

July 22, 1958

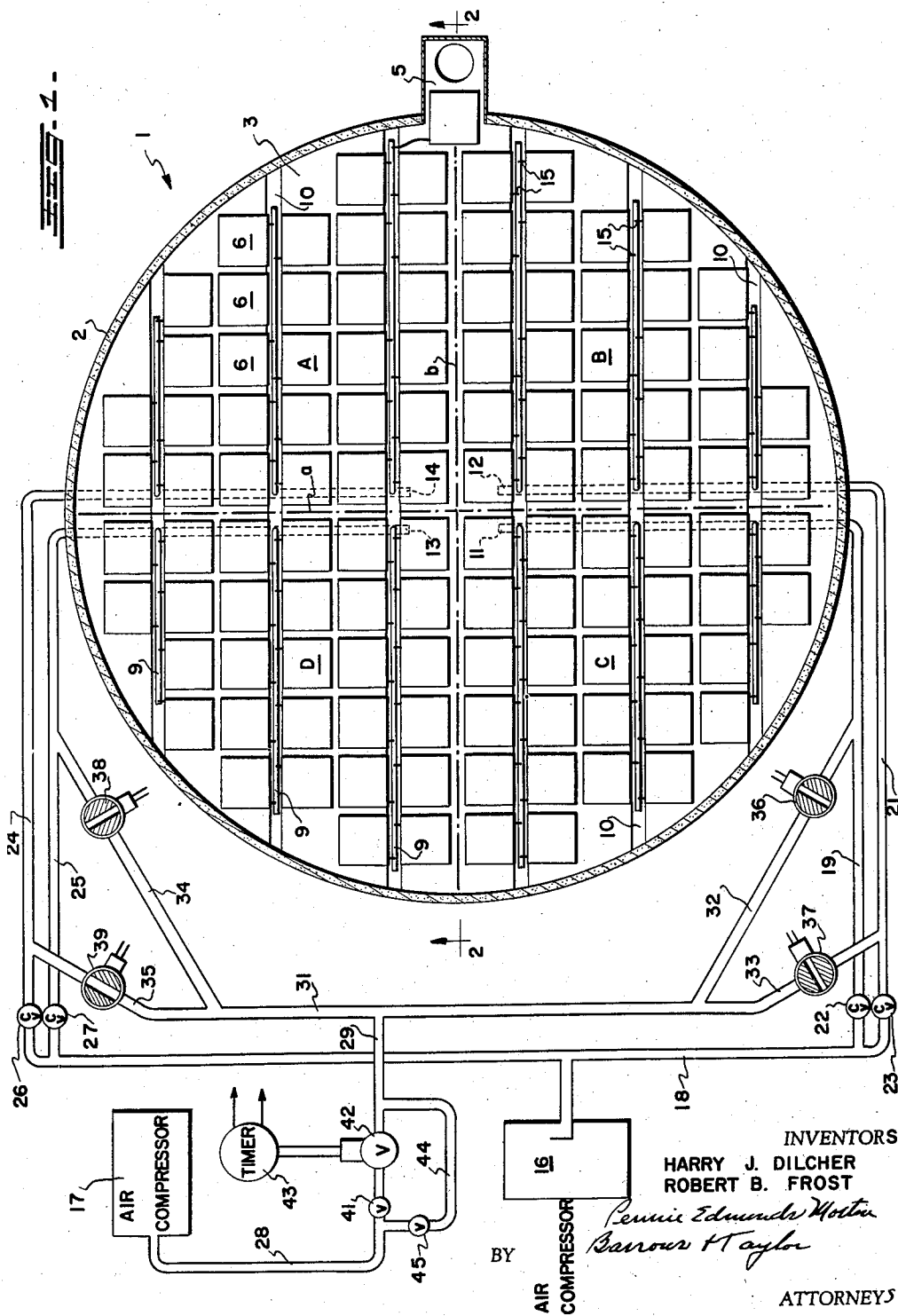
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2,844,361

METHOD AND APPARATUS FOR BLENDING PULVERULENT MATERIAL

Filed June 28, 1955

3 Sheets-Sheet 1



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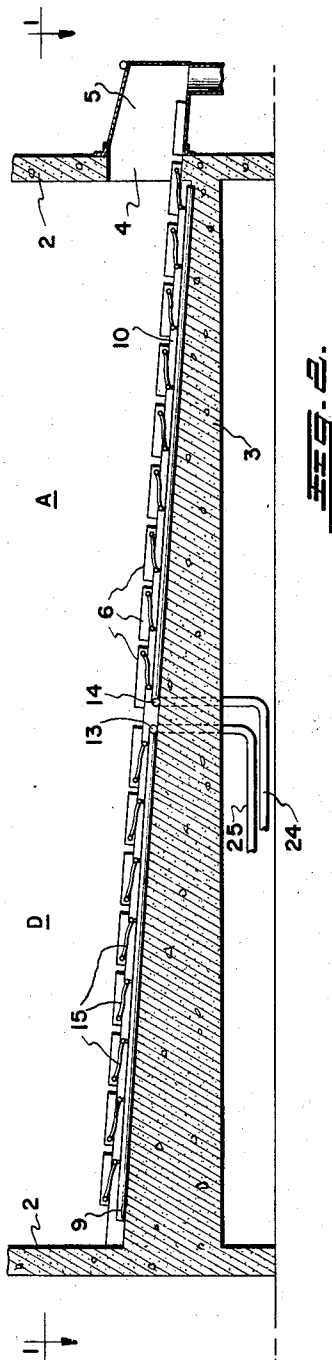


Fig. 2.

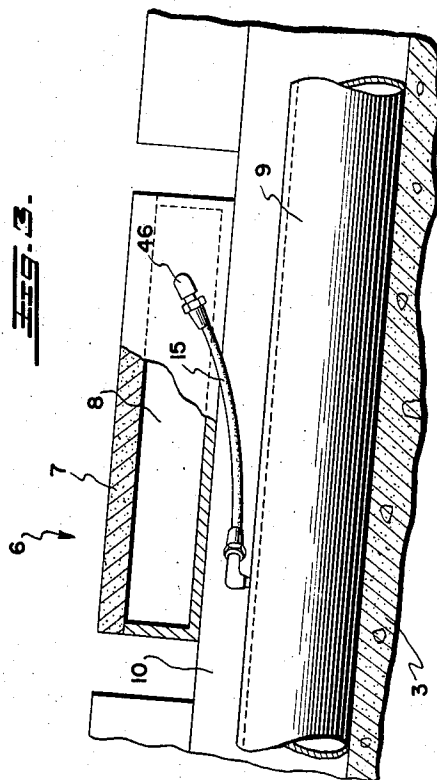


Fig. 3.

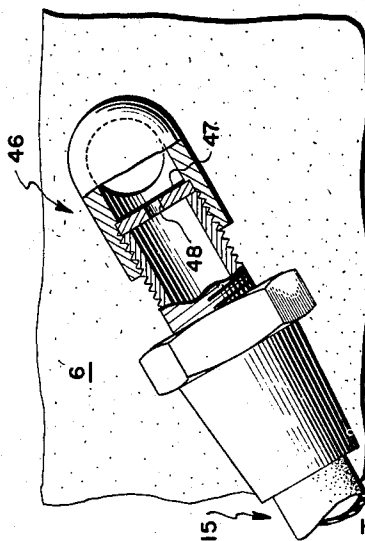


Fig. 4.

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3 Sheets-Sheet 3

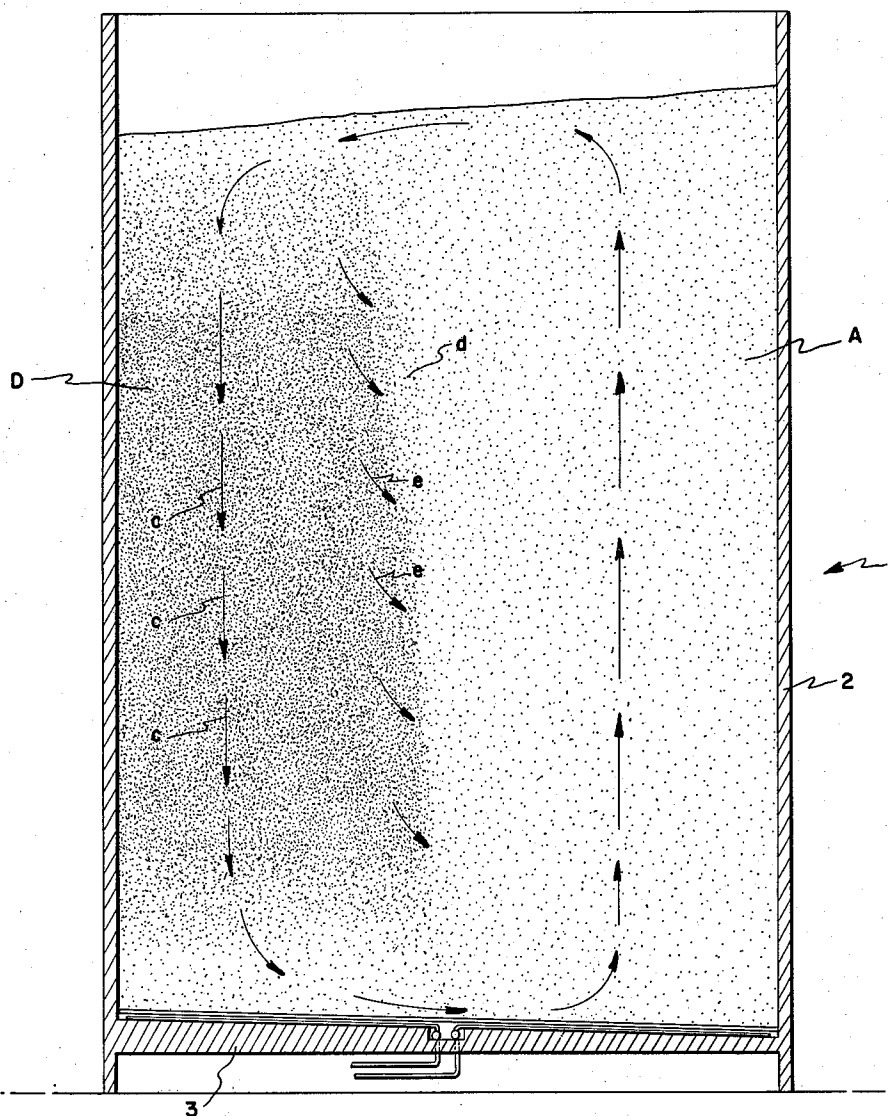


Fig. 5.

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METHOD AND APPARATUS FOR BLENDING PULVERULENT MATERIAL

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The present invention relates to a method and apparatus for the blending of pulverulent material while the pulverulent material is maintained in an aerated or fluidized state.

It presently is common practice to perform a variety of unit operations in fluidized fixed beds. By "fixed beds" is meant that the dense phase solids-gas mixture is confined in a vessel having a substantial height, as distinguished from shallow moving beds. Such fixed beds have provided one of the best methods of mixing solids yet developed due to the turbulence and inner currents within the bed. A fluidized bed thus provides an excellent means for blending solids to produce a homogeneous mixture of different materials or to average the variables in a continuously produced stream of a single material.

High efficiency of mixing within a continuously fluidized bed has heretofore been restricted to the use of relatively coarse or granular materials having an appropriate range of particle size. In general, it may be said that when no substantial proportion of particles are below 0.075 mm. (about 200 mesh), or in some cases below 0.05 mm. (about 325 mesh), in size, good internal movement, i. e. mixing, will occur with the use of an appropriate fluidizing gas velocity. As the average particle size decreases below this range, it becomes progressively more difficult to maintain a continuously fluent bed without the use of mechanical aids, or of special procedures to induce a mass shift of material within the vessel. When a material is substantially all in the fine micron size range, such as is the case with a pigment, fluidization under any conditions becomes very difficult or impossible.

Whether or not a particular material may be fluidized depends upon the characteristics of the particles making up the body of the material. The particle characteristics which primarily determine the ability of any particular body of pulverulent material to be fluidized depends upon (1) the shape of the individual particles, (2) the size of the particles, and (3) the relative amounts of particles of different size within the body of material. However, the optimum relative amounts of particles of different sizes may vary according to the particular material and the shape of the individual particles making up the body thereof.

As far as fluidization is concerned, pulverulent materials normally are characterized as (a) those which are not normally fluidized by the dissemination of air upwardly through them, (b) those which may be fluidized, but with difficulty and with the use of relatively large amounts of air, for example, those materials in which the particle characteristics are such that the air, instead of disseminating uniformly through the mass of pulverulent particles tends to form channels upwardly through the material through which the fluidizing gas tends to by-pass and escape, and (c) those materials

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relatively easily fluidized by the upward dissemination of air therethrough.

The present invention is particularly concerned with a method and apparatus for blending of pulverulent materials of the normally non-fluidizable and the difficultly-fluidizable types. However, it also is useful in the blending of pulverulent material which is readily fluidized since it speeds up the blending operation, although such materials normally present no great problem as far as actually obtaining blending is concerned when subjected to air under conditions such as to maintain them in a properly fluidized state.

In the production of cement, due to the variations in the composition of the component raw materials, the changes in moisture content and to various other factors, it is practically impossible to effect the initial proportioning of raw materials on a commercial scale in a manner such as to avoid abrupt changes in composition of the raw feed material that are beyond tolerable limits. Hence, it has been the practice in the cement industry to introduce a blending operation to assure that the kiln feed will have a substantially uniform composition well within the desired tolerance. Cement manufacture by the dry process involves the use of a variety of raw materials, and although the degree and type of grinding used will result in quite different particle size distributions and physical property variations, such materials normally have a particle size range distribution from about 0.1 mm. (150 mesh) down to the sub-micron sizes, with some 80% to 90% normally being finer than 0.075 mm. (200 mesh). While the present method and apparatus for blending pulverulent materials is particularly adapted for the blending of raw cement kiln feed materials, it also is applicable to the blending of pulverulent material generally where the particle characteristics of the pulverulent material are such as to enable a body of the material to be aerated and fluidized under the conditions of the invention.

More specifically, the present invention is concerned with a method and apparatus in which a body of pulverulent material is not uniformly subjected to treatment with a fluidizing gas, but in which at any particular time at least one vertical section of the body of material is subjected to air in sufficient volume and at sufficient pressure to bring about a fluidization of the material in that section, and in which the flow of air into the lower portion of the body of the pulverulent material for bringing about the fluidization thereof is intermittently interrupted so as to create waves in or cause a pulsation of the material within the particular section being fluidized. At such time as one particular section of the body of pulverulent material is being fluidized, it is also preferable to introduce air into the other sections in amount sufficient to aerate it but not to an extent sufficient to cause a fluidization thereof. Thus, for example, if the pulverulent material is maintained in a circular bin or silo, one quadrant of the pulverulent material may be subjected to air in sufficient volume and at sufficient pressure to bring about fluidization thereof while the pulverulent material in the other three quadrants merely has sufficient air disseminated therethrough to bring about an aeration thereof. In such a situation, the quadrant of material which is fluidized substantially expands in volume and since it is relatively confined by the adjacent quadrants, can expand only by moving upwardly in the fluidized quadrant. As the fluidized material in that quadrant reaches the upper level of the material in the silo, it spills over onto the top of the material in the other quadrants and gradually becomes de-aerated. Since there is a constant upward flow of the pulverulent material in the fluidized quadrant, the aerated material from

the other quadrant flows into the fluidized quadrant to take the place of the material which has been carried to the top of the fluidized quadrant and has spilled over into the other quadrants which are merely aerated. The result of this is that there is a constant circulation of the entire body of the pulverulent material in the silo, with the material in the quadrant which is being fluidized flowing upwardly and the aerated material in the other quadrants flowing downwardly due to the greater density of the material in the non-fluidized sections compared to density of the material in the fluidized section. Also, there will be flow of the material into the quadrant being fluidized from the adjacent side walls of the other quadrants.

The supply of air to the particular quadrant being subjected to fluidization is intermittently interrupted, or has its pressure substantially reduced, so that the air is introduced in pulses, thus causing sections of the fluidized material throughout the height of that quadrant to pulsate as the air moves upwardly therethrough in waves. That has been found advantageous in connection with the blending of pulverulent material which normally is not fluidizable, or is only difficultly fluidizable because its surface characteristics are such that the fluidizing gas is not uniformly disseminated upwardly through the mass of pulverulent material but rather forms vertical channels through the material. Since any gas will take the path of least resistance through a material, such channels form by-passes for the fluidizing gas so that other portions of the material are robbed and do not receive sufficient air to maintain them in a properly fluidized state. When the flow of fluidizing air to the pulverulent material is periodically interrupted, or its pressure substantially reduced, the aerated or fluidized material tends to collapse and such collapsing of the material results in a closing up of the vertical channels, with the result that when the next pulse or wave of the fluidizing gas is supplied to the pulverulent material the previously-formed channels no longer exist and the material again is properly fluidized until channeling again begins. If the time during which the air is supplied to the pulverulent material and the time during which it is cut off, that is, the cycle of pulsation, is properly timed, it is possible to maintain a body of material which otherwise is not fluidizable because of its particle characteristics into a thoroughly fluidized bed without permitting time for the gas by-passing channels to form. In other words, the cycle of pulsation should be of such duration that the supply of air is interrupted, or substantially reduced, just after channeling begins, so that the material will collapse as soon as the channels are formed. This repeated formation of channels and the collapsing of the material into the channel areas further assist in the blending of the material. Such cycle of pulsation may vary from less than one second, such as 0.7 of a second, to as much as 15 seconds, and possibly more, depending upon the particle characteristics of the particular pulverulent material. Normally a cycle of from 0.9 to 5 seconds will be found to give the best results with most materials. When the cycle of pulsation is of such frequency, the entire fluidized bed of material will not all be expanded and collapsed at the same time but there will be a progressive expanding and collapsing of the pulverulent material upwardly through the body thereof, thus creating upwardly-extending waves in the material.

The several quadrants or sections of the body of pulverulent material are serially subjected to fluidization, although it is not necessary that the several quadrants be fluidized in any particular order. They may be fluidized serially in clockwise or counterclockwise direction or in any other desired order. The essential thing is that at least one section of the material be fluidized while the adjacent sections are non-fluidized but preferably maintained in an aerated state which will facilitate

the circulation of the pulverulent material in the manner indicated above.

The net result of subjecting the body of pulverulent material to sectionalized, pulsating fluidization, as described above, is that it is possible to bring about very satisfactory fluidization and blending of pulverulent material whose particle characteristics are such that it normally could not or could only with difficulty be blended by fluidization.

The invention will be further described in connection with the accompanying drawings which illustrate a preferred form of apparatus in which the blending operation may be carried out.

In the drawings:

Fig. 1 is a horizontal sectional view, partly diagrammatic, taken on line 1—1 of Fig. 2, of a silo or bin in which the blending operation may be carried out;

Fig. 2 is a vertical central sectional view through the silo or bin of Fig. 1;

Fig. 3 is a detailed view, partly in section, showing the aerating units and the manner of supplying the aerating gas thereto;

Fig. 4 is a detailed cross sectional view showing the means for restricting the passage of air to the individual aerating units; and

Fig. 5 is a diagrammatic view illustrating the circulation of the pulverulent material in the bin during a blending operation.

Referring now to the drawings, the blending operation is carried out in a bin or silo 1 having a vertical wall 2 and a bottom wall 3. The bin may be of any cross-sectional shape and may be of any size, and preferably is of a size and shape generally similar to present silos used for the blending of raw cement kiln feed.

The bottom 3 of the bin is inclined at an angle of from 1 to 13° towards a discharge opening 4 at its lower edge, the degree of inclination in any particular case depending upon the particle characteristics of the pulverulent material. The pulverulent material, after proper blending, is discharged through the opening 4 into the casing 5 from which it is discharged to a kiln or storage bin.

Resting on the bottom 3 are a plurality of individual aerating units 6 closely spaced to one another to provide a porous, gas-permeable surface on which the pulverulent material rests. As shown in Fig. 3, each of the aerating units comprises a porous gas-permeable member 7 which may be stone, densely woven fabric, such as multi-ply canvas of the general type used for belting, or other suitable porous material, and an underlying air or plenum chamber 8 to which air is supplied for passage upwardly through the gas-permeable member into the overlying pulverulent material for the purpose of aerating or fluidizing it.

As shown in Figs. 1 and 2, the upper surface of the floor is provided with a plurality of channels 10 which receive headers 9 for supplying air to the individual units. The inner ends of the headers 9 are connected to diametrically-extending manifolds 11, 12, 13 and 14. Air from the several headers 9 is supplied to the air chambers of the individual aerating units through flexible conduits, such as copper tubes 15. Flexible conduits preferably are used for supplying air to the individual aerator units so that any vibration resulting from pulsing of the air through the headers, as hereinafter described, will not damage the conduits or their connections to the headers or the aerating units.

As shown in Fig. 1, the silo is divided into quadrants A, B, C and D, the boundaries of the several quadrants being indicated by the dot-and-dash lines *a* and *b*. While the drawing shows the silo as being divided into quadrants, it is to be understood that it might be divided into any number of sectors, if circular, or into any number of sections, if non-circular, with the aerating units of each sector or section being supplied with air from headers

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supplied by a manifold which furnishes air to that sector or section only.

Each of the manifolds 11, 12, 13 and 14 is supplied with air from two independent compressor units 16 and 17. Air from the compressor unit 16 passes from the discharge outlet thereof into the conduit 18 which extends to opposite sides of the silo. At one end the conduit 18 is connected to a pair of supply pipes 19 and 21 which in turn are connected to manifolds 11 and 12, respectively. The flow of air from the conduit 18 into each of pipes 19 and 21 is through check valves 22 and 23, respectively. At its other end, the pipe 18 is connected to supply pipes 24 and 25, which in turn are connected to and supply air to manifolds 13 and 14. The supply of air from the conduit 18 to the pipes 24 and 25 is through check valves 26 and 27.

Air compressor unit 17 supplies air at the same pressure as compressor unit 16, but in greater volume. Air from its discharge outlet passes through pipes 28 and 29 to conduit 31, which generally parallels conduit 18, and like conduit 18 extends to opposite sides of the silo. At one end the conduit 31 is connected through branch pipes 32 and 33 to supply pipes 19 and 21, respectively. At its other end, conduit 31 is connected through branch pipes 34 and 35 to supply pipes 24 and 25, respectively. Supply of air from conduit 31 through the branch pipes to the supply pipes is controlled by valves 36, 37, 38 and 39. These valves preferably are remotely controlled and may be of any type, but preferably are of the solenoid-operated type.

The supply of air from air compressor unit 17 through the pipe 29 to conduit 31 is controlled by manually-operated valve 41, which normally is maintained in the open position, and by an automatic, intermittently-operated, remotely-controlled valve 42. As shown in the drawing, valve 42 is of the solenoid type and the frequency of its opening and closing is controlled by a timing mechanism 43 which is supplied with electric current from any suitable source. While the use of a solenoid-operated valve is preferred, since it provides for a quick opening and closing, in some instances it may be desired to use a remotely-controlled valve of some other type, such as a rotating butterfly valve.

A by-pass 44 is located in pipe 29, about the manually and intermittently-operated valves 41 and 42. Flow through by-pass 44 is controlled by manually-operated valve 45.

Check valves 22, 23, 26 and 27 operate normally to permit flow of air from compressor unit 16 through supply pipes 19, 21, 24 and 25 into manifolds 11, 12, 13 and 14, from which it passes through the headers 9 and conduits 15 into the several aerating units. The volume of air supplied by the unit 16 is sufficient to cause an aeration of the pulverulent material in the silo, but is insufficient in volume to cause its fluidization. On the other hand, compressor unit 17 is adapted to furnish air to a selected supply pipe in a volume in excess of that furnished to the selected supply pipe by compressor unit 16, and in volume sufficient to cause fluidization of the pulverulent material. Consequently, the greater volume of air furnished to the selected supply pipe by the compressor unit 17 will create a greater pressure in that pipe, causing the check valve therein to close. Thus, with valves 36, 37 and 38 closed, and valve 39 open, as shown in Fig. 1, the pressure in supply pipe 24 will be sufficiently great to cause the check valve 26 to close. Since supply pipe 24 leads to manifold 14, which supplies the aerating units of quadrant A with air, no air will pass from the compressor 16 to the aerating units of that quadrant, but air will be furnished through supply pipes 19, 21 and 25 to manifolds 11, 12 and 13 in amount sufficient to bring about an aeration but not a fluidization of the pulverulent material overlying the aeration units in quadrants B, C and D. However, air from compressor 17 will pass through the open valve 39 to supply pipe 24

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and thence to manifold 14 with the result that the aeration units in quadrant A will be supplied with air in sufficient volume to bring about fluidization of the pulverulent material in that quadrant.

In order to provide for a uniform supply of air to the several aerating units 6, irrespective of their distance from the manifolds 11, 12, 13 and 14, each connecting nipple 46 (Fig. 4) has a disk 47 provided with a small orifice 48 extending across it. The small orifice so restricts the flow of air from the headers 9 through the conduits 15 into the air chamber of the aerating units that each aerating unit will receive the same amount of air, regardless of its distance from the manifold.

The manner in which the blending of pulverulent material is effected by the present invention will be more apparent from a consideration of Fig. 5, in conjunction with Fig. 1. With the valves 36, 37, 38 and 39 set as described above, that is, with valves 36, 37 and 38 closed and valve 39 open, air in volume sufficient only to bring about an aeration of the pulverulent material will be supplied to the aerating units in quadrants B, C and D from the compressor unit 16, while simultaneously compressor unit 17 is supplying air in volume sufficient to bring about fluidization in quadrant A.

The fluidization of the pulverulent material in quadrant A brings about a separation of the particles from one another, resulting in a substantial increase of the volume of the material in that quadrant. Since the pulverulent material in quadrants B, C and D is not aerated sufficiently to fluidize it, the volume of the material in those quadrants remains substantially unchanged. Thus, the vertical walls of the material in quadrants B and D adjacent quadrant A tend to laterally confine the material in quadrant A to that quadrant even though its volume has been substantially increased. Hence, the fluidized material in that quadrant is caused to rise, and, as the rising material reaches the level of the pulverulent material in the silo, it spills over into quadrants B, C and D. In a circular silo, as shown in Fig. 1, it has been found that while the fluidized material in quadrant A spills over into each of quadrants B, C and D, the major flow of the material from the upper portion of quadrant A is across the center of the silo into quadrant C.

The lighter density of the fluidized material in quadrant A is indicated by the lighter stippling in that quadrant. The fluidized material which spills over into quadrants B, C and D from the upper portion of quadrant A progressively becomes de-aerated and settles onto the top of the merely aerated material in those quadrants, as indicated by the downward progressive densification of the stippling at the top of the material of quadrant D of Fig. 5.

Since the material in quadrant D is denser than that in quadrant A, it will move downwardly and over into quadrant A, thus setting up a circulation of the material in the silo such as indicated by long arrows *c* in Fig. 5. This circulation of the material in the silo is facilitated by the fact that there will be a slight fluidization of the pulverulent material at the bottom of quadrant D adjacent the aerating units, this also being indicated by the light stippling at that point. As the fluidized material has the general characteristics of a fluid and is less dense than material in the main portion of quadrant D, the main body of denser material in quadrant D will settle upon the underlying fluidized material and cause it to flow laterally into the bottom of quadrant A to take the place of material overflowing from that quadrant, thus acceleration of the main circulation of the material, as indicated by arrows *c* is obtained.

As there is some dissemination of the air laterally from quadrant A into the adjacent quadrants there will be no sharp boundary between the fluidized material in quadrant A and the merely aerated material in the adjacent quadrants. There will be a transition section in which

the material is aerated to a lesser degree than in quadrant A but to a greater degree than in the adjacent sections. This section is indicated at *d* in Fig. 5.

Simultaneously with the circulation of the material, as indicated by the arrows *c* of Fig. 5, there will be a lesser flow of material from the vertical bounding sides in quadrants B, C and D adjacent quadrant A, into quadrant A. This is indicated by the small arrows *e* of Fig. 5.

The continuous operation of the valve 42 during the supply of air from the compressor unit 17 to quadrant A to bring about a fluidization of the pulverulent material in that quadrant causes the air to be introduced thereinto in pulses. This is particularly advantageous where the material undergoing blending, because of particle characteristics, normally could not be fluidized or could be fluidized only with the use of large amounts of air. With such materials fluidization usually is prevented or made difficult because the introduced air does not remain uniformly disseminated through the body of the material, but forms vertical air channels. Since air will take the path of least resistance in passing upwardly through a body of pulverulent material, such channels tend to function as by-passes or vents for the escape of the air from the body of the material. This either robs adjacent portions of the body of such an amount of air that the material in those portions no longer remains in a fluidized state, or else requires the use of substantially larger amounts of air to maintain the pulverulent material in a fluidized state.

In carrying out the present invention advantage may be taken of the tendency of certain materials to form vertical air channels upon the introduction of air into them. Thus, the air preferably is introduced into the pulverulent material in such volume and under such pressure as to form vertical air channels, but the time during which the air is introduced into the pulverulent material during each "on" period of a pulsating cycle, a cycle being the time from the beginning of one "on" period to the beginning of the next "on" period, is so limited as not to be substantially greater than that necessary for the air channels to form. Momentary interruption of the supply of air to the body of material will cause the collapsing of the fluidized material, because of a lack of sufficient air to maintain it in the fluidized state. This collapsing of the material causes the channels to close, so that when the air again is introduced new channels in different places will be formed. This constant formation of the vertical air channels and the collapsing of the pulverulent material into them materially facilitates the blending of the material constituting the body.

The duration of the pulsating cycles will be determined by the particle characteristics of the particular pulverulent material being blended and may vary from about 0.7 second to about 15 seconds. For most pulverulent materials, a cycle of from 0.9 second to 5 seconds is preferred.

The ratio of the "on" period to the "off" period in each cycle will also depend upon the particle characteristics of the particular material. The "off" period normally is determined by the de-aeration rate of the particular material, which is the time it takes the material to return from its fully fluidized state to its original unaerated state, after the supply of fluidizing air is shut off. The "off" period preferably should not be of such duration that the material will completely return to its non-aerated state, and only long enough to assure collapsing of the air channels which have formed. In other words the duration of the "off" period of the respective pulse cycles preferably is less than the time it takes for the pulverulent material fluidized during the "on" period of the respective pulse cycles to become completely de-aerated.

When the fluidizing air is supplied to the pulverulent material in pulses, as set forth above, it progressively passes upwardly through the material in waves and causes

pulsation of the material in each wave section, with the material in each wave section first being buoyed up for a certain distance and then collapsing a part of the distance, each collapsing back of the material serving to break up the channels formed in the material during the "on" period. This breaking up of the air channels not only facilitates the blending of the material, but also enables satisfactory fluidization to be obtained with less air, since substantially all air introduced is used in the fluidizing operation and does not escape through the air channels. Such air as does form in the air channels in any one wave section, upon collapsing of the channels, is forced back into the body of the pulverulent material and helps in its fluidization.

In some instances it may not be desired to completely cut off the supply of fluidizing air in the so-called "off" period of the pulsating cycle, but merely to reduce the amount of air supplied for that purpose. In such cases manually-operated valve 45 in the pipe 44, which bypasses the intermittently-operated valve 42, may be opened to an extent sufficient to supply the desired reduced volume of air during the "off" period, when the valve 42 is closed. Therefore, when reference is made herein and in the appended claims to introduce the air in "pulses," and in corresponding terms, it is to be understood that the pulses or pulsations may be obtained merely by periodically reducing the volume of air supplied the fluidizing section as well as completely cutting off the supply of air during the "off" period. Thus, regardless of whether the pulses or pulsations are obtained merely by periodically reducing the volume of air supplied to the fluidized section, or whether it is entirely cut off during the so-called "off," the duration of the respective periods of each pulse cycle are such that during fluidization of the fluidizing section, the material therein is repeatedly buoyed up and then at least partially collapsed.

Should it at any time be desired to supply air to quadrant A, or to any other quadrant in which the pulverulent material is being fluidized, continuously rather than in pulses, it is only necessary to close manually-operated valve 41 in pipe 29 and open manually-operated valve 45 in the by-pass line 44. The entire volume of air from compressor unit 17 will then flow from its discharge outlet through pipe 28, by-pass 44, and pipe 29 into conduit 31, from which it passes through the selected branch pipe and supply to the manifold of the quadrant to be fluidized in a continuous stream.

Instead of having the valve 42 operate to abruptly cut off the supply of fluidizing air, such as is obtained by the use of a solenoid-operated valve, the valve may be more gradually opened and closed to gradually increase and decrease the supply of air to the pulverulent material, thereby causing waves of air of a different character in the fluidized material. Such a gradual increase and decrease in the volume of air supplied for the fluidization of the pulverulent material may be obtained by the use of a continuously-rotating butterfly valve in place of the solenoid valve 42.

The several sections will be subjected serially to the air in a fluidizing volume in any desired cycle. The cycle may run clockwise, counterclockwise or in any other order. Also, if desired, more than one sector or section may be subjected to fluidization at any one time, particularly if the silo is a large one and is divided into a large number of sections. Also, the number of sectors or sections is not critical as long as there is at least one section in which the pulverulent material is subjected to air in fluidizing volume and at least one adjacent section in which the material is merely aerated and not fluidized.

The length of time during which the material in any one sector or section is maintained in a fluidized state also is not critical. For many materials it is satisfactory to use a fluidizing cycle of from 2 minutes to 15 minutes for each sector or section.

To provide for serially subjecting the several quadrants of the silo to air in fluidizing volume, solenoid valves 36, 37, 38 and 39 are connected to an electrical timing mechanism of conventional design which will cause those valves to open in the desired sequence and to remain open for the length of time it is desired to subject the pulverulent material in the several quadrants to fluidization.

The amount of air pressure which will be maintained in the manifolds 11, 12, 13 and 14 will depend upon the particle characteristics of the pulverulent material and the depth of the material in the silo or bin, since these are the factors which determine the number of C. F. M. per unit of aerating space which are needed to maintain the overlying pulverulent material in a properly aerated and fluidized state, respectively. This pressure may vary from about 5 to 25 pounds per square inch, but in many installations a manifold pressure of from 10 to 15 pounds per square inch will be preferred.

Due to restricting the flow of air from the headers 9 to the several aerating units by means of the restricted orifice 46, the pressure throughout the length of the headers will be substantially that existing in the manifolds, although there will be approximately one pound differential between those portions of the headers connected to aerating units nearest D and farthest from the manifolds.

The method of blending pulverulent materials as herein described is essentially a combination of two different fluidization techniques, namely, (1) a periodically shifting differential multiple area aeration, and (2) the introduction of the fluidization air in short increments or pulses. This combination of techniques has been found to be particularly effective in the blending of pulverulent material which normally is either non-fluidizable or at best requires the use of large amounts of air to bring it to a fluidized state. The combination of the two fluidization techniques enables fluidized blending to be accomplished with pulverulent materials which heretofore have not been amenable to such blending when subjected to either technique alone. With respect to materials which are amenable to fluidized blending by either of said techniques, the present method enables a more thorough and uniform blending to be obtained in any unit of time.

Various changes may be made in the method of operation and the apparatus described herein without departing from the spirit of the invention or sacrificing any of the advantages thereof.

We claim:

1. The method of blending fluidizable pulverulent material which comprises maintaining a body of material to be blended, separately and simultaneously disseminating a gas upwardly substantially throughout different vertical communicating sections of the body of the material, the gas disseminated into at least one section being introduced in pulses and in such volume and at such pressure as to cause a fluidization of the pulverulent material in that section, the duration of the respective periods of each pulse cycle being such that during fluidization of said one section the material therein is repeatedly buoyed up and then at least partially collapsed, the gas disseminated into a contiguous section being in such volume and at such pressure as to aerate the material in that section but not to bring it to a fluidized state, the fluidization of the material in said one section, in conjunction with the mere aeration of the material in the contiguous section causing the material to flow upwardly in said one section and to spill over into the contiguous section and the material in the contiguous section to flow into the section being fluidized.

2. The method of blending fluidizable pulverulent material which comprises maintaining a body of material to be blended, separately and simultaneously disseminating a gas upwardly substantially throughout different vertical communicating sections of the body of the material,

the gas disseminated into at least one section being introduced in pulses and traveling upwardly through the material in waves, the particle characteristics of the material being such and the gas being introduced in said one section in such volume and under such pressure as to cause fluidization of the pulverulent material in said one section and the formation of vertical gas channels in the respective wave sections, the gas disseminated into a contiguous section being in such volume as to aerate the material in that section but not to bring it to a fluidized state, and limiting the duration of the "on" period of the respective pulse cycles, during which gas is being disseminated into the body of pulverulent material to a time not substantially greater than that necessary for the air channels to form in the body of fluidized material, the fluidization of the material in said one section, in conjunction with the mere aeration of the material in the contiguous section, causing the material to flow upwardly in said one section and to spill over into the contiguous section and the material in the contiguous section to flow into the section being fluidized.

3. The method of blending fluidizable pulverulent material as defined in claim 2 in which the duration of the "off" period of the respective pulse cycles is less than the time it takes for the pulverulent material fluidized during the "on" period of the respective pulse cycles to become completely de-aerated.

4. The method of blending fluidizable pulverulent material as defined in claim 1 in which the duration of the "off" period of the respective pulse cycles is less than the time it takes for the pulverulent material fluidized during the "on" period of the respective pulse cycles to become completely de-aerated.

5. The method of blending fluidizable pulverulent material as defined in claim 1 in which the duration of the pulse cycles is from 0.7 second to 15 seconds.

6. The method of blending fluidizable pulverulent material as defined in claim 1 in which the duration of the pulse cycles is from 0.9 second to 5 seconds.

7. The method of blending fluidizable pulverulent material as defined in claim 1 in which the several vertical sections are subjected serially to gas in such volume and at such pressure as to cause fluidization of the pulverulent materials therein.

8. The method of blending fluidizable pulverulent material which comprises maintaining a body of the material to be blended, disseminating a gas upwardly through at least a portion of said body in pulses at frequencies such that it travels upwardly through said portion of the body in waves, the particle characteristics of the material constituting the body being such and the gas being introduced in such volume and under such pressure as to cause fluidization of the pulverulent material in such portion of the body and the formation of vertical gas channels in the respective wave sections, and limiting the duration of the "on" period of the respective pulse cycles during which gas is being disseminated into the body of pulverulent material to a time not substantially greater than that necessary for the gas channels to form in the fluidized material.

9. The method of blending fluidizable pulverulent material as defined in claim 8 in which the duration of the "off" period of the respective pulse cycles is less than the time it takes for the pulverulent material fluidized during the "on" period of the respective pulse cycles to become completely de-aerated.

10. The method of blending fluidizable pulverulent material which comprises maintaining a body of material to be blended, disseminating a gas upwardly through at least a portion of said body in pulses at frequencies such that it travels upwardly through said portion of the body in waves, the particle characteristics of the material constituting the body being such and the gas being introduced in such volume and under such pressure

as to cause fluidization of the pulverulent material in such portion of the body and the formation of vertical gas channels in the respective wave sections, and limiting the duration of the "off" period of the respective pulse cycles so that it is less than the time it takes for the pulverulent material fluidized during the "on" period of the respective pulse cycles to become completely deaerated.

11. Apparatus for blending fluidizable pulverulent material comprising a bin or silo to receive the material to be blended, aerating units at the bottom of the bin to underlie material in the bin to be blended for the introduction of a gas into pulverulent material in the bin or silo, said aerating units being arranged in contiguous sections and the spaces above said sections communicating with one another, means for separately supplying a gas to the aerating units of each section, means for supplying the gas to the aerating units of at least one of said sections in such volume and at such pressure as to cause fluidization of fluidizable pulverulent material overlying the aerating units of that section, means for simultaneously supplying gas to the aerating units of a contiguous section in such volume and at such pressure as to aerate but not to fluidize fluidizable pulverulent material overlying the aerating units of such section, whereby the pulverulent material overlying the aerating units to which gas may be supplied in volume and pressure to cause fluidization of overlying material may be caused to flow upwardly and to spill over into the space above the aerating units of the contiguous section and the material in the space overlying the aerating units in said contiguous section may be caused to flow into the space overlying the units to which fluidizing gas is supplied, and means for causing the gas supplied to the section where fluidization is to take place to be supplied thereto in pulses, with the duration of the "off" period of the respective pulse cycles, during which gas is not being disseminated into the body of pulverulent material in said one section, being sufficient to permit at least partial collapsing of the material fluidized in said section.

12. Apparatus as defined in claim 11 including means for supplying gas to the aerating units of the section where fluidization is to take place from a source different from that which supplies gas to the sections where merely aeration is to take place.

13. Apparatus as defined in claim 11 which includes means for periodically reducing the volume of gas supplied to the aerating units of the section where fluidization is to take place to obtain the pulsing of the gas.

14. Apparatus as defined in claim 11 which includes means for periodically stopping the flow of gas to the aeration units of the section where fluidization is to take place to obtain the pulsing of the gas.

15. Apparatus as defined in claim 11 which includes means for serially supplying the gas to the several sections for predetermined times and in sufficient volume and at such pressure as to cause fluidization of overlying pulverulent material.

16. Apparatus for blending fluidizable pulverulent material comprising a bin or silo to receive the materials to be blended, aerating units at the bottom of the bin to underlie material in the bin, said aerating units being arranged in contiguous sections, separate manifolds for supplying the gas to the aerating units of each of said sections, gas compressor means, a piping system for supplying gas from said compressor means to said manifolds, and means for selectively and intermittently supplying gas in greater volume to at least one of said manifolds than is supplied to the other of said manifolds.

17. Apparatus as defined in claim 16 which includes

separate compressor means for selectively supplying said gas in greater volume.

18. Apparatus as defined in claim 16 in which the bin or silo is divided into quadrants, and which includes means for serially supplying the gas in greater volume to the manifolds for the aerating units of the different quadrants.

19. Apparatus for blending fluidizable pulverulent material comprising a bin or silo to receive the materials to be blended, aerating units at the bottom of the bin to underlie material in the bin, said aerating units being arranged in contiguous sections, separate manifolds for supplying gas to the aerating units of each of said sections, gas compressor means, a piping system for supplying gas from said compressor means to said manifolds and including a branch pipe connected to each manifold, a check valve in each branch pipe, a second piping system for supplying gas from said compressor means to said manifolds, said second piping system including branch pipes communicating with the branch pipes of said first piping system, whereby said first branch pipes form a part of both piping systems, selectively closable valves in the branch pipes of the second piping system, the check valves in the branch pipes of the first piping system being arranged to be closed by the creation in such branch pipes of a pressure, on the downstream side of said check valves, greater than that in such branch pipes at the upstream side of said check valves created by the admission of gas into such branch pipes from said branch of said second piping system, and means for causing the gas passing through said second piping system to pass there-through in pulses.

20. Apparatus as defined in claim 19 in which the selectively closable valves of the branch pipes of the second piping system are remotely controlled.

21. Apparatus as defined in claim 19 which includes means in said second piping system, at the upstream side of the valves in the branch pipes of that system, for periodically reducing the volume of gas supplied through said second piping system to the aerating units.

22. Apparatus as defined in claim 19 which includes means in the second piping system, at the upstream side of the valves in the branch pipes of that system, for periodically stopping the flow of gas supplied through at least one branch pipe of said second piping system to the aerating units.

23. Apparatus as defined in claim 21 in which the means for reducing the volume of gas supplied through said second piping system to the aerating units is a valve in the second piping system and which includes a by-pass in the second piping system around said volume-reducing valve, and a valve in said by-pass.

24. Apparatus as defined in claim 19 which includes separate gas-compressing means for supplying gas to said second piping system.

25. Apparatus as defined in claim 19 which includes means for serially opening and closing the selectively-closable valves in the branch pipes of the second piping system.

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