Feb. 9, 1960 W. E. CONLEY ET AL 2,924,271

CONTINUOUS VACUUM DEHYDRATOR

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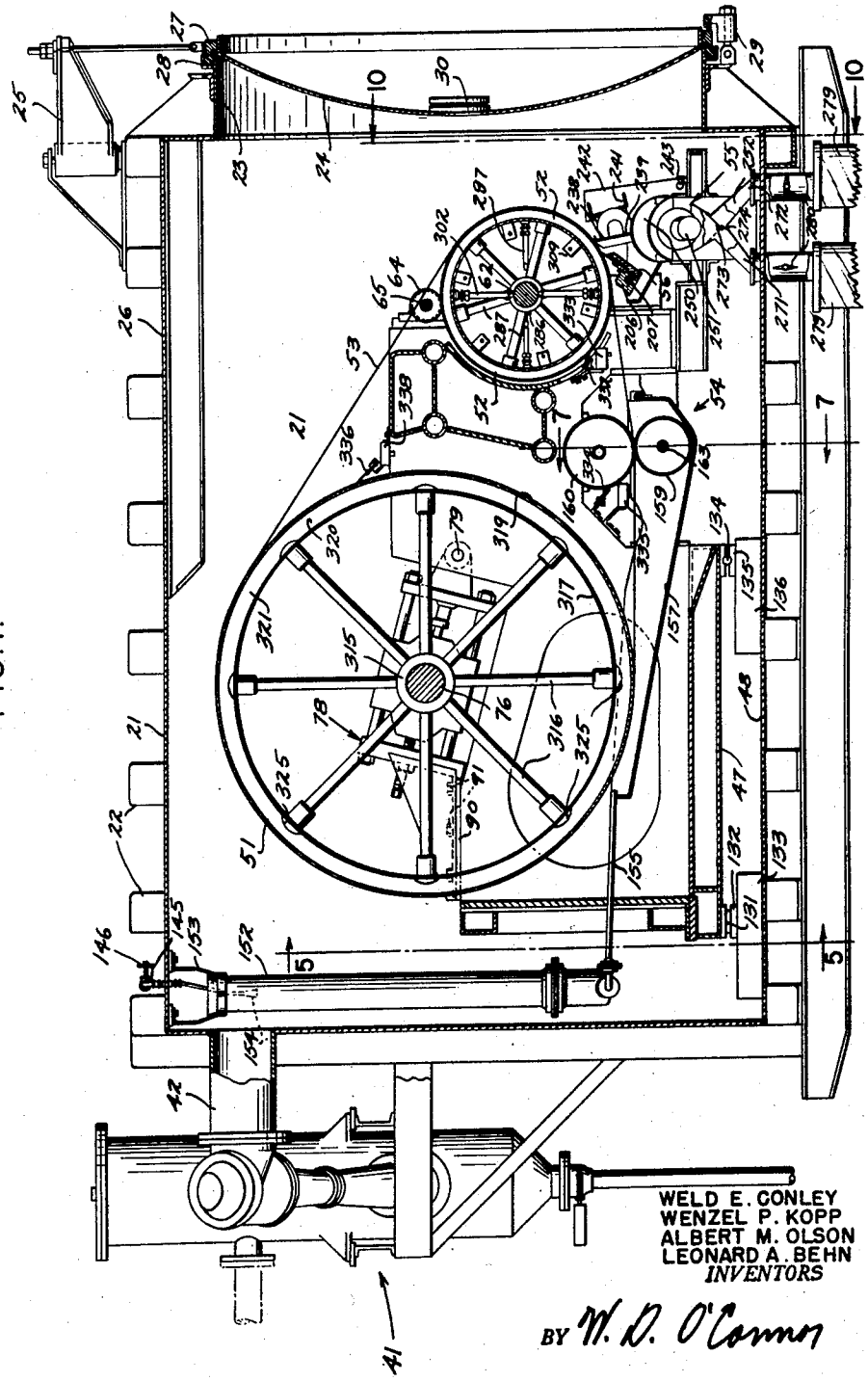

FIG. 1.

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FIG. 2.

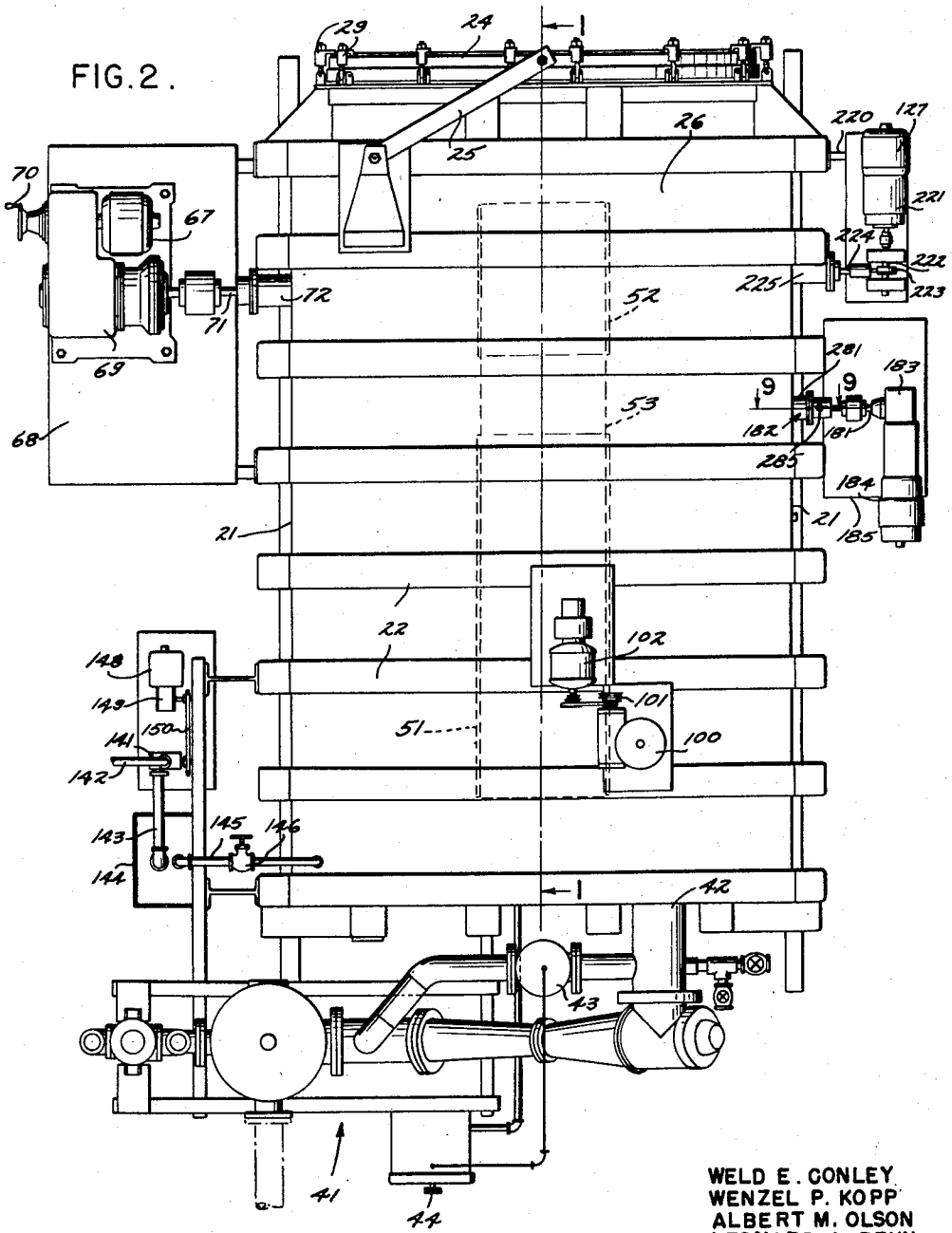

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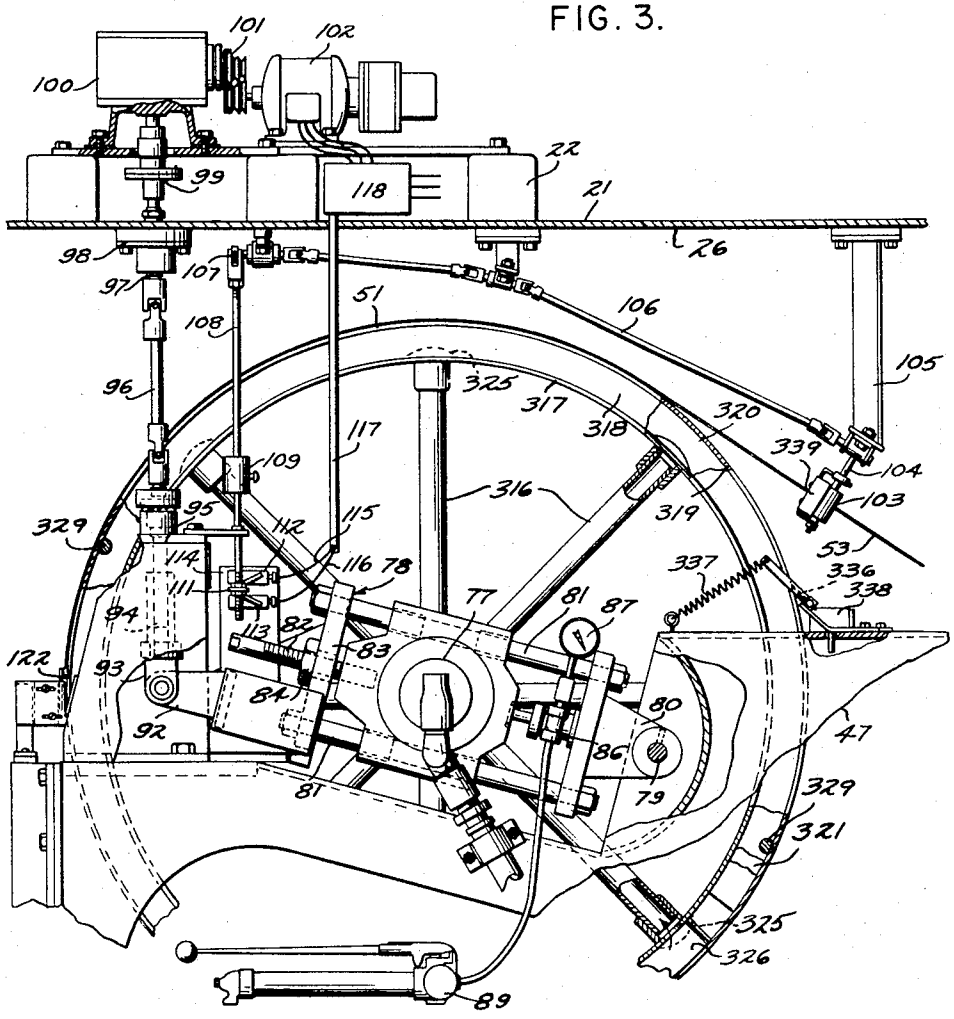
FIG. 3.



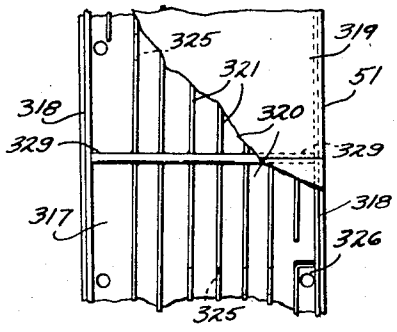


FIG. 4.

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FIG. 5.

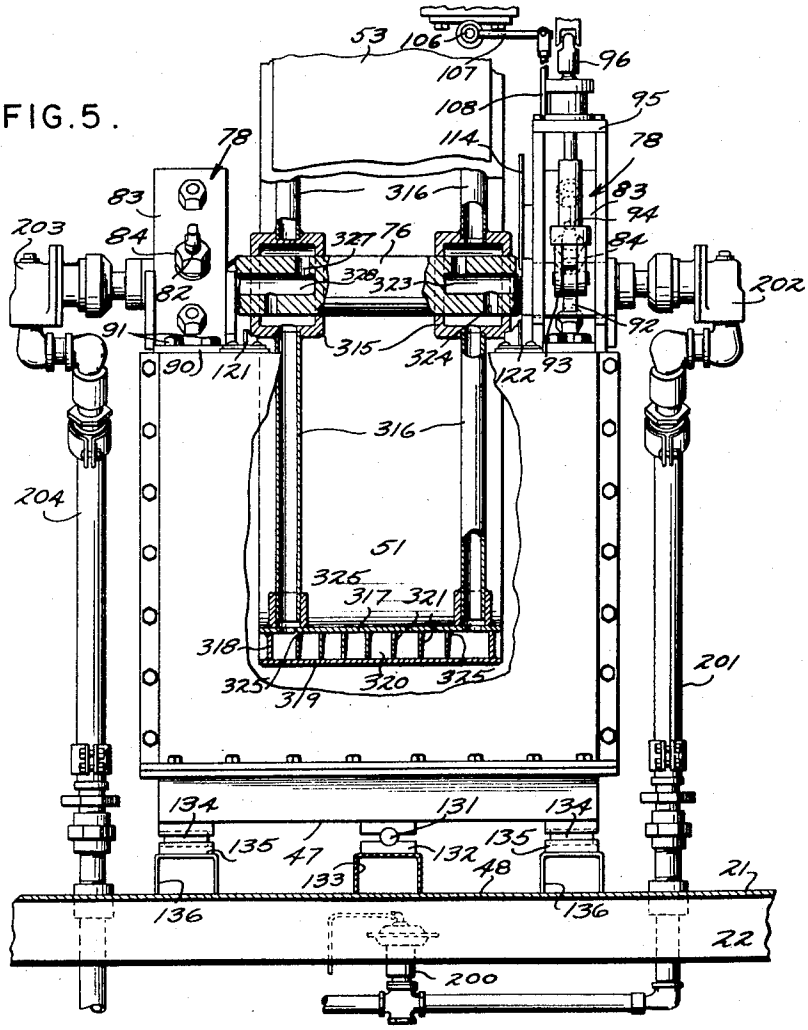
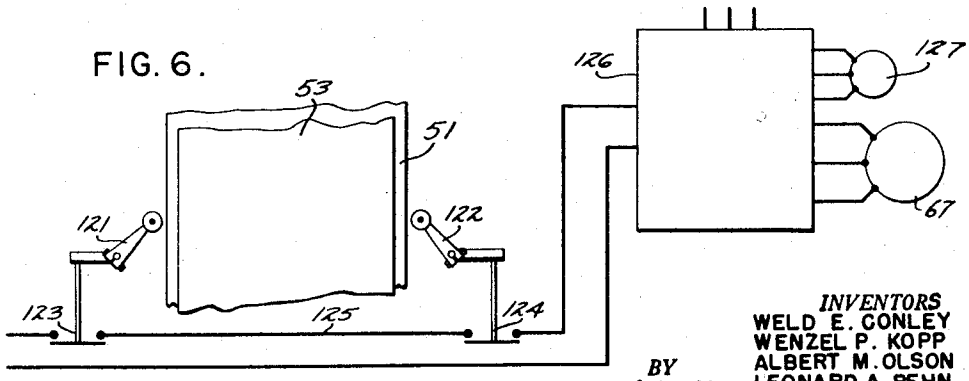


FIG. 6.



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CONTINUOUS VACUUM DEHYDRATOR

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FIG. 7.

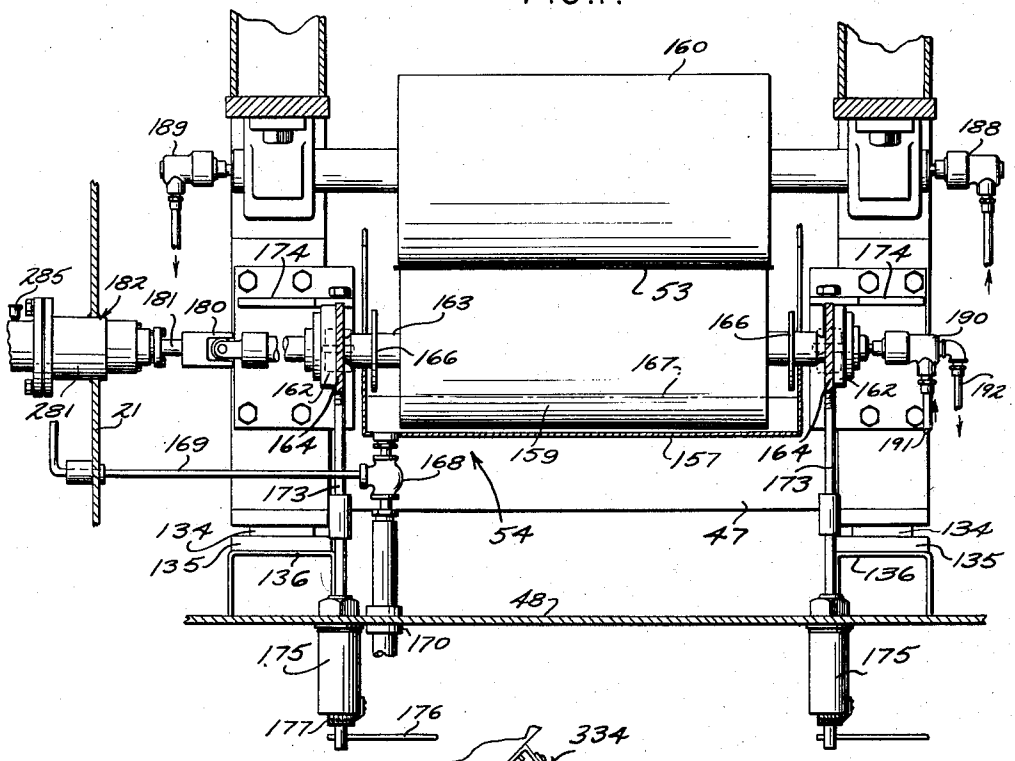

FIG. 8.

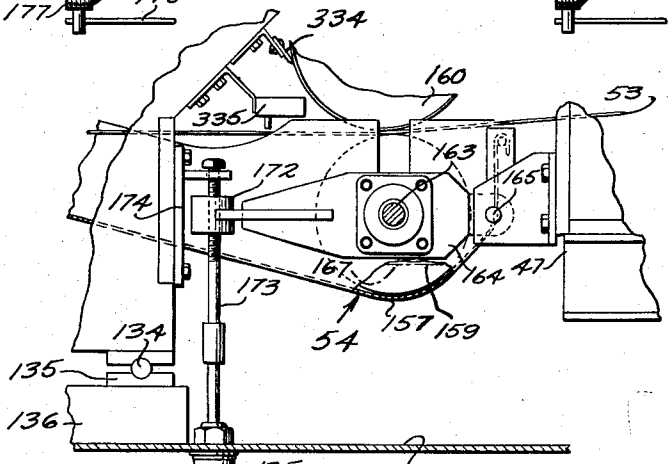

FIG. 9.

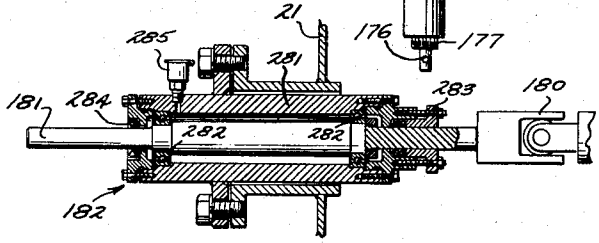

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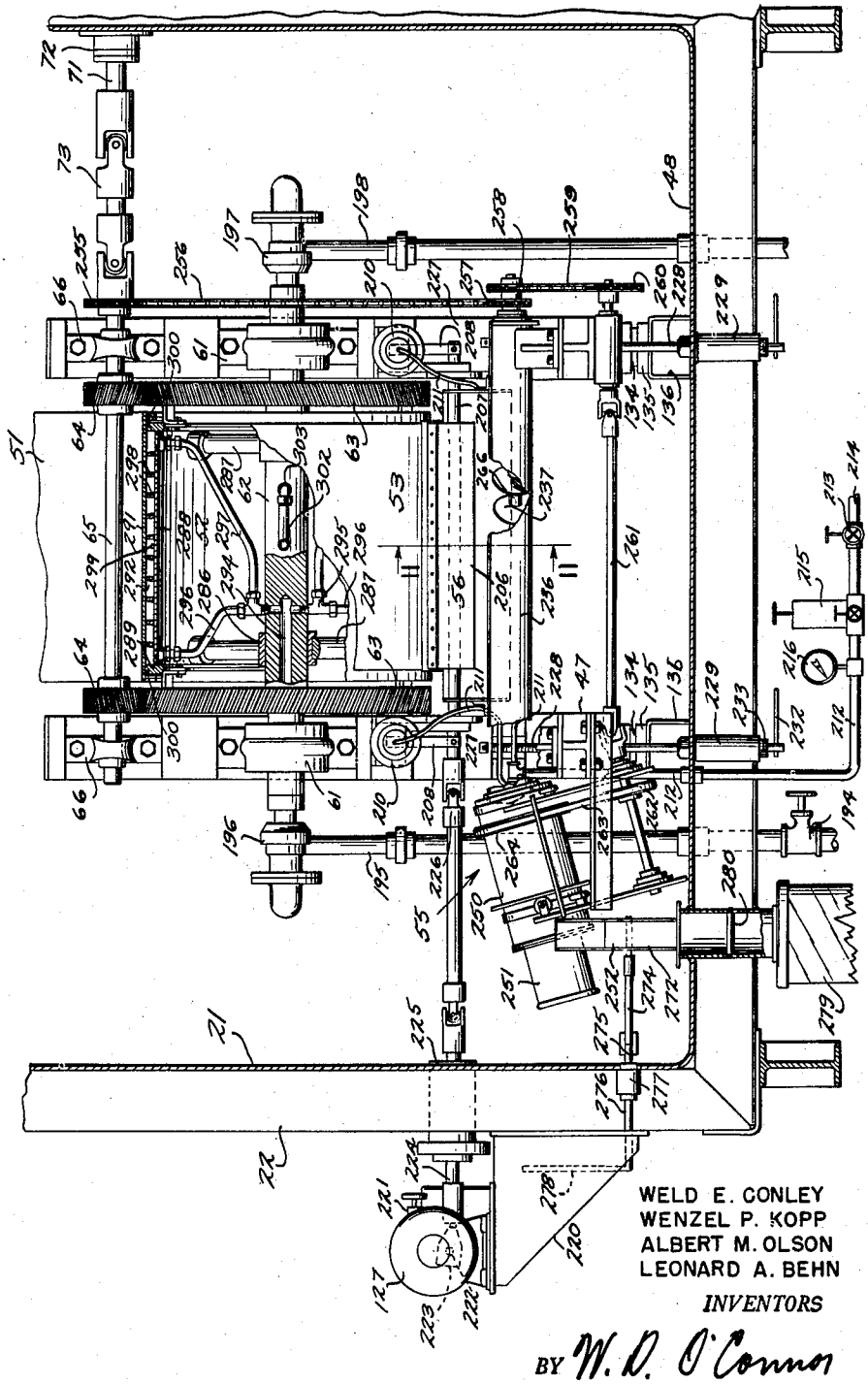
FIG. 10.



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CONTINUOUS VACUUM DEHYDRATOR

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FIG. 11.

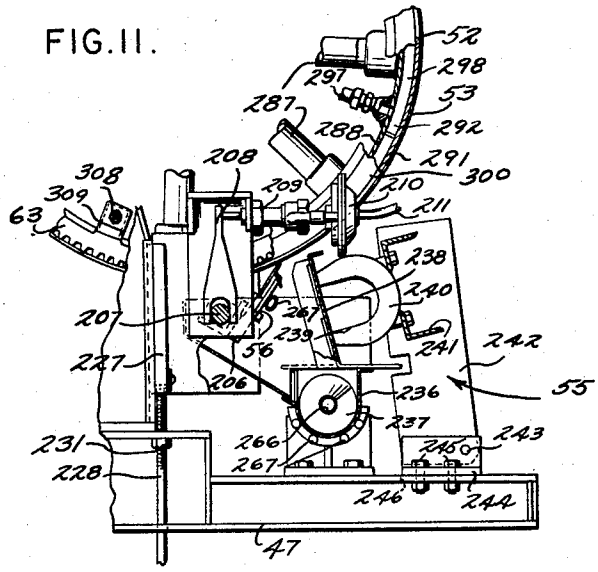
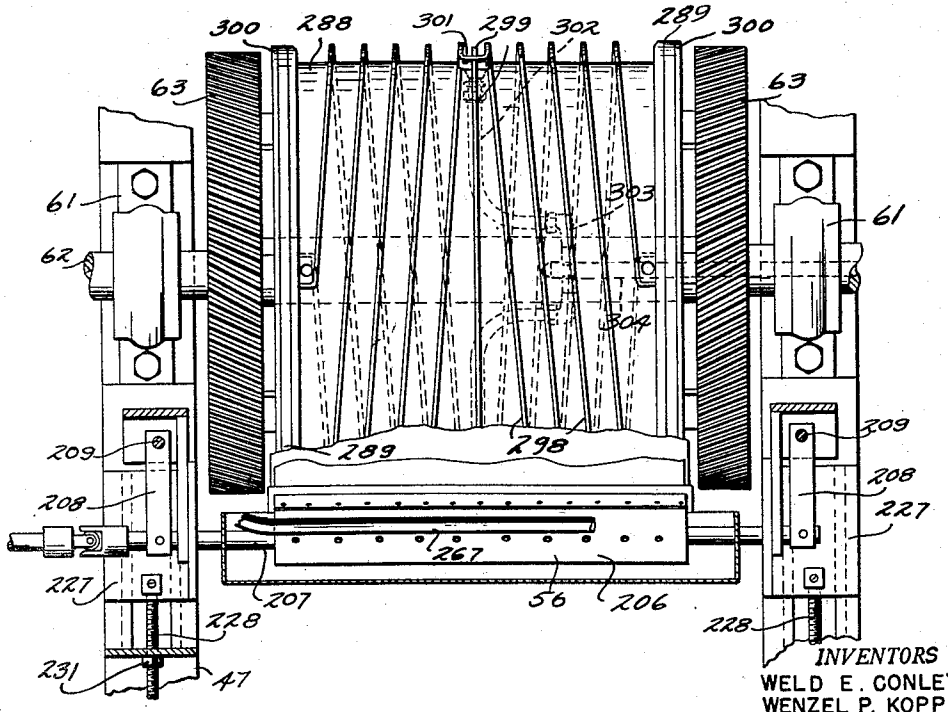


FIG. 12.



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United States Patent Office 2,924,271 Patented Feb. 9, 1960

2,924,271

CONTINUOUS VACUUM DEHYDRATOR

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Application June 26, 1953, Serial No. 364,458

20 Claims. (Cl. 159—7)

This invention relates, generally, to apparatus for dehydrating materials and more particularly to an improved low temperature vacuum dehydrator having a continuously moving belt on which the material reposes while it is being dried.

In drying various materials a great many variables are encountered and it is found that almost every material presents a peculiar drying problem. Materials that are heat sensitive must be dried at low temperatures while some materials must be dried in an air-free atmosphere and some must be cooled immediately after drying to prevent deterioration. Heretofore the successful drying of certain sensitive materials has been accomplished, if at all, only is small quantities and at great expense. Still other materials, while dried commercially, suffer greatly by loss of properties during drying and the product is not well accepted. Consequently the need for economical low temperature drying apparatus is urgent and has been recognized for many years.

It is therefore a general object of the present invention to provide an improved vacuum dehydrator that is particularly adapted to effect economical dehydration of sensitive materials.

Another object of the invention is to provide an improved continuous dehydrator for a variety of sensitive materials so arranged that the drying pressure, the drying temperature and the drying rate as well as the temperature of the dried product and other factors may be varied and closely controlled to suit the particular material being dried.

Another object is to provide a dehydrator capable of rapidly applying heat to the material being dried and then rapidly cooling the dried material in a manner to hold the drying temperature and the drying time at a minimum to best preserve the qualities of the product.

Another object is to provide a dehydrator arranged to dry material continuously from a thin film at low temperature in a vacuum under aseptic conditions, the dried product being cooled rapidly and delivered as discrete, crystalline particles forming a highly soluble powder that is easily transported and stored.

A further object is to provide an improved dehydrator so arranged that its various conditions of operation may be regulated as necessary to adapt the drying process to the special requirements of the particular material being dried for effecting dehydration with the least possible deleterious effect upon the product.

According to this invention, improved apparatus is provided to effect drying of heat sensitive materials and the like under aseptic conditions at low pressure and temperature and out of contact with air. The drying is accomplished continuously from a thin film of wet material on a traveling belt conveyer in a vacuum chamber with the degree of vacuum, the speed of the belt and various other factors under control from the exterior of the chamber. Heat for vaporizing the liquid content is provided by means of a heating drum over which the belt

travels, the temperature of the drum being controlled to effect the transfer of vaporizing heat as rapidly as possible without deleteriously increasing the temperature of the material. A cooling drum constituting the second belt pulley, cools the material on the belt as rapidly as required for limiting the time during which it is exposed to the heating action and for preparing the material for removal from the belt. By this arrangement, the material is dried to the desired degree at a low temperature in the shortest practical period of time to avoid deterioration.

The prepared material to be dried is fed into the vacuum chamber in liquid form and is preferably deaerated to reduce its tendency to foam under vacuum. The liquid material then enters a feed pan and is applied to the outer surface of the drying belt on the under side of the conveyer by means of a feeding roller. To regulate the thickness of the film of material on the belt the clearance space between the roller and the belt may be adjusted, together with the speed of rotation of the roller. Both of these adjustments may be made from the exterior of the vacuum chamber while the apparatus is operating. A backing drum is provilded on the upper or inner side of the lower belt run in the region of the feed roller to maintain the belt flat and in a predetermined relationship with the roller. Both the backing drum and the feeding roller may be provided with heating or cooling means to adapt their temperatures to the requirements of the material being dried. While passing over the cooling drum, the dried material is removed from the belt by means of an oscillating doctor blade. The angle of contact of the doctor blade and the pressure with which it engages the belt as well as the rate of oscillation are all adjustable from the exterior of the chamber. By suitably adjusting the degree of vacuum, the drying temperature, the drying time, and other factors in accordance with the requirements of the particular material being dried, the moisture content thereof may be reduced to the extent necessary to insure proper keeping qualities while preserving the potency and flavor of the dried material. Cooling of the material as it is scraped from the belt also facilitates its removal and assists in the formation of particles having large surface areas, making them quickly soluble. The drying belt is maintained under tension and is guided by an automatic tracking mechanism in running over the heating and cooling drums. The frame for supporting the drums and the belt is a rigid structure that rests on three points of support within the vacuum chamber in a manner to be free from deleterious distortions resulting from the effect of changes of temperature and pressure upon the structure of the chamber.

By reason of these several features of the improved dehydrating apparatus, the particular requirements of any of various materials being dried may be accommodated through suitably adjusting the elements of the mechanism to operate in the manner best suited to effect drying to the desired degree with the least detrimental effect upon the product.

The foregoing and other objects of this invention will become more fully apparent as the following detailed description of an exemplary embodiment thereof in an improved vacuum dehydrator is read in conjunction with the accompanying illustrative drawings, wherein:

Figure 1 is a view in longitudinal vertical section through an improved vacuum dehydrator embodying the present invention, taken on the plane represented by the line 1—1 in Fig. 2;

Fig. 2 is a plan view of the vacuum dehydrator showing the general arrangement of the housing and the exterior auxiliary equipment;

Fig. 3 is an enlarged view in side elevation of part of the interior equipment illustrated in Fig. 1 and showing particularly the heating drum and the arrangement for tensioning and guiding the conveyer belt, some parts having been broken away;

Fig. 4 is a fragmentary view of a segment of the heating drum face with part of the outer shell broken away to show the helical baffle plates;

Fig. 5 is a view in transverse section through the heating drum and its supporting structure, taken generally on the plane represented by the line 5—5 in Fig. 1, some parts having been broken away;

Fig. 6 is a circuit diagram of limit switch control apparatus for stopping the machine in the event the belt runs off either edge of the heating drum;

Fig. 7 is a view in transverse section through the apparatus in the region of the feeding roller, taken generally on the plane represented by the line 7—7 in Fig. 1;

Fig. 8 is a fragmentary view showing the feeding roller adjusting mechanism as viewed from the left end in Fig. 7;

Fig. 9 is an enlarged view in longitudinal section through the sealed shaft bearing shown in Figs. 2 and 7, the view being taken on the plane represented by the line 9—9 in Fig. 2.

Fig. 10 is a view in transverse section through the dehydrating apparatus in the region of the cooling drum taken generally on the plane represented by the line 10—10 in Fig. 1, some parts having been broken away;

Fig. 11 is a fragmentary view mostly in longitudinal section through the apparatus in the region of the product removal mechanism, taken generally on the plane represented by the line 11—11 in Fig. 10; and,

Fig. 12 is another view in transverse section in the region of the cooling drum as it is shown in Fig. 10 with part of the outer drum shell broken away to show the double helix baffle arrangement.

The improved vacuum dehydrator shown in the drawings as exemplifying the present invention is arranged for continuous drying in air-free aseptic surroundings under operating conditions that are closely controlled and readily adjustable for accommodating the drying process to the special characteristics and requirements of the particular material being dried. By effecting the drying operation as rapidly as possible under close control of the temperature, pressure and other variable conditions, it is possible to produce powder dry, high soluble products while at the same time avoiding deterioration of heat sensitive materials and the like. The apparatus is especially arranged to provide for convenient adjustment of the various drying conditions and the final temperature of the dried product whereby the drying time and other important variables may be so regulated as best to suit the requirements of the particular material being dried.

Referring more particularly to the drawings and especially to Figs. 1 and 2 thereof, the improved dehydrator there shown is capable of continuous operation and is especially adapted to facilitate the dehydration of perishable materials. The apparatus comprises in general a relatively large housing 21 that constitutes the vacuum chamber and encloses an improved double drum and belt operating mechanism. As appears in the drawings, the housing 21 is of generally rectangular shape and is formed of welded steel plates suitably reinforced on the exterior by spaced beams 22 that strengthen the flat surfaces for better resisting the external atmospheric pressure encountered when the chamber is evacuated.

To permit moving the internal operating mechanism into and out of the vacuum chamber, the housing 21 is provided at one end with a large access opening 23. As shown, the opening 23 is normally closed by a cooperating door 24 that is suspended from the outer end of a crane arm 25 pivotally mounted on the top 26 of the housing 21. By means of the crane arm 25, the door 24

may be swung to the side of the machine and entirely clear of the opening 23. The door 24 is circular in shape and is provided with a circumferential, axially extending flange 27 arranged to abut against a complementary circular gasket 28 mounted on the end of the housing and encircling the opening 23, the door being held in closed position against the gasket by a series of screw clamps 29. Furthermore, when the chamber is evacuated, the door 24 is pressed strongly against the gasket 28 by the external atmospheric pressure.

An observation window 30 is provided in the center of the door 24 to enable observation of the operation of the mechanism within the housing. Other similar windows (not shown) are provided at various appropriate positions in the walls of the housing 21 to provide for observation of various parts of the apparatus from different angles.

The housing 21 may be evacuated through operation of a vacuum producing and regulating system comprising in this instance a multiple stage steam jet vacuum pump indicated generally by the reference numeral 41 and that is connected to the housing by means of a relatively large suction pipe 42. For regulating the degree of vacuum within the housing 21, the vacuum producing system 41 is provided with a bypass regulator, indicated in Fig. 2 by the numeral 43, that may be adjusted during operation by manipulating a control knob 44 and that functions to maintain automatically any desired degree of vacuum within the housing 21 up to the limit of the capacity of the pump 41.

The material supporting apparatus within the housing 21 comprises essentially a belt conveyer carried by a rigid steel frame 47 that rests upon the floor 48 of the housing 21, as shown in Fig. 1. The conveyer consists of a relatively large heating drum 51 that is rotatably mounted with its axis horizontal in the frame 47 and a cooperating relatively small cooling drum 52 likewise rotatably mounted in the frame 47 and positioned in parallel horizontally spaced relationship with the heating drum 51. The spaced drums 51 and 52 carry a conveyer belt 53 that operates over them to carry the material being dried. The belt 53 is preferably a continuous band of relatively thin, stainless steel or equivalent material arranged with its lower run disposed substantially horizontal and maintained under tension by reaction of the rigid frame 47 that carries the drums 51 and 52. The material to be dried is applied to the under side of the conveyer in liquid form by means of a feeding mechanism 54 that feeds it to the under or outer surface of the lower horizontal run of the belt 53. As the material is carried by the belt around the heating drum 51, the water vapor or other solvent is extracted by the action of the vacuum in the chamber operating in conjunction with the heat of vaporization supplied by the heating effect of the drum. Since the drying heat is absorbed as the latent heat of vaporization of the liquid content, the temperature of the material being dried remains substantially equal to the vaporizing temperature at the pressure obtaining within the vacuum chamber until most of the liquid evaporates.

After passing over the heating drum, the belt 53 carries the warm dried material around the cooling drum 52 to cool it as quickly as possible and to condition it for removal from the belt by a product removal apparatus 55 including a doctor blade 56 that scrapes the dried material from the belt just before the belt leaves the cooling drum. As appears in Fig. 1, the elements of the conveyer mechanism and the frame 47 may be removed from or installed in the housing 21 by passing them through the large access opening 23 whenever necessary in connection with the assemblying or maintenance of the dehydrating apparatus.

The cooling drum 52 is rotatably mounted in horizontally spaced parallel relationship with the heating drum 51 by means of bearings 61 that are fixed in the respective sides of the supporting frame 47 and that engage

journals on the ends of a shaft 62 extending through and carrying hub members for the drum 52, as best shown in Fig. 10. The drum 52 is provided on each end with a driving gear 63, the gears being substantially equal in diameter to the diameter of the drum. Each gear 63 is engaged by a meshing pinion 64, both of said pinions being mounted on a countershaft 65 disposed above and parallel with the drum 52 and rotatably supported in bearings 66 mounted on the opposite sides of the frame 47 above the drum bearings 61. The gears 63 and pinions 64 are preferably of the helical type and the shaft 65 is arranged for limited endwise movement to provide for equalized driving action at the respective ends of the drum.

Power for driving the countershaft 65 is derived from a main driving motor 67 mounted on the outside of the housing 21 by means of a supporting bracket 68 as best shown in Fig. 2. A variable speed reducing mechanism 69 also mounted on the bracket 68 is driven by the motor 67 and is adjustable to regulate the speed of the belt 53 by means of a hand wheel 70. From the speed regulating mechanism 69 a shaft 71 projects through the side wall of the housing 21 into the vacuum chamber, a suitable packing gland or sealed bearing 72 being provided to prevent leakage of air into the housing along the shaft. Within the housing, the shaft 71 is connected, as shown in Fig. 10, to the adjacent end of the countershaft 65 by means of a universal joint coupling or connector 73 that provides for relative movement between the wall of the housing 21 and the conveyer supporting frame 47 without danger of exerting binding or cramping action on the shafts. By this arrangement, power for driving the conveyer including the two spaced drums 51 and 52 and the belt 53 is applied to the apparatus in the region where the greatest resistance is encountered. As appears in the drawing, the frictional or dragging action of the doctor blade 56 on the belt 53 in scraping the dried product from the belt occurs at the cooling drum and by driving this drum, the tension in the belt in transmitting power between the drums is minimized.

The heating drum 51 is carried on a through shaft 76 that supports hub elements at the respective ends of the drum and is provided on its extending ends with journals rotatably mounted in bearings 77. As best shown in Fig. 3, the housings of the bearings 77 are slidably mounted in yokes or brackets 78 constituting subframes that are in turn pivotally mounted on pins 79 fitted in the sides of the frame 47 at positions spaced from the drum axis. As shown, each subframe or yoke 78 comprises an end plate or base 80 that receives one of the pivot pins 79 and carries upper and lower guide bars 81 which pass through openings in the associated bearing housing 77. This arrangement permits sliding movement of the bearings along the yokes 78 in a generally horizontal direction to provide for moving the heating drum 51 in a direction to tighten the conveyer belt 53. To maintain the sliding bearings in adjusted position, each bearing housing is provided with a threaded rod 82 projecting therefrom through an opening in a place 83 secured to the ends of the guide bars 81 to constitute the outer end of the yoke 78. A nut 84 threaded on the rod 82 is arranged to bear against the plate 83 for holding the bearing 77 in position to maintain tension in the belt 53.

In establishing the desired operating tension in the belt 53, the bearngs 77 are moved in the direction to tension the belt through the action of removable hydraulic jacks 86 provided with pressure gages 87 by means of which the degree of tension may be ascertained with accuracy. As shown, each jack 86 is interposed between the bearing housing 77 and the base or end plate 80 that constitutes the end of the yoke engaged by the pivot pin 79. A hand operated hydraulic puump 89 is connected to each jack 86 in such a manner that by operating both pumps the bearings 77 at both ends of the shaft 76 may be moved simultaneously. To effect the desired tension in the belt 53, the gages 87 associated with the two jacks 86 are observed as the pressure is applied until they both indicate predetermined readings. After the desired tension has been achieved, the nuts 84 on the threaded rods 82 are turned down against the plates 83 and tightened until the gages 87 indicate by falling pressure readings that the forces restraining the bearings 77 in position are being assumed by the nuts 84. The hydraulic pressure on the jacks 86 is then relieved and the jacks then may be removed from the machine with assurance that the belt 53 is ready to operate under the desired degree of tension.

Proper tracking of the belt 53 in running over the drums 51 and 52 may be effected by tilting the heating drum one way or the other as required through up or down pivoting action of one of the bearing supporting yokes under the control of an electrical servo-motor mechanism 85. The yoke 78 at the left end of the shaft 76 as seen in Fig. 5, although pivoted on one of the pins 79, is restrained from pivoting movement relative to the frame 47 by means of an extension 90 projecting from the lower edge of the end plate 83 and secured to the frame by cap screws 91. At the other or right hand end of the shaft however, the yoke 78 is free to pivot and is provided with an extending arm 92 that is secured to the end plate 83 of the yoke and has a pivotal connection at its outer end, as best shown in Fig. 3, with the lower end of a nut element 93 of the servo or follower-mechanism 85. The nut element 93 is threaded on a vertically disposed adjusting screw 94 that is rotatably mounted in the top of a bracket 95 fixed on and projecting upward from the side of the frame 47, the arrangement being such that when the screw 94 is rotated in the one or the other direction, the nut 93 is moved up or down to raise or lower the outer end of the yoke 78, thereby tilting the drum 51 to provide for correcting the tracking of the belt 53 in running over the drums.

As best shown in Fig. 3, the upper end of the rotatable screw 94 is connected by means of a universal joint coupling or connector 96 to a shaft 97 extending upward through a packing gland or sealed bearing 98 in the top 26 of the housing 21. The upper end of the shaft 97 is connected by means of a torque limiting or shear pin device 99 to and driven by an external gear reduction mechanism 100 that is driven by a speed change belt transmission 101 from a reversible electric motor 102. As appears in Fig. 3, both the motor 102 and the gear reduction mechanism 100 are mounted on the top 26 of the housing 21 outside of the vacuum chamber. By energizing the motor 102 for operation in the one or the other direction, the pivoted yoke 78 and the corresponding end of the drum shaft 76 can be raised or lowered to tilt the drum 51 for correcting the tracking of the belt. The bearings 77 are preferably of the self-aligning type to permit the limited canting of the shaft 76 that occurs when the drum is tilted.

To control the belt tracking operation there is provided a follower roller 103 positioned to engage one edge of the belt 53 and rotatably mounted on the lower end of an arm 104 that is pivotally mounted for swinging movement on a bracket 105 secured to and extending downward from the top 26 of the housing. The arm 104 is arranged to control the belt tracking servo-mechanism 85 by its swinging movement under the influence of the shifting belt edge in engagement with the roller 103 to register changes in the tracking of the belt 53 on the drums. This swinging movement is transmitted through a jointed shaft 106 to a horizontally disposed arm 107, shown best in Fig. 5, the outer end of which is connected to a vertically disposed control rod 108. The control rod 108 carries a weight 109 which functions to bias the arm 107 and the shaft 106 in direction to maintain the roller 103 in contact with the edge of the belt.

The lower end of the control rod 108 is provided with a control disc 111 that operates between an "up" switch

112 and a "down" switch 113 both mounted on a switch bracket 114 that is secured to the arm 92 on the pivoted bearing yoke 78. By this arrangement, when the belt 53 departs from its central position and approaches the near side of the heating drum 51, for example, as seen in Fig. 3, the action of the roller 103 in following the belt edge turns the shaft 106 in direction to lift the control rod 108 whereupon the disc 111 effects closing of the "up" switch 112. Conversely, movement of the belt in the other direction causes the control rod to move down and close the "down" switch 113. Electrical conductors 115 and 116 lead from the "up" switch and the "down" switch respectively through a conduit 117 to a control box 118 associated with the tracking motor 102. When the "up" switch is closed it completes an electrical circuit through the conductor 115 that operates in the control box 118 to cause the motor 102 to turn in the direction causing the elevating screw 94 to lift the bearing yoke 78 for tilting the drum 51 to correct the belt tracking. This upward movement of the yoke 78 also effects movement of the switch bracket 114 in the same direction thereby moving the "up" switch 112 away from the control disc 111 to open the circuit and stop the motor 102 as soon as sufficient movement has been effected. In a similar manner, when the belt shifts in the other direction, the "down" switch 113 is closed causing the yoke 78 to move downward thereby tilting the drum in the direction to correct the tracking and at the same time moving the "down" switch away from the control disc 111 to permit it to open again. Accordingly, whenever the belt 53 moves appreciably to the one or the other side of the central running position on the drum 51 the follower control or servo mechanism 85 operates automatically to effect tilting of the drum 51 in the proper direction to guide the belt back to its central position. The exact position at which the belt normally runs on the drums may be adjusted by adjusting the position of the control disc 111 on the control rod 108.

To stop the conveyer in the event of failure of the follower tracking mechanism 85, or if for some other reason the belt 53 should run off the edge of the drum 51, limit switch operators 121 and 122 are provided at the respective edges of the drum. Upon being contacted by the belt edge, either of these limit switch operators will operate to open a control circuit for stopping the conveyer driving motor 67. As shown in the wiring diagram in Fig. 6, the limit switch operators 121 and 122 are arranged to actuate normally closed switch contacts 123 and 124 in a control circuit 125 connected to actuate a motor controller 126 that is operatively connected to start and stop the belt driving motor 67 and also an auxiliary motor 127 that operates to effect oscillation of the doctor blade 56. As can be seen in Fig. 6, whenever the belt 53 runs off either edge of the drum 51 it will engage with the limit switch operator 121 or the limit switch operator 122 and by opening the corresponding switch contacts 123 or 124 operate to open the control circuit 125 and thereby actuate the controller 126 to stop both the main conveyer driving motor 67 and the doctor blade oscillating motor 127.

It is apparent that any twisting or weaving of the drum supporting frame 47 during operation of the machine would tend to interfere with proper belt tracking and might cause the belt to run off the edge of the drums. Since the chamber 21 is evacuated and is also subjected to changes in temperature, the floor 48 and the walls of the chamber are subjected to deflections in the nature of warping or bending actions. To avoid transmitting the housing deflections resulting from the changes in pressure and temperature to the drum supporting structure, the frame 47 is in the form of a rigid unitary member entirely separate from the housing 21 and mounted as a unit on the floor 48 by means of three spaced feet to constitute a three point supporting arrangement.

As shown in Fig. 1, the left end of the frame 47 is provided with a single central supporting foot in the form of a short piece of round shafting 131 disposed longitudinally of the frame at right angles to the drum axes and secured as by welding to the lower surface of the frame cross member to constitute one point of support. The supporting foot or shaft 131 fits into a complementary groove in a lug or pad 132 secured on the top of a channel member 133 that is fastened to the floor 48. This arrangement permits tilting movement of the frame 47 about the central longitudinal axis coaxially of the cylindrical foot 131, as may be seen in Fig. 5, while preventing transverse movement of the frame 47 relative to the housing 21. The other or right end of the frame 47, as seen in Fig. 1 and which is foreshortened to provide more room for the feeding mechanism 54 and the product removal apparatus 55, is supported by a pair of spaced feet constituting the other two points of support and formed by short pieces of round shafting 134 arranged in axial alignment at spaced positions under the outer edges of the frame and between the drums as shown in Fig. 5. These two cylindrical feet 134 fit in complementary grooves or sockets in lugs or pads 135 that are secured to channel members 136 mounted on the floor 48 in parallel relationship with the channel 133. The cylindrical feet 134 permit limited longitudinal tilting or weaving movement of the frame about their aligned transverse axis but prevent end-wise movement of the frame within the housing 21. By reason of this three point supporting arrangement it is apparent that considerable warping or twisting movement of the housing floor 48 may occur as a result of changes in temperature or pressure without causing corresponding deflections of the frame 47. Furthermore, the pivoting actions permitted by the three cylindrical supporting feet allow both longitudinal and transverse tilting movements of the conveyer apparatus to occur without causing deflections of the frame 47.

The material to be dried is fed into the drying apparatus, as shown in Fig. 2, by means of a feed pump 141 that receives the liquid material through an inlet pipe 142 and serves as a metering pump to deliver it under moderate pressure at a predetermined rate through a feed pipe 143. When the material enters the housing 21 it is, of course, subject to the vacuum in the chamber and this results in the release of occluded air causing foaming of the material and making it difficult to control in the feeding mechanism 54. Accordingly, since it tends to preserve the quality of the material as well as to prevent foaming, it is preferable to deaerate the material before it reaches the feeding mechanism. As the first step in deaerating, it is desirable to warm the liquid material and this is accomplished in a heating unit 144 into which the feeding pipe 143 delivers the material from the pump 141. From the heating unit 144, a pipe 145 including a control valve 146 extends above the top of the housing 21 and enters through the top 26 thereof to deliver the material into the vacuum chamber. Power for driving the feed pump 141 is derived from an electric motor 148 that drives a gear reduction unit 149 coupled to the pump 141 by a belt transmission 150. By suitably regulating the speed at which the pump 141 is driven and the setting of the control valve 146 the rate at which the liquid material is delivered into the dehydrating chamber may be controlled and coordinated with the rate at which it is applied to the drying belt 53 by the feeding mechanism 54.

As best shown in Fig. 1, the liquid material entering the top of the vacuum chamber 21 through the pipe 145 flows into a deaerating apparatus comprising a relatively large vertically disposed pipe 152 suspended from the top of the housing by brackets 153 and open at its upper end, the pipe being preferably of glass or some other inert substance. The liquid material from the pipe 145 passes through a spray nozzle 154 located within the upper end of the deaerator and is sprayed thereby onto the inner wall of the open large pipe 152, the spray of

material being subject to the vacuum within the chamber. The action of the vacuum upon the finely divided material in the spray removes the air that was occluded in the material thereby greatly reducing the tendency of the liquid to foam as it is being fed onto the belt 53. The sprayed material collects on the inside of the deaerator pipe 152 and flows down to the closed bottom end thereof from which the liquid is conducted through a smaller pipe 155 into the outer end of a long sloping drip trough and feed pan 157. The drip trough or pan 157 is suspended from the frame 47 beneath the heating drum 51 and slopes downwardly toward the feeding mechanism 54. The liquid material flows by gravity along the trough into the lower feed pan or hopper portion thereof beneath the lower run of the belt 53 about midway between the cooling drum 52 and the heating drum 51.

A feeding roller 159, preferably of stainless steel and presenting a sand blasted periphery, is rotatably mounted within the feed pan 157 in position to be partially submerged in the liquid material therein and is operative to carry the liquid upward on its periphery and apply it to the lower surface of the belt 53. As the applicator roller 159 turns within the feed pan 157 it applies to the moving belt 53 a thin uniform layer of the material to be dried, the material being applied to the belt before it contacts the heating drum. Any material which may drip from the belt or be blown off by vapor formed in the material upon contact of the belt with the heating drum 51 falls back into the drip trough 157 and returns with the incoming material along the sloping feed pan to the feeding roller 159. The portion of the belt 53 to which the material is applied is relatively cool since it has previously been in contact with the cooling drum 52 and its surface has been prepared to receive the liquid by action of the doctor blade 56 in scraping the previously dried material from the belt. Since the material is applied to the belt 53 at a position prior to its contact with the heating drum 51, full advantage is taken of the heat transferring effect of the drum.

To stabilize the lower run of the belt 53 and cause it to follow a predetermined path relative to the applicator roller 159 there is provided above the belt in the region of the feed roller a backing drum 160 that is rotatably mounted at its ends in the frame 47 as shown in Fig. 7. The backing drum 160 engages the inner or upper surface of the lower run of the belt as appears in Fig. 1 with sufficient pressure to deflect it somewhat for maintaining its lower surface flat and running in a fixed path for the purpose of receiving from the feeding roller 159 a material film of uniform, predetermined character.

As best shown in Figs. 7 and 8 the feeding roller 159 is rotatably mounted in bearings 162 that cooperate with journals on a through shaft 163 which serves to drive the roller. As in the case of the heating drum, the bearings 162 of the applicator roller are carried in pivotally mounted sub-frames or brackets 164 each pivoted to the main frame 47 at one end to constitute a pivot point spaced horizontally from the axis of the roller. By this arrangement the roller 159 may be positioned closer to or farther from the surface of the belt 53 through pivoting the brackets 164 about the pivot pins 165. This provides for regulating the thickness of the film of material applied to the belt in order that the film may be of the characteristics best suited to the requirements of the material being dried.

In order that the roller 159 may move within the feed pan 157 in effecting adjustment relative to the belt, the sides of the pan 157 are slotted from the top downward to receive the shaft 163 near both ends of the roller. To prevent the escape of liquid material along the shaft 163 and through the slots in the pan, the shaft is provided inwardly of the slots at each side of the pan with a slinger disc 166. The discs 166 are so arranged that any liquid material reaching either disc tends to drip or be thrown from its periphery to forestall further creepage of the material along the shaft from the ends of the roller 159. The depth of the material within the pan 157 may be regulated by adjusting the rate of delivery to the deaerator as previously explained and is indicated in the drawings by the dot dash line 167. A drain valve 168 in the bottom of the pan 157 is arranged to be operated from the outside of the housing 21 by means of an actuating rod 169 and may be opened to drain the pan 157 through a drain connection 170 leading through the floor 48 of the housing.

Movement of the applicator roller 159 in adjusting its position relative to the belt 53 is effected by screw and nut mechanisms operating on the ends of the brackets 164 remote from the ends thereof engaged by the pivot pins 165, there being a separate adjusting means at each end of the roller to provide for correcting inequalities in the thickness of the material film across the face of the belt 53. As best shown in Fig. 8, the end of each bracket 164 carries a nut element 172 that engages complementary threads on a vertically disposed screw shaft 173, the upper end of which is provided with a step bearing that engages a bracket 174 secured to the frame 47. In order that adjustment of the feed roller spacing may be effected while the dehydrating apparatus is in operation, the screw shafts 173 extend downward through the floor 48 of the housing, packing glands 175 being provided to prevent leakage of air into the housing while permitting rotation of the shafts. The lower end of each adjusting shaft 173 is provided with an actuating handle 176 and an indicating dial 177 whereby precise independent adjustment of the position of each end of the applicator roller 159 may be effected without interferring with the operation of the drying apparatus.

The feed roller driving shaft 163 is connected by a universal joint connector 180 to a shaft 181 that extends through a packing gland and sealed bearing 182 in the side wall of the housing 21, the sealing arrangement being shown in detail in Fig. 9. As shown in Fig. 2 the shaft 181 is connected at its outer end to a gear reduction mechanism 183 driven by a motor 184 both mounted on a bracket 185 secured to the outside of the housing 21. The gear reduction mechanism 183 is of the variable speed type and is operated to turn the feeding roller 159 in a manner to cause its upper surface to move in the direction of travel of the belt 53 and at a somewhat faster speed. The speed may be regulated by manipulating a speed controlling hand wheel 186 on the variable speed gear reduction mechanism 183. By adjusting the speed changing gearing 183 in this manner, the speed of rotation of the roller 159 may be regulated from the exterior of the chamber without interferring with the operation of the dehydrator. Thus by changing both the spacing of the feeding roller 159 relative to the belt 53 and the speed of rotation of the roller, the amount of material applied to the belt 53 and the characteristics of the resulting film of material on the belt may be regulated as the drying operation proceeds to effect application of the material film in the manner best suited for efficient drying of the particular material under the conditions then prevailing within the vacuum chamber.

Furthermore, the temperature of both the feeding roller 159 and the backing drum 160 may be controlled as desired to best adapt them for handling the particular liquid material being applied to the belt. The backing drum 160 may be of hollow construction and may be cooled or heated by heat exchanging liquid that may be introduced through a rotary joint or coupling 188 at the right end as shown in Fig. 7 and that flows off through a similar rotary coupling 189 at the left end of the drum structure. The applicator roller 159 may also be hollow and have fitted to the right end of its shaft 163, as shown in Fig. 7, a combined inlet and outlet rotary coupling 190 presenting a conduit 191 through which heat

exchanging liquid may be admitted and a second conduit 192 for the discharge of the liquid.

When the machine is in operation, the cooling drum 52 is similarly provided with a cooling liquid which enters through a control valve 194 and a conduit 195 extending upward through the floor 48 of the housing to a rotary coupling 196 on the left end of the drum shaft 62 as shown in Fig. 10, the liquid being discharged through a rotary coupling 197 to the other end of the shaft and a conduit 198 leading down through the floor 48. The heating drum 51 is preferably heated by steam which enters through an automatic temperature regulating control valve 200 and a conduit 201 that passes upward through the floor 48 to a rotary coupling 202 on the right end of the drum shaft 76 as shown in Fig. 5. From the other end of the drum shaft 76 water resulting from condensation of the steam is lead out through a rotary coupling 203 and a conduit 204 that leads downward through the floor 48.

The thin film of liquid material applied to the belt 53 by the applicator roller 159 is carried by the belt toward the left as seen in Fig. 1, that is, toward the heating drum 51, at the rate of about fifty feet a minute. As the belt passes around the drum the steam in the drum supplies the heat for vaporization of the moisture content of the material on the belt but does not increase its temperature greatly because the moisture is being evaporated at low vaporizing temperature under the vacuum condition obtaining within the drying chamber. It is, of course, advantageous to use the highest temperature in drying that is consistent with retaining the desired product quality, thereby permitting the use of relatively high vacuum chamber pressure for reasons of economy in evacuating the vapor.

By properly controlling the degree of vacuum in conjunction with the thickness of the material film, the speed of the belt and the amount of heat applied to the material, a desirable condition can be established which results in slight puffing of the material in the film through formation of small bubbles which tend to make the film porous and to increase the surface area of the material thereby promoting rapid drying. By the time the material on the belt has travelled around the drum, it is substantially dry and tending to increase in temperature although some further drying occurs upon the upper run of the belt as the material travels toward the cooling drum 52. With suitable adjustment of the apparatus, the product can be dried to a moisture content as low as 1 percent or lower if necessary. This adds greatly to the good storage properties of the dried product.

When the material on the belt arrives at the cooling drum 52 it is cooled quickly to avoid keeping it at the drying temperature any longer than necessary thereby limiting the possibility of deterioration from the effects of the heat applied for drying. Cooling of the material on the belt also crystallizes it and facilitates removal by the doctor blade 56 particularly if the material is thermoplastic and has melted somewhat after drying. If the dried material is highly hydroscopic, however, the cooling action should be limited to avoid reocclusion of moisture. When the doctor blade scrapes the chilled thin film of dried material from the belt the individual particles are in the form of granular crystalline flakes presenting large surface areas and are instantly soluble in liquid upon reconstituting the material.

By properly adjusting and coordinating the actions of the cooperating heating and cooling elements the liquid content of the material being dried may be vaporized as rapidly as possible without exceeding the preferred drying temperature. Then after being dried to the desired moisture content, the material may be cooled as rapidly as possible to room temperature or whatever other temperature is best adapted to preserve its essential qualities. Concurrently, the degree of vacuum and various other factors are regulated in cooperation to provide the most favorable drying conditions and to produce the desired density and other preferred characteristics of the product. by the arrangement of the invention whereby proper regulation of the apparatus may be effected from the exterior of the housing during operation, it is possible to adjust the mechanism to dry any of various liquid materials to the desired extent at the lowest feasible drying temperature in the shortest period of time whereby drying is effected with the least detrimental effect upon the quality of the dried product.

As shown in Figs. 10 and 11, the doctor blade 56 is held in contact with the surface of the belt 53 by fluid pressure means which may be adjusted from the outside of the housing to effect the product removing engagement with the desired degree of pressure. The blade 56 is a relatively thin strip of suitable metal adjustably mounted in a blade carrying bracket 206 which is secured to a transverse shaft 207 rotatably mounted beneath the cooling drum 52. At each end the shaft is provided with a vertically disposed lever arm 208 the upper ends of which are engaged by horizontally disposed piston rods 209 associated with fluid pressure cylinders 210. When pressure is applied to the cylinders 210, the piston rods 209 are forced to the left as shown in Fig. 11 thereby turning the arms 208 and the shaft 207 counter clockwise to force the doctor blade 56 into scraping engagement with the surface of the belt 53. As best shown in Fig. 10 the pressure cylinders 210 are connected by tubing 211 to a vertically disposed pipe 212 extending downward through the floor 48 of the vacuum chamber.

As indicated diagrammatically in the drawing, pressure for actuating the cylinders 210 is admitted to the pipe 212 by opening a shut off valve 213 to admit fluid under pressure from a supply pipe 214. A suitable pressure regulating device 215 is provided in the pipe line for adjusting the pressure applied to the cylinders, a pressure gage 216 being provided to indicate the pressure applied. In starting the machine, the valve 213 remains closed in order that the belt 53 may start to move without resistance from the doctor blade 56. As soon as dried material appears on the belt, however, the shut off valve 213 is opened and the doctor blade is forced against the belt with the desired degree of pressure as established by the setting of the pressure regulating device 215. At any time during operation of the machine the regulating device 215 may be adjusted to increase or decrease the pressure exerted by the doctor blade to best suit the reqiurements of the particular dried product being scraped from the belt. The pressure fluid used in the cylinders 210 may be air but is preferably water since any leakage which might occur would be less detrimental to operations in the vacuum chamber than leakage of air for example. When water is used as the pressure fluid, it is preferable to apply the pressure to the water by means of air under pressure in which case the pressure regulating device is arranged to control the pressure of the air.

To provide for smoother operation of the doctor blade 56, it is arranged to be oscillated endwise by operation of the oscillating motor 127 previously mentioned. As shown in Figs. 2 and 10 the oscillating motor 127 is mounted on the outside of the housing by means of a supporting bracket 220 and is connected through speed changing reduction gearing 221 to drive a cam shaft 222. The cam shaft 222 carries a cam 223 which cooperates with a push rod 224 that extends through a packing gland or sealed bearing 225 into the vacuum chamber. The inner end of the push rod 224 is connected by a universal joint coupling 226 to the end of the doctor blade supporting shaft 207. By this arrangement the doctor blade oscillating force is transmitted from the cam 223 to the blade regardless of misalignment between the push rod 224 and the shaft 207 which might occur through warping of the housing 21 under changes in temperature and pressure. Furthermore, since the motor 127 and the gearing 221 are mounted externally of the housing

the speed of oscillation of the doctor blade may be adjusted by manipulating a speed changing hand wheel 230 on the reduction gearing 221 while the apparatus is in operation to establish the speed best suited to the circumstances. Oscillation of the doctor blade reduces the frictional drag upon the belt 53 and thereby reduces the tendency of the blade to chatter as well as distributing the wearing action on both the blade and the belt.

In addition to adjusting the pressure exerted by the blade and its rate of oscillation from outside of the housing it is also desirable to adjust the angle of contact or the angle of attack of the blade relative to the belt. To accomplish this each end of the blade carrying shaft 207 is rotatably mounted in a bearing bracket 227 that is slidably mounted for vertical movement on the frame 47 as shown in Figs. 10, 11 and 12. By sliding the brackets 227 up or down along the frame 47 the shaft 207 is moved closer to or farther from the drum 52 thereby causing the blade 56 to assume different angles of contact with the belt. This, of course, results in turning the shaft 207 slightly which is accommodated by corresponding movement of the pressure actuated piston rods 209 without materially changing the pressure between the blade and the belt.

As shown in Fig. 12 each bearing bracket 227 has rotatably connected to it the upper end of a vertically disposed adjusting shaft 228 that extends downward through the floor 48 of the housing, the usual packing glands 229 being provided to prevent leakage. Each adjusting shaft 228 has threaded engagement with a nut 231 secured to the frame 47, the arrangement being such that when the shaft is rotated in the nut the bracket 227 is raised or lowered. The lower exposed end of each adjusting shaft 228 is provided as shown in Fig. 10 with an actuating handle 232 and a cooperating indicating dial 233 which may be graduated to indicate the angle of incidence of the doctor blade with the surface of the belt. Thus by turning the actuating handles 232 and referring to the indicating dials 233 the angle of incidence of the doctor blade 56 may be adjusted at any time during operation of the machine to the angle best suited for removing from the belt the granular particles of the particular material being dried in the dehydrator.

As the dried product is scraped from the belt 53 by the doctor blade 56 it falls into a product receiving pan or trough 236 formed semicircular at its bottom to receive a rotary screw conveyor 237 disposed transversely of the machine parallel with the axis of the drum 52. As shown in Fig. 11, one wall of the trough 236 is formed by a removable chute or plate 238 that constitutes the face of a magnetic separator 239 for removing magnetic impurities such as tramp iron particles from the product as it falls away from the doctor blade. The magnetic separator 239 comprises a row of permanent horseshoe magnets 240 arranged along the plate 238 parallel with the face of the drum 52 and secured to the plate by the clamping action of an angle iron frame 241. The frame 241 is secured at each end to a vertically disposed supporting plate 242 that is pivotally connected at its lower end by a pivot pin 243 to a bracket 244, the arrangement being such that the entire magnetic separator 239 including the plate 238 may be swung about the pivot pin 243 to open the product receiving trough thereby providing accessability for cleaning or for adjustment of the doctor blade 56 or the like. The supporting brackets 244 are adjustably secured to the frame 47 by bolts 245 that pass through longitudinal slots 246 in the frame. By loosening the bolts 245 and sliding the brackets 244 along the frame, the position of the magnetic separator relative to the doctor blade may be adjusted in order to provide the best action in guiding the dried product into the conveyor 237 and in removing magnetic particles from the product.

As shown in Fig. 10, the transverse screw conveyer 237 operates to move the dried product along the trough 236 toward the left and into an inclined rotary ball mill or similar grinding device 250. The ball mill 250 discharges into a coaxial rotary screen 251 through which the product is shifted into a divided discharging hopper 252. Although both the grinding mill 250 and the rotary screen 251 are shown in the drawing, it is to be understood that different dried products require different kinds of treatment and it may be desirable to substitute for the grinder a plain rotary conveyer tube which may in some cases be further extended to replace the screen also, thereby discharging the product from the conveyer screw 237 directly into the product hopper 252. Likewise, the grinder 250 may be utilized by itself without the rotary screen 251 if desired.

As best shown in Fig. 10, both the screw conveyer 237 and the rotary grinder and screen are driven from the main countershaft 65 that drives the cooling drum 52. To this end, the countershaft 65 is provided with a sprocket wheel 255 that is operatively connected by a transmission chain 256 to a sprocket 257 on an extending shaft at the right end of the conveyer screw 237. A second sprocket 258 on the screw conveyer shaft is connected by a chain 259 with a sprocket 260 on the end of a jointed transmission shaft 261 extending transversely of the apparatus beneath the screw conveyer 237. At its left end, the jointed shaft 261 is inclined parallel with the grinder and screen and is provided with a belt pulley 262 that transmits motion through a belt 263 to a pulley 264 encircling and mounted on the rotary grinder 250.

By this arrangement, the screw conveyer 237 and the grinding and screening apparatus are always driven in proper synchronism with the conveyer belt 53 to convey away the dried material as rapidly as it is scraped from the belt and regardless of changes in the belt speed that may be effected by changing the adjustment of the belt driving transmission mechanism 69. In the event that it is desired to change the relationship between the speed of the screw conveyer and the speed of the conveyer belt 53 this may be accomplished by substituting a different sprocket for either the sprocket 255 or 257 or both to change the driving ratio. Likewise the speed of rotation of the rotary grinder 250 relative to the screw conveyer may be changed by changing the sprocket 258 or 260. This may be desirable in some instances to control the amount of grinding and thereby assist in controlling the density of the powdered product being delivered to the hopper 252.

In some instances it may be desirable to further cool the powdered product after it has been scraped from the belt to prevent melting and sticking of thermoplastic material in the product removal apparatus. For this purpose the screw conveyer 237 may be provided with a hollow shaft presenting a longitudinal passageway 266 as indicated in Fig. 11 through which cooling water may be circulated in the manner in which it is circulated through the cooling drum 52 or the backing drum 160 for example. Further cooling may be effected by cooling pipes 267 arranged along the outer surface of the product receiving pan 236 and along the doctor blade bracket 206, as indicated diagrammatically in Fig. 11.

As best shown in Fig. 1, the product receiving hopper 252 is divided at its lower end into two discharge chutes 271 and 272 a deflector plate or gate 273 being pivotally mounted between the chutes and arranged to divert the product into the one of the other chute. The gate 273 is carried on a shaft 274 extending through and journalled in the sides of the hopper 252 as shown in Figs. 1 and 10. A jointed shaft 275 connects the shaft 274 with an actuating shaft 276 that passes through a packing gland 277 in the wall of the housing 21 and is provided at its outer end with an actuating lever 278. By swinging the lever 278 from side to side, the gate 273 may be caused to swing across the hopper 252 for diverting the dried product into the one or the other of the chutes 271 or 272. The product chutes 271 and 272 discharge into suit-

able portable product receiving tanks or containers 279, each chute being provided with a shut off valve 280 that may be closed to prevent leakage of air into the vacuum chamber while changing containers. For example, when the container 279 on the chute 271 becomes filled with material, the gate 273 is swung over to divert the product into the chute 272 for filling another container 279. The shut off valve 280 in the chute 271 is then closed and the vacuum in the filled container is broken, preferably by admitting an inert gas. The filled container is then removed from the machine and an empty container is substituted for it, the closed valve 280 in the chute 271 preventing leakage of air into the vacuum chamber during the change. The substituted empty container 279 is then secured on the chute 271 and evacuated after which the valve 280 in the chute is opened to prepare it for receiving the product again as soon as the container on the chute 272 is filled.

The various sealed bearings and packing glands that are utilized throughout the apparatus for passing rotary and oscillating shafts through the wall of the vacuum chamber are exemplified by the feed roller shaft bearing 182 that is shown in detail in Fig. 9. As there shown, the sealed bearing 182 comprises a cylindrical bearing casing 281 that is securely mounted in the wall of the housing 21 in a manner to prevent leakage of air around it. The bearing casing 281 carries at each end an antifriction bearing 282 which bearings rotatably support the shaft 181 at spaced positions. At its inner end the casing 281 carries a packing gland 283 that engages the shaft 181 to prevent leakage into the vacuum chamber. At its outer end the casing 281 is provided with an oil seal 284 to prevent the escape of oil from the bearings. In order to insure against leakage of air into the vacuum chamber, the space within the casing 281 between the two bearings 282 is completely filled with oil or some equivalent fluid that is admitted through an oil cup 285 on the outer end of the casing. By maintaining the oil cup 285 filled with oil the possibility of air entering through the casing 281 is obviated. Even in the event that the packing gland 283 should leak somewhat, no air will be admitted and whatever oil leaks through the packing will be apparent upon observing the inner end of the packing gland through one of the observation ports such as the window 30 and will serve as a reminder to tighten the gland 283.

As previously mentioned, the cooling drum 52 is carried by a through shaft 62 that is provided at its ends with a water intake rotary coupling 196 and a water discharge rotary coupling 197, respectively. As indicated in Fig. 10, the shaft 62 is fitted with two spaced hub elements 286 positioned inwardly of the ends of the drum. From each hub 286, six spokes 287 radiate to and support a cylindrical inner shell member 288. End rings 289 secured to the ends of the inner shell 288 project radially to the ends of an outer shell 291 that is spaced outwardly from the inner shell and that constitutes the belt engaging surface of the drum. The outer shell 291 is preferably of material having good heat transmitting properties such as copper.

The space between the inner shell 288 and the outer shell 291 and enclosed by the end rings 289 constitutes a chamber 292 for the cooling water that serves to cool the dried material on the belt 53. As shown in Fig. 10, the cooling water which enters through the control valve 194, the pipe 195 and the rotary coupling 196 flows through a passageway 294 that is bored into the end of the shaft 62 and extends inwardly just beyond the hub 286. From the passageway 294, the cooling water flows into two radial fittings 295 disposed at 180° to each other and from each of which a branching conduit leads to the cooling chamber 292. As shown, one branch conduit 296 leads to the chamber 292 in the region of the left end of the drum and another branch conduit 297 leads to the chamber at the right end of the drum. By this arrangement, the product on the respective edges of the belt is cooled uniformly and the ends of the drum are cooled equally to avoid any inequality in expansion which might otherwise interfere with proper tracking of the belt in running over the drum 52. The cooling water flowing into the chamber 292 flows generally circumferentially thereof and is guided by helically arranged edgewound baffle plates 298 toward the mid-portion of the chamber. As best shown in Fig. 12, the baffle plates 298 are in the form of a double helix, the helixes at the opposite ends of the drum being of opposite hand and converging upon a radially disposed circumferential dividing flange or plate 299 that encircles the inner shell 288 at its mid-section. Diametrically opposed pockets 301 formed in the dividing flange 299 are connected by out-flow tubes 302 which lead to fittings 303 that connect radially with a bore or passageway 304 in the right end of the shaft 62 as shown in Fig. 12. The bore 304 in the shaft connects with the rotary coupling 197 through which the cooling water is discharged into the pipe 198 leading through the floor 48 of the housing. By withdrawing the water from the mid-portion of the drum 52, any distortion from inequality in temperature existing between the ends of the drum and the mid-portion will result only in a slight crowning effect upon the drum which will not adversely affect the operation of the belt 53 in running over the drum. In assembling the drum 52, the periphery of the end rings 289 and of the baffle plates 298 and flange 299 are machined to an accurate cylindrical shape to support the outer shell after which the copper outer shell 291 may be shrunk on in a manner to form a tight heat conducting contact with the peripheries of the end rings and the baffle plates. After the outer shell 291 is shrunk on the drum it is sealed to the end rings by suitable sealing or packing rings 300 and its outer surface is machined concentric with the journals of the shaft 62 for receiving the belt 53 with good heat conducting contact.

The driving gears 63 at the respective ends of the drum 52 are secured thereto by means of a circle of bolts 308, indicated in Fig. 11, arranged in angularly spaced relationship and passing through aligned holes in the web of the gears and in cooperating lugs 309 secured to the inner surface of the end rings 289. The holes in the lugs 309 may be elongated to provide for angular adjustment of the gears 63 for the purpose of eliminating backlash and chatter. In the particular apparatus shown, the cooling drum 52 is about 30 inches in diameter and is slightly longer than the width of the belt which in this instance is 24 inches.

The heating drum 51 is in many respects generally similar in construction to the cooling drum 52 but is larger, being in this apparatus six feet in diameter. As best shown in Fig. 5, the drum 51 is supported on the transverse through shaft 76 by two hollow hub elements 315 disposed in spaced relationship approximately in line with the respective edges of the drum. From each hollow hub 315, eight hollow spokes 316 extend radially to and support the respective edges of an inner drum shell 317. End rings 318 at the respective edges of the inner shell 317 extend radially outward to an outer shell 319 that forms the belt receiving surface. The space between the inner and outer shells and enclosed by the end rings constitutes a heating chamber 320 and is subdivided by a helical edgewound baffle plate 321. As best shown in Fig. 4, the baffle plate 321 extends continuously across the face of the drum as a single helix. As previously mentioned, steam for heating the drum is admitted through the automatic pressure regulating valve 200 (Fig. 5) and the vertical pipe 201 to the rotary connection 202, from which it flows through a passageway 323 bored into the end of the shaft 76 to a position beneath the hub 315. Radial passageways 324 in the shaft 76 permit the steam to flow from the passageway 323 into the interior of the hollow hub 315. From the hollow hub 315 the

steam flows outwardly through all of the hollow spokes 316, associated therewith, into the right end of the heating chamber 320 as seen in Fig. 5. In order that the steam may be distributed rapidly across the face of the drum, the inner edges of the helical baffle plates 321 are notched in axial alignment with each spoke 316 to constitute a transverse steam passage 325.

Water which condenses from the steam when its latent heat is released to the belt 53 collects in the bottom of the chamber 320 between the turns of the helical baffle plate 321. Since the helix formed by the baffle plate 321 extends from side to side of the drum the condensate which collects is urged toward the left as seen in Fig. 5 as the drum turns and is discharged from the left end of the drum. As appears in Fig. 4, the helical baffle plate 321 terminates in a pocket or dipper space 326 that communicates with one of the hollow spokes 315 at the discharge side of the drum, the other seven spokes at this side being closed at their ends. Upon each revolution of the drum 51 the water which finds its way to the dipper space 326 at the end of the helix drains away through the hollow spoke 316 as soon as the dipper space arrives at a position above the axis of the drum. From the hollow spoke 316 the water flows into the hollow hub 315 and thence through radial passageways 327 into a bore 328 in the left end of the shaft 76 that constitutes a passageway leading to the rotary coupling 203 from which the water discharges through the pipe 204 to the exterior of the housing 21.

In fabricating the heating drum, the end plates 318 and the helical baffle plate 321 are secured to the periphery of the inner drum shell 317 preferably by welding. Two diametrically opposed transverse backing strips 329 are then fitted to the periphery of the baffle plates by suitably notching the plates and welding the strips in the notches as shown in Figs. 3 and 4. The periphery of the baffle plates including the transverse backing strips is then machined to accurately cylindrical shape for receiving the outer shell 319. In this drum the outer shell is preferably formed of stainless steel and is applied in two semi-cylindrical segments joined at their ends over the two backing strips 329. In applying the two semi-cylindrical stainless steel sheets or segments to the drum they are first clamped in position preferably by clamp hoops wrapped around the segments and drawn tight as by nuts threaded on their ends. The two segments are then welded together over one of the backing strips leaving the other two ends free in spaced relationship over the other backing strip. Both of the stainless steel sheets are then heated as by playing gas torches over them to expand them a predetermined amount whereupon their free ends are welded together. Heating of the shell is then discontinued and the clamping hoops are removed. Both welds are then completed to join the two segments securely together and to the two backing strips by deposits of weld metal. As the stainless steel segments cool, circumferential residual tension stresses are established within them insuring close conformity of the outer shell 319 to the outer periphery of the baffle plate and end rings despite the differences in external and internal pressures and variations which may occur in the temperature of the drum during operation. The edges of the outer shell 319 are then welded to the end rings 318 and the periphery of the drum is then machined to accurately cylindrical shape concentric with the journals of the shaft 76 to provide a surface suitable for good heat transferring contact with the material conveying belt 53.

In applying the belt 53 to the heating drum 51 and the cooling drum 52, a long strip of suitable stainless steel sheet material is passed around the drums and cut to the required length with accurately squared ends. With the heating drum in its retracted position, the ends of the belt strip are joined by butt welding to form a continuous endless band trained about the drums. The heating drum is then moved along its supporting brackets 78 to tighten the belt as previously explained. As is evident from the description, and generally well known, establishing accurately cylindrical smooth surfaces on the heating and cooling drums is a troublesome and expensive procedure. One of the great advantages of using the conveyor belt 53 to support the material being dried as compared with a drum dryer for instance is that the belt serves to protect the accurately formed cylindrical surfaces of the drums. Hence should any injury befall the material receiving and transporting surface, it can be renewed readily and inexpensively simply by removing the damaged belt and replacing it with a new one. This is accomplished without the necessity of dismounting the drums or operating upon their peripheral surfaces.

As another guard against injury to the drum surfaces, each drum is provided with an auxiliary scraper for removing any debris which may accumulate on the drum face thereby preventing it from building up between the drum and the belt. As shown in Fig. 1, the cooling drum 52 is engaged by a transversely disposed auxiliary scraping blade 332 beneath which is arranged a catch pan 333 to receive any debris scraped from the drum surface. Likewise the backing drum 160 is provided with an auxiliary scraping blade 334 and a cooperating catch pan 335. As best shown in Fig. 3 the heating drum 51 is provided with an auxiliary scraper blade 336 that is pivotally mounted on the frame 47 and resiliently held in engagement with the drum periphery by a spring 337, the arrangement being such that the spring retains the blade in proper contact with the drum periphery regardless of tilting movement of the drum axis in effecting tracking of the belt as previously explained. A suitable catch pan 338 is also provided to receive debris from the blade 336. Likewise the follower roller 103 contacting the edge of the belt 53 is fitted with a scraper blade 339 to remove debris which might otherwise accumulate thereon and interfere with its belt guiding action. Thus the dehydrator may be operated continuously over long periods of time without the necessity of shutting down for cleaning operations.

From the foregoing description and explanation of operation of the exemplary dehydrating apparatus set forth herein it will be apparent that the improved material drying equipment provided by this invention is especially adapted to effect the drying of a large variety of heat sensitive materials and the like because of the fact that it is possible to control closely the drying pressure and temperature, the rate of drying and the temperature of the product while effecting dehydration at low temperature under aseptic conditions in vacuo. By effecting thorough dehydration while avoiding overheating or oxidation of the material being dried, the resulting product retains the texture, color and flavor of the original material with its moisture content so reduced as to effect greatly improved storage properties and having a high degree of solubility for complete and rapid reconstitution of the material.

Furthermore, because of the construction features described, the apparatus has the ability to operate continuously over relatively long periods of time, so that after the chamber is initially evacuated, the material may be fed to the belt without interruption for a long running period and the machine shut down only when good practice demands a complete cleaning of the material contacting components. Apparatus of the size and operating as described herein is capable, for instance, of producing sixty to sixty-five pounds of coffee powder per hour from an extract concentrated to about 40% solids in commercial operations.

Although a single example of dehydrating apparatus illustrative of the present invention has been set forth in considerable detail by way of a full disclosure of a practical, useful embodiment of the invention, it is to be understood that other arrangements of the apparatus and different proportional relationships of its elements may

be utilized by those familiar with the art without departing from the spirit and scope of the invention as defined by the subjoined claims.

The invention having now been fully described, what is claimed is:

1. In a dehydrator for drying liquid materials on a continuous basis, a rotatably mounted heating drum, a rotatably mounted cooling drum in parallel spaced relationship with said heating drum, a material conveying belt trained over said heating drum and said cooling drum, power actuated means operatively connected to drive said drums and said belt, a feeding roller disposed with its periphery in cooperating relationship with the outer side of the run of said belt moving from said cooling drum to said heating drum and at a substantial distance from said heating drum and rotatably mounted for applying material to be dried to said belt, a backup drum disposed to engage the inner side of said run of said belt in the region of said feeding roller for maintaining said belt in predetermined relationship with said feeding roller, means to apply liquid material to the periphery of said feeding roller for application thereby to said belt, variable speed power actuated driving mechanism operatively connected to turn said feeding roller at selected speed in a manner to move its feeding periphery in the direction of travel of said belt for applying material to said belt, control means to adjust the speed of rotation of said feeding roller, and adjusting means to adjust the clearance distance between said feeding roller and said belt, the arrangement being such that the thickness of the film of material applied to said belt may be regulated during operation of the dehydrator by adjusting the speed of rotation of said feed roller and the clearance between it and said belt.

2. In a vacuum dehydrator for continuously drying from a liquid condition any of various heat sensitive materials having different drying characteristics, an enclosing vacuum chamber, evacuating apparatus operatively connected to effect evacuation of said chamber, a control system arranged to control said evacuating apparatus in a manner to maintain a desired degree of vacuum within said chamber, means to adjust said control system to regulate the degree of vacuum to the necessities of the material being dried, a heating drum rotatably mounted within said chamber, a cooling drum rotatably mounted in spaced parallel relationship with said heating drum, a material conveying belt trained about and running over said spaced drums, regulatable heating means arranged to effect heating of said heating drum to a selected temperature adapted to cooperate with the selected degree of vacuum in said chamber to effect drying of the material on said belt in the most expeditious manner consistent with the least deleterious effect upon the quality of the dried material, regulatable cooling means arranged to effect cooling of said cooling drum to a selected temperature adapted to cool said belt and the dried material thereon to prevent overheating the material and to facilitate removal thereof from said belt, means to remove the dried material from said belt after it is cooled on said cooling drum, a feeding roller disposed with its periphery in cooperating relationship with the outer surface of the run of said conveyor belt moving from said cooling drum to said heating drum and at a substantial distance from said heating drum for applying to said cooled belt the liquid material to be dried, driving means adjustable from the exterior of said chamber and operative to turn said feeding roller at selected speed in the direction to move its feeding periphery in the direction of travel of said belt, positioning means operable to adjust the clearance between said feeding roller and said belt for cooperating with the speed of rotation to effect the application to said belt of a film of material having characteristics best adapted for drying under the selected conditions of heat and vacuum, and a backing drum rotatably mounted to engage the inner side of said belt in the region of said feeding roller to stabilize said belt and maintain it in position to receive the film of material applied by said roller.

3. In dehydrating apparatus for drying material from a liquid condition, a pair of drums rotatably mounted in parallel spaced relationship, a conveyer belt trained about said spaced drums for conveying material being dried, a feeding roller rotatably mounted with its periphery in rolling cooperating relationship with said belt for applying to said belt the liquid material to be dried, and control apparatus connected to effect precise independent adjustment of the spacing between each end respectively of said feeding roller and said belt to regulate the thickness of the film of material applied to said belt by said roller, whereby the film thickness may be regulated throughout the width of said belt while the dehydrating apparatus is in operation.

4. In dehydrating apparatus, a rotatably mounted drum, a second drum rotatably mounted in spaced parallel relationship with said first drum and arranged for tilting movement, a drying conveyer belt running over said spaced drums for advancing material being dried, a follower mechanism responsive to the position of said belt axially of said drums, tracking mechanism responsive to said follower mechanism and operative in accordance therewith to effect tilting of said second drum in a manner to maintain correct tracking of said belt in running over said drums, a scraper blade pivotally mounted and resiliently held in position to engage and scrape the periphery of said tilting second drum at a position thereon not engaged by said belt and regardless of tilting movement of said drum, whereby accumulation of debris between said belt and said drum may be prevented.

5. In a dehydrator for the continuous drying of materials from a liquid condition, a pair of drums rotatably mounted in parallel spaced relationship, a continuous conveyer belt trained over said drums, a backup drum disposed to engage the inner surface of one run of said conveyer belt between said spaced drums to maintain said belt in a fixed track in the region thereof, a feeding roller rotatably mounted adjacent the outer surface of said belt in the region maintained in a fixed track by said backup drum, adjusting means to adjust the position of said feeding roller for regulating the clearance space between said roller and said belt, means to apply material to be dried to the periphery of said feeding roller for application thereby to said conveyer belt, variable speed power driving apparatus operatively connected to drive said feeding roller in a manner to roll upon said belt with its periphery moving in the direction of travel of said belt, and control means to adjust the speed of rotation of said feeding roller, the arrangement being such that by adjusting the clearance between said feeding roller and said belt and adjusting the speed of rotation of said roller during a drying operation the characteristics of the film of material applied to said belt by said roller may be regulated in a manner best adapted to facilitate the drying of the particular material being dried.

6. The deaerator as set forth in claim 5 in which the drums are mounted in horizontally spaced relationship.

7. In vacuum dehydrating apparatus, a vacuum chamber, evacuating means operatively connected to evacuate said chamber, a heater arranged to warm liquid material to be dried, a conduit connected to feed the warmed liquid material from said heater into said vacuum chamber, a deaerator within said vacuum chamber connected to receive the warm liquid material from said conduit to deaerate it, conduit means connected to the lower end of said deaerator to receive deaerated liquid therefrom, a feeding pan within said chamber connected to receive deaerated liquid material from said conduit means, said deaerator deaerating said liquid material and said conduit means delivering deaerated liquid to said feeding pan, whereby frothing in said feeding pan is prevented, a drying device presenting a moving drying surface mounted

within said vacuum chamber, feeding means arranged to receive liquid material from said feeding pan and to apply it to said moving drying surface, and collecting means arranged to collect dried material from said moving drying surface, the arrangement being such that objectionable foaming of the liquid material in said feeding pan under the influence of the vacuum in said chamber is obviated by deaerating the liquid in said deaerator before it reaches said feeding pan.

8. In a dehydrating apparatus, a pair of spaced, generally parallel drums, a drying belt trained over said parallel drums, power actuated driving mechanism operatively connected to drive said drums and said belt, means to apply liquid material to be dried to said belt, means to scrape dried material from said belt, a conveyer disposed to collect the dried material scraped from said belt, grinding means disposed to receive dried material from said conveyer to grind it, power transmitting mechanism connected to be driven by said power actuated belt driving means and connected to drive said conveyer and said grinding means in synchronism with said belt, said power transmitting mechanism including a speed changing device arranged to provide for varying the ratio between the speed of said belt and the speed of said conveyer and said grinding means, and a product discharging device disposed to receive the dried product from said grinding means to discharge it from said apparatus.

9. In a belt dehydrator, a pair of spaced belt drums, a belt running over said spaced drums, means to apply material to be dried to said belt including an applicator roller disposed in feeding relationship with the outer surface of one run of said belt, means to adjust the position of said roller relative to said belt, means to drive said roller, control means operative to adjust the speed of rotation of said roller, the arrangement being such that the amount of material fed to said belt may be regulated by adjusting the spacing of said roller relative to said belt and the speed of said roller, a backing drum disposed to engage the inner surface of said run of said belt in position to stabilize said belt in the region of said applicator roller, and means to regulate the temperature of said backing drum to cool or warm said belt selectively at the position of receiving the material to be dried.

10. A drying apparatus comprising a first drum, a second drum disposed in parallel relationship with said first drum, a material conveying belt trained around and running over said parallel drums, a backing drum mounted to engage the inner surface of one run of said belt to stabilize it, a scraper blade mounted in position to engage and scrape the periphery of each of said drums at a point thereon not engaged by said belt, and a drip pan disposed to catch debris scraped from said drums by said blades, whereby the debris is prevented from accumulating between the inner surface of said belt and the outer surfaces of said drums.

11. In a belt drying apparatus, a first rotatably mounted drum, a second drum rotatably mounted in parallel spaced relationship with said first drum, a conveyer belt trained over and running on said spaced drums, means to remove dried material from said belt, a feeding roller arranged to cooperate with the outer surface of said belt between said drums and operative to apply to said belt a film of liquid material to be dried, a backing drum rotatably mounted to engage the inner surface of said belt in the region of said feeding roller to stabilize said belt in relation to said roller, and means to regulate the temperatures of said feeding roller and of said backing drum to control the characteristics of the film of material being applied to said belt by said feeding roller, whereby the film applied to said belt may be of the nature best suited to the requirements of the particular material being dried.

12. In a belt type of dehydrator, a pair of spaced belt drums, a belt running over said spaced drums, means to apply material to be dried to said belt between said horizontally spaced drums including an applicator roller disposed with its periphery in feeding relationship with the outer surface of one run of said belt between said spaced drums, means to adjust the position of said roller relative to said belt, variable speed driving means to drive said roller in a manner to roll upon said belt with its feeding periphery moving in the direction of travel of said belt, and control means operative to regulate said variable speed driving means to adjust the speed of rotation of said roller, the arrangement being such that the amount of material fed to said belt may be regulated by adjusting the spacing of said roller relative to said belt and the speed of rotation of said roller.

13. In a belt dehydrator, a pair of spaced belt drums, a belt running over said spaced drums, means to apply material to be dried to said belt including an applicator roller disposed in feeding relationship with the outer surface of one run of said belt, means to adjust the position of said roller relative to said belt, the arrangement being such that the amount of material fed to said belt may be regulated by adjusting the spacing of said roller relative to said belt, a backing drum disposed to engage the inner surface of said run of said belt in position to stabilize said belt in the region of said applicator roller in a manner to maintain the adjusted spacing between said roller and said belt, and means to regulate the temperature of said backing drum to cool or warm said belt selectively at the position of receiving the material to be dried.

14. In vacuum drying apparatus, a vacuum chamber, an evacuating system operatively connected to evacuate said chamber, material conveying mechanism within said vacuum chamber presenting a moving drying surface, a doctor blade disposed to scrape dried material from said moving drying surface, adjusting means operative from the exterior of said vacuum chamber to adjust the angle of contact of said blade with said surface in selecting the most advantageous angle for removing a particular dried material in the course of a drying operation, fluid pressure actuating mechanism operative upon said doctor blade to effect movement of said blade into engagement with said drying surface, control mechanism operative from the exterior of said vacuum chamber to regulate said fluid pressure actuating mechanism for establishing the degree of pressure with which said blade engages said moving drying surface, a power operated oscillating mechanism mounted on the exterior of said vacuum chamber, control means operative from the exterior of said vacuum chamber to control the speed of operation of said oscillating mechanism, and a universal coupling mechanism operatively connecting said externally mounted oscillating mechanism to oscillate said doctor blade transversely of said drying surface for facilitating the removal of dried material from said surface, whereby the angle of contact of said blade and the position thereof relative to said drying surface may be adjusted without interfering with the transverse oscillation of said blade relative to said drying surface.

15. In a dehydrating apparatus a rotatably mounted drum, a second drum rotatably mounted in spaced parallel relationship with said first drum, means for adjusting the relative angular position of the axis of said second drum with respect to the axis of said first drum, a belt trained around said spaced drums for advancing material being dried, and a scraper blade pivotally mounted and resiliently held in position to engage and scrape the periphery of said second drum at a position thereon not engaged by said belt and independently of the relative angular adjustment of said drum, whereby accumulation of debris between said belt and said drum may be prevented.

16. In a dehydrating apparatus, a pair of spaced, generally parallel drums, a drying belt trained over said parallel drums, a power-actuated driving mechanism op-

eratively connected to drive said drums and said belt, means to apply liquid material to be dried by said belt, means to scrape dried material from said belt, a conveyor disposed to collect the dried material scraped from said belt, a screening device disposed to receive dried material from said conveyor to screen it, power-transmitting mechanism connected to be driven by said power-actuated belt driving means and connected to drive said conveyor and said screening device in synchronism with said belt, said power-transmitting mechanism including a speed-changing device arranged to provide for varying the ratio between the speed of said belt and the speed of said conveyor and said screening device, and a product discharging device disposed to receive the dried product from said screening device to discharge it from said apparatus.

17. In a vacuum dehydrator a housing including walls constituting a vacuum chamber, one of said walls presenting a shaft-received aperture and another of said walls having an observation window, an evacuating system operatively connected to evacuate said chamber for drying material therein, a drying conveyor apparatus within said chamber arranged to carry the material being dried under vacuum therein, material feeding means disposed to feed onto said conveyor apparatus liquid material to be dried thereon, product removal apparatus disposed to remove dried product from said conveyor apparatus, power-actuated driving mechanism mounted externally of said housing for driving said internal conveyor apparatus, a power transmitting shaft passing through said aperture in said wall of said housing and arranged to operatively connect said external driving mechanism to said driven conveyor apparatus within said housing, a sealed bearing structure mounted in said housing wall aperture to support said shaft, said bearing structure comprising a cylindrical casing fixed in said wall aperture, spaced bearings mounted within said cylindrical casing and rotatably supporting said shaft, an oil seal associated with one of said bearings at the outer end of said cylindrical casing to prevent leakage of oil therefrom, a packing gland arranged in said casing inwardly of the other of said spaced bearings at the inner end thereof and engaging said shaft to prevent leakage along said shaft into said housing, and an oil reservoir on said casing externally of said housing and connected to maintain a body of oil within said cylindrical casing between said spaced bearings, whereby leakage of air into said vacuum chamber along said shaft is prevented and any leakage of oil which may occur through said packing gland is observable through said observation window and may be checked by tightening said packing gland.

18. In a drying apparatus, a pair of drums rotatably mounted in parallel, spaced relationship, a conveyor belt trained around and running over said drums, a backup drum rotatably mounted between said spaced drums in position to engage and roll upon the inner surface of one run of said belt between said spaced drums to stabilize said belt, a feeding roller rotatably mounted in position to cooperate with the outer surface of said run of said belt in the region stabilized by said backup drum for applying material to be dried to the belt, supporting means adjustably mounted to rotatably support the respective ends of said feeding roller in selected, cooperative, spaced relationship with the stabilized outer surface of said run of said belt, means for independently effecting adjustment of the respective adjustably-mounted supporting means to vary the spacing between each end of said feeding roller and said belt to regulate the thickness of the film of the material applied to said belt by said roller, and means to apply material to be dried to said rotatable feeding roller for transfer thereby to said belt.

19. In a dehydrator for drying liquid materials, a rotatably mounted heating drum, a rotatably mounted cooling drum in parallel spaced relationship with said heating drum, a material conveying belt trained over said heating drum and said cooling drum, power actuated means operatively connected to drive said drums and said belt, and feeding means disposed in cooperating relationship with the outer surface of the run of said belt moving from the cooling drum to the heating drum and at a substantial distance from said heating drum for applying liquid to be dried to the belt, whereby the liquid is applied to the belt before it is substantially heated by the heating drum.

20. In a dehydrating apparatus, a vacuum chamber, a drum and belt drying conveyor mounted within said vacuum chamber, means to drive said conveyor, feeding means arranged to feed liquid material onto said belt for drying, a doctor blade disposed in cooperating relationship with said conveyor belt to scrape dried material therefrom, means operative from the exterior of said vacuum chamber to change the peripheral position and the angle of incidence of said doctor blade in adjusting its relationship with said conveyor belt, power actuated oscillating mechanism mounted on the exterior of said vacuum chamber, a universal coupling operatively connecting said oscillating mechanism to oscillate said doctor blade transversely of said belt to facilitate the operation of said blade in removing dried material from said belt, and control means operative from the exterior of said vacuum chamber to control the speed of oscillation of said doctor blade.

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UNITED STATES PATENT OFFICE

CERTIFICATE OF CORRECTION

Patent No. 2,924,271 February 9, 1960

Weld E. Conley et al.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction and that the said Letters Patent should read as corrected below.

Column 2, line 23, for "provilded" read -- provided --; column 3, line 47, for "high" read -- highly --; column 5, line 59, for "place" read -- plate --; line 65, for "bearngs" read -- bearings --; line 72, for "puump" read -- pump --; column 14, line 4, for "shifted" read -- sifted --.

Signed and sealed this 2nd day of August 1960.

(SEAL)
Attest:

KARL H. AXLINE
Attesting Officer

ROBERT C. WATSON
Commissioner of Patents