April 11, 1961 M. J. GREAVES 2,979,235

HOPPER HAVING MEANS CAUSING ATMOSPHERIC INFLOW

Filed Jan. 9, 1958 2 Sheets-Sheet 1

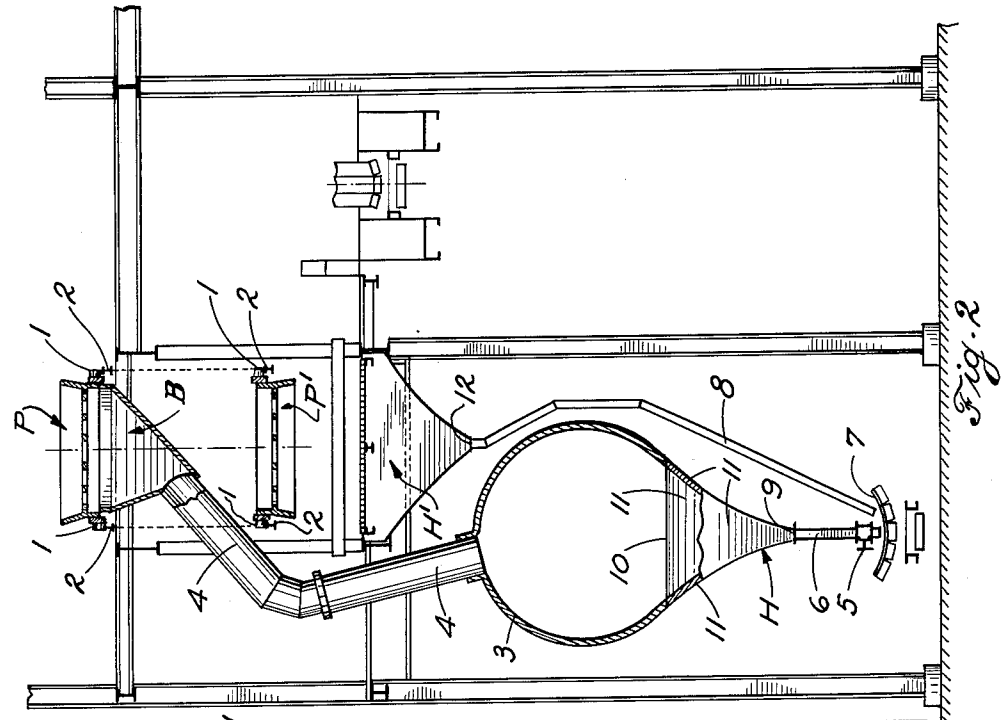


Fig. 2

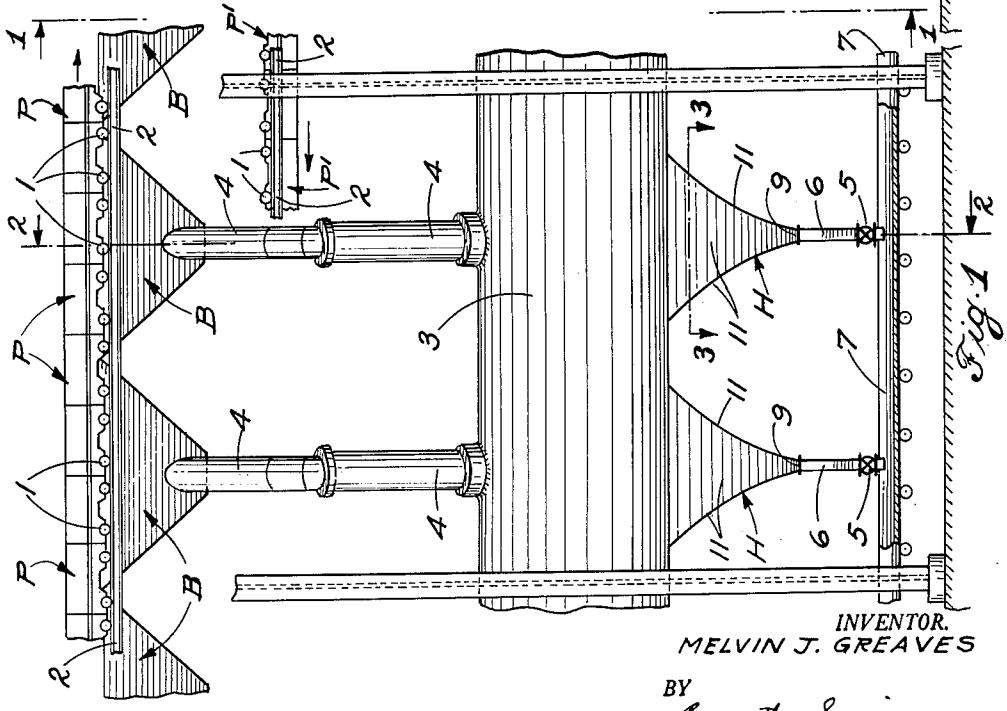


Fig. 1

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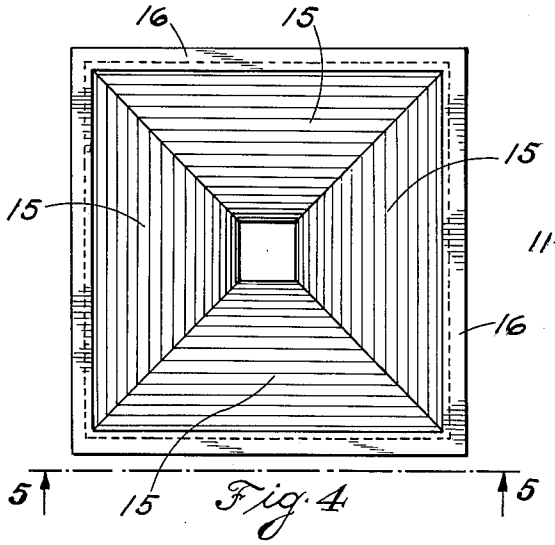


Fig. 4

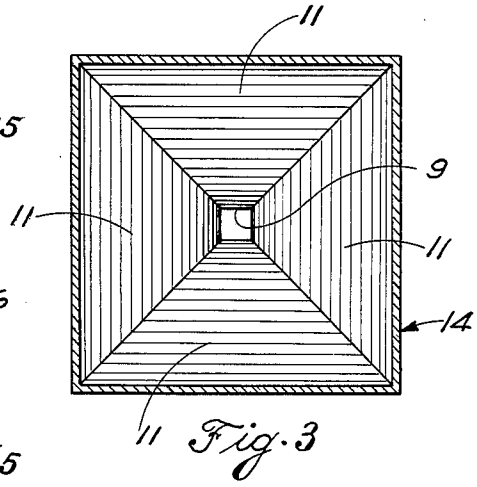


Fig. 3

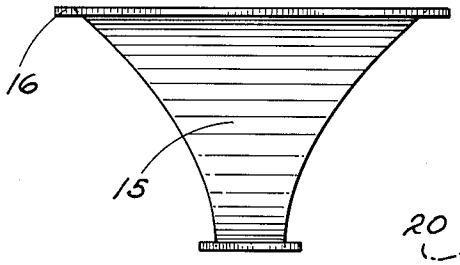


Fig. 5

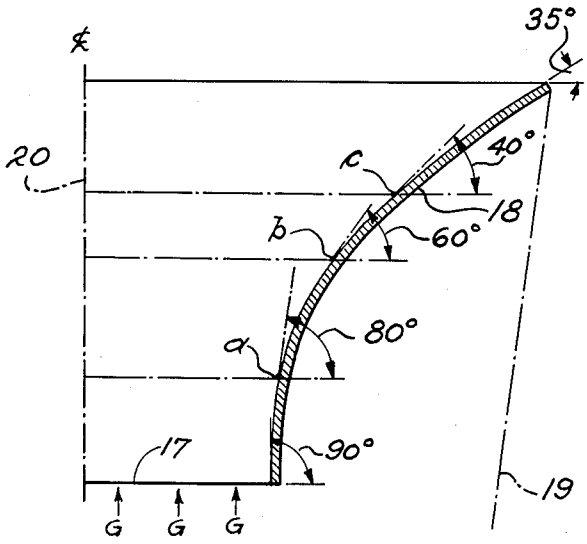


Fig. 6

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HOPPER HAVING MEANS CAUSING ATMOSPHERIC INFLOW

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This invention relates to material handling and more particularly to improvements in hoppers or similar vessels for receiving flowable materials and discharging same from an outlet at the bottom of a vessel.

In modern industry flowable materials that are non-liquid in nature, such as dust, sand, gravel, etc., are frequently deposited in bins or hoppers that are provided with bottom outlet openings from which the material may be discharged. In a common form of hopper the bottom structure comprises downwardly and inwardly converging walls and may be either of generally conical or inverted pyramidal form. In designing such hoppers for handling a particular type of flowable material the slope of the bottom walls should be correlated with the angle of repose of material to be handled. Thus, to insure that the material will flow from the hopper without sticking or bridging when the bottom discharge is open and equal pressure conditions obtained inside and outside the hopper, the angle of the bottom wall to the horizontal should be approximately equal to or slightly greater than the angle of repose of the material.

However, when a hopper or the like is operating under conditions tending to cause a flow of air, or other atmosphere, into the hopper through the outlet, the positive pressure and/or the aerodynamic drag of the air at the hopper outlet tends to oppose and retard the flow of material downwardly in the hopper bottom and through the outlet. Under such conditions, with the usual straight-sided hopper bottom arrangements, it is necessary to make the angle of the hopper walls to the horizontal sufficiently greater than the angle of repose of the material so that not only the normal angle of repose of the material will be taken care of, but also the added resistance to flow caused by the action of the air against the material will be overcome. As the type of hopper bottoms with which the present invention is concerned flare outwardly and upwardly, such positive pressure and/or areodynamic drag of the atmosphere will be greatest at the bottom outlet opening where the horizontal cross-sectional area of the hopper bottom is smallest. As the horizontal cross-sectional area progressively increases upwardly of the hopper bottom the retarding effect of the atmosphere against the material in the hopper progressively diminishes. Thus, although there may be relatively great opposition to the flow of material at the outlet opening, the opposition at the top of the hopper bottom walls will be much less because of the increase in area. To insure flow of material adjacent the outlet opening, the angle of the hopper bottom walls in this point must be sufficiently greater than the angle of repose of the material to take care of the maximum atmospheric opposition situation. The height of the converging wall hopper bottom structure is determined by the size of its upper end and the angle at which the walls must be disposed to insure flow of material therefrom. Thus, with previous hoppers with which I am familiar, the bottom structure when the hopper is operating under sub-atmospheric conditions, or when, for other reasons, there is a positive

tendency for inward atmospheric flow at the hopper outlet, must be of substantially greater vertical height than is required for a hopper that operates with the same conditions inside the hopper as exist outside of the outlet.

It is, therefore, an object of the present invention to provide a hopper bottom, for use with flowable materials when the conditions inside and outside of the hopper outlet are such that a positive tendency for inward air flow exists at the outlet, which will insure flow of material at all times without bridging or sticking, regardless of whether the hopper is full or has only a layer of material on the walls thereof, and which is of substantially less height than previous hoppers that would be effective under the same conditions. Other objects of my invention include the provision of a hopper having a bottom structure that is inherently of great strength and rigidity, thus largely eliminating the necessity for external bracing and stiffening members; which requires a minimum of material, which occupies a minimum of vertical space, and which is particularly adapted for use with moving grate type sintering machines such as are comomnly used for sintering iron ore or the like.

The above and other objects of my invention will appear from the following description, reference being had to the acompanying drawings in which:

Figure 1 is a more or less diagrammatic side elevational view of a portion of an iron ore sintering machine of the continuous moving grate type, having my improved hoppers installed to receive the particles of material which fall from the bottom of the grates in the air which is drawn through the grates to effect combustion thereon;

Figure 2 is a vertical cross-sectional view taken substantially on line 2—2 of Figure 1;

Figure 3 is a horizontal cross-sectional view taken substantially on line 3—3 of Figure 1;

Figure 4 is a plan view of a typical hopper bottom structure embodying my invention;

Figure 5 is an elevational view of the hopper bottom of Figure 4, taken substantially on line 5—5 of Figure 4; and

Figure 6 is an illustrative vertical cross-sectional view through one side of a hopper bottom embodying my invention, the angle of the bottom wall to the horizontal at a series of vertically spaced points being indicated.

Although my invention is adapted for use in the handling of many different types and kinds of flowable solid materials, I have illustrated my improved hopper bottom structure as incorporated in the hoppers that are normally used in a continuous grate type sintering machine for the sintering of iron ore or the like.

Referring to Figure 1, the sintering machine includes a traveling grate made up of a plurality of pallets P supported on wheels 1 and adapted to move along a track 2 in well-known manner. The pallets P move in a continuous loop and, when they come to the end of the machine, the sinter is dumped and the pallets returned in inverted position as seen at P'. The bottoms of the pallets P are in the form of open grids or grates and, in order to insure proper combustion and sintering, air is caused to flow downwardly through the pallets P into the windbox B. This windbox is open on top and seals are provided between the pallets P and the sides of the windbox to prevent leakage therebetween. The returning inverted pallets P' are disposed below the windbox B and a collector main 3 extends longitudinally of the sintering machine below the inverted returning pallets P'. Suitable means, such as a fan or the like, not shown, are provided for drawing air through the collector main 3, and downcomer pipes 4 connect the collector main 3 to the windbox B. A plurality of dust hoppers H extend along, and in effect form the bottom of, the collector main 3. Each of the hoppers H is provided with a valve

5 at the lower end of a vertical discharge pipe section 6, and a conveyor belt 7 extends below the series of valves 5 and is adapted to receive and carry away the material discharged therefrom.

As seen in Figure 2 (but not shown in Figure 1), a second hopper structure H' is disposed below the inverted returning pallets P'. The hopper or hoppers H' are employed adjacent the discharge end of the sintering machine and are adapted to receive any dust or other material which may remain in the pallets P after they have been inverted and dumped. The hopper H' discharges through a suitable open pipe 8 which leads to a point above the belt 7 whereby material collected by hopper H' will be carried away on the belt.

When the sintering machine is in operation, a sub-atmospheric pressure is maintained within the collector main 3 in order to provide the required draft downwardly through the pallets P. A sub-atmospheric pressure will, of course, also exist within the hoppers H. Dust and the like which accompanies the gas that moves through the pallets P, windbox B, the downcomers 4, and into the collector main 3, drops out into the hoppers H. The valves 5 at the lower ends of the pipes 6 are kept closed except when it is desired to discharge dust to the conveyor belt 7. Under the conditions of operation of sintering machines, the valves 5 almost invariably leak, even when closed, and thus permit air to be drawn inwardly up through the pipe 6 into the hoppers H. Of course when the valves are opened, atmospheric pressure is imposed directly against the outside of the hopper outlets while sub-atmospheric pressure exists within the hoppers.

Thus there is present at substantially all times in the operation of this type of equipment a pressure differential between the inside and outside of the hoppers H at the discharge outlet such that air will tend to enter the hopper through the discharge outlet. The positive pressure and/or the aerodynamic drag exerted by such air against material in the hopper opposes downward movement thereof over the hopper walls. As previously noted, this opposition or resistance to movement has its greatest value at the outlet openings 9 and, due to the progressive enlargement of the horizontal cross-sectional area of the hoppers H, has a minimum value at the top 10 of the hoppers.

As seen in Figure 3, the hoppers H are rectangular in form and the bottom structures are made up of four generally triangular bottom wall panels 11 which converge inwardly and are welded or otherwise secured together at their edges to form a generally inverted pyramidal structure. As clearly seen in Figures 1 and 2, and as will be more fully referred to later, the wall panels 11 are concave as seen from the outside of the hopper and are curved, on a vertical plane therethrough that extends normal to a horizontal line lying on the panel, in such a manner that the angle of any one of the walls 11 to the horizontal is greatest adjacent the discharge outlet 9 and becomes progressively smaller until the top of the outwardly flaring hopper bottom structure is reached. Where the term "curved" is used herein in reference to the hopper wall it is intended to include a series of straight lines joined end to end as well as the true "curves" shown in the drawings. As various factors influence the exact form of the hopper bottom walls, it may be stated that the angle of the walls to the horizontal in some cases may vary inversely as the horizontal cross-sectional area of the hopper and, in other cases, may depart somewhat from such an exact mathematical relation.

The hopper H' which collects the drippings from the inverted pallets P' is generally of the same arrangement as the hoppers H. However it does not have a valve at its bottom outlet but is provided with an elongated discharge pipe 8. The material which falls into the hopper structure H' is very hot, and as it passes through the discharge pipe 8, the walls thereof are heated so that a chimney effect is created causing a continuous and substantial upward flow of air up through pipe 8 into the outlet 12 of the hopper structure H'. Thus there is a positive air movement at the outlet 12 tending to oppose the flow of movement of the material through the hopper H'. Due to the progressive increase in cross-sectional area of the hopper H' this opposition progressively diminishes from the bottom up until, at the top of the hopper, it is substantially ineffective to impede flow of material over the hopper walls.

My improved bottom construction is equally effective in its application to the hoppers H' as to the hoppers H at the bottom of the collector main 3 as it insures discharge of material from the hoppers H' without bridging or sticking to the wall and also permits of substantial reduction in the height of the hopper structure.

Figures 4 and 5 illustrate a typical hopper bottom structure embodying my invention. It will be understood that the complete hopper may, in some cases, include walls that extend above the top of the "bottom" structure to increase the capacity of the hopper, and that in other installations, such as seen in Figures 1 and 2, the entire hopper may consist only of the so-called "bottom" structure. In Figures 4 and 5 the hopper bottom is square in cross-section and is made up of four curved, converging, generally triangular wall panels 15 which may be welded together at the junctions therebetween and provided with a reinforcing flange 16 at the top. Due to the stiffening effect resulting from the curvature of the panels 15, an extremely rigid hopper structure is obtained which, in many cases, completely eliminates the necessity for external bracing or stiffening members such as are normally required with the usual straight sided hopper bottoms. Furthermore, although I have illustrated my invention as incorporated in hoppers of rectangular horizontal cross-section, it will be understood that my curved walls may be employed in multi-sided bottom structures other than rectangular and also in hoppers of circular, oval, or other horizontal cross-section.

In Figure 6 I have diagrammatically illustrated in a vertical cross-sectional view one side of a hopper bottom incorporating the principles of my invention. This figure shows the cross-sectional contour of the bottom wall of my improved hopper designed to handle material having an angle of repose of approximately 35°. The slope of the wall at various points in its height is such that material of 35° angle of repose will slide over the inner face of the wall even though an upward force (indicated by the arrows G) is exerted at the outlet 17 that is just below that necessary to hold the material against downward movement through the outlet. Thus at the outlet 17, the angle between a line tangent to the inner face of the hopper wall 18 and the horizontal is 90°. At point *a* on the wall 18 the cross-sectional area of the hopper has increased, with corresponding reduction in the value and the retarding effect applied at G, so that movement of the material over the wall 18 will be insured although the angle between the tangent and the horizontal is decreased to 80°. In like manner, at point *b* the angle is reduced to 60° and the point *c* to 40°. At the top of the hopper wall 18 the angle has been decreased to 35° because at this point the cross-sectional area of the hopper has increased to such an extent that substantially no retarding effect is present due to the flow of atmosphere in the hopper. If desired the wall 18 can be extended outwardly beyond the point indicated and such extension would normally also be at the 35° angle if it is desired to secure minimum hopper bottom height for a given top opening.

To indicate the saving in hopper height which may be obtained by my improved design the dot and dash line 19 has been drawn parallel to the tangent to the curved hopper wall 18 at point *a*. This line 18 represents the slope or inclination which would have to be given a straight

or flat hopper wall to insure proper flow of material, without bridging, etc., under the opposing pressure conditions which exist at point *a*. Room on the drawing sheet does not permit the line 19 to be extended to a point spaced from the center line 20 one-half the width of bottom outlet 17, but it will be readily observed that a straight sided hopper which would achieve the results that are obtained by my hopper would have to be much greater in height for the same top opening size.

Although I have described the illustrated embodiments of my invention in considerable detail, it will be understood that my improved hopper construction may be employed in many different types of installations. For example, centrifugal dust catchers are frequently operated with sub-atmospheric pressure within the dust catcher structure. This type of equipment commonly has a bottom outlet for removal of the collected dust, and my invention may advantageously be used with such equipment. Accordingly, I do not wish to be limited to the exact structural arrangements herein shown and described but claim as my invention all embodiments thereof coming within the scope of the appended claims.

I claim:

1. In combination, a hopper having a bottom discharge outlet of reduced area for flowable material, a rigid bottom wall converging downwardly to said outlet, said bottom wall being curved on a vertical plane therethrough whereby the angle of said wall to the horizontal varies substantially inversely as the horizontal cross-sectional area of the hopper, and means for maintaining conditions inside and outside of said hopper at said outlet such that atmosphere will tend to enter said hopper through said outlet.

2. In combination, a hopper having a bottom discharge outlet of reduced area for flowable material, a rigid bottom wall converging downwardly to said outlet, said bottom wall being curved on a vertical plane therethrough whereby the angle of said wall to the horizontal is greatest adjacent said discharge outlet and becomes progressively smaller at successively higher points on the wall, the minimum value of said angle being approximately equal to the angle of repose of the material intended to be handled in said hopper, and means for maintaining conditions inside and outside of said hopper at said outlet such that atmosphere will tend to enter said hopper through said outlet.

3. In combination, a hopper for flowable material including a bottom wall structure having a bottom outlet opening of reduced area and a rigid downwardly and inwardly converging wall, said wall being concave as seen from outside the hopper and the angle of the wall to the horizontal at the top of said hopper bottom being not less than the angle of repose of the material to be deposited in said hopper and increasing to a maximum value adjacent said outlet opening, and means for creating a flow of atmosphere inwardly through said bottom outlet opening.

4. In combination, a hopper for flowable material including a bottom wall structure having a bottom outlet opening and a plurality of inwardly converging wall panels, said wall panels being concave as seen from outside the hopper and the angle of each of said panels to the horizontal at the top of said bottom structure being not less than the angle of repose of the material to be deposited in said hopper and increasing to a maximum value adjacent said outlet opening, and means for creating a flow of atmosphere inwardly through said bottom outlet opening.

5. In combination, a hopper for flowable material including a bottom structure having a discharge outlet at its lower end and comprising a plurality of generally triangular bottom wall panels disposed in inverted pyramidal arrangement, each wall being curved in vertical cross-section and concave as seen from outside the hopper, the angle between each of said walls and the horizontal, on a plane extending normally to a horizontal line lying on the panel in question, at successive points vertically of the wall being greatest adjacent said outlet and becoming progressively smaller upwardly toward the top of each of said walls, and means tending to cause atmosphere to flow inwardly into said hopper through said outlet.

6. In a hopper for flowable material, a bottom structure having a discharge outlet at its lower end and comprising a plurality of generally triangular bottom wall panels disposed in inverted pyramidal arrangement, each wall being curved in vertical cross-section and concave as seen from outside the hopper, the angle between each of said walls and the horizontal, on a plane extending normally to a horizontal line lying on the panel in question, at successive points vertically of the wall varying inversely as the horizontal cross-sectional area of the bottom structure, and means tending to cause atmosphere to flow inwardly into said hopper through said outlet.

7. In a hopper for flowable material having a bottom discharge outlet of reduced area, the conditions inside and outside of said hopper at said discharge outlet being such that atmosphere will tend to enter said hopper through said discharge outlet and oppose the flow of said material through said hopper bottom, a bottom wall converging downwardly to said outlet, said wall being curved on a vertical plane therethrough whereby the angle of said wall to the horizontal is greatest adjacent said discharge outlet and becomes progressively smaller at successively higher points on the wall, the value of said angle at the top of said wall being approximately equal to the angle of repose of the material intended to be handled in said hopper and said angle at each other vertical point on said wall being of a value sufficiently greater than said angle of repose to cause said material to move downwardly in the hopper against the atmospheric opposition to such movement at such other vertical point.

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