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Controlling Flow Patterns in Bins by Use of an Insert

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Summary

A cone-in-cone bin insert, the BINSERT™, is presented as a means of controlling the flow pattern in existing bins and in new bin designs. The most significant applications can be seen in eliminating segregation problems and accomplishing in-bin blending. The advantages and possible future uses of this recently patented hopper configuration are described.

1. Introduction

In general, flow patterns can be classified into funnel flow — Fig. 1, or mass flow — Fig. 2. Hopper configurations to cause mass flow usually have steep and smooth hopper walls. Funnel flow occurs with flat rough walls. Most conical bins used in industry with hopper slopes of 45 to 60 degrees from the horizontal do not produce mass flow even with smooth liners.

Controlling flow patterns in bins is often the key to solving many flow problems. For example, a stationary rathole or central pipe shown in Fig. 1 is completely eliminated by causing mass flow at the walls of the hopper as illustrated in Fig. 2. The segregation [1] is caused when material of different size consists are charged into a bin and can be reduced or eliminated by imposing a uniform withdrawal of material from the bin so that horizontal layers of solids are remixed upon discharge. More subtle uses of controlled flow patterns include blending of solids moving through the bin and control of retention time in a bin either for chemical reaction reasons or for deaeration of fine dry powders.

2. The BINSERT™ Concept

This article discusses a new concept for controlling flow patterns and making typical funnel flow hoppers into mass flow without the excessive headroom required for steel cones. The BINSERT™ hopper configuration was recently patented by the author [2] and is illustrated in Fig. 3. The small hopper inside of the large hopper is designed in accordance with mass flow principles [3, 4, 5]. The inside walls are smooth and steep enough to produce flow along them. The location of the insert relative to the outer hopper is such that the included angle between the two hoppers also satisfies the mass flow criteria. Consequently, the solid in this annular region also flows in mass flow. This allows the outside hopper to be at twice the hopper half angle (measured from the vertical) than is normally required for mass flow. This feature of the BINSERT™ allows for mass flow in much less headroom than with normal hoppers.

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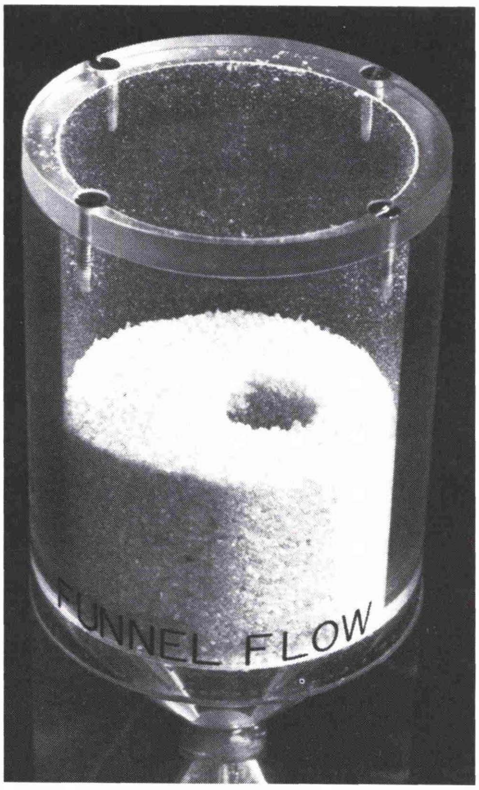
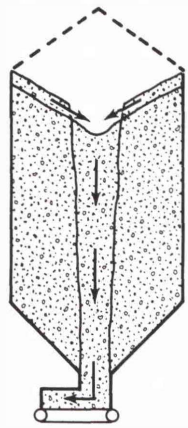
The average relative velocity of the inside and outside flow channels is controlled by the velocity profile introduced at the bottom of the insert. For example, if a mass flow cone is attached at the bottom as shown in Fig. 3, then a more rapid velocity will occur through the inside cone than through the outside annular region. This type of flow pattern is useful in blending solids in the bin [7]. If a vertical section is imposed between the bottom of the insert and a mass flow hopper or feed device (see Fig. 4), a uniform flow pattern can be imposed causing uniform velocity throughout the bin and hopper. This type of velocity pattern is useful in eliminating segregation problems associated with filling bins.

By making the length of the vertical section variable, a continuous change in flow pattern can be achieved from uniform to a maximum velocity gradient. This allows a fine tuning of the hopper if it is to be used for blending. It also allows a change from blending mode to anti-segregation mode.

Blending is usually accomplished by recycling solids through the BINSERT™. During the recirculation the vertical cylinder is minimized or eliminated as shown in Fig. 3. At the time of discharge the cylinder is lengthened as shown in Fig. 4 to produce a uniform velocity in the outside and inside regions of the blender thereby causing a discharge of horizontal layers of solid and a uniform mixture of coarse and fines to leave the bin.





CHARACTERISTICS
- LOW HEADROOM
- FIRST-IN-LAST OUT
- RATHOLES MAY DEVELOP
- FLOW MAY BE ERRATIC
- POWDERS WILL FLUSH
- SEGREGATION PROBLEMS ARE MADE WORSE

Fig. 1: Funnel flow
Some material is stationary while the rest is moving

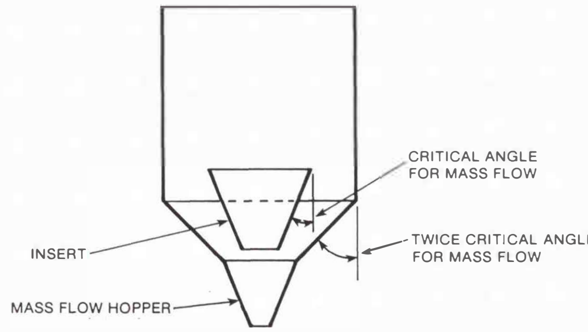


Fig. 3: BINSERT™ concept
Mass flow hopper design controls flow problems

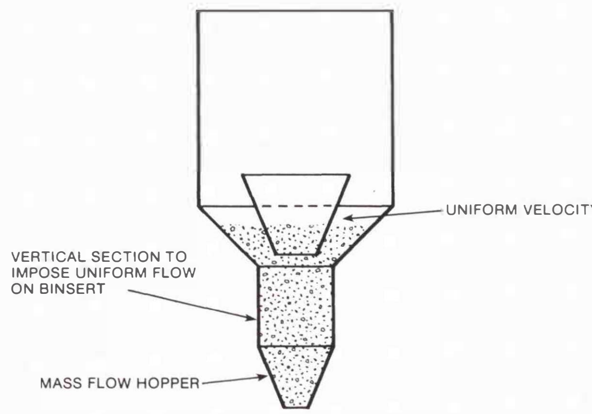
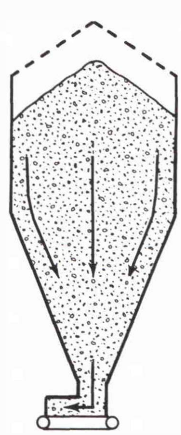


Fig. 4: BINSERT™ for anti-segregation



CHARACTERISTICS
- SMOOTH STEEP HOPPER
- FIRST-IN-FIRST OUT
- FINE POWDERS DEAERATE
- SEGREGATION PROBLEMS ARE MINIMIZED
- MATERIAL IS FED UNIFORMLY AT CONSTANT DENSITY

Fig. 2: Mass flow
All the material is in motion whenever any is withdrawn

3. Applications of BINSERT™

3.1 In-Bin Blending

The first BINSERT™ applications were with in-bin blending of solids using a configuration similar to Fig. 5. One case required the blending of plastic pellets, powder, and turnings. Such a mixture has problems of segregation, cohesion and blending of dissimilar shapes that make it unsuitable for most in-bin blenders. Another blending application involved

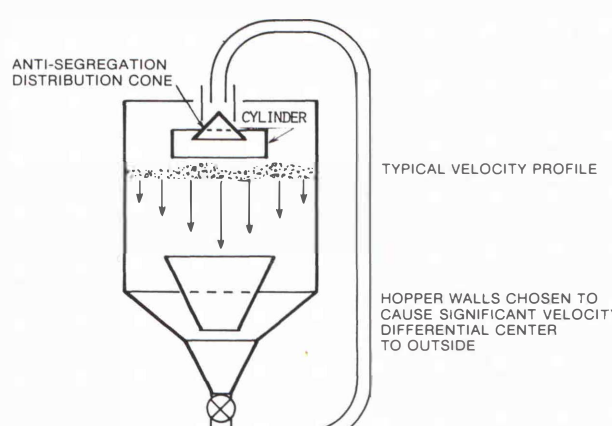


Fig. 5: Recirculating blender design for badly segregating material

a crushed oil shale with a wide range of particle sizes and associated segregation problems. Since the shale bin was large it was not practical to use a variable vertical section below the binsert to change the flow pattern from blending during recycling to anti-segregation during discharge. Consequently, an anti-segregation distribution cone as shown in Fig. 4 was used at the top of the bin. The distribution arrangement (also part of the patent [2]) consists of a distribution cone and an outer deflector cylinder and serves to remix the falling stream of coarse and fine particles. A model of the blender was run with minus 1/4 inch shale. A layer (5 % of the total volume) consisting of plus 1/4" markers was placed at the top of the blender. The three bin volumes of shale were recycled through the blender. The blender was then emptied and sampled upon discharge. Figures 6 and 7 show the test results. The markers were uniformly distributed through the blender discharge to within ± 1 %. Furthermore, when the samples were analyzed for size consist, the amount of plus 20 mesh particles during discharge was 63 % ± 2 % for the entire discharge. This shows the effectiveness of both the blending action and the anti-segregation charging device.

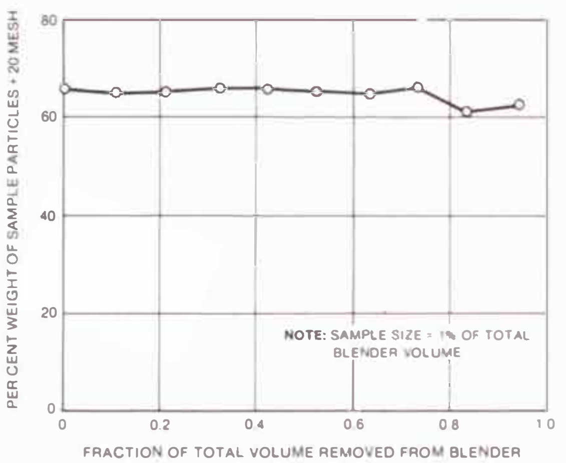


Fig. 6: Per cent weight of particles sized + 20 Mesh per sample

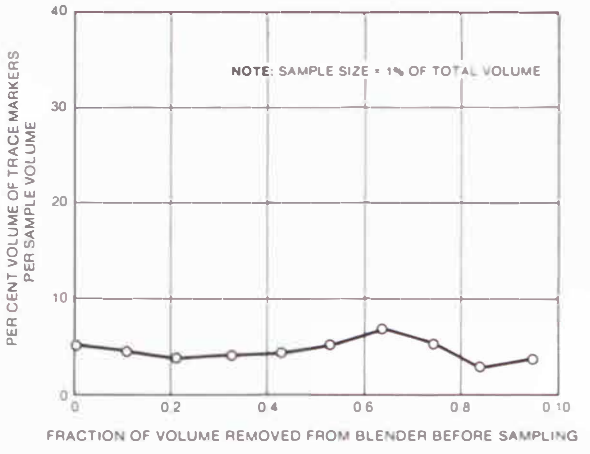


Fig. 7: Per cent volume of pellets per sample

The BINSERT™ blender configuration can also be used for continuous blending. In a continuous blending test, a single layer of markers constituting about 8 % of the total volume was placed at the top of the blender and the blender was subsequently charged with unmarked original material at the same rate as material was being withdrawn. The discharge was continuously monitored for markers. In this particular case the markers discharged continuously for a period of about 1.5 blender volumes of material removed. With the exception of about 5 % of total volume at either end of the discharge cycle, the amount of markers contained within each sample was uniform to within ± 1 % of the mean of 8 %. These test results indicate the capability of the BINSERT™ to blend continuously over a volume of material in excess of that contained within the blender.

3.2 Handling Sticky Solids

Another recent application for the BINSERT™ was over-the-road handling of fine metallic power in portable hoppers. The BINSERT™ allowed the hopper to be 60 degrees from the horizontal and still produce mass flow. The mass flow eliminated the hangups previously encountered and provided immediate and consistent availability of the power to subsequent process equipment. Design concepts for sticky materials are the same as for any hopper: first the outlet must be large enough to prevent arching; second, the walls must be steep enough to cause mass flow. The advantage of the BINSERT™ is that the walls of the outside hopper can be twice the hopper half-angle (measured from the vertical) as for a normal mass flow hopper.

3.3 Eliminating Segregation Problems

One of the most extensive uses of the binsert so far has been the elimination of segregation problems in pharmaceutical and food processing applications. This is accomplished by causing a uniform flow pattern in the bin so that even though the material segregates upon charging, remixing occurs during the discharge. Such a remixing can be accomplished with any mass flow type bin; however, the level of solid in the bin has to be maintained above the converging hopper portion of the bin. With batch type operations such as encountered in pharmaceutical applications the entire hopper must be emptied with a good mixture of the segregated solid. This can be accomplished by the use of a BINSERT™.

3.4 Making Conical Hoppers Flow in Mass Flow

Throughout industry there are many hoppers sloped 60° from the horizontal. Most of them do not flow in mass flow; thus resulting in ratholing, flooding, flushing and segregation problems associated with funnel flow. By taking such an existing hopper and installing a properly designed BINSERT™, it is possible to cause an otherwise funnel flow cone to act as the equivalent of a cone that is sloped 75° from the horizontal. Such an extremely steep cone usually flows in mass flow, even without special liners.

The same concept can be effective for a hopper having a slope as low as 45°. In this case the addition of a BINSERT™ will convert the hopper into the equivalent of a hopper sloped 67.5° from the horizontal. Many materials will flow in mass flow from such a hopper with a proper lining.

In making field modifications for conversion to mass flow, it is necessary to recalculate the structural loads imposed upon a bin [9]. With a BINSERT™ the bin will receive mass flow loadings in the hopper in addition to loads associated with support of the BINSERT™. Indiscriminate placement of these inserts in existing bins risks bin failures unless necessary structural modifications are also implemented.

Fig. 8 shows the comparison of headroom requirements for a typical case of a twenty foot diameter bin. It is evident that even for new designs the BINSERT™ can save significant headroom when compared to a typical mass flow bin design.

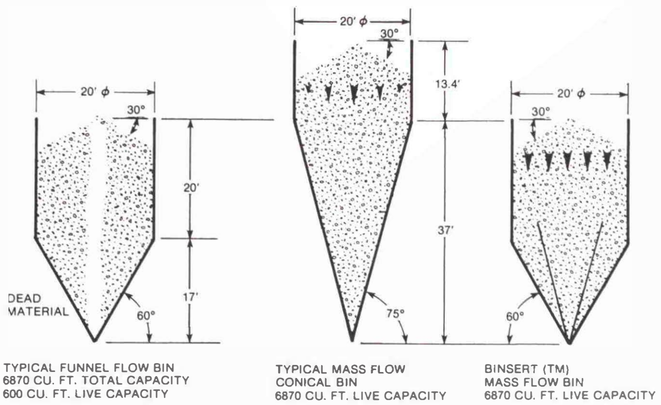


Fig. 8: Saving headroom with BINSERT™

3.5 Gas Contacting Systems

Process handling equipment often requires that gas contacts solids uniformly to achieve desired heat transfer or chemical reaction. Frequently, the solids velocity profile does not compliment the gas velocity profile. Attempts to overcome this with gas distribution pipes inside a process reactor often leads to solids flow problems. The more usual and safe way to introduce gas into a moving bed is at the periphery of the vessel, preferably in a vertical section. Unfortunately, this means that because of higher gas flow the peripheral material will benefit more from the gas introduction than the central regions. Ideally, the outside region should move faster than the central region to compensate for this maldistribution of gas. In a typical mass flow bin the opposite occurs with the central region having a tendency to move faster. However, proper design of a BINSERT™ can produce a flow pattern in which the outside regions move faster than the inside. Such a system has been designed by the author for the heating of grinding media. Laboratory models of the system have demonstrated the BINSERT™ effectiveness in creating this "inverted" flow pattern of solids.

4. Conclusion

The cone-in-cone BINSERT™ concept has already been used successfully in a wide variety of applications where control of the flow pattern is important. At present its most significant single application is in eliminating segregation problems in both existing bins and new bin designs. Its use for in-bin blending ranks a close second. However, the author anticipates that in the future it will increasingly be used to obtain mass flow in existing funnel flow bins. The author also expects to see new bins designed using the BINSERT™ to achieve significant savings in plant headroom and associated expenses. Finally, there are many new potential applications to moving bed process equipment where special flow patterns are required to optimize the process.

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