of the dried material discharged from the apparatus.

Additional accuracy of heat profiling is achieved by controlling the amount of steam delivered to each compartment of the inner drum **28** through steam pipes **56*a*** and **56*b***.

In the drying of tobacco, as well as cereals, it is often desirable to toast the substantially uniformly tempered flowable material. This is readily achieved by so controlling the amount of steam in at least the last bank of coils **54**, such as that fed by line **55*e***, and the amount of steam in pipe **56*a*** leading into the end compartment of the inner drum **28**, that the temperature of the end wall portions of outer drum **20** and inner drum **28** are high enough to toast the material to the desired degree. By virtue of the profile heating, the controlled pressure condition in the chamber **10** and the tumbling action, substantially uniform toasting is achieved.

Continuous operation

The apparatus of this invention has been used to dry puffed cereals, such as rice, wheat, etc., with excellent results. It may also be used very satisfactorily to dry tobacco in both shredded and leaf form as well as powder and flour.

It is seen that all such materials may be dried in an uninterrupted continuous operation in which the moist, solid, flowable material is continuously introduced at one end of the apparatus and is periodically discharged through discharge port **12** at the other.

The above detailed description of this invention is given for clearness of understanding only. No unnecessary limitations should be understood therefrom, as modifications will be obvious to those skilled in the art.

I claim:

1. An apparatus for treating flowable, liquid-absorbing solid material, which comprises: an elongated hermetically sealed material treating chamber, means for controlling the pressure in the chamber, an input port at one end of the chamber and an output port at the other end of the chamber, an outer drum and an inner drum arranged concentrically to each other and longitudinally aligned in the chamber, the outer drum having a receiving end and a discharge end, the inner drum being fixedly attached to the outer drum to form a drum unit, means for concentrically rotating the drum unit, the inner side of the outer drum and the outer side of the inner drum having means for tumbling material in the drum unit, means for feeding material from the input port to the receiving end of the outer drum, means for progressively conveying the material from the receiving end of the outer drum, between the outer and inner drums, and out the discharge end of the outer drum, means communicating with the discharge end and output port, and heating means provided in the chamber between the inner chamber wall and the outside of the outer drum, said heating means having means for heating portions of the outer drum to different predetermined temperatures.

2. The apparatus of claim 1 in which the inner drum is closed at both ends and has heating means inside.

3. The apparatus of claim 1 in which the inner drum is shorter than the outer drum and is positioned intermediate the ends of the outer drum, the inner drum being closed at both ends.

4. The apparatus of claim 1 in which the receiving end of the outer drum is frustum shaped.

5. The apparatus of claim 1 in which the inner drum is shorter than the outer drum, one end of the inner drum being positioned inside the outer drum and spatially positioned from the receiving end of the outer drum, and a feed wheel in the outer drum positioned about at the said end of the inner drum, said feed wheel being fixed to rotate simultaneously with the drum unit.

6. The apparatus of claim 1 in which the output port has means communicating with a lock out chamber, said means containing at least two valves, one of said valves being capable of stopping passage of flowable solid material without forming a hermetic seal, the second of said valves being placed in said communicating means subsequent to the first valve and having means for creating a hermetic seal.

7. An apparatus for treating flowable, liquid-absorbing solid material, which comprises: an elongated hermetically sealed material treating chamber, means for controlling the pressure in the chamber, an input port at one end of the chamber and an output port at the other end of the chamber, an outer drum and an inner drum arranged concentrically to each other and longitudinally aligned in the chamber, the outer drum having a receiving end and a discharge end, the inner drum being fixedly attached to the outer drum to form a drum unit, said inner drum being shorter than the outer drum, one end of the inner drum being positioned inside the outer drum and spatially positioned from the receiving end of the outer drum, means for concentrically rotating the drum unit, the inner side of the outer drum and the outer side of the inner drum having means for tumbling material in the drum unit, feed wheel in the outer drum positioned about at the said end of the inner drum, said feed wheel being fixed to rotate simultaneously with the drum unit, means for feeding material from the input port to the receiving end of the outer drum, means for progressively conveying the material from the receiving end of the outer drum, between the outer and inner drums, and out the discharge end of the outer drum, and means communicating with the discharge end and output port.

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