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(54) Multi-stage particulate material dryer having channelized discharge.

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Description

This invention relates generally to gravity flow dryers for particulate material and, more particularly, to a multi-stage gravity flow dryer for particulate material wherein the discharge of the dryer is channelized.

It is often necessary or desirable to dry freshly harvested grain before it is processed or stored. Storage of grain with excess moisture may cause quality deterioration and spoilage during subsequent storage.

The need to dry grain prior to storage has long been recognized in the art and many grain drying systems have been developed to accomplish this purpose. In many such prior systems, the grain is heated by air at a predetermined temperature during a first drying process and then the grain is quickly cooled to a desired storage temperature by exposing the grain to a flow of ambient air. One such system is the cross-flow column type grain dryer in which grain flows downwardly by gravity through a column having perforate walls and heated air is forced transversely through the perforate walls of the column to contact the grain to dry the grain or remove moisture. Typical of such cross-flow grain dryers are the grain dryers shown and described in US—A—3238640 and DE—C—717052.

While the prior art cross-flow type grain dryers are generally effective in drying grain, the entire quantity of grain is not uniformly dried. A further drawback associated with this type of prior art drying system has been that the rapid temperature change occurring as a result of exposing the wet grain to a flow of high temperature air has tended to result in stress cracking of the grain. Although several different attempts have been made to improve the cross-flow grain dryers to alleviate stress cracking, as well as to improve the quality of the grain, such attempts have had mixed success and have resulted in greater complexity in the grain drying structure. The present invention provides a multi-stage cross-flow type grain dryer which provides a greater uniformity of drying of the grain, while minimizing the problems associated with stress cracking of the grain.

What constitutes the invention is defined in the following claim 1, the first portion of which is based on the known cross-flow dryer described in DE—C—717052.

Advantageous embodiments of the invention are featured in the dependent Claims 2 to 9.

Constructional details of the discharge means of a dryer according to Claim 1 are the subject-matter of divisonal application EP—A—0206069.

The foregoing summary, as well as the following detailed description of preferred embodiments of the present invention, will be better understood when read in conjunction with the accompanying drawings, in which:

Fig. 1 is a perspective view, with parts broken away, of a grain dryer in accordance with the present invention;

Fig. 2 is a side elevational view of the dryer shown in Fig. 1 (with the addition of an alternative air heating system 200 described in EP—A—0068733).

Fig. 3 is a sectional view of a slightly modified version of the dryer of Fig. 1;

Fig. 4 is an end elevational view of the dryer of Fig. 1 and showing the end wall removed;

Fig. 5 is a slightly enlarged end elevational view of a module portion of the dryer of Fig. 4 and showing the module removed from the housing;

Fig. 6 is an enlarged plan view of the drying column module of Fig. 5;

Fig. 7 is an enlarged side sectional view with parts broken away of the lower portion of the dryer of Fig. 2;

Fig. 8 is a sectional view taken along the lines 8—8 of Fig. 7; and

Fig. 9 is an enlarged side elevational view of one of the dryer arrangements of a portion of Fig. 7 and showing parts broken away.

Referring to the drawings, and particularly to Fig. 1, there is shown a column type gravity flow dryer for particulate material, for example, corn or other type grain. The dryers, generally designated 10, includes a generally square-shaped housing 12 comprised of a pair of solid end walls 14 and 16 and a pair of side walls 18 and 20. Each of the side walls 18 and 20 includes solid upper and lower portions 22 and 24, respectively, and a perforate intermediate portion 26. The housing 12 further includes a suitable roof 28 and is supported at the bottom by suitable support means or legs 30. At the top of the housing 12 is a means for introducing moist particulate material or grain into the top portion of the housing, in this embodiment, a suitably sized wet grain inlet 32.

On the outside of the housing 12 adjacent end wall 14, is an assembly or means 34 for providing drying air and cooling air to the housing 12. The assembly 34, which is supported by a suitable support frame 36, generally includes a blower section 38 and a heater section 40.

The blower section 38 comprises a pair of blowers or fans 42 and 44 both of which are mounted for rotation on a single shaft 46. The fan shaft 46 extends outwardly through a generally circular cooling air inlet opening 48 in the blower section 38 and is journaled for rotation within a suitable bearing 39. A suitable drive pulley 50 is mounted on the outwardly extending end of the fan shaft 46. The drive pulley 50 is driven to rotation by means of a standard drive belt system 52 which also engages a second drive pulley 54. The drive pulley 54 may be driven by any suitable means, for example, an electric motor or a power takeoff mechanism on a tractor or other vehicle (not shown).

The fan 42, which is closest to the cooling air inlet opening 48, is the cool air fan and the fan 44, which is furthest from the air inlet opening 48, is the hot air fan, the fans being separated by a vertical partition 43 to form individual chambers surrounding each fan. Cooling air is drawn in through the inlet opening 48 by the cool air fan 42 and is directed into a pair of cool air ducts 56 which in turn direct the cooling air into the dryer housing 12. The hot air fan 44 draws air in through a second generally rectangular air inlet opening 49 located in the other housing end wall 16 at the opposite end of the housing and the hot air fan 44 directs the flow of air upwardly into the heater section 40. The heater section 40 includes a burner 58 which heats the air received from the fan 44. In the preferred embodiment, the burner 58 may be a standard Maxon gas burner. The heated air from the burner 58 passes into a collector chamber 60 and thereafter is directed into the housing 12 by a pair of generally cylindrical hot air ducts 62.

The heater section 40 and the blower section 38 are separated by a generally horizontally disposed partition 64 which contains an airflow control means, comprising in this embodiment, a plurality of adjustable dampers 66. The adjustable dampers 66 are provided to control the flow of air from the hot air fan 44 to the burner 58. In this manner, it is possible to effectively regulate the hot air flow into the housing 12 to efficiently dry a variety of different types of particulate material. For example, it may be desirable to provide a large hot air flow into the housing 12 for drying high moisture content corn and a much smaller hot air flow into the housing 12 for drying lower moisture content rice. Thus, the adjustable dampers 66 may be set in a substantially fully open position to apply a large hot air flow to dry corn or in a substantially closed position to apply a small hot air flow when drying rice.

Referring now to Fig. 3, there is shown the interior configuration of the dryer of Fig. 1 with a slight variation which will hereinafter be described. The dryer 10 comprises a pair of generally vertical outer drying columns 68, each column being defined by first and second substantially parallel opposed spaced perforate walls 70 and 26. A wet grain hopper 72 is provided at the top portion of the dryer for receiving and temporarily storing the moist grain introduced into the top of the housing 12 through the wet grain inlet 32. The wet grain hopper 72 is defined by the roof panels 28, the side wall upper solid portions 22 and a pair of sloping interior hopper walls 74. The wet grain hopper 72 also functions to distribute the moist grain into the top portions of each of the outer drying columns 68.

In order to provide for a more uniform and less restricted grain flow through the outer drying columns 68, the columns are tapered outwardly from top to bottom so that the width of each of the columns is greater at the bottom than at the top. By tapering the columns in this manner, the air flow is less restricted at the top of the columns (where the grain is wetter and provides a high air flow rate through the outer columns 68) than at the bottom of the columns (where the grain is drier), thereby providing for a more volume controlled airflow through the columns over their entire length.

At the bottom of each of the outer drying columns 68 is a dividing wall means, in the present embodiment a generally vertical partition 76, for dividing the lower portion of each of the drying columns 68 into two generally parallel channels 78 and 80. Each of the channels 78 and 80 preferably contains separate discharge means, in the present embodiment metering rolls 82 and 84, respectively, for discharging particulate material from the channels 78 and 80 at predetermined rates. Both of the metering rolls 82 and 84 are driven by a system of drive belts and pulleys generally designated 85. As shown, the drive pulley for the metering roll 84 is of a smaller diameter than the drive pulley for metering roll 82. Accordingly, metering roll 84 rotates faster than metering roll 82 to thereby discharge grain from the innermost channel 80 at a faster rate than the grain is discharged from the outermost channel 78. The grain from both channels 78 and 80 is discharged by the respective metering rolls 82 and 84 into a receiving hopper 86.

As shown in Fig. 3, heated air from the hot air ducts 62 passes outwardly through the outer drying columns 68 to contact and dry the grain in the columns. Since the heated air enters each of the columns 68 through the inner perforated walls 70, the hottest driest air impinges upon the grain on the side of the drying columns adjacent the inner perforated walls 70. As the heated air continues on its path across the columns, a certain amount of heat is lost to the grain in the columns and the air picks up and retains moisture from the grain. By the time the air reaches the grain adjacent the outermost perforate walls 26, a significant portion of the heat has been lost to the grain and the same flow of air is also somewhat moisture laden and not able to dry the grain as effectively. Thus, the drying of the grain is somewhat uneven across the column, the grain adjacent the inner perforate walls 70 becoming drier as it flows down the columns than the grain flowing down the columns adjacent the outer perforate walls 26. By controlling the downward flow rate of the grain through the columns 68 to have the grain adjacent the inner perforate walls 70 flow downwardly at a faster rate than the grain adjacent the outer perforate walls 26, as described above, the faster drying grain adjacent wall 70 is more quickly removed from the columns and the slower drying grain adjacent wall 26 is retained in the columns for a longer period of time and is exposed to the drying air for a longer period of time to promote more uniform drying across the column. In this manner, not only is all of the grain discharged into the receiving hopper 86 with a more uniform moisture content, but, by having the grain adjacent the inner perforate wall 70 moving more rapidly down through the columns, the problems of grain cracking and checking inherent in prior art grain dryers are reduced, since the rapidly dried grain is exposed to the hottest driest air for a shorter period of time.

In order to further control the division of the grain into the channels 78 and 80, the upper end of each of the partitions 78 is provided with an adjustable or pivotable section or divider 79. The adjustable or pivotable sections 79 may be adjusted depending upon the initial moisture content and type of grain being dried to change the relative proportions of the grain entering the channels 78 and 80 in order to further improve the uniformity of the drying across the columns. For example, when drying corn with a very high initial moisture content, it may be desirable to adjust the pivotable sections 79 to provide for a smaller portion of the grain flowing into channels 80 than is flowing into channels 78. In this manner, more of the corn is retained in the drying columns 68 for a longer time period. Correspondingly, when drying corn with a very low moisture content, it may be desirable to adjust the pivotable sections 79 to provide for a larger portion of the grain flowing into channels 80 than is flowing into channels 78, thereby discharging more of the corn from the dryer in a shorter time period. Thus, by adjusting the position of the pivotable sections 79 in conjunction with the predetermined discharge rate from each of the channels 78 and 80, more uniform drying of the grain is accomplished.

The uniformly dried grain discharged from each of the channels 78 and 80 of the outer drying columns 68 is received and collected in the receiving hopper 86. Mounted generally in the centre of the receiving hopper 86 is a tube member 88 which extends vertically upwardly into the dryer housing 12. Located within the vertical tube member 88 is a conveyor means, for example, a grain carrying auger 90 which is driven to rotation by means of a suitable drive pulley 92 extending outwardly from the bottom of the receiving hopper 86. The drive pulley 92 may be driven by any suitable means, for example, an electric motor or the power takeoff from a tractor or other vehicle (not shown).

The lower end of the tube member 88 contains a plurality of openings 94 which allow the partially dried grain from the outer columns 68 which has accumulated within the receiving hopper 86 to pass into the tube member 88. The grain passing into the tube member 88 is conveyed or transported upwardly by the rotating grain auger 90 and is discharged from the tube member 88 into a substantially enclosed inner chamber 96. In the present embodiment, the rotation of the grain auger 90 is sufficient to evenly distribute the grain discharged from the tube member 88 over the inner chamber 96. However, in a larger model of the dryer having a larger inner chamber 96, cross-augers or other suitable means (not shown) may be employed to provide an even distribution of the grain across the length and width of the inner chamber 96.

The inner chamber 96 serves as a steeping or tempering chamber for the grain. By allowing the grain to steep or sweat as it moves downwardly through the chamber 96, the moisture removal efficiency, drying uniformity and quality of the grain is greatly improved. Preferably, the grain remains in the steeping chamber for at least one hour. The sloping lower walls 98 of the steeping chamber 96 are at an angle of not less than 45° in order to provide for an acceptable flow of the moist grain downwardly through the steeping chamber. The sloping lower walls 98 of the steeping chamber include suitable insulation 102 to prevent the grain flowing through the steeping chamber adjacent the lower walls 98 from becoming overheated due to its proximity to the incoming heated air passing through the hot air ducts 62. The upper walls 74 of the steeping chamber 96 are also sloped at an angle of not less than 45° to assure an acceptable flow of the incoming moist grain from the wet grain inlet 32 into the outer drying columns 68.

In order to provide for most efficient use of the steeping chamber 96, it should be preferably kept full of grain. To this end, the upper steeping chamber walls 74 include means, for example, a plurality of slots 106 extending therethrough which allow some of the incoming moist grain to pass directly into the steeping chamber 96, in order to make up for any shrinkage of the grain which may have occurred as a result of the drying of the grain as it passed through the outer drying columns 68. The slots 106 may also be employed to control the moisture content of the grain in the steeping chamber in a manner which will hereinafter become apparent. In the steeping chamber, the moisture in the grain tends to be uniformly distributed amongst all the grain in the chamber.

The roof 28 may also contain a level control means 104 positioned slightly above the slots 106. The level control means 104 functions to actuate an elevator bucket or infeed auger (not shown) to maintain the grain in the wet grain hopper 72 at a level above the slots 106 in order to ensure that there is sufficient moist grain available for adding to the steeping chamber 96 to make up for any shrinkage which may have occurred.

The grain in the steeping chamber 96 flows downwardly at a controlled rate and passes into a pair of inner drying columns 100 which are also comprised of first and second perforate walls 108 and 110, respectively. The perforate walls 108 cooperate with perforate walls 70 and with the housing end walls 14 and 16 to form a pair of substantially enclosed plenum chambers 112. The plenum chambers 112 receive the heated air from the hot air ducts 62 and distribute the heated air so that it passes outwardly through the outer drying columns 68 and inwardly through the inner drying columns 100 along the entire length of the columns. The plenum chambers 112 may include suitable adjustable damper means 114 extending across the plenum chambers 112 between the end walls 14 and 16 to further control the distribution of the heated air to the inner and outer drying columns 68 and 100. The damper means 114 limits the amount of air which passes into the lower portion of the plenum chamber 112 to force more air through the upper section of the columns 68 and 100. In order to provide for a more uniform distribution of the heated air within the lower portions of the plenum chambers 112, the openings of the adjustable damper means 114 are tapered extending across the plenum chambers with the larger openings being adjacent end wall 14 or in close communication with the hot air ducts 62 to provide a generally uniform distribution of drying air into the lower portion of each plenum chamber.

Figs. 1, 4 and 6 show a slightly different structural arrangement for evenly distributing the heated air within the plenum chambers 112. As shown in Figs. 1 and 6, a pair of tapered perforate tubes 116 (116′ in Fig. 6) extend across the plenum chambers 112 between the end walls 14 and 16. The larger end of the tapered tubes 116 re connected to and communicate with the hot air ducts 62 to receive the flow of heated air therefrom. Because the tubes 116 are tapered, the amount of heated air that passes along the length of the tube is restricted, thereby providing a uniform static pressure distribution along the length of the tube to ensure a uniform airflow out of the perforations therein. The uniform air flow from the tapered tubes 116 provides a generally uniform distribution of the heated air along the tubes and throughout the plenum chamber 112, thereby providing a more uniform flow of the heated air through the columns 68 and 100 along their entire length. Alternatively, the tapered tubes 116 may be replaced with constant diameter tubes. (not shown) having perforations varying in size and percentage of total opening along the length of the tubes, (the end of the tubes connected to the hot air ducts 62 having the larger diameter perforations and greater percentage of openings) to provide the desired generally uniform static pressure distribution along the length of the tubes into the plenum chamber.

Referring again to Fig. 3, the inner drying columns 100 also have a generally vertical partition 118, which divides each column into inner and outer channels 120 and 122 in a manner corresponding to the partitions 76 for the outer drying columns 68. Discharge means in the form of metering rolls 124 and 126 are also provided for discharging grain from the inner and outer channels 120 and 122, respectively. As with the metering rolls associated with the outer drying columns 68, the metering rolls 124 and 126 also turn at different predetermined rates for discharging the grain from the channels 120 and 122 at different rates. Preferably, the metering rolls 126 adjacent the first perforate walls 108 discharge the material at a rate faster than the metering rolls 124.

As shown on Figs. 1 and 3, a pair of distribution ducts 127 having triangular cross-sections extend across the plenum chambers 112 between the end walls 14 and 16. One end of the distribution ducts 127 is connected to the cool air ducts 56 for receiving the cooling air flow. The ducts 127 have one wall provided by the perforated walls 108, which provide for the passage of cooling air into the lower portion of the inner drying columns 100. Adjacent each of the ducts 127 are small access or clean-out doors 129 to provide for the removal of debris which may accumulate within the plenum chambers 112.

The inner drying columns 100 may also be wider at the bottoms than at the tops in a manner similar to that of the outer drying column 68 for substantially the same reasons as discussed above. Grain from the channels 120 and 122 of the inner drying columns 100 is discharged into a second or inner receiving hopper 130. Grain from the second receiving hopper 130 may be removed from the dryer by means of a discharge tube 132 and may thereafter be transported to a suitable storage facility (not shown).

The dryer 10 also includes a central inner chamber 134 surrounding the vertical tube member 88 and formed on opposite sides by the innermost perforate walls 110. The central chamber 134 extends the entire length of the dryer between end walls 14 and 16 (shown on Fig. 1) and provides the conduit between the hot air fan 44 and the second air inlet opening 49 for the movement of ambient air into the inlet of the hot air fan 44. The central chamber 134 also receives and collects both the heating and cooling air exhausted from the inner drying columns 100 and recycles or recirculates this exhausted air back to the hot air fan 44. By mixing the incoming ambient air with the air exhausted from the inner drying columns 100 in this manner, the air entering the heater section 40 is effectively preheated, thereby requiring the addition of considerably less thermal energy to raise the air to the desired by requisite drying temperature. Although the benefits of recirculating or recycling air in a grain dryer are well known, recycling heated air through an inner chamber in this manner is highly desirable because the heated recycled air is insulated by the surrounding dryer structure, thereby preventing any substantial radiation loss of the heat energy contained within the recycled air. In addition, by employing such a central recycling chamber 134, the dryer structure can be greatly compacted. Furthermore, due to the insulation of the surrounding structure, moisture condensation and dripping problems, which have plagued some prior art recirculating dryers of other designs, are avoided.

Figs. 7, 8 and 9 show additional details of the lower portion of the dryer, including the grain discharge means. As shown on Fig. 9, metering roll 82 is retained within a plurality of aligned spaced-apart tubular members 136. Adjacent to and above the tubular members 136 are a plurality of inverted V-shaped members 138, which serve as deflectors to direct the downward flow of grain into spaces 140 between the tubular members 136. The metering roll 82 further comprises a horizontal rotating grain auger 142 disposed within the tubular members 136. The grain auger is supported by, for example, a suitable bearing 144 and is driven, for example, by means of a suitable drive pulley of the type hereinbefore described. Grain flowing downwardly in each of the channels of the drying columns is deflected by the inverted V-shaped members 138 into the spaces 140 between the tubular members 136 where it is received and carried by the rotating grain auger 142 as shown by the flow arrows. Thereafter, the grain is discharged from the grain auger 142 through a plurality of openings 146 located between the lower portions of each of the tubular members 136 and the grain enters the receiving hopper 86, as shown in Fig. 3. Each of the spaces 140 between the tubular members 136 is enclosed and includes a removable bottom panel 148, which is retained in place as shown by means of a pair of supporting side flanges 150 and a pair of suitably sized U-shaped clamps 152. By removing the U-shaped clamps 152, the bottom panels 148 may be conveniently removed for cleaning out the spaces 140 and the grain auger 142. The combination of the metering rolls and the inverted V-shaped members 138 provide for a uniform withdrawal of grain across each of columns of the dryer. Additional details concerning the structure and operation of the grain discharge means may be obtained from US—A—4152841. The other metering rolls 84, 124 and 126 operate and are constructed similarly to metering rolls 82.

In cross flow dryers of the type shown, it is desirable to use the same dryer to dry particulate materials or grains of widely varying dimensions. For example, it may be desirable to dry either corn or rice in the same dryer. In order to be able to dry such different types of grains in the same dryer without any considerable loss of product or drying efficiency, it is necessary to have the ability to conveniently vary the size of the openings in the dryer's perforate walls forming the drying columns.

Referring to Figs. 5 and 6, embodiments of the invention employ removable modules 160 to accomplish this result. Each module, generally designated 160, is complete in itself and comprises four generally parallel perforate side panels 110', 108', 70' and 26', which are fixed to a plurality of generally vertical support members or cross braces 172. In Figs. 5 and 6, primes are used to designate component parts of the module 160, the primes being dropped when the module 160 is installed in the dryer 10 as shown on Fig. 4 (Fig. 3 does not show the modular construction features of the dryer 10). The perforate panels 110', 108', 70' and 26' may all be of one piece construction or may be made up of a plurality of individual smaller panels which are attached to the cross braces 172. The perforate panels 110', 108', 70' and 26' cooperate to form a pair of drying columns 100' and 68' with a plenum chamber 112' therebetween. A tapered perforate tube 116', a generally triangularly-shaped distribution duct 127' in cross-section having a perforated side wall 108' as a part thereof, and a clean-out door 129' are also included as part of the module 160 as shown.

When a pair of complementary modules 160 are placed in position in the dryer housing 12 as shown in Fig. 4, they form the drying columns 68 and 100. The upper and lower portions of the modules 160 are suitably contoured to enable the modules to be appropriately positioned within the dryer housing 12 as shown in Fig. 4. The tapered perforate tubes 116 are connected to and cooperate with the hot air ducts 62 (shown in Fig. 1) for the distribution of hot air within the plenum chamber 112. Likewise, the triangular-shaped air ducts 127 are connected to and cooperate with the cooing air ducts 56 (shown in Fig. 1) to provide a flow of cooling air when the modules 160 are in place within the dryer housing 12. Suitable sealing means (not shown) may be provided to prevent air leakage from around the connection of the perforate tubes 116 and the triangular-shaped ducts 127 with the hot air ducts 62 and cooling air ducts 56. A number of small flanges 178 on the corners of the modules 160 engage suitable complementary flanges 180 on the dryer housing 12 in order to properly position and retain the modules 160 in place within the housing 12. A plurality of sealing means, for example, neoprene flaps 182, are employed to close any gaps or openings which may occur along the joint lines where the modules 160 meet the dryer housing 12 and to prevent the leakage of any grain through any such gaps or openings.

From the above description of the modules 160, it is readily apparent that the modules 160 may be installed or removed from the dryer housing 12 shown in Fig. 4 with relative ease. Each dryer 10 has one or more pairs of such modules 160. Each pair of such modules 160 has perforate side panels 110', 108', 70' and 26' with perforations of a different size than the other pairs of modules. For example, one pair of modules have perforations ideally suited for drying rice, whereas another pair of modules will have perforations ideally suited for drying corn. In this manner, greater flexibility and drying efficiency may be achieved with a single basic dryer structure.

The dryer 10 may be operated as a batch-type dryer or as a continuous flow-type dryer. In either type of dryer operation, an operator makes a determination as to what type of grain is to be dried and the initial moisture content of the grain. The operator then selects the appropriate pair of modules 160 for the grain to be dried and installs the modules in the dryer housing 12 as shown in Fig. 4. The operator also adjusts the adjustable air flow dampers 66 (shown in Fig. 1) to the proper setting to provide the desired air flow to provide optimum drying for the particular grain being dried. Likewise, the operator adjusts the pivotable sections 79 on the partitions 76 and 118 (shown in Fig. 1) to determine the relative portion of the grain which will be rapidly discharged from the grain columns 68 and 100 as described in detail above.

In operation as a continuous flow dryer (referring to Fig. 3), the dryer is then activated and the grain to be dried is fed into the wet grain inlet 32. The grain from the wet grain inlet 32 flows downwardly into the wet grain hopper 72 and is introduced into the top of the outer drying columns 68. As the grain flows downwardly through the outer drying columns 68, heated air from the plenum chamber 112 flows outwardly through the grain to heat the grain and remove moisture therefrom. The drying air passes outwardly through the outer perforate wall 26 to the atmosphere. As the grain flows downwardly through the column, it becomes increasingly drier due to its continued contact with the heated air. As discussed in detail above, the grain flowing down the columns adjacent to perforate walls 70 is dried more rapidly than the grain flowing down the column adjacent outer walls 26. Accordingly, as also discussed in detail above relative to Fig. 3, the grain flowing through the columns 68 adjacent perforate walls 70 is discharged from the columns 68 at a faster rate than the grain flowing down the column adjacent the perforate walls 26.

All of the grain discharged from the outer columns 68 is received and collected in the first receiving hopper 86. The collected grain flows downwardly within the hopper 86 and enters the vertical tube member 88 through the openings 94. The rotating grain auger 90 within the vertical tube member 88 transports the grain upwardly to the top of the tube member 88 where it is discharged into the steeping chamber 96.

After an initial startup period, the steeping chamber 96 is generally filled with partially dried grain. Due to the relatively large size of the steeping chamber 96 with respect to the inner drying columns 100 which receive the grain discharged from the steeping chamber, the grain introduced to the top of the steeping chamber 96 moves slowly down from the steeping chamber 96 at a predetermined uniform rate. It is anticipated that the grain remains in the steeping chamber for at least a one hour period. While within the steeping chamber, the grain is steeped or sweats in a manner well known in the art.

After passing out of the steeping chamber 96, the grain enters the inner drying columns 100 and passes downwardly therethrough. At the top of the inner drying columns 100, the grain is again exposed to a flow of heated drying air, which passes inwardly from the plenum chambers 112, through the columns 100 and into the central chamber 134, as shown in Fig. 3. As the grain moves further down the inner columns 100, it is exposed to the cooling air which passes inwardly from the cooling air distribution ducts 127, through the columns 100 and into the central chamber 134. The dried and cooled grain is then discharged into the second or inner receiving hopper 130. The grain may then be removed from the dryer by means of the discharge tube 132 for subsequent storage and/or use.

In addition to making up for the shrinkage of the grain within the steeping chamber 96, the slots 106 may be employed in conjunction with the metering rolls 124 and 126 at the bottom of the inner drying columns 100 to further control the moisture content of the grain discharged from the dryer 10. More specifically, by putting the metering rolls 124 and 126 on a separate drive (not shown), the amount of wet grain which enters the steeping chamber 96 through the slots 106 may be accurately controlled. For example, by having the metering rolls 124 and 126 turning faster than the metering rolls 82 and 84 of the outer drying columns 68, the flow of wet grain through the slots 106 is increased, thereby increasing the overall moisture content of the grain in the steeping chamber and, correspondingly, increasing the overall moisture content of the grain discharged from the dryer. By controlling the moisture content through grain mixing in this manner, the dryer 10 is better able to dry various types of grains having various initial moisture contents to a specified final moisture content.

As discussed in detail above, the heated air passing through the inner drying columns 100 enters the central chamber 134 and is recycled back to the hot air fan 44 for reuse. Likewise, the cooling air which has passed through the inner columns 100 and has picked up heat from the heated grain within the columns is recycled back to the hot air fan 44 in the same manner. The heated air passing through the outer columns 68 is too saturated with moisture which has been removed from the grain, to be of desired use in recycling, and, thus, is exhausted to the atmosphere through the outer perforate walls 26.

From the foregoing description, it can be seen that the present invention comprises a multistage gravity flow dryer for particulate material in which the particulate material is discharged in a channelized manner in order to provide improved uniformity of drying, as well as prevents overheating and cracking of the particulate material being dried.

Claims

1. A gravity flow dryer (10) for particulate material including a first generally vertical drying column (68) having first and second opposed spaced perforate walls (70, 26), first input means (32) for introducing moist particulate material into a top portion of the first drying column (68), first discharge means (82, 84) for removing partially dried particulate material from a bottom portion of the first drying column (68), a second generally vertical drying column (100) having first and second opposed spaced perforate walls (108, 110) the first and second drying columns being spaced apart, a plenum chamber (112) defined by the first perforate walls (70, 108), of each drying column, second input means (90, 96) for introducing partially dried particulate material to a top portion of the second drying column (100), second discharge means (124, 126) for removing dried particulate material from a bottom portion of the second drying column (100), means (40) for providing drying air to the plenum chamber (112) whereby the drying air passes into the first and second drying columns (68, 100) through the first perforate walls (70, 108) to dry the particulate

material, the drying air being exhausted from the drying columns (68, 100) through the second perforate walls (26, 110), and means (42, 56, 127) for directing a flow of cooling air through a portion of the second drying column (100) to cool the dried particulate material prior to its removal from the second drying column (100), characterised in that conveyor means (88, 90) is provided for receiving the partially dried particulate material from the first discharge means (82, 84) and for conveying the partially dried particulate material to the second input means (90, 96), in that the plenum chamber (112) is provided between the first and second drying columns, and in that the second input means includes a steeping chamber (96) receiving a first flow of the partially dried particulate material from the conveyor means for steeping the partially dried particulate material prior to introduction into the second drying column (100).

2. A dryer as claimed in claim 1, characterised by duct means (134) for receiving the drying air exhausted from the second drying column (100) and for returning the exhausted air from the second drying column (100) to the means (40) for providing drying air.

3. A dryer as claimed in claim 1 or claim 2, characterised in that the steeping chamber (96) includes means (106) for introducing a second flow of moist particulate material therein to maintain the steeping chamber (96) at a predetermined capacity.

4. A dryer as claimed in claim 3, characterised in that the second discharge means (124, 126) is arranged to cooperate with the means (106) for introducing the second flow of material into the steeping chamber (96) to control the amount of particulate material in the steeping chamber (96).

5. A dryer as claimed in any preceding claim, characterised in that it further includes third and fourth generally vertical drying columns (68, 100) substantially the same as the first and second drying columns (68, 100), the third and fourth drying columns being disposed in the dryer (10) to form a four-column dryer, the first input means (32) also introducing moist particulate material into a top portion of the third drying column (68) and the second input means (90, 96) also introducing partially dried particulate material to a top portion of the fourth drying column (100), the third and fourth columns forming a second plenum chamber (112) therebetween, the means (40) for providing drying air also providing drying air to the second plenum chamber (112), and in that the drying air passes into the third and fourth drying columns (68, 100) through corresponding first perforate walls (70, 108) to dry the particulate material, the drying air being exhausted from the third and fourth drying columns (68, 100) through second perforate walls (26, 110), the second and fourth drying columns (100) forming a central chamber (134) therebetween for receiving the drying air exhausted therefrom that is returned to the means (40) for providing drying air.

6. A dryer as claimed in any preceding claim, characterised by dividing wall means (76, 79) extending between the perforate walls (70, 26) of the first drying column for dividing at least a portion of the column (68) into at least two channels (78, 80), said first discharge means (82, 84) including a first channel discharge means (84) associated with a first of the channels (80) and a second channel discharge means (82) associated with a second of the channels (78), the first channel (80) being adjacent the first perforate wall (70) and the first channel discharge means (84) being adapted to discharge particulate material at a rate faster than the second discharge means (82).

7. A dryer as claimed in claim 6, characterised in that second dividing wall means (118) extend between the perforate walls (108, 110) of the second drying column (100) for dividing at least a portion of the second column (100) into at least two channels; said second discharge means (124, 126) including third channel discharge means (126) associated with one of the channels (122) of the second column (100) and fourth channel discharge means (124) associated with a different channel (120) of the second column (100) than the third channel discharge means (126), the third channel discharge means (126) being adjacent the first perforate wall (108) of the second column (100) and being adapted to discharge particulate material at a rate faster than the fourth channel discharge means (124).

8. A dryer as claimed in any preceding claim, characterised in that the or each drying column (68) is substantially rectangular in cross section and has a greater width at the bottom than at the top.

9. A dryer as claimed in claim 6, characterised in that the dividing wall means (76, 79) is located at the bottom portion of the first drying column (68), the first and second channel discharge means (84, 82) serving as the first discharge means for removing dried particulate material from the column (68), at least a portion (79) of the dividing wall means (76) being adjustable to vary the relative sizes of the channels (78, 80).

Patentansprüche

1. Gravitationstrockner (10) für Feststoffpartikel, umfassend eine erste im allgemeinen vertikale Trocknungskolonne (68) mit ersten und zweiten gegenüberliegenden, mit Abstand zueinander angeordneten Lochwänden (70, 26), erste Eintragsvorrichtungen (32) für die Einführung von feuchten Feststoffteilchen in einen oberen Abschnitt der ersten Trocknungskolonne (68), erste Austragsvorrichtungen (82, 84) für den Abzug teilweise getrockneter Feststoffpartikel aus einem unteren Abschnitt der ersten Trockungskolonne (68), eine zweite im allgemeinen vertikale Trocknungskolonne (100) mit ersten und zweiten gegenüberliegenden, mit Abstand zueinander angeordneten Lochwänden (108, 110), wobei die ersten und zweiten Trocknungskolonnen mit Abstand zueinander angeordnet sind, eine Luft-

kammer (112), die durch die ersten Lochwände (70, 108) jeder Trocknungskolonne definiert ist, zweite Eintragsvorrichtungen (90, 96) für die Einführung teilweise getrockneter Feststoffpartikel in einen oberen Abschnitt der zweiten Trocknungskolonne (100), zweite Austragsvorrichtungen (124, 126) für den Abzug getrockneter Feststoffpartikel aus einem unteren Anschnitt der zweiten Trockungkolonne (100), Vorrichtungen (40) für die Zufuhr von Trocknungsluft zur Luftkammer (112), wobei die Trocknungsluft in die ersten und zweiten Trocknungskolonnen (68, 100) durch die ersten Lochwände (70, 108) strömt, um die Feststoffpartikel zu trocknen, wobei die Trocknungsluft aus den Trocknungskolonnen (68, 100) durch die zweiten Lochwände (26, 110) abgelassen wird, und Vorrichtungen (42, 56, 127), um einen Kühlluftstrom durch einen Abschnitt der zweiten Trocknungskolonne (100) zwecks Kühlung der getrockneten Feststoffpartikel vor ihrem Abzug aus der zweiten Trocknungskolonne (100) zu leiten, dadurch gekennzeichnet, daß Fördervorrichtungen (88, 90) vorgesehen sind, um die teilweise getrockneten Feststoffpartikel aus den ersten Austragsvorrichtungen (82, 84) aufzunehmen und die teilweise getrockneten Feststoffpartikel zu den zweiten Eintragsvorrichtungen (90, 96) zu fördern, daß die Luftkammer (112) zwischen den ersten und zweiten Trocknungskolonnen vorgesehen ist, und daß die zweite Eintragsvorrichtung eine einen ersten Strom der teilweise getrockneten Feststoffpartikel von den Fördervorrichtungen aufnehmende Feuchtkammer (96) für das Anfeuchten der teilweise getrockneten Feststoffpartikel vor Einleitung in die zweite Trocknungskolonne (100) umfaßt.

2. Trockner gemäß Anspruch 1, gekennzeichnet durch eine Kanalvorrichtung (134), um die aus der zweiten Trocknungskolonne (100) abgegebene Trocknungsluft aufzunehmen und die aus der zweiten Trocknungskolonne (100) abgegebene Luft zur Vorrichtung (40) zurückzuführen, um so für Trocknungsluft zu sorgen.

3. Trockner gemäß Anspruch 1 oder Anspruch 2, dadurch gekennzeichnet, daß die Feuchtkammer (96) Vorrichtungen (106) für die Einführung eines zweiten Stroms feuchter Feststoffpartikel in die Kammer umfaßt, um die Feuchtkammer (96) auf einem vorgegebenen Kapazitätsniveau zu halten.

4. Trockner gemäß Anspruch 3, dadurch gekennzeichnet, daß die zweite Austragsvorrichtung (124, 126) so angeordnet ist, daß sie mit der Vorrichtung (106) für die Einführung des zweiten Materialstroms in die Feuchtkammer (96) zusammenwirkt, um die Feststoffpartikelmenge in der Feuchtkammer (96) zu regeln.

5. Trockner gemäß irgendeinem der vorstehenden Ansprüche, dadurch gekennzeichnet, daß er ferner dritte und vierte im allgemeinen vertikale Trocknungskolonnen (68, 100), im wesentlichen die gleichen wie die ersten und zweiten Trocknungskolonnen (68, 100), umfaßt, wobei die dritten und vierten Trocknungskolonnen unter Bildung eines Vier-Kolonnen-Trockners im Trockner (10) angeordnet sind, wobei die erste Eintragsvorrichtung (32) auch feuchte Feststoffpartikel in einen oberen Abschnitt der dritten Trocknungskolonne (68) einführt, und wobei die zweite Eintragsvorrichtung (90, 96) auch teilweise getrocknete Feststoffpartikel in einen oberen Anschnitt der vierten Trocknungskolonne (100) einführt, wobei die dritten und vierten Kolonnen eine dazwischen angeordnete zweite Luftkammer (112) bilden, wobei die Vorrichtung (40) für die Zufuhr von Trocknungsluft auch Trocknungsluft zur zweiten Luftkammer (112) liefert, und daß die Trocknungsluft in die dritten und vierten Trocknungskolonnen (68, 100) durch entsprechende erste Lochwände (70, 108) zur Trocknung der Feststoffpartikel strömt, wobei die Trocknungsluft von den dritten und vierten Trocknungskolonnen (68, 100) durch zweite Lochwände (26, 110) abgeführt wird, wobei die zweiten und vierten Trocknungskolonnen (100) eine dazwischen angeordnete zentrale Kammer (134) bilden, um die daraus abgeführte Trocknungsluft, die zur Vorrichtung (40) für die Zufuhr von Trocknungsluft zurückgeführt wird, aufzunehmen.

6. Trockner gemäß irgendeinem der vorstehenden Ansprüche, gekennzeichnet durch Trennwandvorrichtungen (76, 79), die sich zwischen den Lochwänden (70, 26) der ersten Trocknungskolonne erstrecken, um mindestens eine Abschnitt der Kolonne (68) in mindestens zwei Kanäle (78, 80) aufzuteilen, wobei die genannte erste Austragsvorrichtung (82, 84) eine erste Kanalaustragsvorrichtung (84) in Verbindung mit einem ersten der Kanäle (80) und eine zweite Kanalaustragsvorrichtung (82) in Verbindung mit einem zweiten der Kanäle (78) umfaßt, wobei der erste Kanal (80) sich in der Nähe der ersten Lochwand (70) befindet, und wobei die erste Kanalaustragsvorrichtung (84) so ausgeführt ist, daß sie die Feststoffpartikel mit höherer Geschwindigkeit als die zweite Austragsvorrichtung (82) austrägt.

7. Trockner gemäß Anspruch 6, dadurch gekennzeichnet, daß sich die zweite Trennwandvorrichtung (118) zwischen den Lochwänden (108, 110) der zweiten Trocknungskolonne (100) erstreckt, um mindestens einen Abschnitt der zweiten Kolonne (100) in mindestens zwei Kanäle aufzuteilen, wobei die genannte zweite Austragsvorrichtung (124, 126) eine dritte Kanalaustragsvorrichtung (126) in Verbindung mit einem der Kanäle (122) der zweiten Kolonne (100) und eine vierte Kanalaustragsvorrichtung (124) in Verbindung mit einem anderen Kanal (120) der zweiten Kolonne (100) als die dritte Kanalaustragsvorrichtung (126) umfaßt, wobei sich die dritte Kanalaustragsvorrichtung (126) in der Nähe der ersten Lochwand (108) der zweiten Kolonne (100) befindet und so ausgeführt ist, daß sie Feststoffpartikel mit einer höheren Geschwindigkeit als die vierte Kanalaustragsvorrichtung (124) austrägt.

8. Trockner gemäß irgendeinem der vorstehenden Ansprüche, dadurch gekennzeichnet, daß die

oder jede Trocknungskolonne (68) im wesentlichen einen rechtwinkligen Querschnitt und am Fuß eine größere Breite als am Kopf aufweist.

9. Trockner gemäß Anspruch 6, dadurch gekennzeichnet, daß die Trennwandvorrichtung (76, 79) am unteren Abschnitt der ersten Trocknungskolonne (68) angeordnet ist, wobei die erste und zweite Kanalaustragsvorrichtung (84, 82) als erste Austragsvorrichtung für den Abzug getrockneter Feststoffpartikel aus der Kolonne (68) dient, wobei mindestens ein Abschnitt (79) der Trennwandvorrichtung (76) zur Veränderung der relativen Größe der Kanäle (78, 80) eingestellt werden kann.

Revendications

1. Séchoir (10) à écoulement par gravité pour matière granuleuse, comprenant une première colonne de séchage (68) généralement verticale comportant une première et une seconde parois perforées (70, 26) opposées et écartées, des premiers moyens d'entrée (32) pour introduire la matière granuleuse humide dans une partie supérieure de la première colonne de séchage (68), des premiers moyens d'évacuation (82, 84) pour extraire la matière granuleuse partiellement séchée d'une partie inférieure de la première colonne de séchage (68), une deuxième colonne de séchage (100) généralement verticale comportant une première et une seconde parois perforées (108, 110) opposées et écartées, les première et deuxième colonnes de séchage étant écartées l'une de l'autre, un collecteur d'air (112) délimité par les premières parois perforées (70, 108) de chaque colonne de séchage, des seconds moyens d'entrée (90, 96) pour introduire la matière granuleuse partiellement séchée dans une partie supérieure de la deuxième colonne de séchage (100), des seconds moyens d'évacuation (124, 126) pour extraire la matière granuleuse séchée d'une partie inférieure de la deuxième colonne de séchage (100), des moyens (40) pour fournir de l'air de séchage au collecteur d'air (112) par lesquels l'air de séchage passe dans les première et deuxième colonnes de séchage (68, 100) à travers les premières parois perforées (70, 108) pour sécher la matière granuleuse, l'air de séchage étant rejeté des colonnes de séchage (68, 100) à travers les secondes parois perforées (26, 110), et des moyens (42, 56, 127) pour diriger un courant d'air de refroidissement à travers une partie de la deuxième colonne de séchage (100) pour refroidir la matière granuleuse séchée avant sa sortie de la deuxième colonne de séchage (100), caractérisé en ce qu'il est prévu des moyens de transport (88, 90) pour recevoir la matière granuleuse partiellement séchée provenant des premiers moyens d'évacuation (82, 84) et pour transporter la matière granuleuse partiellement séchée jusqu'aux seconds moyens d'entrée (90, 96), en ce que le collecteur d'air (112) est prévu entre les première et deuxième colonnes de séchage et en ce que les seconds moyens d'entrée comprennent une chambre de trempage (96) recevant un premier courant de la matière granuleuse partiellement séchée provenant des moyens de transport pour tremper la matière granuleuse partiellement séchée avant son introduction dans la duxième colonne de séchage (100).

2. Séchoir suivant la revendication 1, caractérisé par des moyens de conduit (134) pour recevoir l'air de séchage rejeté de la deuxième colonne de séchage (100) et pour renvoyer l'air rejeté de la deuxième colonne de séchage (100) vers les moyens (40) pour fournir de l'air de séchage.

3. Séchoir suivant la revendication 1 ou la revendication 2, caractérisé en ce que la chambre de trempage (96) comprend des moyens (106) pour introduire un second courant de matière granuleuse humide dans celle-ci afin de maintenir la chambre de trempage (96) à un niveau prédéterminé de remplissage.

4. Séchoir suivant la revendication 3, caractérisé en ce que les seconds moyens d'évacuation (124, 126) sont agencés de façon à coopérer avec les moyens (106) pour introduire le second courant de matière dans la chambre de trempage (96) afin de régler la quantité de matière granuleuse dans la chambre de trempage (96).

5. Séchoir suivant l'une ou l'autre des revendications précédentes, caractérisé en ce qu'il comprend en outre une troisième et une quatrième colonnes de séchage (68, 100) généralement verticales, substantiellement les mêmes que les première et deuxième colonnes de séchage (68, 100), les troisième et quatrième colonnes de séchage étant disposées dans le séchoir (10) pour former un séchoir à quatre colonnes, les premiers moyens d'entrée (32) introduisant également la matière granuleuse humide dans une partie supérieure de la troisième colonne de séchage (68) et les seconds moyens d'entrée (90, 96) introduisant également la matière granuleuse partiellement séchée dans une partie supérieure de la quatrième colonne de séchage (100), les troisième et quatrième colonnes formant entre elles un second collecteur d'air (112), les moyens (40) pour fournir de l'air de séchage fournissant également de l'air de séchage au second collecteur d'air (112), et en ce que l'air de séchage pénètre dans les troisième et quatrième colonnes de séchage (68, 100) à travers des premières parois perforées correspondantes (70, 108) pour sécher la matière granuleuse, l'air de séchage étant rejeté des troisième et quatrième colonnes de séchage (68, 100) à travers des secondes parois perforées (26, 110), les deuxièe et quatrième colonnes de séchage (100) formant entre elles une chambre centrale (134) pour recevoir l'air de séchage rejeté de celles-ci, qui est renvoyé vers les moyens (40) pour fournir de l'air de séchage.

6. Séchoir suivant l'une ou l'autre des revendications précédentes, caractérisé par des moyens de paroi de division (76, 79) s'étendant entre les parois perforées (70, 26) de la première colonne de séchage pour diviser au moins une partie de la colonne (68) en au moins deux canaux (78, 80), lesdits premiers moyens d'évacuation (82, 84)

comprenant des premiers moyens (84) d'évacuation d'un canal associés à un premier des canaux (80) et des seconds moyens (82) d'évacuation d'un canal associés à un second des canaux (78), le premier canal (80) étant adjacent à la première paroi perforée (70) et les premiers moyens (84) d'évacuation d'un canal étant agencés pour évacuer la matière granuleuse à une vitesse plus élevée que les seconds moyens d'évacuation (82).

7. Séchoir suivant la revendication 6, caractérisé en ce que des seconds moyens de paroi de division (118) s'étendent entre les parois perforées (108, 110) de la deuxième colonne de séchage (100) pour diviser au moins une partie de la deuxième colonne (100) en au moins deux canaux, lesdits seconds moyens d'évacuation (124, 126) comprenant des troisièmes moyens (126) d'évacuation d'un canal associés à un des canaux (122) de la deuxième colonne (100) et des quatrièmes moyens (124) d'évacuation d'un canal associés à un canal (120) de la deuxième colonne (100) différent de celui des troisièmes moyens (126) d'évacuation d'un canal, les troisièmes moyens (126) d'évacuation d'un canal étant adjacents à la première paroi perforée (108) de la deuxième colonne (100) et étant agencés pour évacuer la matière granuleuse à une vitesse plus élevée que les quatrièmes moyens (124) d'évacuation d'un canal.

8. Séchoir suivant l'une ou l'autre des revendications précédentes, caractérisé en ce que la ou chaque colonne de séchage (68) présente une section transversale substantiellement rectangulaire et a une plus grande largeur au pied qu'au sommet.

9. Séchoir suivant la revendication 6, caractérisé en ce que les moyens de paroi de division (76, 79) sont situés à la partie inférieure de la première colonne de séchage (68), les premiers et seconds moyens (82, 84) d'évacuation d'un canal servant de premiers moyens d'évacuation pour extraire la matière granuleuse zéchée hors de la colonne (68), au moins une partie (79) des moyens de paroi de division (76, 79) étant réglable pour faire varier les grandeurs relatives des canaux (78, 80).

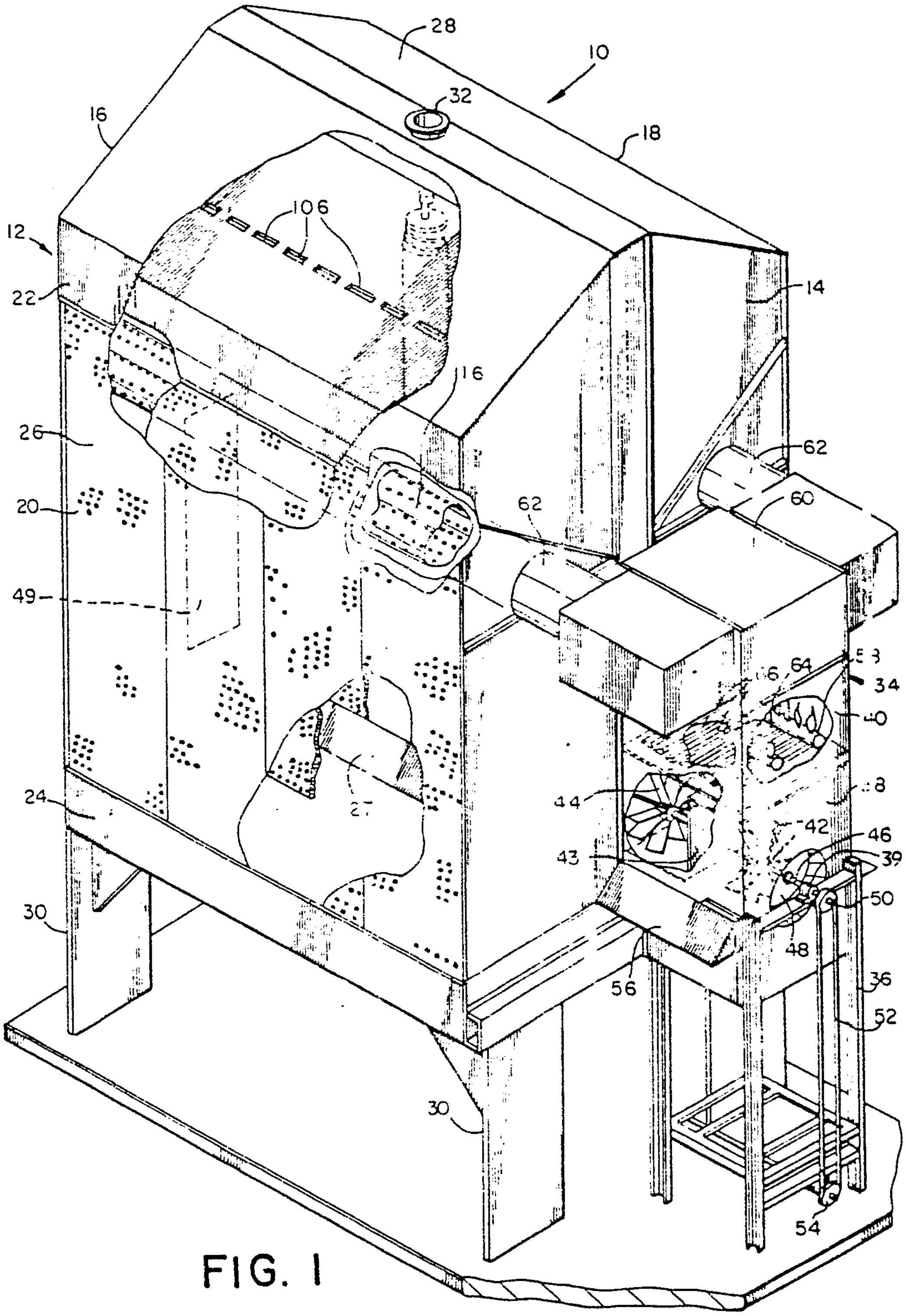

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FIG. 1

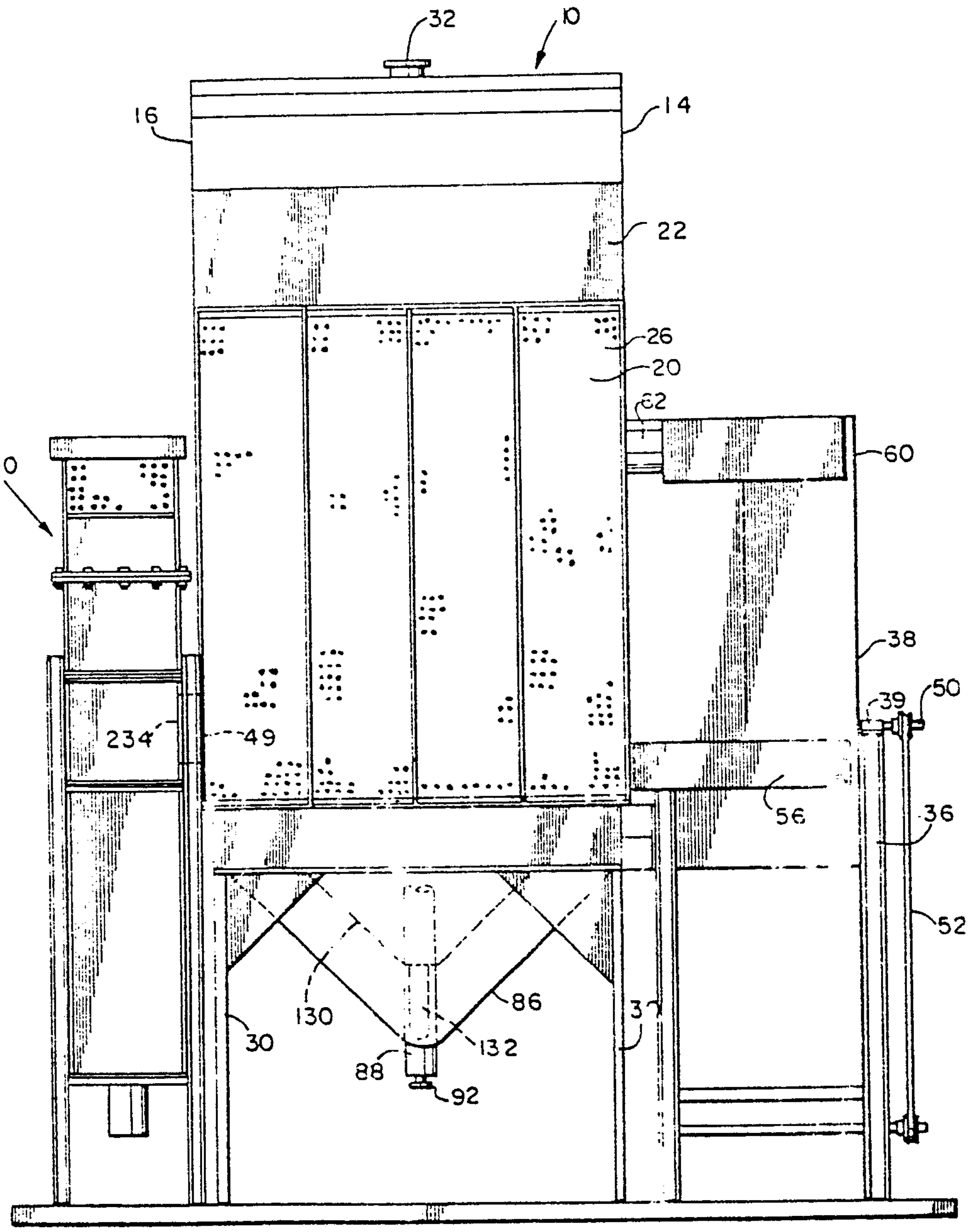
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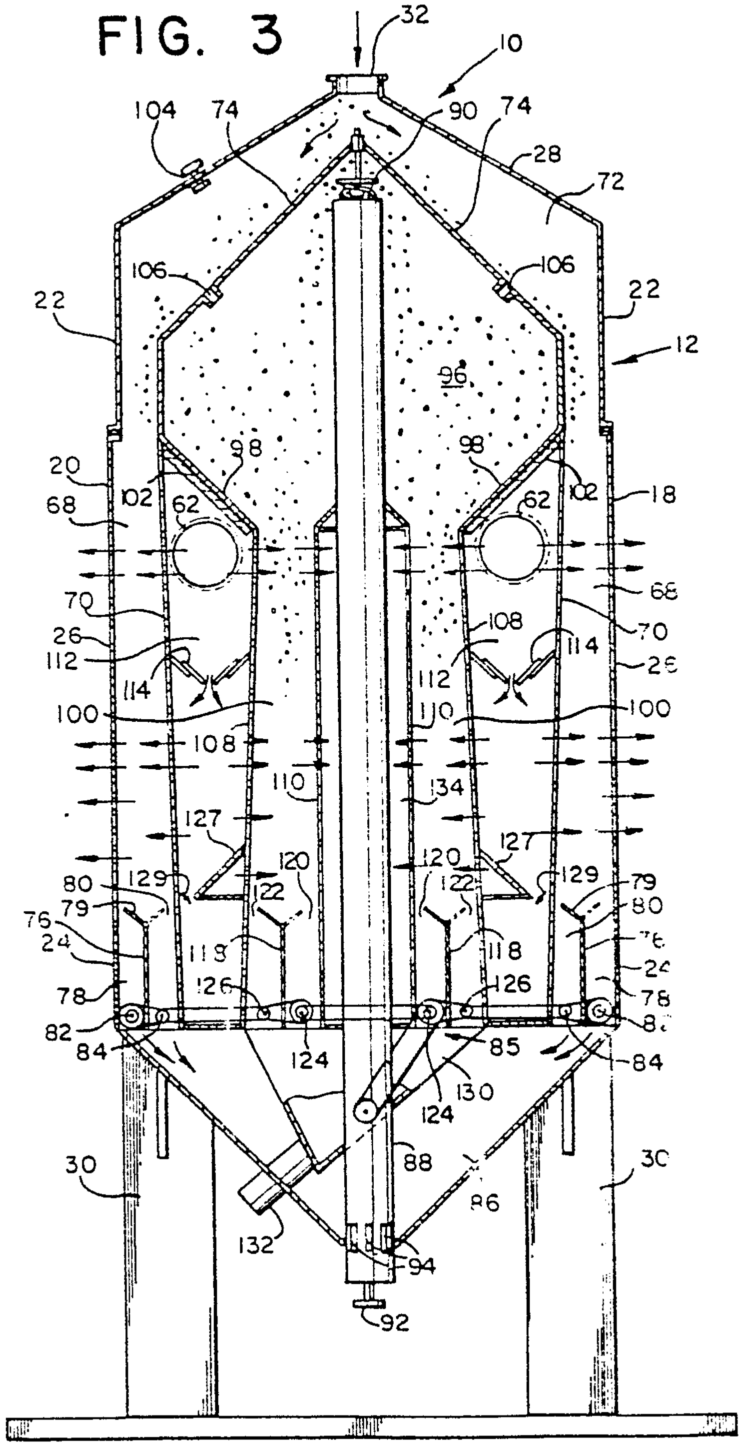
FIG. 2

FIG. 3



32
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104
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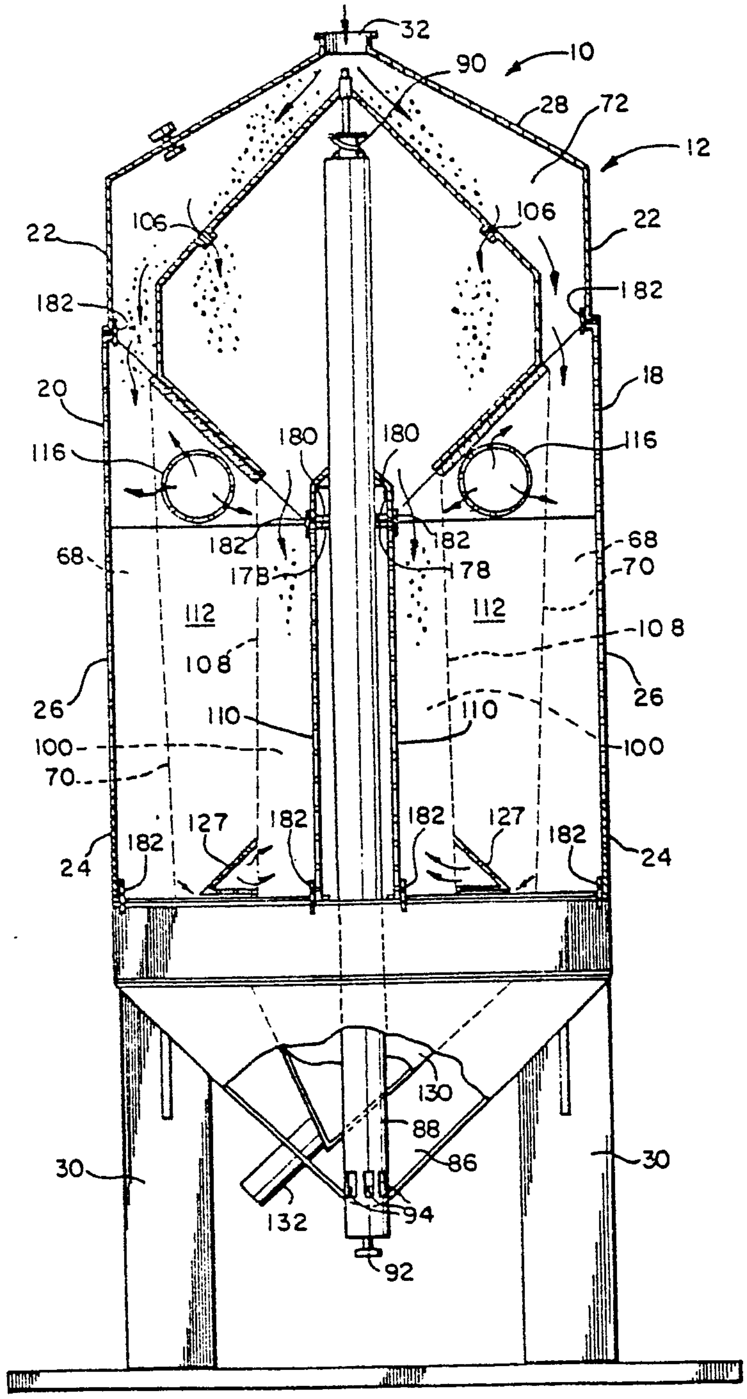
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112
112
108
108
26
26
110
110
100
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94
92

FIG. 4

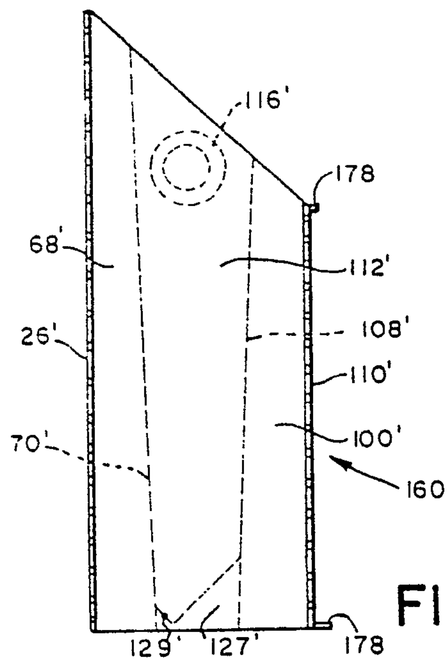
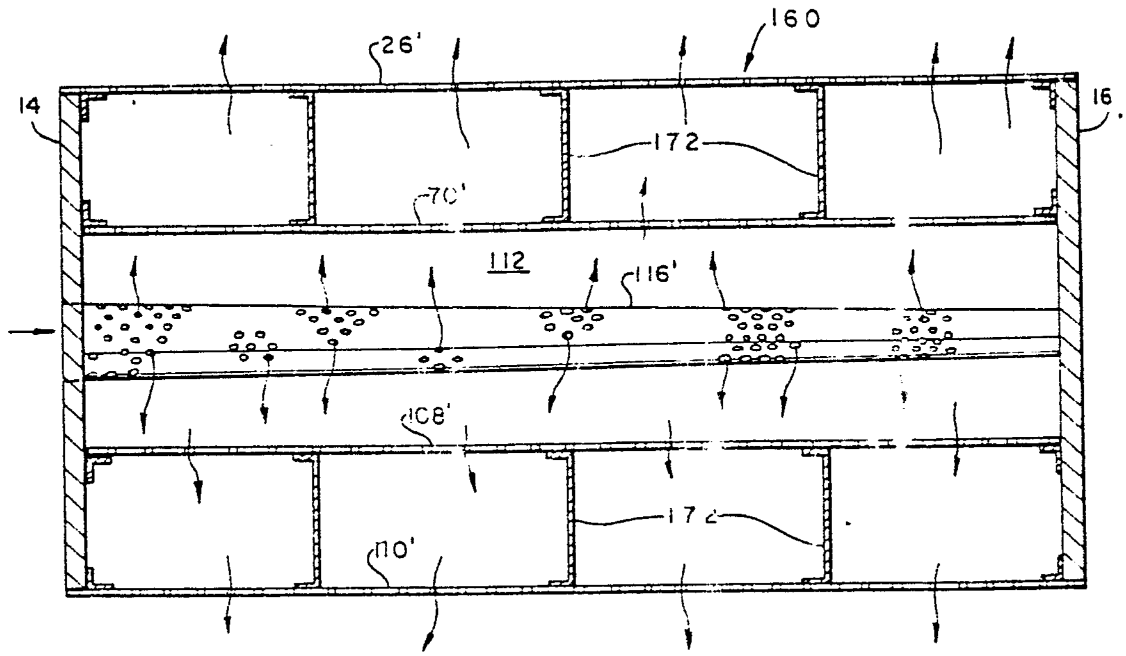

116'
178
68'
112'
108'
26'
110'
70'
100'
160
129'
127'
178

FIG. 5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26'
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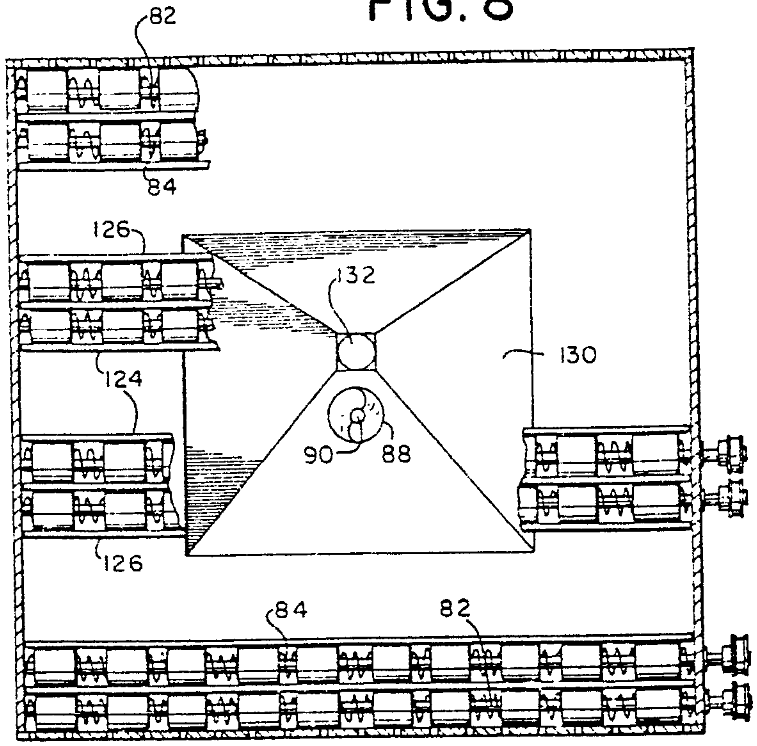
16
172
70'
112
116'
108'
172
110'

FIG. 6

FIG. 8



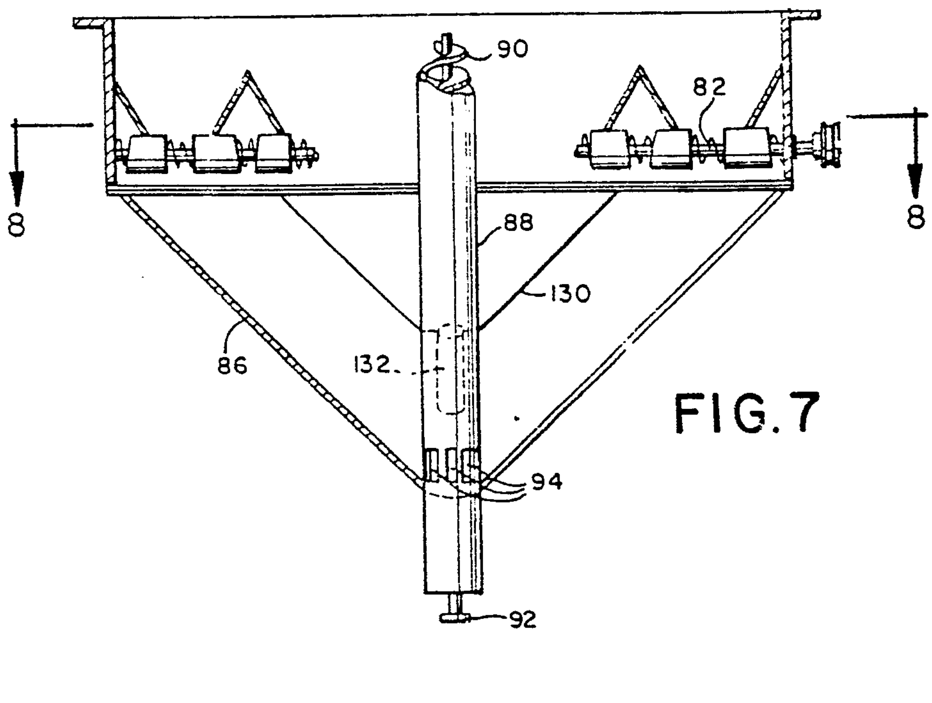
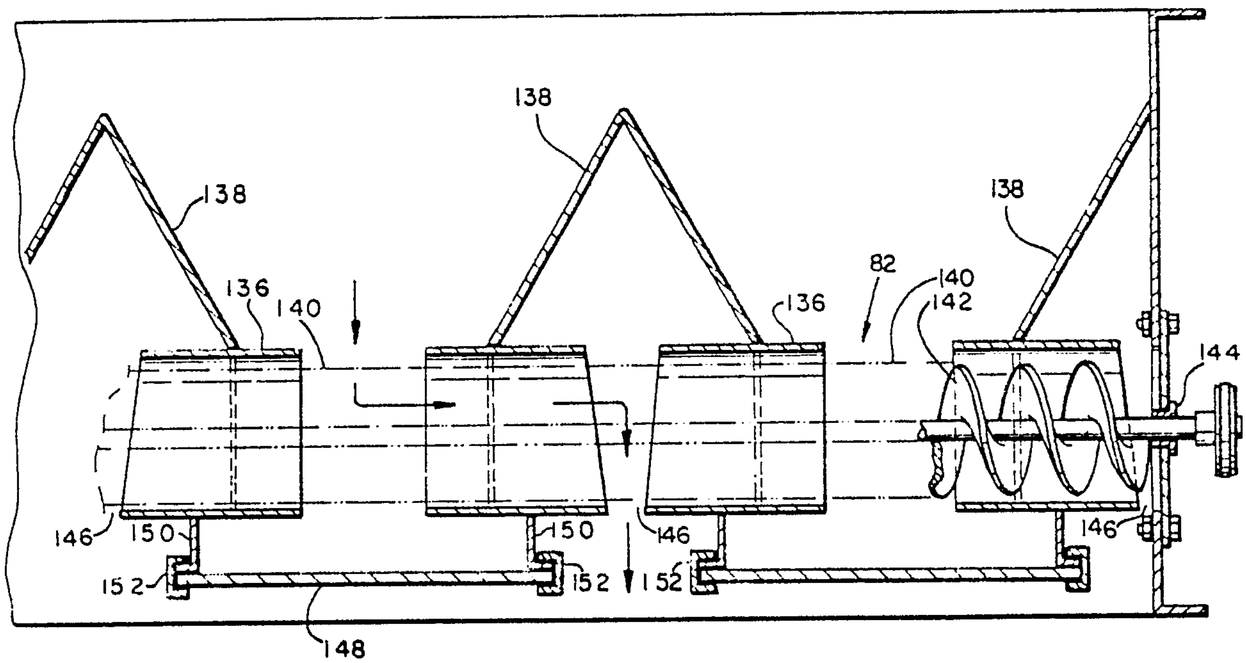


FIG. 7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148

FIG. 9