Dec. 24, 1963 W. N. OLDHAM ET AL 3,114,930

APPARATUS FOR DENSIFYING AND GRANULATING POWDERED MATERIALS

Filed March 17, 1961 2 Sheets-Sheet 1

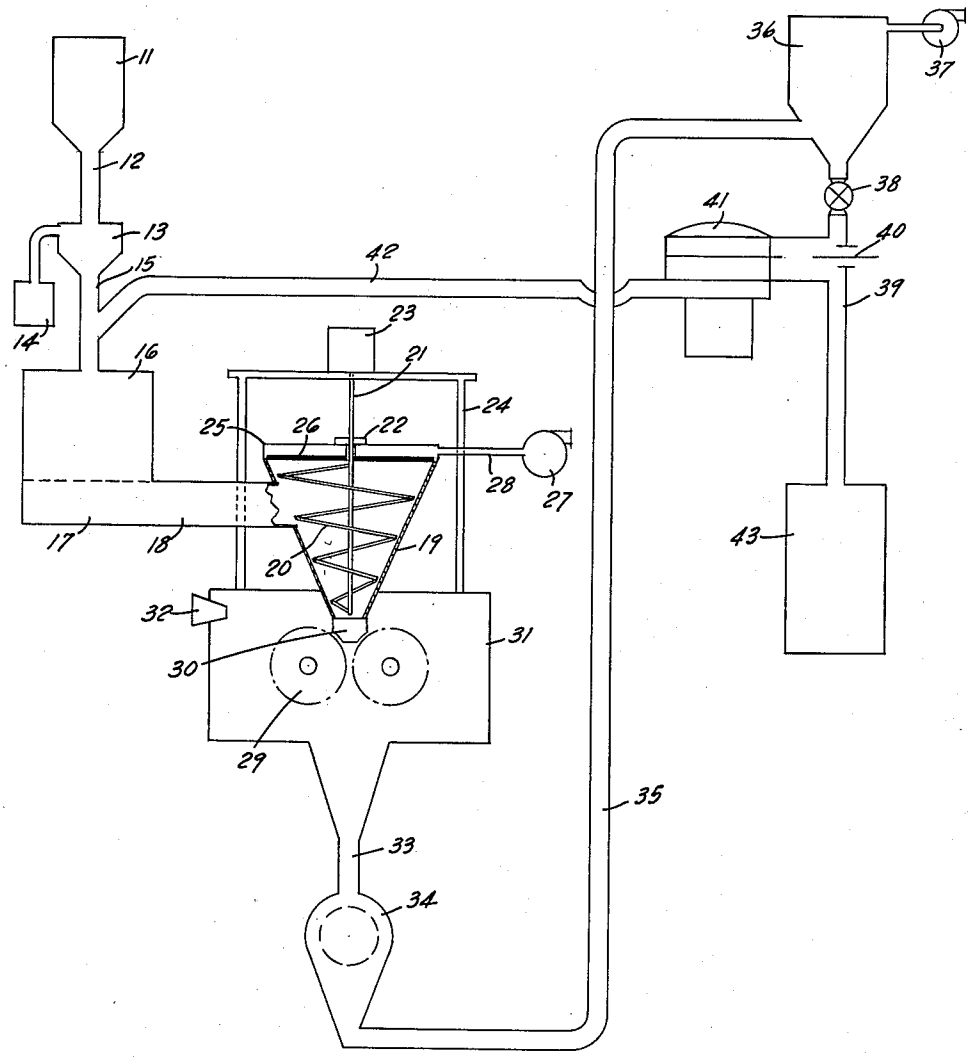


Fig. 1.

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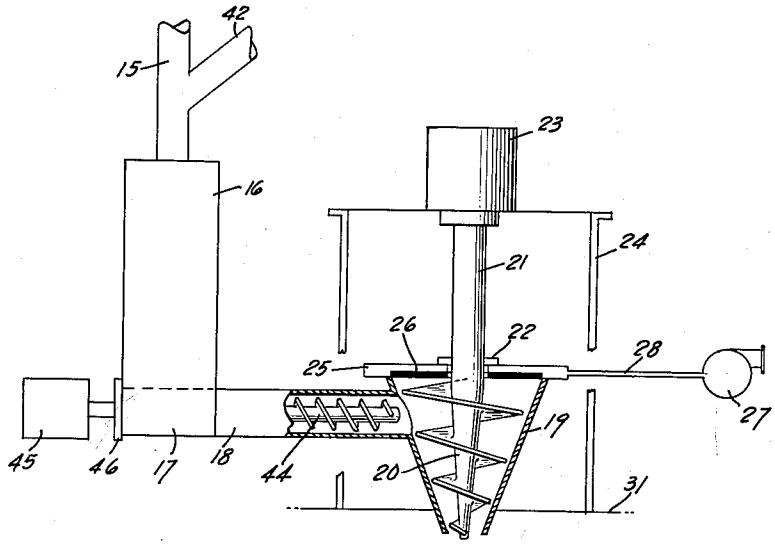


Fig. 2.

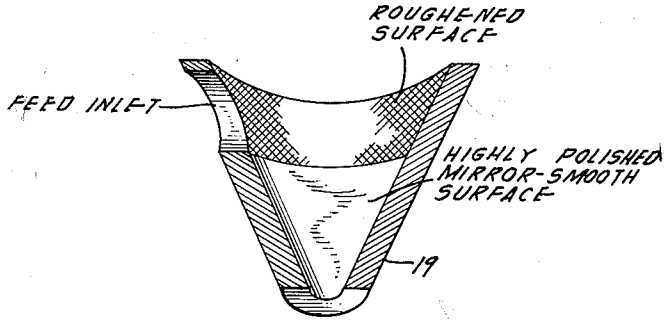


Fig. 3.

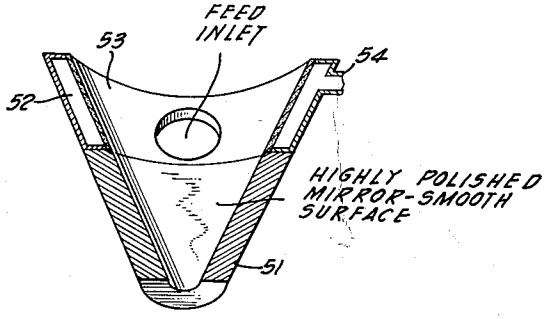


Fig. 4.

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3,114,930
APPARATUS FOR DENSIFYING AND GRANULATING POWDERED MATERIALS

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20 Claims. (Cl. 18—1)

This invention relates to the conversion of powdered substances, and particularly fluffy, aerated powdered substances having low bulk densities, to granular form. More particularly, this invention relates to novel apparatus useful in deaerating and densifying powdered substances, without the use of any substantial amounts of heat, and to the subsequent conversion of the resulting densified substances to granular form.

In numerous processes for the manufacture of granulated or tableted materials, there is usually one stage at which the materials which are to be granulated exist in the form of fluffy, aerated powders having low bulk densities. The processing of materials in this form in any subsequent steps presents many difficulties, thus, the common practice in the art is to densify such fluffy, aerated powders before granulating or tableting them.

Various methods for suitably increasing the bulk densities of fluffy, aerated powders have been practiced by those skilled in the art. Common methods include the use of such devices as Banbury mixers, preform machines, and the like. A recent development in this art involves the use of pressure rolls. Briefly stated, densification by the pressure roll method involves feeding the fluffy, aerated powder through a set of juxtaposed pressure rolls to convert the material to a more compacted form. One advantageous feature which might be expected to result from the use of this method is the potentially large output of densified material that may be obtained. Nevertheless, the use of pressure rolls as the sole means of densifying materials of the type in question has posed a significant practical problem antithetic of the above-mentioned potential advantage. This problem concerns the efficiency with which fluffy, aerated powders can be fed into the nip of the pressure rolls.

Numerous attempts have been made by those skilled in the art to solve this problem. For example, densification systems employing pressure rolls having corrugations designed to facilitate the engagement of the powder by the rolls have been tried, but with limited success. Another expedient which has been tried involves increasing the coefficient of friction of the powdered material by wetting it down with water or some other suitable liquid. However, this too is not a complete solution, inasmuch as the use of rather substantial amounts of liquid is required and, accordingly, large amounts of liquid must be eventually removed from the densified product, thus creating additional difficulty and expense. Furthermore, certain types of powdered materials, particularly those soluble to any significant extent in the liquid employed, are not amenable to such treatment.

This last-mentioned difficulty leads to a further, and perhaps most important consideration. Aside from the problems involved in feeding any fluffy, aerated powdered material to a pressure roll system in amounts sufficient to provide for efficient operation of the system, certain classes of powdered materials have inherent properties which introduce additional difficulties in their handling during densification and granulation. As a case in point, it has been proposed that fluffy, aerated powdered materials be preheated (for example by passing them, at a depth of about 4 to 6 inches on an endless

conveyor belt, through an induction oven) to drive off air and thus increase their bulk densities before they are passed through the pressure rolls. However, such a treatment is not possible in cases where the powdered materials to be densified and granulated are heat-sensitive. One such class of heat-sensitive powdered materials includes thermosetting resinous molding compositions. If an attempt were made to treat such materials by a process of the type just described, the amount of heat required to sufficiently deaerate the material would, in almost every case, be such that the degree of polymerization of the resinous component of the molding composition would be materially advanced. It is true that in a properly functioning process of this type the degree of polymerization advancement experienced falls considerably short of that represented by the thermoset state, and that, therefore, barring a mechanical breakdown in the preheating operation, the thermosetting resinous condensate employed in the molding composition may be prepared in a manner which takes into account the degree of polymerization advancement experienced in the preheating step. Nevertheless, heating or advancing the degree of polymerization of such molding compositions still presents a serious disadvantage, for this reason. In carrying out any densification step, but particularly one where a pressure roll densifier is employed, a certain amount, often as much as 30%, of by-product fines, i.e., powder which has not been effectively densified, results. For obvious reasons, these fines must be reprocessed and ultimately re-introduced to the densification step. In a densification procedure involving the use of preheating, these fines will usually be collected and re-introduced to the stream of powder about to enter the preheating oven. Thus, it is probable that some portions of the recirculated fines will be subjected to the preheating step several times. When these reheated fines are at last effectively densified and eventually passed into the final granulated molding composition they will have a deleterious effect on the appearance and durability of articles molded therefrom, due to their considerably advanced degree of polymerization.

We have now devised a novel apparatus, as described in greater detail hereinbelow, which increases the coefficient of friction of fluffy, aerated powdered materials by pre-densifying them, i.e., forceably de-aerating and compacting them to the required minimum bulk densities, without the application of heat, thus providing powdered materials which may be efficiently fed to a pressure roll densifier without the attendant disadvantages of the various prior art methods. Furthermore, due to the fact that our novel apparatus effects this beneficial pre-densification in the absence of any substantial amounts of heat, by-product fines may be re-introduced into the system as often as is necessary for their ultimate densification.

It is, therefore, an object of our invention to provide an apparatus which will efficiently densify and granulate fluffy, aerated powdered materials.

A further object of our invention is to provide an apparatus which is especially suited for the efficient densification and granulation of fluffy, aerated powdered materials which are heat-sensitive.

These and other objects of our invention will be discussed in greater detail hereinbelow.

Our novel apparatus is illustrated in FIGURES 1, 2, 3 and 4 wherein like reference symbols indicate the same parts of the apparatus, and in which:

FIGURE 1 is a diagrammatic view of the various parts of our novel apparatus;

FIGURE 2 is a side view, in fragmentary perspective, showing the feed screw mechanism;

FIGURE 3 is a view in fragmentary perspective showing the interior surface of the conical chamber 19; and

FIGURE 4 is a view in fragmentary perspective showing an alternative conical chamber 51.

Referring to the drawings, a conduit 12 leads from a feed source 11, such as a powder box or a plurality of such boxes, to a sifting device 13. The use of a sifting device is not essential in all cases, inasmuch as powdered materials having wide ranges of particle sizes may be satisfactorily processed in our novel apparatus. However, the use of such a device is preferred in normal plant operation, inasmuch as it acts as a means of screening out of the feed extremely coarse particles and also such unwanted foreign objects as balls from the ball mill, dirt, and the like, which might interfere with efficient operation of the apparatus or introduce undesirable characteristics into the granulated final product. The sifting device 13, if employed, is furnished with a collector 14 for removal of feed tails and foreign objects.

The conduit 15 leads from the sifting device 13 to a hopper 16. Either the conduit 15 or the hopper 16 may be furnished with control means (not shown) for regulating the head of powder in the hopper 16. The powder head in the hopper 16 should be of sufficient height to insure a continuous, uniform feed of powdered material from said hopper through the side feed chamber 17 to the rotary rolls feed screw 20, thus facilitating the maintenance of a vacuum seal by said powder in the side feed chamber 17. For example, it has been found from experience that a powder head of approximately 20 inches should be maintained in a vertical straight-walled hopper to facilitate uniform passage of powdered feeds (for example, feeds such as those which comprises a filler, e.g., α-cellulose, impregnated with a melamineformaldehyde resin, and which have bulk densities of approximately 0.35 g./cc. or less) from said hopper, while at the same time maintaining the necessary vacuum seal in the side feed chamber 17. The base of the hopper 16 feeds into the side feed chamber 17, said side feed chamber 17 having a lateral extension 18 which extends from the base of the hopper 16. The side feed chamber 17 is equipped with feeding means (not shown in FIGURE 1) for conveying powdered feed material from the hopper 16 through the side feed chamber 17 to between the top and second flights of the rotary rolls feed screw 20 in the conical chamber 19. In a preferred embodiment (shown in FIGURE 2), the feed means in the side feed chamber 17 is a rotary side feed screw 44 of uniform cross-section, actuated by the drive means 45, with the end plate 46, which is machined to allow connection between the drive means 45 and the rotary side feed screw 44 and which is preferably fabricated from a glass fiber-Teflon material, acting as an additional sealing means on the side feed chamber 17. The total gap between the rotary side feed screw 44 and the inner surface of the side feed chamber 17 preferably should not exceed about 0.025 inch. The design of this side feed screw and its rate of rotation must be such as to permit it to convey an amount of powdered feed material to the rotary rolls feed screw 20 sufficient to insure efficient operation of said rolls feed screw, especially when fluffy, aerated powdered materials, e.g., those having densities of approximately 25 lbs./ft.^{3} or less are being treated. As will be readily appreciated by those skilled in the art, the length of the rotary side feed screw 44 and, correspondingly, the length of the side feed chamber 17, may be varied to a considerable extent. The efficiency of the vacuum seal provided by the side feed screw 44 and feed powder in said side feed chamber 17 will increase as the length of said side feed screw is increased and, correspondingly, the height of the powder head maintained in the hopper 16 may be decreased. However, as the rotary side feed screw 44 is increased in length it becomes more difficult to keep said side feed screw properly centered in the side feed chamber 17, inasmuch as said side feed screw is only supported at one end. In extreme cases, said side feed screw may bind to an extent which will cause it to abrade small quantities of metal from the inner surface of the side feed chamber 17 or, more probably, from said side feed chamber's lateral extension 18. In cases where the presence of these small quantities of metal will lead to discoloration of the final product, for example, when the feed powder is a light-colored thermo-setting resinous molding composition, this cannot be tolerated. Thus, the rotary side feed screw 44 is shortened to obviate this difficulty. In cases where the color of the final product is of no consequence, for example, when powdered coal is being densified, abrasion may be neglected so long as the binding experienced does not materially retard the operation of the rotary side feed screw 44. However, any other practical means for conveying powdered feed material from the hopper 16 to the rotary rolls feed screw 20 which will maintain a vacuum seal in the side feed chamber 17 while, at the same time, providing sufficient powdered feed material to the rolls feed screw 20, may be employed.

The lateral extension 18 of the side feed chamber 17 feeds into the roughened portion of the conical chamber 19, which portion has the greatest cross-sectional area. The conical chamber 19 has a cross-section which decreases regularly downward, and it is open at both ends. Extending downward from the widest cross-section of the conical chamber 19 for a distance of about one third of its interior surface, as measured along the axis of the cone, said surface is especially roughened. This may be accomplished, for example, by first air-blasting said surface as fabricated with No. 4 aluminum oxide grit until substantial pitting occurs, and then chrome plating the pitted surface to accentuate the sharpness of the pits. This specially roughened surface (see FIGURE 3) serves to prevent feed powder from freely spinning in the upper portion of the conical chamber 19, thus providing for positive screw action by the rotary rolls feed screw 20.

In contrast to this, the remainder of the interior surface of the conical chamber 19 (see FIGURE 3) is a highly polished, smooth surface. This high polish may be achieved, for example, by first honing or polishing this portion of the interior surface of the chamber as originally fabricated, then plating this polished surface with a coating of from about 10 to 15 mils of hard chrome, and then polishing the chrome surface to as high a mirror finish as is commercially available. This highly polished portion of the interior surface of the conical chamber 19 facilitates the passage of feed powder towards the discharge end of said chamber, without significant powder holdup on the walls, once said powder reaches this smooth portion of the chamber. This, in turn, facilitates positive displacement of the feed powder from the top flight of the rotary rolls feed screw 20.

In a preferred embodiment, the hopper 16 is a vertical straight-walled hopper, the side feed chamber 17 is a horizontal cylindrical chamber, and the conical chamber 19 is a vertical conical chamber. However, this preferred embodiment merely represents the best mechanical construction of the apparatus known at the present time. Thus, the design and position of the hopper 16 and the relative positions of the side feed chamber 17 and the conical chamber 19 may be adjusted in any way which will enable deaerated, pre-densified powdered material to be fed from the discharge end of the conical chamber 19 onto the nip of the pressure roll densifier 29. For example, the assembly comprising a horizontal cylindrical chamber 17 and a vertical conical chamber 19 could be rotated as much as 90 degrees from the vertical and still perform in the manner described.

Similarly, in a preferred embodiment, the sides of the conical chamber 19 make an angle of about 22 degrees with the axis of the cone. However, conical chambers whose sides make, with the axis of the cone, angles approaching the vertical may be employed, as may conical chambers whose sides make, with the axis of the cone, angles of up to about 45 degrees, inasmuch as the degree

of slope found in the sides of the conical chamber 19 largely depends on the material being pre-densified and the compression ratios which it can undergo without being injured. For example, heat-sensitive powdered materials, such as thermosetting resinous molding compositions, are unable to undergo compression ratios as high as those which may be utilized with various other less sensitive materials without experiencing some degree of polymerization advancement. Thus, the degree of slope found in the sides of a conical chamber 19 used in pre-densifying heat-sensitive materials would be less than that found in a conical chamber 19 used in pre-densifying materials which are not particularly heat-sensitive.

The rotary rolls feed screw 20 contained in the conical chamber 19 also has a very highly polished surface, which may be obtained in the manner described above for the lower portion of the interior surface of the conical chamber 19. The top flight of the rotary rolls feed screw 20 begins just below the top of the conical chamber 19, while the lowest flight of the rotary rolls feed screw 20 discharges powdered feed material which has been compacted and deaerated (predensified) onto the nip of the pressure roll densifier 29, where the principal degree of densification takes place.

In a preferred embodiment, the rotary rolls feed screw 20 has three flights of uniform pitch. The diameter of the top flight of the rotary rolls feed screw 20 is approximately the same as that of the cross-section of the top of the conical chamber 19, and said rolls feed screw 20 is tapered downward in relation to the conical chamber 19, with a maximum clearance of 0.125 inch at all points. This type of screw gives a volume: compression ratio of from about 16:1–18:1. Again, however, the design of the rotary rolls feed screw 20 may be altered in relation to the compression ratio desired in the conical chamber 19, e.g., by changing the pitch of its flights, going from uniform to variable flights, and the like.

A vacuum manifold 25 is positioned above the conical chamber 19 to form a substantially airtight seal between said conical chamber and said manifold. The vacuum manifold 25 is in communication with the conical chamber 19, the opening in the vacuum manifold 25 having approximately the same diameter as that of the interior cross-section at the top of the conical chamber 19. Of course, smaller openings may be provided if desired. A vacuum producing means 27, such as a vacuum pump, connected with the vacuum manifold 25 through a conduit 28, maintains the vacuum manifold 25 and the conical chamber 19, when the apparatus is in use, under a partial vacuum. Partial vacuums ranging from about 1–380 inches of water, i.e., up to one full atmosphere (vacuum) may be employed. The precise partial vacuum required depends, in every case, on a number of factors, e.g., the material being pre-densified, the degree of compacting required, the rate at which feed is passing through the system, etc. However, operation of the vacuum manifold 25 and the conical chamber 19 under a degree of reduced pressure is essential to the proper deaeration of the powdered feed in the conical chamber 19, as will be described in greater detail hereinbelow.

The shaft 21 of the rotary rolls feed screw 20 passes through the vacuum manifold 25 and is connected to the drive means 23 for the rotary rolls feed screw 20. A filter plate 26, having an opening at its center large enough to accommodate the shaft 21 of rotary rolls feed screw 20, provides a porous filter barrier between the vacuum manifold 25 and the conical chamber 19. In a preferred embodiment, the filter plate 26 is a stainless steel sintered plate of from about 5–40 microns in porosity. The shaft seal 22, positioned around the shaft 21 of rotary rolls feed screw 20 and above the vacuum manifold 25, acts at this end of the assembly to maintain the partial vacuum in the vacuum manifold 25 and the conical chamber 19. The vacuum seal at the other end of this assembly, i.e., at the discharge end of the conical chamber 19, is provided by the plug of compacted, deaerated powdered feed material being discharged onto the nip of the rolls in the pressure roll densifier 29. The shaft seal 22 is preferably fabricated from a glass fiber-Teflon material. The clearance between the top flight of the rotary rolls feed screw 20 and the filter plate 26 is preferably in the order of about 0.65 inch or less, in order to prevent the buildup of a cake of powder between said top flight and said filter plate 26 which would interfere with the passage of the air being exhausted from the feed powder by the vacuum manifold 25 through the filter plate 26.

An alternative embodiment of the conical chamber 19 is shown in FIGURE 4. In this embodiment, the conical chamber 51 is similar in many respects to the conical chamber 19. Each has a cross-section which decreases regularly downward, each is fed through its upper portion, i.e., that portion having the greatest cross-sectional area, by the lateral extension 18 of the side feed chamber 17, and each has a lower portion whose interior surface, for a distance of about two thirds of the height of the conical chamber, as measured from the bottom of said chamber along the axis of the cone, is a highly polished, smooth surface. However, in place of the upper portion of the conical chamber 19, whose interior surface is specially roughened, the conical chamber 51 has an arrangement of a vacuum manifold 52 and a filter plate surface 53. Said surface 53 comprises the interior surface of the upper portion of the conical chamber 51, and may be fabricated from the same type of material mentioned above in connection with the filter plate 26. The vacuum manifold 52 extends entirely around the filter plate surface 53, and forms a substantially airtight seal with the upper and lower rims of said surface 53. The lateral extension 18 of the side feed chamber 17 feeds through the vacuum manifold 52 and the filter plate surface 53 into the conical chamber 51. A vacuum producing means, such as a vacuum pump, is connected with the vacuum manifold 52 through a conduit 54 to maintain a partial vacuum in the same manner and for the same purpose as stated above in connection with the conical chamber 19. The conical chamber 51 may be used in place of the conical chamber 19 shown in FIGURE 2, but together with the arrangement of the vacuum manifold 25, the filter plate 26, the vacuum producing means 27, the conduit 28 and the shaft seal 22 shown in said figure, thus providing an additional means of deaerating the feed powder. In this case, the conical chamber 51 is considered as being open at both ends. If, on the other hand, it is desired to use the vacuum manifold 52 as the sole vacuum manifold in communication with the interior surface of the conical chamber 51, said conical chamber 51 will be closed at the top and open at its discharge end. However, there will be an opening in the top closure to accommodate the shaft 21 of the rotary rolls feed screw 20, and a shaft seal, positioned around said shaft above said opening, will be provided.

The partial vacuum provided by the above-recited arrangement in the conical chamber 51 holds the feed powder against the filter plate surface 53 while said powder is being deaerated, thus preventing the feed powder from freely spinning in this upper portion of the conical chamber 51, and providing for positive screw action by a rotary rolls feed screw in said conical chamber 51, an action quite similar to that provided by the roughened portion of the interior surface of the conical chamber 19.

As previously stated, the pressure roll densifier 29, having drive means connected therewith (not shown in FIGURE 1, inasmuch as this figure is not in perspective), is located below the discharge end of the conical chamber 19, with the nip, or the point where the two rolls come closest together, being directly below the lowest flight of the rotary rolls feed screw 20. The type of

pressure roll densifier that we prefer to use has two unheated, juxtaposed pressure rolls having equal diameters ranging from about 10–20 inches. Each of these rolls will contain from about 54–108 longitudinal depressions, with rolls having 72 depressions each being preferred. The cross-sectional design of the individual depressions will range from about 0.25–0.50 inch. The rolls may be spring loaded or hydraulically loaded, the latter being preferred, permitting them to be brought together or moved apart as desired. For most efficient densification, the pressure rolls should have a minimum clearance of approximately 0.010 inch in the closed position and a maximum clearance of approximately 0.250 inch in the open position. However, these limits may be varied in relation to both the material being densified and the degree of densification required. It is further preferred that the two rolls be matched so that the longitudinal depressions of one correspond to the undepressed portions of the other. This preferred pressure rolls design and the manner in which the rolls are matched minimizes the fall-flow of powdered fines, i.e., powdered material which does not pass through the nip of the rolls.

The pressure roll densifier 29 is enclosed in a substantially airtight rolls jacket 31, the discharge end of the conical chamber 19 being in communication therewith. A pair of check plates fits between the discharge end of the conical chamber 19 and the top of the pressure rolls (one such plate 30 is indicated in FIGURE 1, not in perspective). The cheek plates act to guide the flow of powdered material from the discharge end of the conical chamber 19 to the nip of the pressure rolls, thereby further minimizing the release of powdered fines. A frame 24 is fitted to said rolls jacket 31 to provide support for the drive means 23 for the rotary rolls feed screw 20. However, any other suitable means of support for said drive means 23 may be provided. Air nozzle 32 feeds a stream of conditioned air into the space around the pressure rolls contained by said rolls jacket 31. The stream of conditioned air serves to convey powdered fines, together with the granulated product obtained from the granulator 34, to the product collector 36. A plurality of such nozzles may be inserted in the airtight rolls jacket 31, if desired.

A conduit 33 leads from the pressure roll densifier 29 through the rolls jacket 31 to a granulator 34, of conventional design, e.g., a conventional knife and screen granulator, which chops the ribbon of densified material emerging from the nip of the rolls in the pressure roll densifier 29 into the desired granular size. A conduit 35 leads from the granulator 34 to a product collector 36, to which there is attached a vacuum blower 37.

It should be noted at this point that the compacted, deaerated powdered material leaving the conical chamber 19 is impelled by the positive screw action of the rotary rolls feed screw 20, and that the ribbon of densified material emerging from the pressure roll densifier 29 moves under the influence of gravity to the granulator 34. Nevertheless, the slightly reduced pressure produced by the action of the vacuum blower 37 and the stream of conditioned air fed into the system by the air nozzle 32 acts to facilitate the movement of granular product and powdered fines to the product collector 36. The degree of slightly reduced pressure produced is not critical, and depends entirely on the rate at which it is desired to move granular product and powdered fines and the distance through which they must be moved.

An air lock valve 38 at the discharge end of the product collector 36 communicates with a branched conduit 39. The branched conduit 39 feeds into a screener 41. A slide gate 40, positioned in the branched conduit 39 at the point where said conduit 39 feeds into the screener 41, permits varying ratios of granular product and powdered fines to pass to the screener 41, and to the storage means 43. The screener 41 acts to screen out powdered fines from granular product returning the former through a conduit 42 to the hopper 16 and passing the latter, through the conduit 39, to a final product collector or storage means 43.

One class of powdered substances whose heat-sensitivity renders them especially suited for processing in our novel apparatus comprises aminoplast molding compositions of the type wherein a suitable filler has been impregnated with a thermosetting aminoplast resinous condensate. Molding compositions of this type are used extensively in the preparation of decorative molded articles such as dinnerware, telephone handsets, home appliances, and the like, where good decorative appearance is a prime consumer requisite. The uniformity of color and uniform surface appearance found in molded articles of this type are no doubt due, to some extent, to the nature of the aminoplast resins themselves. Nevertheless, these qualities are fundamentally imparted to the final molded articles by the manner in which the molding compositions themselves are processed. For example, if a pigment is incorporated into a molding composition of this type, the achievement of color uniformity basically depends on the methods employed in reducing the dry, resin-impregnated filler to a fine particle size and in blending, usually concurrently, finely divided pigment particles therewith. Furthermore, in both pigmented and unpigmented molding compositions of this type, the dry, powdered materials must be properly densified in order to secure compositions which, when molded, will exhibit uniform surface appearance.

Typical thermosetting aminoplast resinous compositions which may be employed in preparing molding compositions of this type are those wherein one or more amidogen compounds, i.e., compounds containing one or more amino, imino, amido or imido radicals, or combinations thereof, such as melamine, benzoguanamine, urea, and the like have been reacted with an aldehyde such as formaldehyde, to yield a potentially thermoset resinous condensate, i.e., one which has been carried to an intermediate stage of condensation whereby it remains as a resinous material soluble or readily dispersible in aqueous systems while also remaining capable of being converted, under suitable conditions of heat and pressure, to a substantially insoluble and infusible form.

Many types of particulate and fibrous materials may serve as fillers in compositions of this type. Among a few that may be mentioned are fibrous fillers such as α-cellulose, asbestos fibers, fiberglass, yarn cuttings, and a variety of cloth cuttings, such as those from silk, rayon, nylon, linen, or cotton cloth, or from cloth made from glass fibers or from polymeric or copolymeric acrylonitrile fibers, and the like. Particulate fillers, such as wood flour, walnut shell flour, and the like, may be substituted in whole or in part for a fibrous filler if the degree of decorative qualities sought in the final molded article so permits. The presence of a fibrous filler in molded articles of this type obviates the inherent cracking or crazing tendencies of the thermoset resinous component and, additionally, contributes to the mechanical strength of the article.

At this point, a brief outline of the commercial practices commonly employed in manufacturing aminoplast molding compositions of this type will serve to provide a more complete understanding of the present invention.

In common practice, the fibrous filler and the thermosetting aminoplast resinous condensate in syrup form are first charged to a mixer. Where α-cellulose is the filler material employed, it is ordinarily cut or shredded prior to begin impregnated. However, this is not always necessary, as α-cellulose in sheet form may be charged directly to a mixer containing the resinous syrup. During this impregnation step various commonly employed additives, such as pigments, curing catalysts, mold lubricants, premature polymerization inhibitors, and the like may be added and homogeneously dispersed throughout the composition. However, the more prevalent practice is to in-

corporate the pigments, curing catalysts and premature polymerization inhibitors immediately before or during the subsequent grinding and milling step, as will be discussed hereinbelow, and to delay adding the mold lubricants until the aminoplast molding composition is obtained in its final form. It has been found from experience that the nature of the conventional mold lubricants permits of their more efficient incorporation by merely tumbling or similarly mixing them with the final granular composition.

Once the filler has been suitably impregnated, it is then dried to a low volatile content, usually in the order of about 6%, by means of devices such as a continuous type oven, wherein the impregnated filler progresses, in contact with hot air, through the oven on an endless belt, the conditions in said oven being controlled so as to effect the required degree of drying without materially advancing the degree of polymerization of the resin. The material leaves the oven in a coarse granular form, which is generally referred to in the art as "popcorn." At this point there may be added to the popcorn the additives mentioned hereinabove. The composite material is then ground, milled and blended, preferably in a single operation. The essential purpose of this operation is to comminute the popcorn to a fine particle size, usually in the order of 50–200 microns, and at the same time uniformly blend the additives, and particularly the pigments, therewith.

This grinding, milling and blending operation is commonly carried out by ball milling the composite material. A ball mill is a rotatable, drum-like apparatus which is filled to a depth of between about one-third and two-thirds of its diameter with a charge of flint or porcelain balls, or the like, of varying diameters. The material to be comminuted fills the interstices between the balls and part of the free space above them. As the mill rotates, the balls are set in motion, and a substantial portion of the composite material and balls rises along the wall of the drum and then cascades over the remaining portion, an action that is unique in that it permits grinding, milling and blending to take place in a single operation.

The composite material leaves the ball mill in the form of a fine, fluffy powder, possessing a bulk density in the order of 0.35 g./cc. or less. This material is unsuitable for direct use as a molding material for several reasons. First of all, if an attempt were made to mold this fine, fluffy powder large amounts of dust, or fines, would be lost, creating both a health hazard to workers in the area and an economic disadvantage. In addition, because of the material's low bulk density, inordinately large and expensive molds would be required.

Furthermore, fluffy areated powdered materials of this type are not ideally suited for direct feeding to a pressure roll densifier of the type we prefer to employ. The output of densified ribbon by such a densifier is directly related to the amount of powdered material which can be efficiently fed into the nip of the rolls, and powdered materials having excessively low bulk densities do not provide a constant and uniform supply of material to the rolls, inasmuch as feeding the materials to the rolls in this aerated form results in large amounts of powdered fines escaping the nip of the rolls, which in turn results in the rolls doing less work, i.e., densification, than they are capable of doing. Thus, it has been estimated that a thermosetting resinous molding composition of the type just described, having a bulk density of 0.35 g./cc. or less, must have its bulk density increased to at least about 0.65 g./cc. before being fed into the nip of the rolls in a pressure roll densifier of the type which we prefer to employ in order to provide for efficient operation of said densifier.

In order to show how efficient densification and granulation of such a material may be accomplished by means of our novel apparatus, the following illustrative example is set forth. This example is given solely by way of illustration and should not be considered as expressing limitations unless so set forth in the appended claims. All parts and percentages are by weight, unless otherwise stated.

Example

A production batch of a melamine-formaldehyde resin syrup having a mol ratio of formaldehyde to melamine of 2:1, respectively, was charged to a mixer and mixed with approximately 27% (on a dry basis) of chopped α-cellulose filler at 134–135° F. for 30 minutes. The impregnated filler was then dried in a continuous drier at a temperature of about 172° F. (dry bulb) until a volatile content of about 5% was reached. The dried, impregnated filler was then ball-milled, together with appropriate amounts of mold lubricant, curing catalyst and pigment, to give a fine, fluffy powder having a bulk density of about 0.25 g./cc.

This powdered material was fed from the feed source 11 through the conduit 12 to the sifting device 13. From the sifting device 13, the powdered material was fed to a vertical straight-walled hopper 16, wherein a sealing powder head of 22 inches was maintained.

A rotary horizontal feed screw 44 in a horizontal cylindrical side feed chamber 17, actuated by the drive means 45, fed powdered material from said hopper 16 to between the top and second flights of a rotary vertical rolls feed screw 20 in a vertical conical chamber 19 at a rate which increased from about 1136 lbs./hr. at the start to about 1700 lbs./hr. once powdered fines, which passed from the product collector 36 through the air lock valve 38, the conduit 39, and the screener 41, were returned to said hopper 16 through the conduit 42. This increase in feed rate represents a 30% rework of powdered fines.

The vacuum pump 27, operating at a pressure of 4 inches of mercury, imparted a negative pressure of 5 inches of water to the powdered material in the vertical conical chamber 19, thereby drawing air from the powdered material through the filter plate 26, the vacuum manifold 25, and the conduit 28.

The rotary vertical rolls feed screw 20, rotated at 250 r.p.m. by the drive means 23, fed compacted, deaerated powdered material from the discharge end of the vertical conical chamber 19 into the nip of the pressure rolls in the pressure roll densifier 29, which comprised a pair of hydraulically loaded cylinders, 10 inches in diameter, of the type described above, which rotated at 50 r.p.m. The air nozzle 32, which fed a stream of conditioned air (75° F.) into the substantially airtight rolls jacket 31, and the vacuum blower 37, attached to the product collector 36 and operating at a pressure of 39 inches of water, maintained a stream of 400 ft.^{3}/min. of conveyer air.

A ribbon of densified material (having a bulk density of 1.1–1.3 g./cc.), together with powdered fines, was fed from the nip of the pressure rolls through the conduit 33 to the granulator 34. Granulated and powdered material were conveyed from the granulator 34 through the conduit 35 to the product collector 36. Separation of granular product and powdered fines took place in the screener 41. The powdered fines were returned, as described above, to the vertical straight-walled hopper 16. The granular product was conveyed from the screener 41 through the conduit 39 to a product storage means 43. About 1136 lbs./hr. of a granular product having a bulk density of 0.63–0.65 g./cc., 90% of which was retained on a +80 mesh screen, was obtained. This granular product was especially suitable for use as a decorative molding composition, inasmuch as molded pieces produced therefrom were free of granular marking, and showed what is commonly referred to in the art as a "powder surface."

Although particular emphasis has been placed on thermosetting resinous molding compositions, it will be ob-

vious to those skilled in the art that numerous other materials in the form of fluffy, aerated powders may be efficiently densified and granulated in the manner described herein. For example, fluffy organic salts, starch, flour, dextrin, coal dust, charcoal dust, powdered pharmaceuticals, such as aspirin, and the like are all suitable for densification and granulation by means of our novel apparatus.

Furthermore, it will be equally obvious to those skilled in the art that other changes and variations may be made in carrying out the present invention without departing from the spirit and scope thereof as defined in the appended claims.

We claim:

1. In an apparatus for densifying powdered materials the improvement comprising: a conical chamber open at least at its discharge end, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one third of its interior surface, as measured along the axis of the cone, being adapted to restrain aerated powdered material from freely spinning against said portion of the interior surface while air is being evacuated from said powdered material, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface, and means, in communication with said adapted portion of the interior surface of said conical chamber, for evacuating air from said aerated powdered material.

2. In an apparatus for densifying powdered materials the improvement comprising: a conical chamber open at both ends, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one third of its interior surface, as measured along the axis of the cone, being roughened, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; a vacuum manifold positioned above said conical chamber and in communication therewith through a porous filter means, and a vacuum producing means connected to said vacuum manifold.

3. In an apparatus for densifying powdered materials the improvement comprising: a conical chamber closed at the top and open at its discharge end, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one third of its interior surface, as measured along the axis of the cone, comprising a porous filter means, the portion of the exterior surface of said conical chamber corresponding to said porous filter means comprising a vacuum manifold in communication with said porous filter means, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface, and a vacuum producing means connected to said vacuum manifold.

4. In an apparatus for densifying powdered materials the improvement comprising: a conical chamber open at both ends, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one third of its interior surface, as measured along the axis of the cone, comprising a first porous filter means, the portion of the exterior surface of said conical chamber corresponding to said first porous filter means comprising a first vacuum manifold in communication with said first porous filter means, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; a second vacuum manifold positioned above said conical chamber and in communication therewith through a second porous filter means; a first vacuum producing means connected to said first vacuum manifold, and a second vacuum producing means connected to said second vacuum manifold.

5. In an apparatus for densifying powdered materials the improvement comprising: a side feed chamber; a conical chamber open at least at its discharge end, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one third of its interior surface, as measured along the axis of the cone, being adapted to restrain aerated powdered material from freely spinning against said portion of the interior surface while air is being evacuated from said aerated powdered material, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; said side feed chamber feeding into said adapted portion of the interior surface of said conical chamber, and means, in communication with said adapted portion of the interior surface of said conical chamber, for evacuating air from said aerated powdered material.

6. In an apparatus for densifying powdered materials the improvement comprising: a side feed chamber; a conical chamber open at both ends, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one third of its interior surface, as measured along the axis of the cone, being roughened, fhe remainder of the interior surface of said conical chamber being a highly polished, smooth surface; said side feed chamber feeding into the roughened portion of said conical chamber; a vacuum manifold positioned above said conical chamber and in communication therewith through a porous filter means, and a vacuum producing means connected to said vacuum manifold.

7. In an apparatus for densifying powdered materials the improvement comprising: a side feed chamber; a conical chamber closed at the top and open at its discharge end said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one third of its interior surface, as measured along the axis of the cone, comprising a porous filter means, the portion of the exterior surface of said conical chamber corresponding to said porous filter means comprising a vacuum manifold in communication with said porous filter means, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; said side feed chamber feeding into the porous filter means portion of said conical chamber, and a vacuum producing means connected to said vacuum manifold.

8. In an apparatus for densifying powdered materials the improvement comprising: a side feed chamber; a conical chamber open at both ends, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one third of its interior surface, as measured along the axis of the cone, comprising a first porous filter means, the portion of the exterior surface of said conical chamber corresponding to said first porous filter means comprising a first vacuum manifold in communication with said first porous filter means, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; said side feed chamber feeding into the first porous filter means portion of said conical chamber; a second vacuum manifold positioned above said conical chamber and in communication therewith through a second porous filter means; a first vacuum producing means connected to said first vacuum manifold, and a second vacuum producing means connected to said second vacuum manifold.

9. An apparatus for densifying and granulating powdered materials which comprises: a conical chamber open at least at its discharge end, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one third of its interior surface, as measured along the axis of the cone, being adapted to restrain aerated powdered material from freely spinning against said portion of the interior surface while air is being evacuated from said aerated powdered material, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; means for delivering aerated powdered material into said adapted portion of the interior surface of said conical chamber; a rotary rolls feed screw, having a highly polished, smooth surface, positioned in said conical chamber to receive aerated powdered material between its top and second flights, said rolls feed screw being tapered downward in relation to said conical chamber, drive means for said rolls feed screw; means, in communication with said adapted portion of the interior surface of said conical chamber, for evacuating air from said aerated powdered material; a pair of unheated, juxtaposed pressure rolls, having longitudinal depressions, positioned below the discharge end of said conical chamber in deaereated feed relationship therewith, said rolls being positioned so that the longitudinal depressions of one correspond to the undepressed portions of the other, drive means for said rolls; means for granulating the ribbon of densified material feeding from the nip of said rolls, and means for separating powdered fines from granular product.

10. An apparatus for densifying and granulating powdered materials which comprises: a conical chamber open at both ends, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one third of its interior surface, as measured along the axis of the cone, being roughened, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; means for delivering aerated powdered material into the roughened portion of said conical chamber, a rotary rolls feed screw, having a highly polished, smooth surface, positioned in said conical chamber to receive aerated powdered material between its top and second flights, said rolls feed screw being tapered downward in relation to said conical chamber; a vacuum manifold positioned above said conical chamber and in communication therewith through a porous filter means; drive means for said rolls feed screw; a vacuum producing means connected to said vacuum manifold; a pair of unheated, juxtaposed pressure rolls, having longitudinal depressions, positioned below the discharge end of said conical chamber in deaerated feed relationship therewith, said rolls being positioned so that the longitudinal depressions of one correspond to the undepressed portions of the other, drive means for said rolls; means for granulating the ribbon of densified material feeding from the nip of said rolls, and means for separating powdered fines from granular product.

11. An apparatus for densifying and granulating powdered materials which comprises: a conical chamber closed at the top and open at its discharge end, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one third of its interior surface, as measured along the axis of the cone, comprising a porous filter means, the portion of the exterior surface of said conical chamber corresponding to said porous filter means comprising a vacuum manifold in communication with said porous filter means, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; means for delivering aerated powdered material into the porous filter means portion of said conical chamber, a rotary rolls feed screw, having a highly polished, smooth surface, positioned in said conical chamber to receive aerated powdered material between its top and second flights, said rolls feed screw being tapered downward in relation to said conical chamber, drive means for said rolls feed screw; a vacuum producing means connected to said vacuum manifold; a pair of unheated, juxtaposed pressure rolls, having longitudinal depressions, positioned below the discharge end of said conical chamber in deaerated feed relationship therewith, said rolls being positioned so that the longitudinal depressions of one correspond to the undepressed portions of the other, drive means for said rolls; means for granulating the ribbon of densified material feeding from the nip of said rolls, and means for separating powdered fines from granular product.

12. An apparatus for densifying powdered materials which comprises: a conical chamber open at least at its discharge end, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one-third of its interior surface, as measured along the axis of the cone, being adapted to restrain aerated powdered material from freely spinning against said portion of the interior surface while air is being evacuated from said aerated powdered material, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; means for delivering aerated powdered material into said adapted portion of the interior surface of said conical chamber; a rotary rolls feed screw, having a highly polished, smooth surface, positioned in said conical chamber to receive aerated powdered material between its top and second flights, said rolls feed screw being tapered downward in relation to said conical chamber, drive means for said rolls feed screw; means, in communication with said adapted portion of the interior surface of said conical chamber, for evacuating air from said aerated powdered material, a pair of unheated, juxtaposed pressure rolls, having longitudinal depressions, positioned below the discharge end of said conical chamber in deaerated feed relationship therewith, said rolls being positioned so that the longitudinal depressions in one correspond to the undepressed portions of the other, and drive means for said rolls.

13. An apparatus for densifying powdered materials which comprises: a conical chamber open at both ends, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one-third of its interior surface, as measured along the axis of the cone, being roughened so as to restrain aerated powdered material from freely spinning against said portion of the interior surface while air is being evacuated from said aerated powdered material, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; means for delivering aerated powdered material into said roughened portion of the interior surface of said conical chamber; a rotary rolls feed screw, having a highly polished, smooth surface, positioned in said conical chamber to receive aerated powdered material between its top and second flights, said rolls feed screw being tapered downward in relation to said conical chamber; a vacuum manifold positioned above said conical chamber and in communication therewith through a porous filter means; drive means for said rolls feed screw; a vacuum producing means connected to said vacuum manifold; a pair of unheated, juxtaposed pressure rolls, having longitudinal depressions, positioned below the discharge end of said conical chamber in deaerated feed relationship therewith, said rolls being positioned so that the longitudinal depressions in one correspond to the

undepressed portions of the other, and drive means for said rolls.

14. An apparatus for densifying powdered materials which comprises: a conical chamber closed at the top and open at its discharge end said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one-third of its interior surface, as measured along the axis of the cone, comprising a porous filter means, the portion of the exterior surface of said conical chamber corresponding to said porous filter means comprising a vacuum manifold in communication with said porous filter means, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; means for delivering aerated powdered material into the porous filter means portion of said conical chamber, a rotary rolls feed screw, having a highly polished, smooth surface, positioned in said conical chamber to receive aerated powdered material between its top and second flights, said rolls feed screw being tapered downward in relation to said conical chamber, drive means for said rolls feed screw; a vacuum producing means connected to said vacuum manifold; a pair of unheated, juxtaposed pressure rolls, having longitudinal depressions, positioned below the discharge end of said conical chamber in deaerated feed relationship therewith, said rolls being positioned so that the longitudinal depressions of one correspond to the undepressed portions of the other, and drive means for said rolls.

15. An apparatus for densifying powdered materials which comprises: a conical chamber open at both ends, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one-third of its interior surface, as measured along the axis of the cone, comprising a first porous filter means, the portion of the exterior surface of said conical chamber corresponding to said first porous filter means comprising a first vacuum manifold in communication with said first porous filter means, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; a second vacuum manifold positioned above said conical chamber and in communication therewith through a second porous filter means; means for delivering aerated powdered material into said first porous filter means portion of said conical chamber, a rotary rolls feed screw, having a highly polished, smooth surface, positioned in said conical chamber to receive aerated powdered material between its top and second flights, said rolls feed screw being tapered downward in relation to said conical chamber, drive means for said rolls feed screw; a first vacuum producing means connected to said first vacuum manifold; a second vacuum producing means connected to said second vacuum manifold; a pair of unheated, juxtaposed pressure rolls, having longitudinal depressions, positioned below the discharge end of said conical chamber in deaerated feed relationship therewith, said rolls being positioned so that the longitudinal depressions of one correspond to the undepressed portions of the other, and drive means for said rolls.

16. An apparatus for densifying powdered materials which comprises: a conical chamber open at least at its discharge end, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one-third of its interior surface, as measured along the axis of the cone, being adapted to restrain aerated powdered material from freely spinning against said portion of the interior surface while air is being evacuated from said aerated powdered material, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; means for delivering aerated powdered material into said adapted portion of the interior surface of said conical chamber; a rotary rolls feed screw, having a highly polished, smooth surface, positioned in said conical chamber to receive aerated powdered material between its top and second flights, said rolls feed screw being tapered downward in relation to said conical chamber, drive means for said rolls feed screw, and means, in communication with said adapted portion of the interior surface of said conical chamber, for evacuating air from said aerated powdered material.

17. An apparatus for densifying powdered materials which comprises: a conical chamber open at both ends, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one-third of its interior surface, as measured along the axis of the cone, being roughened so as to restrain aerated powdered material from freely spinning against said portion of the interior surface while air is being evacuated from said aerated powdered material, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; means for delivering aerated powdered material into said roughened portion of the interior surface of said conical chamber; a rotary rolls feed screw, having a highly polished, smooth surface, positioned in said conical chamber to receive aerated powdered material between its top and second flights, said rolls feed screw being tapered downward in relation to said conical chamber, drive means for said rolls feed screw; a vacuum manifold positioned above said conical chamber and in communication therewith through a porous filter means, and a vacuum producing means connected to said vacuum manifold.

18. An apparatus for densifying powdered materials which comprises: a conical chamber closed at the top and open at its discharge end, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one-third of its interior surface, as measured along the axis of the cone, comprising a porous filter means, the portion of the exterior surface of said conical chamber corresponding to said porous filter means comprising a vacuum manifold in communication with said porous filter means, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; means for delivering aerated powdered material into said porous filter means portion of the interior surface of said conical chamber; a rotary rolls feed screw, having a highly polished, smooth surface, positioned in said conical chamber to receive aerated powdered material between its top and second flights, said rolls feed screw being tapered downward in relation to said conical chamber, drive means for said rolls feed screw, and a vacuum producing means connected to said vacuum manifold.

19. An apparatus for densifying powdered materials which comprises: a conical chamber open at both ends, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one-third of its interior surface, as measured along the axis of the cone, comprising a first porous filter means, the portion of the exterior surface of said conical chamber corresponding to said first porous filter means comprising a first vacuum manifold in communication with said first porous filter means, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; a second vacuum manifold positioned above said conical chamber and in communication therewith through a second porous filter means; means for delivering aerated powdered material into said first porous filter means portion of said conical chamber, a rotary rolls feed screw, having a highly polished, smooth surface, positioned in

said conical chamber to receive aerated powdered material between its top and second flights, said rolls feed screw being tapered downward in relation to said conical chamber, drive means for said rolls feed screw; a first vacuum producing means connected to said first vacuum manifold, and a second vacuum producing means connected to said second vacuum manifold.

20. An apparatus for densifying and granulating powdered materials which comprises: a conical chamber open at both ends, said conical chamber having a downwardly decreasing cross-section, the portion of the interior surface of said conical chamber extending downward from its widest cross-section for a distance of about one-third of its interior surface, as measured along the axis of the cone, comprising a first porous filter means, the portion of the exterior surface of said conical chamber corresponding to said first porous filter means comprising a first vacuum manifold in communication with said first porous filter means, the remainder of the interior surface of said conical chamber being a highly polished, smooth surface; a second vacuum manifold positioned above said conical chamber and in communication therewith through a second porous filter means; means for delivering aerated powdered material into said first porous filter means portion of said conical chamber, a rotary rolls feed screw, having a highly polished, smooth surface, positioned in said conical chamber to receive aerated powdered material between its top and second flights, said rolls feed screw being tapered downward in relation to said conical chamber, drive means for said rolls feed screw; a first vacuum producing means connected to said first vacuum manifold; a second vacuum producing means connected to said second vacuum manifold; a pair of unheated, juxtaposed pressure rolls, having longitudinal depressions, positioned below the discharge end of said conical chamber in deaerated feed relationship therewith, said rolls being positioned so that the longitudinal depressions of one correspond to the undepressed portions of the other, drive means for said rolls; means for granulating the ribbon of densified material feeding from the nip of said rolls, and means for separating powdered fines from granular product.

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