

[54] **NONDUSTING, HIGH TEMPERATURE DRYER**

18,440 5/1908 Norway

[75] Inventors: **Edward B. Weisselberg**, Old Tappan; **George M. Worden, Sr.**, Park Ridge; **William F. Lamp**, Closter; **Alexander M. Lane**, Allendale, all of

Primary Examiner—Carroll B. Dority, Jr.
Assistant Examiner—Larry I. Schwartz
Attorney—Brumbaugh, Graves, Donohue & Raymond

[73] Assignee: **Wyssmont Company, Inc.**, Fort Lee, N.J.

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[51] Int. Cl. **F26b 17/12**

[58] Field of Search 259/180; 263/7; 34/173, 185, 186; 198/84, 188

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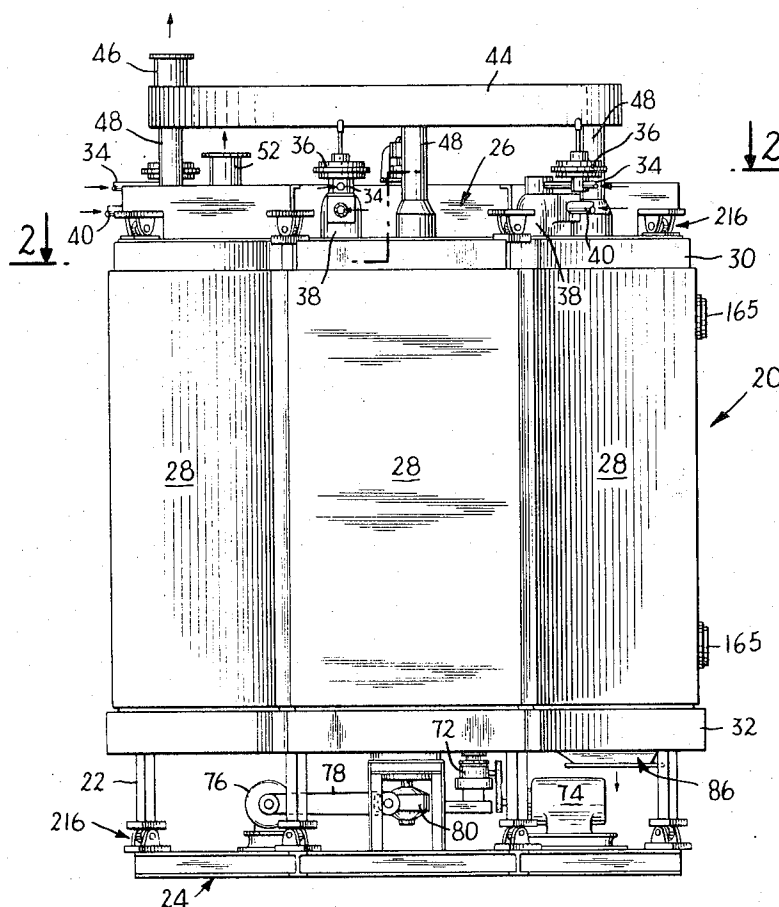
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[57] **ABSTRACT**

Apparatus and method for low dust level drying of material in continuous drying apparatus of the type utilizing a plurality of vertically superimposed, rotating trays to convey the material through the dryer. Billowing of the material, and hence dust formation, is retarded by delivering the material to the dryer, and thereafter transferring it between vertically adjacent trays, through inclined chutes. Upon each revolution of the trays, wiper arms guide the material on each tray over the edge of the tray, while other wiper lever and lever arms distribute the material discharged on to each tray from the next higher tray over the surface of the tray. All side and both end walls of the dryer housing are thermally insulated to maintain high drying temperatures, and the skeletal support structure, as well as the trays and end walls of the housing, are constructed to expand or contract laterally in response to temperature changes within the housing, thus allowing uninterrupted operation of the dryer over a wide range of temperatures, including highly elevated temperatures.

13 Claims, 12 Drawing Figures



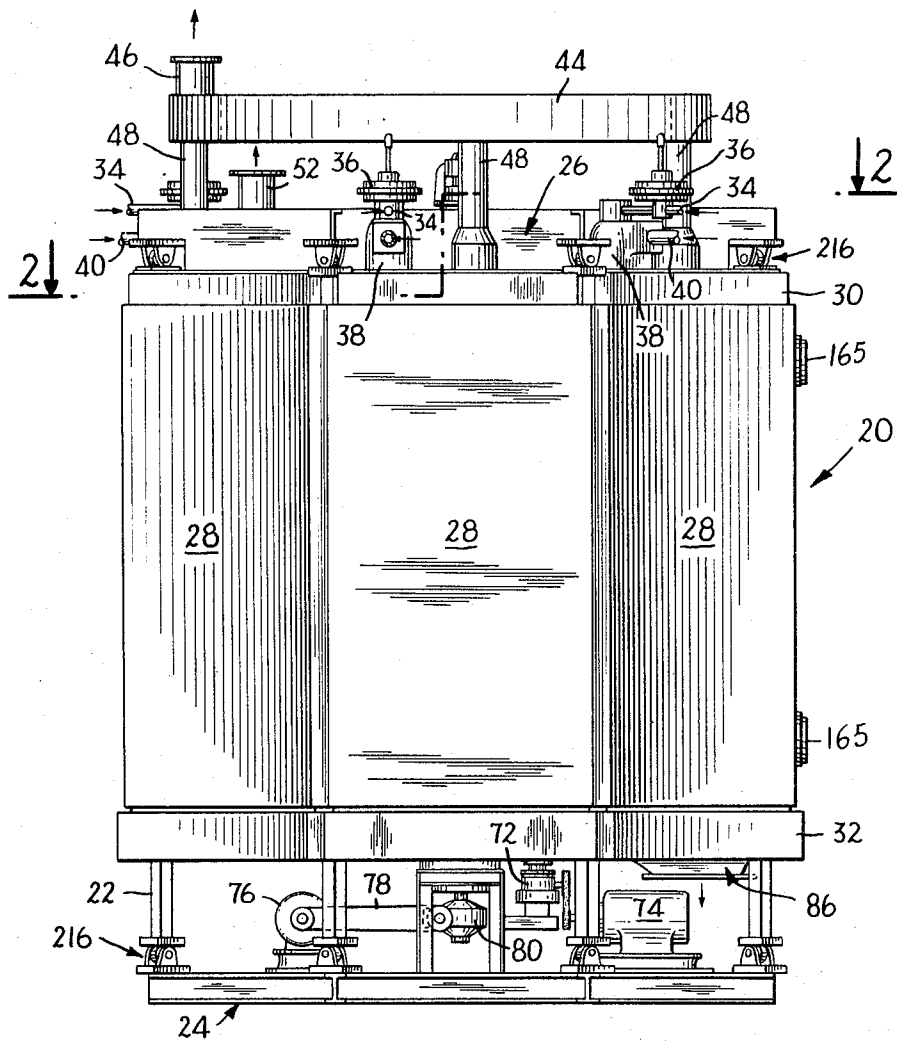


FIG. 1

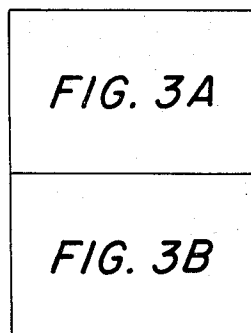
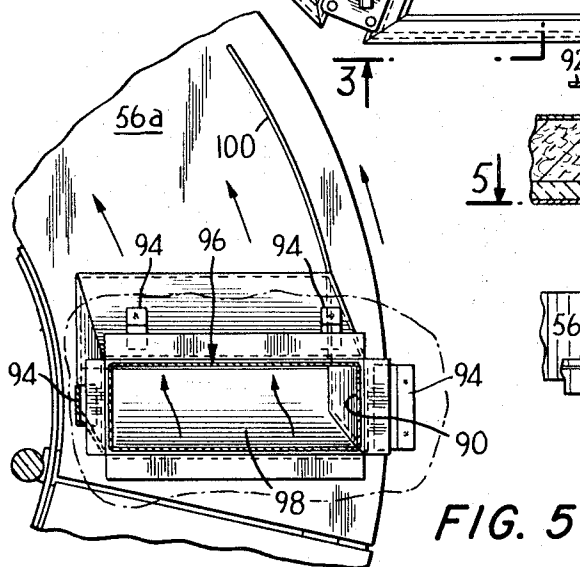
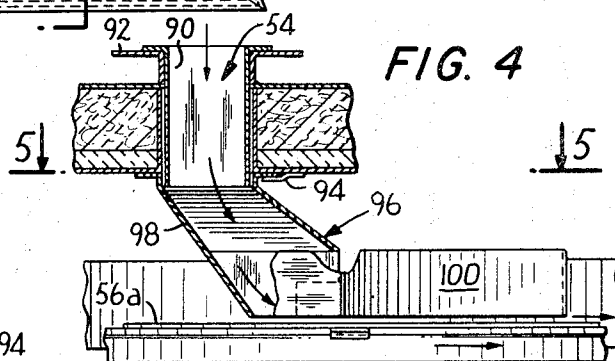
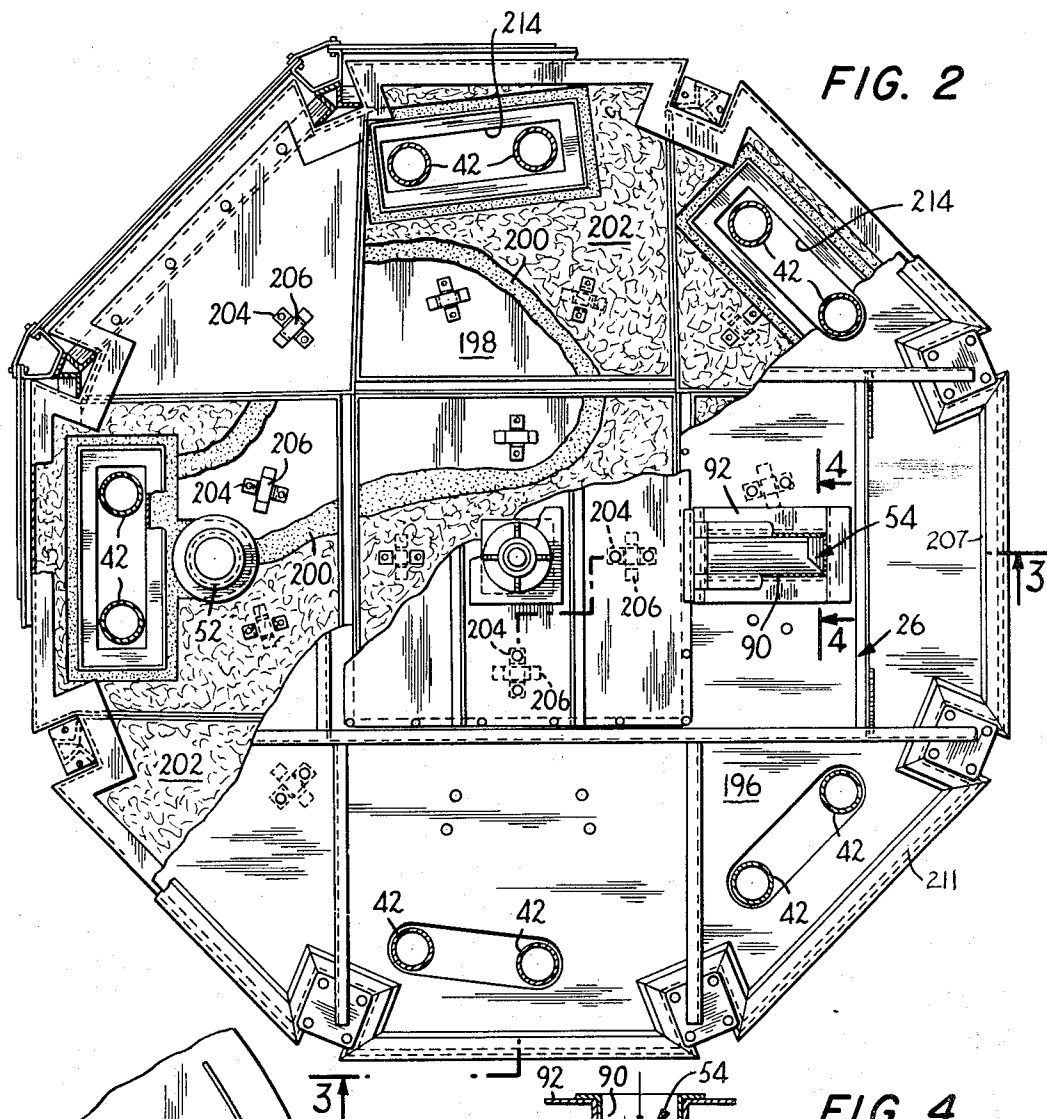


FIG. 3



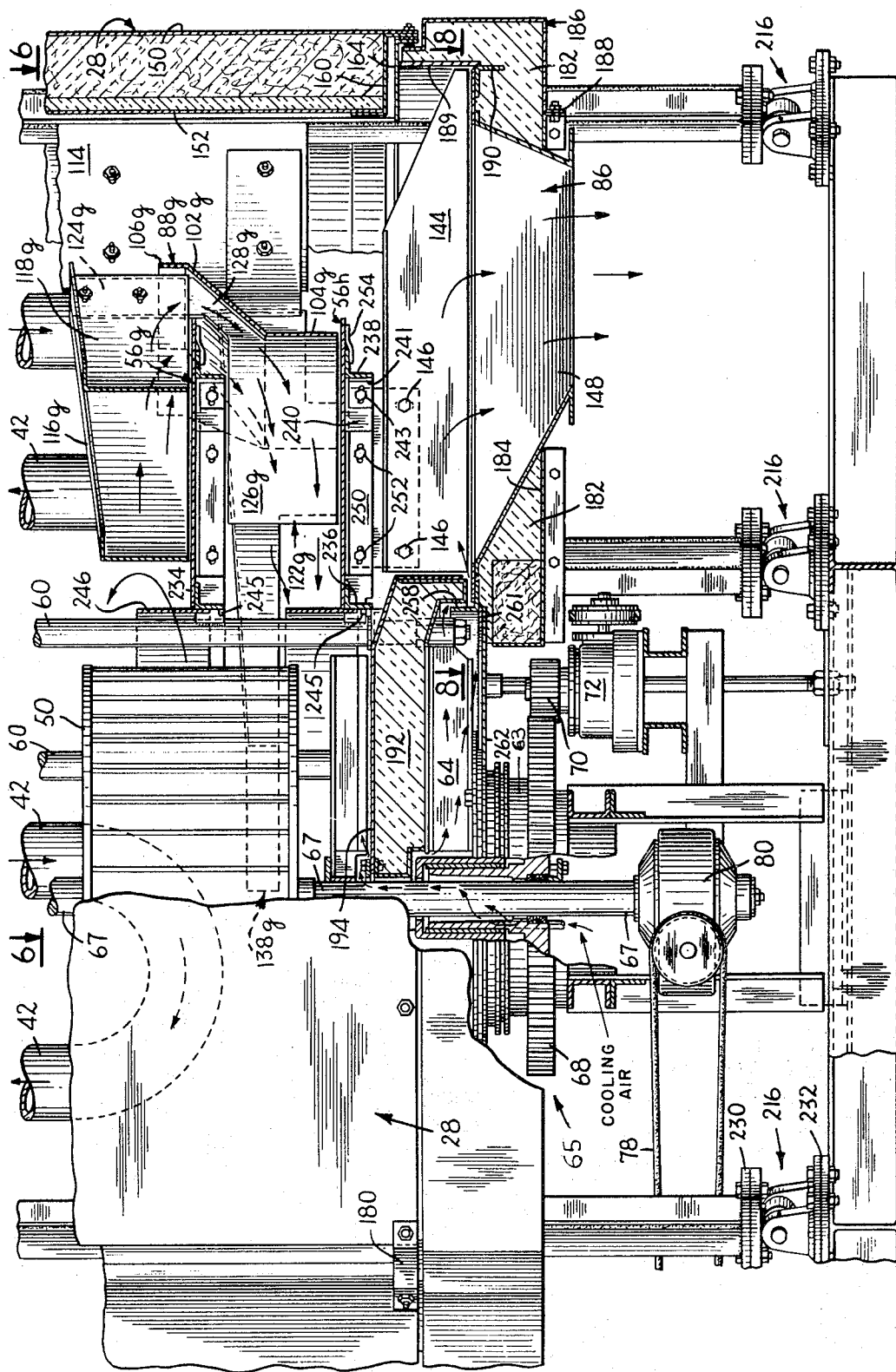
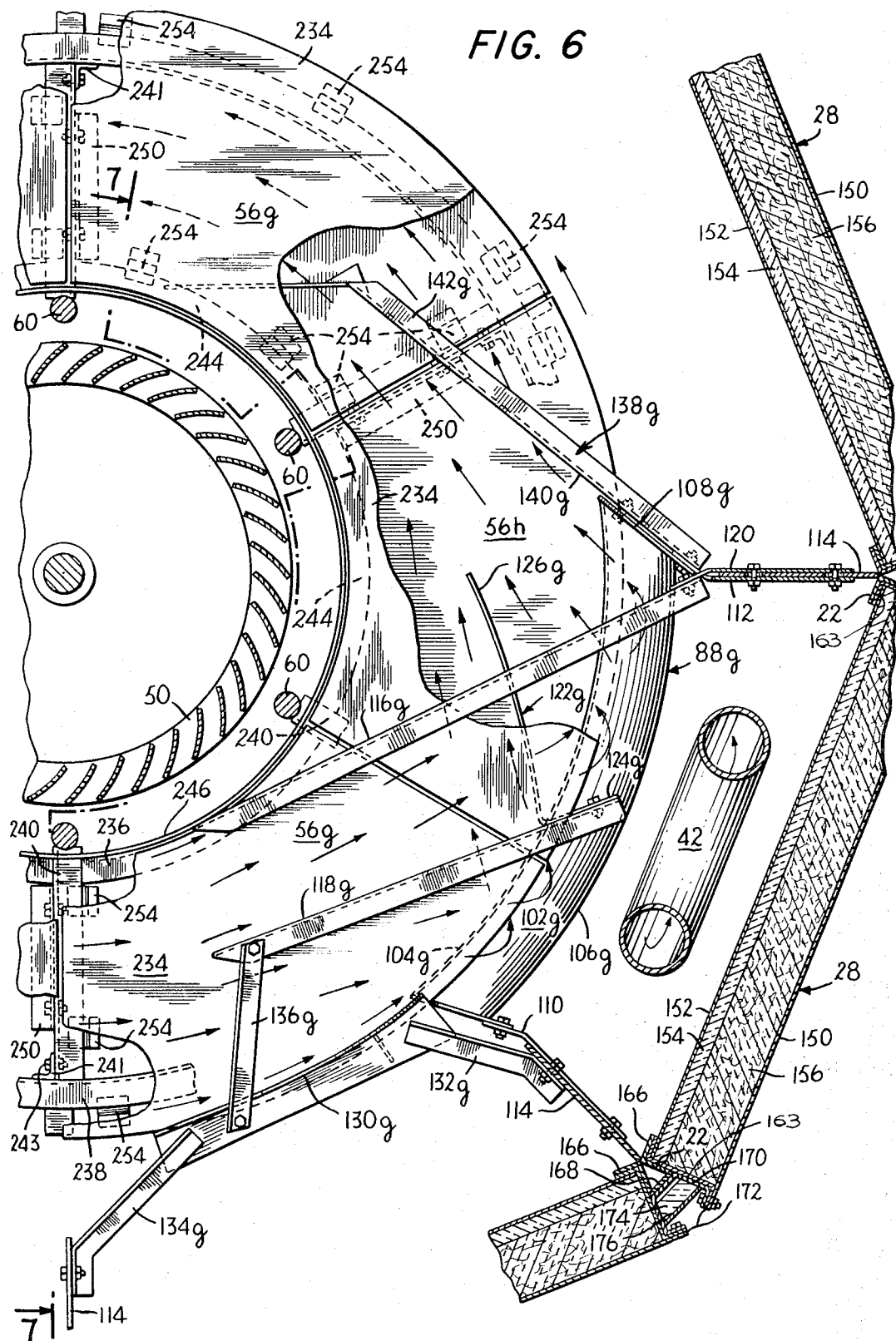


FIG. 3B

FIG. 6



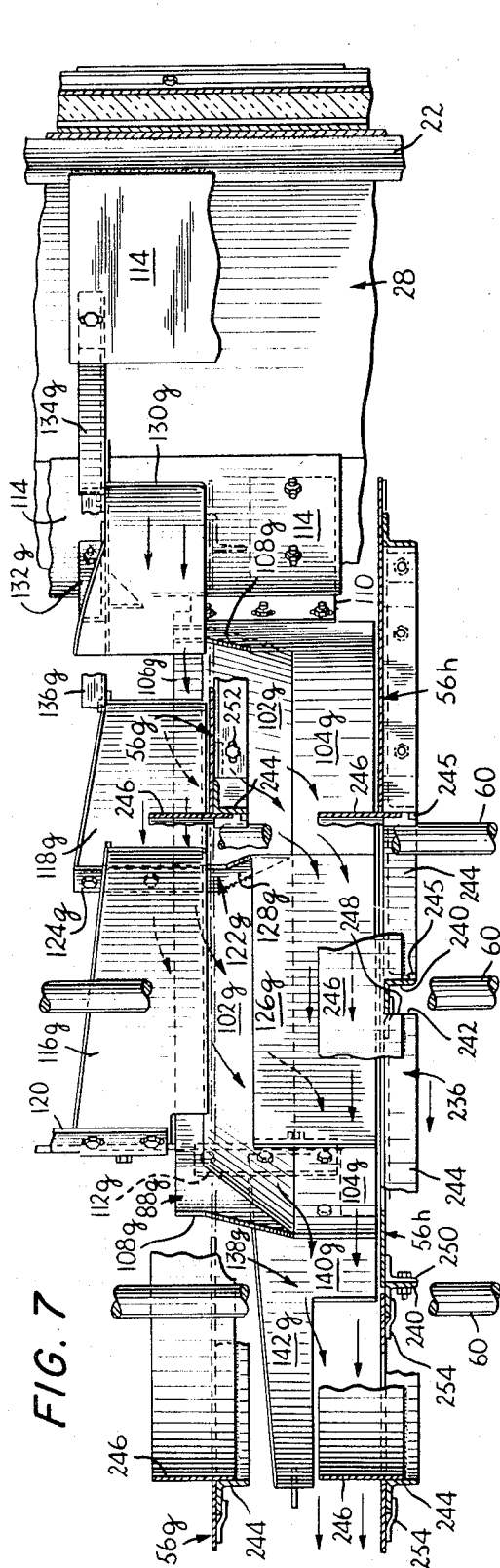
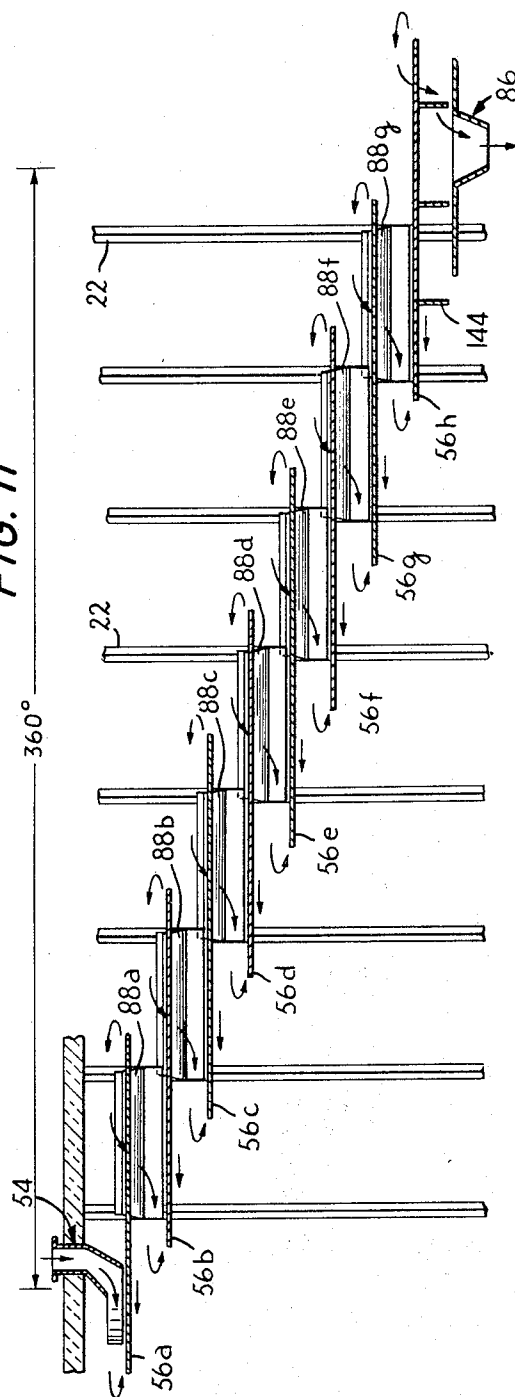


FIG. 11



NONDUSTING, HIGH TEMPERATURE DRYER

This is a division of application Ser. No. 8,985, now U.S. Pat. No. 3,681,855 filed Feb. 5, 1970.

BACKGROUND OF THE INVENTION

The present invention relates to continuous rotary tray dryers of the kind having a plurality of vertically superimposed trays for conveying the material through the dryer by successively transferring the material from tray to tray, and, more particularly, to apparatus and method for processing material in rotary tray dryers while retarding billowing of the material, and hence dust creation, as it is advanced through the dryer. Additionally, the invention is directed to continuous dryers of this type in which the dryer housing is fully insulated, and the dry skeletal structure and material carrying surfaces constructed to allow thermally induced expansion or contraction thereof, to facilitate uninterrupted operation of the dryer at elevated temperatures.

Continuous rotary tray dryers of the kind referred to are known and, in fact, have found wide acceptance in many industries. Such dryers are manufactured under the trademark "TURBO-Dryer" by the Wyssmont Company, Inc., 1470 Bergen Boulevard, Fort Lee, N.J., the assignee of the present application. The Wyssmont dryers generally produce a finished product of high quality and uniformity even where such diverse materials are crystals, powders, pellets, gels and slurries are processed through the dryers and where both high and low drying rates or material outputs are required.

It is desirable in certain applications, however, and in particular where finely divided or fragile materials are to be dried, that special provisions be made for minimizing billowing or breakage of the material as it is conveyed through the dryers so as to retard dust formation. High dust levels within a dryer sometimes lead to operational difficulties, such as explosion hazards and clogging of the dryer and its associated equipment, which result in reduced drying efficiency and increased costs. Moreover, by keeping dust levels within the dryer at a minimum, the need for elaborate dust collection and material return equipment at the exit end of the dryer and, where the drying medium is recirculated, the need for gas cleaning and process equipment can be significantly reduced and, in some instances, entirely eliminated.

It is important also that continuous operation of the dryer at elevated temperatures be possible without interruption due to warping or distortion of the dryer trays or supporting framework caused by differences in temperature between the interior and exterior of the dryer or by temperature variations within the dryer itself. Accordingly, apparatus is needed which will allow for thermally induced expansion and contraction of critical dryer components to the extent necessary to permit operation of the dryer at the desired temperatures.

SUMMARY OF THE INVENTION

In accordance with the present invention, dust levels are minimized in continuous rotary tray dryer apparatus by delivering the material to an upper tray in the dryer through an inclined chute, and thereafter transferring the material through the dryer from tray to tray by passing it through inclined chutes which extend between vertically adjacent trays. Upon rotation of the trays, wiper arms associated with each tray guide the

material over the laterally outer edges of the trays and into the upper ends of the inclined chutes, while additional wiper arms and leveler arms associated with each tray distribute the material transferred to the tray from the next highest tray evenly over the surface of the tray. Thus, the transfer of the material through the dryer is very gentle, in negligible breakage, minimum formation of fines and minimum adhesion of the material to the trays or to the transfer arms and chutes.

As the material advances from tray to tray in the dryer, the lateral position of the material on the tray is alternated; that is to say, the material occupying the laterally outer portion of one tray, upon being transferred to the next lowest tray, is directed to and spaced over the laterally inner portion of the lower tray. Conversely, the portion of the material that occupied the laterally inner portion of the higher tray is moved to the laterally outer portion of the lower tray. All surfaces of the material are thus sought to be uniformly exposed to the drying medium.

High temperature operation of the dryer is made possible through a combination of insulating the dryer housing against heat loss and constructing the load bearing skeletal structure and material carrying surfaces of the dryer to permit lateral expansion and contraction of these components in response to temperature variations. Economies of operation are thus realized, as heat losses are kept at a low level, a significant cost factor at high operating temperatures, and operational difficulties such as warping or jamming of the rotating trays are avoided. Moreover, greater flexibility of use of the dryer is achieved in that high temperatures can be maintained in the upper portions of the housing to dry quickly and uniformly the materials delivered to the dryer, while the lower stages of the dryer can be used to cool the dried material prior to its discharge from the dryer. Although large vertical temperature gradients will exist in such instances, the insulation structure and thermal expansion and contraction capabilities of the dryer permit continuous, uninterrupted operation of the dryer, with accurate temperature control at the various drying and cooling stages.

The insulation structure for the dryer housing includes panel units that extend between the vertical support columns spaced around the housing periphery and individual, elongate insulator members positioned adjacent the exterior side of each support column, thereby tending to maintain the temperature of the support columns at or near the temperature of the more laterally inward portions of the housing. Insulated wall assemblies are located across both the upper and lower ends of the housing. The upper wall assembly includes a hot roof and a cold roof, with the hot roof being suspended from the cold roof in a manner to be laterally movable relative to the cold roof. Aligned openings provided in the hot and cold roofs to admit the various heating elements, drying medium ducts, material inlet assembly, etc., associated with the dryer to the interior of the housing are oversized to an extent that expansion of the hot roof during operation of the dryer will not be impaired by engagement of the roof edges with the elements extending through the openings.

Expansion joints are provided at both ends of the vertical columns so that the columns may be displaced laterally as the housing expands or contracts during operation. Expansion or contraction of the trays and bottom wall, which preferably are segmented, is provided for

by supporting the inner ends of the tray segments on a floating annular ring and by slidably clamping the tray and bottom wall segments to radial support arms and an outer annular ring carried by the radial support arms.

Preferably, slightly negative pressure is maintained within the housing to provide an inward flow of air at any position on the dryer housing where leakage of dust or drying medium from the housing might be expected. Also, at the bearings journaling the lower and upper ends of the tray shaft a pressurized flow of air is provided to prevent leakage of dust along the shaft and also to cool the bearings to temperatures substantially below those maintained within the dryer.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of these and other aspects of the invention, as well as the objects and advantages thereof, reference may be made to the following detailed description and to the drawings, in which:

FIG. 1 is a side elevational view of a continuous rotary tray dryer constructed in accordance with the present invention showing the locations and orientations of the thermal expansion joints on the vertical support columns of the dryer housing;

FIG. 2 is a plan view taken along the line 2—2 of FIG. 1 and looking in the direction of the arrows, with parts broken away from clarity of illustration;

FIGS. 3A and 3B are partial vertical sectional views of the upper and lower ends of the dryer taken along the line 3—3 of FIG. 2 and looking in the direction of the arrows, with parts broken away for clarity;

FIG. 4 is an enlarged detail view of the material inlet chute arrangement of the invention taken along line 4—4 of FIG. 2 and looking in the direction of the arrows;

FIG. 5 is a horizontal view taken along the line 5—5 of FIG. 4 and looking in the direction of the arrows;

FIG. 6 is a horizontal sectional view taken along the line 6—6 of FIG. 3B and looking in the direction of the arrows, with parts broken away for clarity of illustration;

FIG. 7 is a vertical sectional view taken along the line 7—7 of FIG. 6 and looking in the direction of the arrows, with parts broken away for clarity;

FIG. 8 is an enlarged detail view of the bottom wall and material outlet chute arrangement of the invention taken along the line 8—8 of FIG. 3B and looking in the direction of the arrows;

FIG. 9 is an enlarged vertical sectional view taken along the line 9—9 of FIG. 8 and looking in the direction of the arrows;

FIG. 10 is an enlarged vertical sectional view taken along the line 10—10 of FIG. 8 and looking in the direction of the arrows; and

FIG. 11 is an expanded schematic illustration of the circumferential locations of the material transfer chutes extending between vertically adjacent trays and of the paths followed by the material as it advances through the dryer.

DESCRIPTION OF AN EXEMPLARY EMBODIMENT

In FIG. 1, a continuous dryer constructed in accordance with the invention includes a generally octagon-shaped housing 20 having a skeletal support structure including load-bearing columns 22 located at the apices

of the housing sides, a lower support frame 24 for the columns 22 and the drive equipment for the dryer, and an upper support frame 26 for carrying the dryer heating elements, intake and exhaust manifolds and associated equipment and for transmitting the load of this equipment to the support columns 22.

The columns 22 also support a plurality of panel units 28 which, together with an upper wall assembly 30 and a lower wall assembly 32, define an enclosed drying zone within the housing 20. As is more fully disclosed hereinafter, girth members extend peripherally between adjacent columns and with the columns carry the panels 28 and wall assemblies 30 and 32.

A combustion fuel is delivered, as indicated by the arrows in FIGS. 1 and 3A, through an intake manifold (not shown) and pipes 34 to adjustable metering devices 36 and chambers 38, where it is mixed with air delivered through pipes 40. The gas-air mixture is then burned in generally U-shaped heating elements 42, to raise and maintain the temperature of the housing interior to the desired magnitude, and is exhausted, together with the combustion products produced in the elements 42, to an exhaust manifold 44 and thereafter to a stack (not shown) in communication with an exhaust duct 46 (see FIG. 1). As clearly represented in FIG. 2, several heating elements 42 are spaced around the inner walls of the housing 20, with a corresponding number of metering devices 36 and chambers 38 being provided so that the heat generated by each element 42 can be individually regulated. The exhaust manifold 44 (see FIGS. 1 and 3A) takes the configuration of a partial annulus and is arranged to extend above each of the exhaust legs of the heating elements 42 to facilitate connection with the elements, as, for example, by means of the ducts 48. If desired, the exhaust duct 46 and the connector ducts 48 may be covered with insulating material to reduce heat losses and to keep temperatures at the upper end of the dryer from becoming too high.

Instead of burning a gas-air mixture within the heating elements 42, a high temperature transfer liquid can be circulated through the elements. Also, steam, oil or electricity can be used as the heat source rather than a combustible gas.

A drying medium, such as air, inert gas or superheated steam, is admitted into the housing 20 through intake ports (not shown) and is circulated over the heating elements 42 and through the drying zone along generally horizontal paths by a plurality of turbofans 50 (see FIGS. 3 and 6) that are rotatably mounted centrally of the housing. The drying medium is thereafter exhausted from the dryer through a duct 52 leading from the upper end of the housing. It is possible, of course, to recirculate the drying medium, or to pass it through a preheater before feeding it to the housing 20 to augment the heating capacity of the elements 42. Similarly, where a solvent is used to treat the material fed to the dryer, the drying medium, which in this instance may be an inert gas, upon being exhausted from the dryer may be fed through a solvent recovery system. Also, further economies can be realized by passing the effluents from either or both of the exhaust ducts 46 and 52 through appropriate heat recovery systems.

The wet material to be processed in the dryer is fed through an inlet chute assembly 54 (see FIG. 3A) extending through the upper wall assembly 30 of the housing and is directed, as indicated by the arrows,

onto the uppermost tray 56a of a vertical stack of superimposed trays. Each of the trays 56 is generally annular in plan and is supported for rotation within the housing in a generally horizontal plane by a cage assembly 58.

Turning briefly to FIGS. 3A, 3B and 6, the cage assembly 58 is formed by a multiplicity of circumferentially spaced stanchions 60 that are secured at either end to suitable frame structures 62 and 64. The upper frame 62 connects with a hollow, rotatable shaft 66, while the bottom frame 64 is bolted to the rotatable upper part 63 of a thrust bearing assembly 65. The cage assembly 58, and hence the trays 56, is caused to rotate within the housing by a drive train including a driven gear 68 carried by the upper bearing part 63, a driver gear 70, a worm reducer 72 and a primer mover 74. A second shaft 67, passing concentrically through the thrust bearing assembly 65 and shaft 66, rotates the turbfans 50 within the housing. To this end, the shaft 67 is drivably connected to a prime mover 76 (see FIG. 1) through a drive train including a drive belt 78 and a worm reducer 80 connected directly to the end of the shaft 67. Individual control of the rate of rotation of the turbfans 50 and the trays 56 is therefore possible.

The shafts 66 and 67 are suitably journaled at their upper ends in a bearing support 84, while the shaft 67 at its lower end extends through the thrust bearing assembly 65. High temperature bearings can be conveniently used for this purpose, although the insulation structure and cooling air flow feature of the dryer obviates the need for elaborate cooling system for the bearings.

As the trays 56 revolve, the material carried by each tray is transferred to the next lowest tray. In this fashion the material is progressively advanced through the dryer to a material discharge assembly 86 in the bottom of the dryer housing 20, through which it is discharged, as indicated by the arrows in FIG. 3B, to a carryoff conveyor or the like (not shown). The manner in which the material is passed from tray to tray within the dryer will be readily understood by referring to FIG. 11, where an expanded, planar representation of the vertical stack of trays 56 is depicted.

After the material is delivered through the inlet assembly 54, to fall on the upper tray 56a as it rotates beneath the assembly 54, it remains on the tray 56a for approximately one revolution of the tray. The tray is illustrated in FIG. 11 as rotating in the counterclockwise direction. It is then wiped over the outer edge of the tray, as will be more fully described hereinafter, and into a material transfer chute 88a which extends between the tray 56a and the subjacent tray 56b. As shown by the arrows in FIG. 11, the material is guided by the chute 88a onto the next lowest tray 56b, where it remains for approximately one revolution of the tray 56b before being wiped, as before, over the edge of the tray and into the next lowest transfer chute 88b to be delivered to the lower tray 56c. This process is repeated until the material has been discharged from the dryer through the discharge assembly 86.

That is to say, the material remains on each tray for approximately one revolution of the tray and is then diverted into the upper end of the associated transfer chute 88 to be directed onto the next lowest tray. In order that this process of successively passing the material from tray to tray upon each revolution of the trays can be carried out, it is important that material transfer

chute 88 for receiving material carried by a tray be positioned properly in relation to the position of the transfer chute 88 delivering the material to that particular tray. For example, in FIG. 11, the material transfer chute 88a must be located in a direction clockwise from the lower end of the material inlet means 54, since, as noted, the trays rotate in the counterclockwise direction, so that the material will be carried by the tray 56a for approximately a full revolution before reaching the position of the chute 88a. Similarly, the transfer chutes 88b to 88g must be positioned clockwise of the correspondingly higher transfer chutes 88a to 88f. With the transfer chutes 88 thus arranged, the material will be delivered to the trays 56b to 56h at the correct circumferential position to be retained on the respective trays for nearly a full revolution of the trays. Of course, the length of time the material remains on any one tray can be controlled by regulating the speed of rotation of the trays.

It is an important feature of the invention that the material is delivered to the upper tray 56a and is thereafter transferred between trays along a path that is inclined at least over a portion of its length, thereby minimizing billowing of the material and hence retarding the formation of dust within the dryer. In FIGS. 3A, 4 and 5, the structure of the material inlet assembly 54 by which the material is admitted through the upper wall assembly 30 and delivered to the upper tray 56a includes an insert member 90 that is received within an opening provided in the upper wall assembly 30 and rests on a peripheral flange 92 extending around the upper end of the opening. A plurality of clips 94 are attached to the lower side of the wall assembly 30 and are adapted to receive in sliding relation the flanged upper ends of an inclined chute 96, which is of a width approximately the lateral width of the annular tray 56a. Material passing through the insert 90 is deflected along an inclined path by the side wall 98 (see FIG. 4) of the chute 96 and is delivered in a gentle manner onto the surface of the tray 56a as it rotates beneath the lower end of the chute. Feeding of the material to the dryer thus results in minimum breakage, minimum formation of fines and minimum adhesion of the material to the inlet assembly. The laterally outer wall of the chute 96 is extended in the direction of rotation of the tray 56a to form a baffle-like member 100 for preventing the material from flowing over the outer edge of the tray.

Similarly, the material transfer chutes 88 are constructed to transfer the material between trays along an inclined path, thereby further retarding dust creation and minimizing breakage of the material and adhesion of the material to the transfer chutes. For example, in FIGS. 3B and 7, the transfer chute 88g extending between the upper tray 56g and the lower tray 56h, includes an inclined central portion 102g onto which the material falls, as indicated by the arrows in FIG. 3B, upon being wiped off the surface of the tray 56g. Another important feature of the transfer chute construction, is that the inclined portion 102g does not extend to the surface of the tray 56h, but terminates well above the tray surface at the upper end of a vertically extending portion 104g of the chute that defines an outer boundary for the material and confines it to the surface of the tray 56h.

The foregoing configuration of the transfer chutes 88 is preferred inasmuch as it has been discovered that if

the inclined portions 102 extend over the full distance between adjacent trays the openings between the outer edge of the trays and the adjacent surfaces of the transfer chutes tend to clog. Attempts to avoid such clogging by spacing the upper ends of the inclined portions 102 farther from the outer edges of the trays have proved unsatisfactory since this requires that the heating zone within the housing 20 be undesirably enlarged. On the other hand, if the portions 102 are more steeply inclined, poor distribution of the material on the lower tray surface results.

In a preferred embodiment of the transfer chutes, again using the chute 88g as an example, an upper vertical portion 106g and side walls 108g are provided on the chute 88 more fully to confine the material as it moves between trays. Each of the transfer chutes 88 is supported within the housing 20 by metal straps 110 and 112 (see FIG. 6) that are bolted, for example, to the side walls 108g of the transfer chute 88g. The straps 110 and 112 are in turn bolted to vertically extending plates 114 secured to the support columns 22.

Turning now to the manner in which the material is diverted from the tray surfaces and into the upper ends of the transfer chutes 88, FIG. 6 illustrates a pair of wiper arms 116g and 118g extending in close, spaced relation to the surface of the tray 56g for guiding the material off the tray and into the transfer chute 88g. It will be understood, of course, that a similar pair of wiper arms 116 and 118 are associated with each tray 56 in the dryer.

Preferably, the wiper arm 116g is supported by a strap 120 (see FIG. 6), also bolted to a vertical plate 114, so as to extend from a point near the far end, relative to the direction of rotation of the trays, of the transfer chute 88g and across the surface of the tray 56g in a plane generally tangential to the inner circumference of the tray to terminate at a point approximately on the inner edge of the tray. The wiper arm 118g, on the other hand, is mounted so that its leading end is approximately equidistant between the inner and outer edges of the tray 56g and to extend approximately parallel to the arm 116g. A generally L-shaped divider member 122g is positioned between the trays 56g and 56h, for a purpose hereinafter described, and has bolted to the upper end of its vertical leg 124g the rearward end of the wiper arm 118g. The horizontal leg 126g is disposed at approximately a right angle to the vertical leg 124g and extends between the trays 56g and 56h to approximately the midpoint of the trays (see FIG. 6). The vertical and horizontal legs of the L-shaped member 122g are joined by a center portion 128g which is inclined to conform with the inclined portion 102g of the material transfer chute 88g.

Accordingly, as the tray 56g rotates beneath the wiper arms 116g and 118g, the material is pushed by the wiper arms off the outer edge of the tray and is deflected by the inclined chute portion 102g onto the next lowest tray 56h. However, because the vertical leg 124g and the central inclined portion 128g of the divider member 122g in effect divide the transfer chute 88g into two separate material flow channels (see FIG. 7), the material diverted to the transfer chute by the wiper arm 116g is deposited on the tray 56h on one side of the horizontal leg 126g of the divider member while the material diverted by the wiper arm 118g is retained on the other side of the horizontal leg.

By this wiper arm and divider member arrangement not only is the material handled in a very delicate manner, but the position occupied on the tray by the material is interchanged each time the material is transferred to a lower tray. This is clear from FIG. 6, where the arrows indicate that the material moved off the tray 56g by the wiper arm 116g, i.e., the material occupying the inner half of the upper tray 56g, is delivered by the transfer chute 88g and divider member 122g to the outer half of the next lowest tray 56h. Conversely, the material occupying the outer half of the upper tray is diverted by the wiper arm 118g, transfer chute 88g and divider member 122g to the inner half of the lower tray 56h. An important advantage is thus realized inasmuch as thorough mixing of the material is achieved, with the result that new moist surfaces are continuously being exposed to the drying atmosphere to enhance product quality and uniformity and to increase drying efficiency.

A baffle 130g is disposed along the outer edge of the tray 56g immediately in advance of the leading end of the transfer chute 88g to prevent loss of the material over the outer edge of the tray. Appropriate angle iron supports 132g and 134g are provided to hold the baffle 130g in the proper position. Since the area between the wiper arm 118g and the baffle 130g converges as the chute 88g is approached, the baffle 130g preferably is tapered upwardly in the direction of rotation of the tray to provide a boundary of increased height (see FIG. 7). If desired, a support 136g may be attached between the baffle 130g and the wiper arm 118g to stiffen the leading end of the wiper arm.

Upon being delivered to the lower tray 56h, and being carried to the respective portions of the tray by the divider member 122g, the material is distributed evenly over the tray surface to a predetermined level by an elongate leveler arm 138g. The leveler arm is bolted (see FIG. 6) to the far side wall 108g of the transfer chute 88g and extends therefrom over the tray surface, first in a vertically lengthened portion 140g (see FIG. 7), that acts as a wiper arm to deflect the material discharged from the chute 88g on to the tray 56h, and, then, as a vertically shortened portion 142g that actually levels the material. It will be apparent, of course, that the clearance between the lower edge of the piston 142g and the tray 56h can be varied to regulate the depth of material on the tray.

Although the above description of the wiper arms 116g and 118g, transfer chute 88g, divider member 122g, leveler arm 138g and the associated baffles and support structure has been made in connection with only two trays 56g and 56h of the dryer, it will be understood that corresponding elements are associated with all other trays in the dryer, except as otherwise noted.

After one revolution of the tray 56h, the last tray in the dryer, the material is pushed over the edge of the tray by the wiper arms (not shown) associated with the tray 56h and falls on to the bottom wall of the housing 20, where it is pushed upon continued rotation of the trays by one or more blades 144 (see FIG. 3B) suspended from the tray support structure to the discharge outlet assembly 86. The blades 144 preferably are mounted to permit adjustment of the clearance between the blades and the bottom of the housing. Any suitable arrangement, such as the bolt and elongate slot structure 146 illustrated in FIG. 3B, can be used for this

purpose. Desirably, the blades 144 extend substantially beyond the outer edges of the trays 56 so that all of the material falling from the lower tray 56h will be swept along by the blades and discharged from the dryer.

The discharge assembly 86 includes a chute 148 of which the sides slope relatively steeply toward the exhaust end of the chute to ensure that adhesion of the material to the discharge assembly is kept to a minimum. At the material receiving end, the chute 148 is of a transverse width substantially coextensive with the bottom wall of the housing; therefore, it readily receives the material delivered to the bottom wall from the tray 56h. An appropriate carryoff conveyor (not shown), or the like, may be positioned beneath the chute 148 to remove the dried product for packaging or further processing. Alternatively, a vapor lock, for example, a high temperature rotary vapor lock apparatus, may be connected between the chute 148 and whatever material handling apparatus is used to carry the material away from the dryer to reduce the loss of heat, drying medium or solvent, as the case may be, across the discharge assembly 86.

Another important feature of the dryer of the present invention is that it is constructed to permit continuous uninterrupted operation at highly elevated temperatures, for example, temperatures in the range of 1,100° F, without damage being caused to the dryer skeletal or housing structure by thermal expansion or contraction of the components thereof and without warping or jamming of the moving elements of the dryer. Part of this construction includes fully insulating the dryer housing 20 on the side and end walls to reduce heat losses and to maintain as uniform as possible the temperature at the center and periphery of the drying zone, thus improving product uniformity and reducing the magnitude of thermal stresses created in the housing and tray structure.

The side panel units 28, therefore, take a sandwich-like configuration in cross section, including two spaced metal sheets 150 and 152 and a filler of insulating material (see FIG. 3A and 3B). Preferably, two types of insulating material are used, a layer 154 of dense material, such as asbestos board or the like, abutting the outer surface of the inner sheet 152, and a looser layer 156, such as a wire-mesh fiberglass blanket, filling the space between the layer 154 and the outer sheet 150. The sheets 150 and 152 are secured together at their upper and lower ends by generally Z-shaped end members 158 and 160, respectively, which are in turn bolted to flanged support elements 162 and 164 carried by the skeletal structure of the dryer. Similarly, the sheets 150 and 152 are attached along the sides by Z-shaped members 163 (see FIG. 6), thereby forming a complete, enclosing insulating panel unit. At convenient locations around the periphery of the housing 20, one or more gas-tight sight ports 165 (see FIGS. 1 and 3A) may be provided in the panels 28 to allow visual inspection of the interior of the dryer.

Each panel 28 is attached at its sides to adjacent support columns 22, as is illustrated clearly in FIGS. 6 and 8, which are specially designed in accordance with the invention to maintain an unbroken insulating shield around the dryer housing 20. Turning briefly then to the column structure, each column 22 is formed by a pair of L-shaped beams 166 and an elongate plate 168. The beams 166 are welded or otherwise secured together at their heels, and to the opposite ends of the

plate 168 at the outer ends of their adjacent legs, to enclose with the plate 168 a generally triangular area. Desirably, the legs of the beams 166 attached to the plate 168 are arranged at an angle relative to each other such that the panel units 28 are received between the facing beams 166 of adjacent columns 22 at approximately right angles.

Associated with each column 22 is a channel member 170 (see FIG. 6), the legs of which are aligned with the outer legs of the respective L-shaped beams 166 so as to face the side members 163 of the panel units 28. The channel member 170 also has facing flanges 172 at the outer ends of its legs, to which are bolted the ends of the members 163 and outer sheets 150 of the adjacent panel units 28. Accordingly, each panel unit 28 is firmly attached at either side, through the channel members 170, to the adjoining panel units 28, but not so firmly as to prevent expansion and contraction of the housing 20. In fact, the configuration of the channel members 170, by which the panel units 28 are connected to the flanges 172 at the outer ends of flexible legs, facilitates lateral inward or outward movement of the housing walls by allowing limited movement of the panels along the circumference of the housing.

To avoid large temperature drops across the housing walls at the location of the columns 22 and to preserve the integrity of the insulation shield, insulation members 174, preferably of asbestos material, are placed within the channel members 170 and are held in position therein by elongate metal sheets 176. Additional rigidity may be added to the housing 20, if desired, by tying adjacent panel units 28 together with metal straps 178 and 180 (see FIGS. 3A and 3B) located at the upper and lower ends, respectively, of the panels.

The insulation provided in the lower wall assembly 32, as illustrated in FIGS. 3B, may consist substantially of asbestos material 182. This material is contained within a sheet metal enclosure formed by annular, generally L-shaped members 184 underlying the area between the cage 58 and the side walls of the housing and a plurality of end sections 186, corresponding in number to the number of panel units 28, that are bolted, as at 188, to the outer end of the L-shaped members 184. The end sections 186 are supported (see FIG. 8) by the channel members 170 in substantially the same way as the panel units 28, and are further connected at their inner walls 189 to an L-shaped, annular girth member 190 carried by the columns 22 in encircling relation of the lower end of the dryer.

That portion of the lower end of the dryer located within the cage 58 is insulated by an annular pad 192 (see FIG. 3B) of asbestos material enclosed within a sheet metal enclosure 194 and mounted on the cage assembly frame structure 64 for rotation therewith. The pad 192 overlaps the inner end of the insulating material 182 to provide a continuity of insulation material across the lower end of the dryer. Apertures are formed in the pad 192 and enclosure 194 for passage of the stanchions 60 of the cage assembly 58.

The upper wall assembly 30 (see FIG. 3A) has the same basic sandwich structure as the panel units 28, but differs therefrom in that the upper sheet 196 of the assembly, referred to herein for purposes of illustration as the "cold roof," is attached, by welding, for example, to the upper support frame 26 and the lower sheet 198, referred to herein as the "hot roof," together with the overlying layers 200 and 202 of asbestos and fiber-

glass materials, is carried by the cold roof 196 so as to be movable relative thereto. This is accomplished by suspending the hot roof 198 from the cold roof 196 through the use of a plurality of pairs of mating, U-shaped brackets 204 and 206 attached to the cold roof 196 and hot roof 198, respectively (see FIGS. 2 and 3A). As the hot roof 198 is supported solely by the brackets 204 and 206, it is free to expand or contract laterally of the housing in response to variations of the temperature within the housing. If desired, the hot roof 198 may be tied to an upper girth member 208, which may also carry the elements 162 for supporting the panels 28.

To prevent wrinkling of the cold roof 196 caused by the leakage of hot air currents along its lower surface, a gasket 207 (see FIGS. 2 and 3A) is lapped over the end of the hot roof and is held tightly against a facing flange 209 on the cold roof by an L-shaped clamp 211 bolted to the cold roof. As is apparent from FIG. 2, the gasket 207 and clamp 209 extend along the entire periphery of the hot roof.

The upper wall assembly 30 is dimensioned to overlap the upper ends of the panel units 28 (see FIG. 3A), thus fully sealing off the drying zone from the environment. Moreover, as the cold roof 196 and the upper support frame 26 are shielded from the high temperatures within the dryer housing, it is possible to position accurately the shafts 66 and 67, the heating elements 42 and the associated fuel intake and exhaust equipment, in relation to the interior of the dryer housing 20, as well as in relation to the accessory equipment servicing the dryer, and to preserve the alignment of these elements during operation of the dryer. Also, access to the equipment carried by the frame 26 is possible at all times. This is important should it develop that adjustments or repairs need to be made to the equipment during drying operations.

To ensure that the hot roof 198 is free to expand and contract without jamming against the heating elements 42 and the various other equipment extending through the upper wall assembly 30, the openings provided in the hot roof are oversized and offset from the corresponding openings in the cold roof 196 to an extent that the hot roof 198 can expand the full distance anticipated at the highest operating temperature of the dryer without engaging this equipment. For example, in FIG. 3A, the opening 210 formed in the hot roof 198 to admit the material inlet assembly 54 is significantly larger in size than the corresponding opening in the cold roof 196, i.e., the opening surrounded by the peripheral flange 92. Likewise, the openings 214 (see FIG. 2) for the heating elements 42 are also enlarged to allow for expansion of the hot roof.

As mentioned, provision is made for permitting expansion and contraction of the dryer housing 20 and its support structure. In a preferred embodiment, such provision includes load-transmitting expansion joints 216 (see FIG. 1) located between the lower and upper ends of the support columns 22 and the lower and upper support frames 24 and 26, respectively. All of the expansion joints are identical; therefore, only one will be described, it being understood that the description will apply to all equally.

In FIG. 3A, a typical expansion joint 216 includes a pair of spaced plates 218 and 220 to which are attached, respectively, a sleeve 222 and a pair of spaced upstanding ears 224, the sleeve 222 being received be-

tween the ears 224 and in turn receiving, in sliding engagement, a pin 226 carried between the ears 224. A set screw 228 may be provided to anchor the pin 226 in fixed position relative to the ears 224. Desirably, the expansion joints 216 are interposed between and bolted to cooperating plates 230 and 232 secured to the ends of the columns 22 and the support frames 24 and 26 (see FIGS. 3A and 3B), although these latter plates may be omitted if desired.

Preferably the sleeve 222 and pin 226 of each joint 216 are arranged in alignment with a radius of the housing to facilitate lateral movement of the columns 22 as the various dryer elements connected to the columns expand or contract during operation of the dryer. Accordingly, each of the expansion joints 216 associated with any one column 22 are given orientations such that both are aligned along the same radius of the housing (see FIG. 1).

Provision is also made for expansion and contraction of the trays 56 and the bottom wall of the housing to permit high temperature operation of the dryer and to make possible the maintenance of highly elevated temperatures in the upper portions of the dryer while using the lower trays for cooling of the material before discharge. Turning first to the tray structure and referring to FIGS. 3B and 6, where the trays 56g and 56h and the support structure therefore are representative of a preferred embodiment, the annular trays 56g and 56h are formed of a plurality of truncated segments 234 supported in a generally horizontal plane in end to end relation on a pair of laterally spaced, L-shaped annular rings 236 and 238. At each vertical position along the stanchions 60 at which a tray 56 is to be located, L-shaped arms 240 are mounted thereon to extend radially from the stanchions 60 and to be attached at their outer ends to the vertically depending leg of the outer ring 238. To allow for movement of the ring 238, this attachment takes the form of a slidable joint constituted by L-shaped brackets 241 (see FIGS. 3B and 6) that are secured to the arms 240 by a bolt and elongate slot arrangement 243.

The inner annular ring 236 is also supported by the radial arms 240, but instead of being secured directly to the arms, as is the outer ring 238, gaps 242 are formed in the ring (see FIG. 7) so that the ring 236 is in fact a plurality of separate arcuate segments 244 that are circumferentially spaced at their ends a distance sufficient to allow the arms 240 to pass between adjacent segments. An annular metal band 246 is attached to the upper portion of the vertically extending legs of the segments 244 and is notched at 248 (see FIG. 7) at radial positions corresponding to the positions of the arms 240 so that the band 246 fits over the arms 240 and rests against the upper horizontal leg of the arms in a manner such that the horizontal upper legs of the segments 244 are in approximately the same plane as the horizontal upper legs of the arms 240 and the horizontal upper leg of the outer ring 238. The ring 236 is positioned relative to the arms 240 and to the axis of rotation of the trays by stops 245 (see FIG. 3B) welded to the inner end of the arms.

The inner ring 236, therefore, is free to move or "float" radially along the arms 240 in response to thermally induced forces, thus avoiding warping of the trays due to temperature gradients within the dryer. Also, the band 246 serves to keep the material carried by the trays from falling over the inner edges of the

trays. Each tray segment 234 is mounted on the inner ring 236 and the outer ring 238 of the tray support structure in a manner to permit both circumferential and radial expansion and contraction of the segments. Thus in FIGS. 3B, 6 and 7, the tray segments 234 are welded, or otherwise secured, at one end to the horizontal leg of an L-shaped bracket 250, the vertical leg of which is bolted to the vertical leg of the arm 240. Elongate slots 252 in the bracket 250 allow relative movement between the bracket 250 and the supporting arm 240 due to different rates of expansion or contraction of the bracket, or tray segments 234, and the arms 240.

At the other end, and along the inner and outer edges, the tray segments 234 are slidably clamped to the horizontal legs of the adjacent arms 240 and to the inner ring segments 244 and the outer ring 238, respectively. In FIG. 6, the arrangement of the clamps 254 and the annular rings 236 and 238 and arms 240 by which thermal expansion and contraction of the tray segments 234 is possible is clearly shown. There, the clamps 254 that coast with the horizontal legs of the inner ring segments 244 and the outer ring 238 are spaced along the respective edges of the tray segments 234 and are disposed to open in the radially inward direction so as to slip over the outwardly oriented (see FIG. 7) horizontal legs of the rings. Also, the clamps 254 coacting with the horizontal legs of the arms 240 are located to open toward the end of the segments 234 and to slip over the facing legs of the arms 240. The individual tray segments 234 are therefore easily installed on or removed from the tray support structure simply by sliding them inwardly and circumferentially to engage the clamps 254 with the respective horizontal legs of the inner and outer rings 236 and 238 and the radial arms 240. Thereafter, the bolts securing the bracket 250 to the vertical leg of the adjacent arm 240 are tightened sufficiently to hold the tray segment in place, but not so tightly as to prevent expansion or contraction of the segment relative to the arm.

The bottom wall of the dryer is similarly constructed to allow for thermally induced changes in dimension and is further designed to facilitate fabrication of the dryer. In FIGS. 8, 9 and 10, the bottom wall of the dryer is formed by multiple arcuate segments 256 supported at the outer edges by the annular girth member 190 and at the inner edges by an annular ring 258. Radial arms 260 extend between the inner ring 258 and the girth member 190 and support the circumferential ends of the segments 256.

The inner ring 258 is attached to a disc 261 which in turn is attached to a support plate 262 (see FIG. 3B) attached to the dryer skeletal structure. Preferably, the ring 258 is arranged so that its vertical leg extends upwardly to form a boundary against leakage of the material off the inner edge of the bottom wall. A similar function is performed at the outer edge of the bottom wall by the inner walls 189 of the end sections 186 of the lower wall assembly 32.

Each bottom wall segment 256 is attached at one circumferential end (see FIG. 10) to the horizontal leg of a bracket 266, the bracket 266 being bolted to the vertical leg of the adjacent arm 260. At the other end, the segment carries on its undersurface a plurality of L-shaped clamp elements 268 for gripping the arms 260. Similar clamp elements 268 are also positioned along the radially inner and outer edges of the wall segments

to cooperate with the horizontal legs of the ring 258 and the girth 190, respectively (see FIG. 9).

The clamp elements 268 include a fixed L-shaped bracket 270 and an associated movable element 272. The movable elements 272 are adjustable vertically, as by a bolt and elongate slot arrangement 274, so as to be abutted against the horizontal legs of the respective support members. With this arrangement, the lower wall of the dryer is readily assembled in that the segments 256 may be dropped in position on the ring 258 and girth member 190 and thereafter easily secured to the horizontal legs of these members and also to the horizontal leg of the adjacent radial arm 260. The bracket 266 may then be bolted to the vertical leg of the arm 260 to fix the segment 256 in position. However, since the segments 256 are fixedly attached to only one arm 260, they are free to expand or contract in either the radial or circumferential direction. Accordingly, high drying temperatures can be maintained through the vertical extent of the dryer and across the bottom wall, without causing warping or buckling of the bottom wall or without causing misalignment of the discharge assembly 86.

The tray segments 234 and bottom wall segments 256, as well as other parts of the dryer in contact with the material being dried, may be constructed of steel or any special alloy. They may also be of corrosion resistant and cost saving materials such as enameled steel, asbestos cement board or glass fiber laminates.

During operation a slight negative pressure is preferably maintained within the dryer housing 20 so that at any point on the housing where leakage of the drying medium or airborne particles might be expected an inwardly flow of air will exist. Also, it is an important feature of the invention that an inward, pressurized flow of air is maintained along the shafts 66 and 67 at the points where they extend through the dryer housing. Thus, an air line 276 associated with the thrust bearing assembly 65 delivers air under pressure to the interior of the assembly to cool it and to prevent leakage of dust along the shaft (see the arrows in FIG. 3B). Similarly, there is a downward flow of air under pressure through the opening 278 in the upper wall assembly 30 (see the arrows in FIG. 3A), the air being admitted through the air line 280, with additional air flowing through openings 282 in the bearing support 84 and downward between the concentric shafts 66 and 67. It will be appreciated, therefore, that the bearings for both of the shafts 66 and 67 are cooled by these air flows and that leakage along either shaft is prevented. Furthermore, the use of the leakage-preventing air flow to cool the bearings in the manner described precludes the need for elaborate cooling systems for the bearings or the use of expensive high temperature bearing materials.

It will be apparent from the foregoing, that the continuous rotary dryer of the present invention is especially adapted for a wide variety of applications; whether for drying alone; drying and cooling together; drying with solvent recovery; drying in a superheated vapor atmosphere, for example, where steam is used as the drying medium; for purifying solids by sublimation; for reacting gases with solid material carried by the trays; and for cooling alone. Moreover, the dryer finds particular application where fragile and normally dusty materials are to be processed and where breakage and dust levels generated during the handling of these materials are too minimized.

It will further be apparent to those skilled in the art that the above described embodiments are intended to be merely exemplary, in that they are susceptible of modification and variation without departing from the spirit of the invention.

We claim:

1. Rotary material processing apparatus, particularly for processing material at high temperatures, comprising:

a vertically extending housing;

inlet means in an upper region of the housing for admitting material to be processed;

outlet means in a lower region of the housing for discharging the processed material;

a plurality of vertically superimposed trays rotatably mounted in the housing for progressively carrying the material from the inlet means to the outlet means;

means for transferring the material between trays in a manner to minimize breakage and billowing of the material and thereby to minimize dust creation, said transferring means including (1) chute means, having an inclined portion sloping generally downward from a first point spaced radially beyond one edge of an upper tray and terminating at a second point spaced above the surface of a lower tray by a distance sufficient to prevent clogging of the inclined portion and radially within but adjacent to the corresponding edge of the lower tray, and (2) a retainer member depending from the inclined portion of the chute means and extending downwardly therefrom to terminate at a point closely adjacent the surface of the lower tray thereby to prevent the material transferred to the lower tray from spilling over said edge thereof;

means for diverting the material carried by the upper tray over the one edge thereof into the chute means; and

means for distributing the material discharged by the chute means over the surface of the lower tray.

2. Apparatus according to claim 1 wherein the retainer member is generally vertical and is attached to the inclined portion at the lower end thereof.

3. Apparatus according to claim 1 wherein:

the chute means further comprises a generally vertical portion extending upward from the upper end of the inclined portion thereby to form an entrance for the material carried by the upper tray; and the retainer member is generally vertical and extends downward from the lower end of the inclined portion.

4. Apparatus according to claim 1 wherein said one edge of the upper tray is the radially outer edge thereof.

5. Apparatus according to claim 1 wherein:

the means for diverting the material into the chute means includes stationary wiper arm means extending across the upper tray in close, spaced relation to the surface thereof in a direction to guide the material into the chute means upon rotation of the tray; and

wherein the means for distributing the material over the surface of the lower tray includes stationary leveler arm means extending across the surface of the lower tray in a direction to guide the material discharged from the chute means away from the lower end thereof and to spread the material evenly over the tray surface upon rotation of the tray.

6. Apparatus according to claim 1 further comprising means for interchanging the location on the trays of discrete radially inner and radially outer portions of the material upon transfer of the material from the upper to the lower tray.

7. Apparatus according to claim 1 wherein the inlet means in the housing includes inclined chute means for guiding the material onto an upper tray along an inclined path so as to retard breakage or billowing of the material.

8. Apparatus according to claim 6 wherein lower end of the inclined portion of the chute means extending between adjacent trays is positioned to discharge the material from the upper tray onto the lower tray at a location spaced in the direction of rotation of the trays from the upper end of the inclined portion of the chute means extending from the said lower tray to the next lower tray, whereby the material is carried by each tray for approximately one full revolution of the tray.

9. Apparatus according to claim 1 further comprising:

vertically extending shaft means for rotatably supporting the trays within the housing;

means located exteriorly of and spaced from the housing for journalling the shaft means adjacent the upper and lower ends thereof; and

means associated with the journalling means for producing a flow of air inwardly along the shaft means to cool the shaft means and to prevent leakage of the material along the shaft means.

10. Rotary material processing apparatus, particularly for processing material at high temperatures, comprising:

a vertically extending housing;

inlet means in an upper region of the housing for admitting material to be processed;

outlet means in a lower region of the housing for discharging the processed material;

a plurality of vertically superimposed trays rotatably mounted in the housing for progressively carrying the material from the inlet means to the outlet means;

means for transferring the material between trays in a manner to minimize breakage and billowing of the material and thereby to minimize dust creation, said transferring means including (1) chute means, having an inclined portion sloping generally downward from a first point spaced radially beyond one edge of an upper tray and terminating at a second point spaced above the surface of a lower tray by a distance sufficient to prevent clogging of the inclined portion and radially within but adjacent to the corresponding edge of the lower tray, and (2) retainer means for preventing the material transferred to the lower tray from spilling over said edge thereof;

means for dividing the chute means into at least two material flow channels to guide the material occupying a radially inner location on the upper tray to a radially outer location on the lower tray and the material occupying a radially outer location on the upper tray to a radially inner location on the lower tray;

means for diverting the material carried by the upper tray over the one edge thereof into the chute means; and

means for distributing the material discharged by the chute means over the surface of the lower tray.

11. Apparatus according to claim 10 wherein the dividing means includes a generally vertically extending divider member located approximately centrally of the circumferential extent of the chute means and conforming generally at one edge to the laterally adjacent surface of the chute means, the divider member having at its lower end a laterally projecting portion extending over the lower tray in close, spaced relation to the surface of the tray to terminate at approximately the midpoint of the tray.

12. Apparatus according to claim 11 wherein:

the means for diverting the material into the chute means includes stationary wiper arm means extending across the upper tray in close, spaced relation to the surface thereof in a direction to guide the material into the chute means upon rotation of the tray;

the means for distributing the material over the surface of the lower tray includes stationary leveler arm means extending across the surface of the lower tray in a direction to guide the material discharged from the chute means away from the lower end thereof and to spread the material evenly over the tray surface upon rotation of the tray; and

the wiper arm means extending across the upper tray includes (1) a first wiper arm extending from the far end, relative to the direction of rotation of the tray, of the chute means to a point approximately over the radial edge of the tray opposite said one edge and (2) a second wiper arm extending from the upper end of the dividing member to a point approximately over the midpoint of the tray, whereby approximately half of the material carried by the tray is guided by the first wiper arm into the chute means on one side of the dividing member and approximately half of the material is guided by the second wiper arm into the chute means on the other side of the dividing member.

13. Rotary material processing apparatus, particularly for processing material at high temperatures, comprising:

a vertically extending housing;

inlet means in an upper region of the housing for admitting material to be processed;

outlet means in a lower region of the housing for discharging the processed material;

a plurality of vertically superimposed trays rotatably mounted in the housing for progressively carrying the material from the inlet means to the outlet means, the inlet means including (1) inclined chute means for guiding the material onto an upper tray along an inclined path so as to retard breakage or billowing of the material and (2) a baffle extending adjacent the radially outer edge of the upper tray and in the direction of rotation of the tray to prevent the material discharged onto the tray from spilling over the outer edge of the tray;

means for transferring the material between trays in a manner to minimize breakage and billowing of the material and thereby to minimize dust creation, said transferring means including (1) chute means, having an inclined portion sloping generally downward from a first point spaced radially beyond the outer edge of an upper tray and terminating at a second point spaced above the surface of a lower tray by a distance sufficient to prevent clogging of the inclined portion and radially within but adjacent to the outer edge of the lower tray, and (2) retainer means for preventing the material transferred to the lower tray from spilling over the outer edge thereof;

means for diverting the material carried by the upper tray over the outer edge thereof into the chute means; and

means for distributing the material discharged by the chute means over the surface of the lower tray.

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