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The Design and Operation of Bin Activators

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Konstruktion und Betrieb von Silo-Rüttlern
La construction et le fonctionnement des décolmateurs vibratoires pour silos
El diseño el funcionamiento de vibradores de tolvas
ビンの流出促進装置の設計および操作
料箱抖动器的设计及操作
تصميم وتشغيل مفاعلات الصناديق

Konstruktion und Betrieb von Silo-Rüttlern

Der Artikel beschreibt die geschichtliche Entwicklung und die Grundlagen von Silo-Rüttler-Konstruktionen und gibt Einzelheiten über Anwendung und Betrieb eines höchst erfolgreichen Silo-Vibrators.

La construction et le fonctionnement des décolmateurs vibratoires pour silos

Cet exposé trace l'histoire, les bases de la conception des décolmateurs vibratoires pour les silos et les détails de la conception et du fonctionnement du très populaire déchargeur de silo vibratoire.

El diseño y el funcionamiento de vibradores de tolvas

El diseño trabajo se ponen de relieve los antecedentes y los principios del diseño de vibradores de tolvas y se explica en detalle el diseño y el funcionamiento de un descargador de tolvas con vibrador de gran éxito.

Summary

This paper highlights the history and philosophy of bin activator design and details the application and operation of the highly successful vibrated bin discharger.

1. Introduction

The Bin Activator was developed almost 20 years ago in reponse to the basic processing need for reliable material flow from storage. At the time of its conception volumetric vibrator feeders which could meter a variety of materials with accuracies of ± 1 to 2%, were gaining greater acceptance throughout the industry. However, as with all processing units, their performance was dependent upon a continuous supply and flow of material.

Existing bin discharge methods such as bin vibrators and air injection methods, could not be relied upon to provide the flow characteristics required for optimum feeder performance. As a result, a concentrated effort was mounted at that time to find a reliable way to move difficult materials from storage.

The vibrated bin discharger or Bin Activator rapidly proved to be successful in dealing with a wide range of storage problems. Vibrators and air injection methods had a limited success on small hoppers where high headloads did not have to be contended with; the Bin Activator on the other hand, could be used on hoppers of almost any size, regardless of headloads. In addition mass flow designed static hoppers could not accommodate different or even slight changes in a given material's characteristics; the Bin Activator on the other hand permitted a certain hopper to discharge a range of materials, regardless of certain variations in their physical properties.

The value of the Bin Activator was most dramatically demonstrated when used as a prefeed device to downstream processing equipment such as screw, belt and pan feeders, packaging equipment and batch and continuous blenders, as such equipment functions most efficiently when supplied with material on demand and in a uniformly dense flow. The Bin Activator provided this needed type of material flow together with density control.

As a particular example, consider the operation of a Variable Rate Screw Feeder which typically is installed to feed material over a range of different flow rates with accuracies of ± 1 to 2%. Such a feeder derives its accuracy from the uniform filling of the defined area between the screw flights and feed rates, in turn, are determined by the speed of the screw. When the bin supplying the feeder bridges or cloggs the reservoir of material in the feeder in consequence is rapidly depleted, thereby starving the feeder, and should the flow of material become erratic, due to varying density, the screw flights fill unevenly with material, causing fluctuation in the feed rates. If for production reasons the feed rate is suddenly increased the flow of material from the bin or hopper which is largely determined by the flow characteristics of the material itself, may not be able to increase proportionately to meet the demand (Fig. 1).

The majority, but not all vibrated bin dischargers, readily solve problems such as these, several, for example, are improperly designed to handle the full range of flow problems. Let us examine why this is the case by tracing the development of the vibrated bin discharger over the years.

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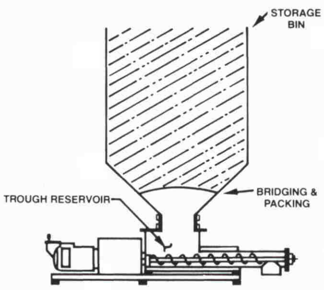

Fig. 1: Static storage bin and screw feeder

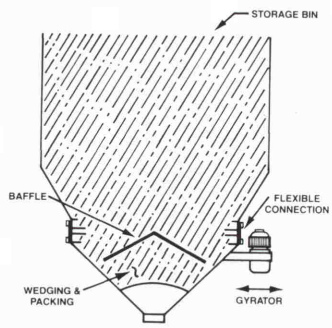

Fig. 2: Early vibrated cone bin discharger

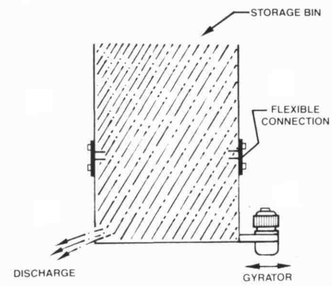

Fig. 3: Flat bottom, side outlet discharger

2. Development of the Bin Discharger

Bin discharger development began, quite naturally, in the problem area of most storage hoppers, the lower cone section of the bin. It was generally recognised that if the cone section had a large enough outlet, material could neither wedge or bridge near the bottom of the bin. However, in order to manage the large flow which was bound to result from such a large opening, some type of funnel was still needed. A first attempt at a solution to this problem was to remove the narrow cone section and replace it with an independently suspended and isolated cone with a small opening. It was hoped that, by vigorously vibrating the cone attachment horizontally, material would flow freely from storage (Fig. 2).

Once tried, however, it became obvious that although the bridging problem was solved, the material still tended to wedge and pack in the vibrated cone. This was due to the headload of material, which, because vibrated material approaches hydrostatic pressure, was larger than before. In an effort to alleviate this increased pressure, a baffle plate was installed just above the outlet in the vibrating cone section. The result was an early bin discharger which proved effective for some materials, but for others, particularly the fine cohesive materials which tended to slide down past the baffle and pack, the problem remained unresolved.

Several studies were subsequently conducted using a flat bottom bucket with a side opening. As with the cone, the flat bottom discharger was subjected to vigorous horizontal vibration (Fig. 3). It was discovered that, unlike in the cone, the flat bottom supported the material unpacked. When horizontal vibrations were applied, material spewed out the side outlet with little resistance, which also provided a most efficient operation since particles disengaged horizontally in response to the horizontally applied force, unlike in the cone where material could only flow downward. A side outlet discharger, however, was not readily adaptable to most installations.

A center outlet bin discharger, incorporating the operating principles of the flat bottom discharger, provided the answer (Fig. 4). An ASME dished head was used as the main body of the new discharger, providing both an inherently strong structure for vibratory service as well as a relatively flat contour to avoid packing of material. To relieve headload, a baffle plate was positioned above the center outlet. As with the flat bucket, material rested unpacked on the relatively flat surfaces of the dish. In operation, vibrations are applied horizontally to the unpacked material, which in turn disengages horizontally to the area beneath the baffle and flows freely through the outlet. The outlet cone is small, thus it cannot become packed or clogged even when filled with material. Flow is continuous and, most importantly, on demand. Another interesting feature was that the dished design was self-throttling. The unclogged state of the material in the dish permitted back-up of material without packing, such as when output rates were less than discharger output. This was to prove a key asset in prefeeding downstream equipment where proper operation demands a constant over-supply of material to service a wide range of downstream rates.

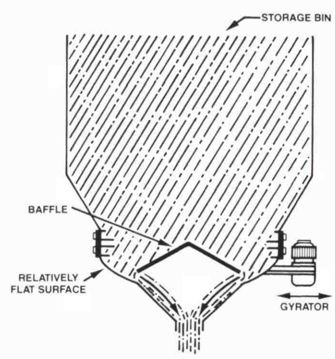

Fig. 4: Dished head vibrated bin discharger

Several vibrating bin discharger designs currently on the market do not provide these advantages. For example, a version of the early cone-shaped bin discharger is commonly still offered today by several manufacturers although with certain requirements for its operation and limitations in use. An attempt is made to overcome the cone's natural tendency to pack by operating the discharger on a cycle, determined by the type of material in the bin and discharger rate desired. Cycling, which is the constant on-off operation of the bin discharger, is done to prevent *over-vibrating* the material, which causes it to pack in a cone. The *on* cycle is usually a few seconds, the *off* cycle several minutes. During the *off* cycle, material is relied upon to flow by gravity. The *on* cycle, if timed just right (or controlled with the aid of a starve switch), will give the discharger a jolt just when the flow of material is running out. When this type of discharger is installed, it requires trial and error field tuning in order to arrive at *on* and *off* cycles which are proper for a given application. Cycled operation is further complicated by the strict maintenance schedule required of the unit's gyrator motor. Because of the severe strain which the motor is put through during *on — off* operation, careful attention to lubrication schedules is required in order to obtain even a minimum of useful life from the gyrator. Also, each time the discharger is shut off, a point is reached in the deceleration of the motor where the discharger is driven through natural frequency, thus causing wild gyrations in the bin structure. Repeated cycling can have damaging long term structural effects.

Perhaps the best evidence of the cone-shaped unit's shortcomings, though, is its problems with prefeeding downstream equipment. Consider the earlier example of the screw feeder, when supplied from a cycled cone-shaped discharger (Fig. 5).

After the discharger is set up through trial and error field tuning to provide flow without packing at a given feed rate, the following pattern occurs. During the *on* cycle, the discharger dispenses a dense plug of material into the feeder trough, where it fills a few screw flights. But, as the unit is cycled *off* and the material continues to flow out by gravity, flow decreases due to the lack of vibration. The screw flights may continue to fill, but now contain less material by weight since the density has decreased. Since the feeder is strictly a volumetric device and cannot compensate for a change in bulk density, the feed rate will start to drop. During the next *on* cycle of the discharger, another dense plug of material is deposited in the feeder trough and rates climb back up dramatically. This pulsation is typical of the best flow conditions that can be expected from a cycled discharger.

What happens therefore if a processing change requires a temporary adjustment to the feed rate?

Since the discharger cycle has been set for a given rate and a readjustment is both time consuming and impractical, flow either starves out if the feeder rate is increased, or stops due to plugging in the cone if the rate is decreased and material backs up.

Other process changes can also cause problems. If, for example, the characteristics of the material change due to a variation in humidity, or if a different grade of material is introduced, the cycled discharger will have to be retuned to assure continued operation. Further, there is always the danger that flow may halt abruptly when the discharger is in its *off* cycle because the material may bridge or clog while depending on gravity.

A continuously operated dished head vibrated bin discharger avoids these problems (Fig. 6). Firstly, it does not require field setup or tuning, and does not have the maintenance problems associated with cycled gyrators, or the structural problems which result from repeated cycled operation. When supplying that same volumetric screw feeder, the only item that is required is an interlock between the equipment so that the bin discharger starts and stops simultaneously with the feeder. The dished head discharger's self-throttling action provides a steady flow of material regardless of feeder rates. In addition, the discharger dispenses material of uniform bulk density, thereby actually enhancing the feeder's accuracy. Even a change in the characteristics of the material, or use of a different material altogether, rarely requires any changes to the discharger. There is therefore never the possibility that flow from the bin will stop abruptly due to a bridge or clog while under gravity flow because the unit runs continuously as required.

While the advantages and disadvantages of various vibrated bin dischargers as they relate to a volumetric screw feeder also apply to other items of processing equipment, there are other considerations that show up when examining each type of equipment in more detail.

3. Belt Feeder

A belt feeder is either volumetric or gravimetric in design (Fig. 7). The volumetric feeder is simply a variable speed belt supplied from a bin nozzle, which defines a given area where material can be deposited on the belt surface. The gravimetric feeder takes this one step further by incorporating a load cell in order to sense the weight of material on the belt and permit the speed to be varied, thereby compensating for any feed inaccuracy. A typical volumetric setup incorporates a three-sided nozzle attached to and vibrating with the bin discharger. The front, or open side is equipped with an adjustable gate. When a discharger is operating continuously, material flows into the nozzle, where it is vibrated to a constant density and deposited onto the belt with a cross-sectional area equal to that of the gate opening. A cycled unit will deliver a dense plug of material to the nozzle and belt during the *on* cycle. During the free-flow *off* cycle, the density of the material drops and rates are adversely effected. Even a gravimetric feeder will, in most cases, fail to compensate for this fluctuation. In fact, such fluctuation in density to a gravimetric feeder can cause the load cell to constantly send corrective signals to the belt drive motor resulting in *hunting*. A continuously vibrated bin discharger is, therefore, necessary for obtaining the ± 1 to $2\,\%$ feed accuracy from a volumetric belt feeder, or $\pm\,^1/_2\,\%$ from gravimetric belt feeder.

Also, unique to a belt feeder, is its tendency to flood much more readily when handling powdery material than a screw feeder, whose screw flights restrict material flooding. Continuous vibration must be applied to the nozzle in order to keep material in a dense state, otherwise, the powders, since they are under free fall conditions, may take on liquid characteristics and flood.

Lastly, of course, there is the problem of when a variation in rate is required and a cycled bin discharger must be re-tuned; a continuous discharger can simply throttle itself without the need for retuning.

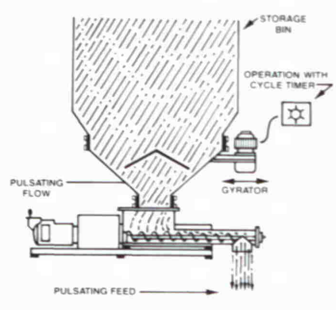

Fig. 5: Cone shaped discharger and screw feeder

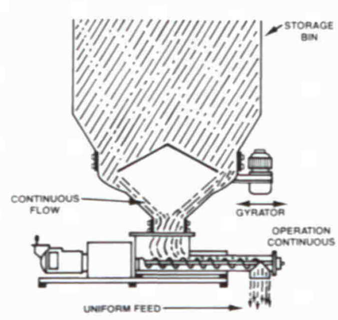

Fig. 6: Dished head discharger and screw feeder

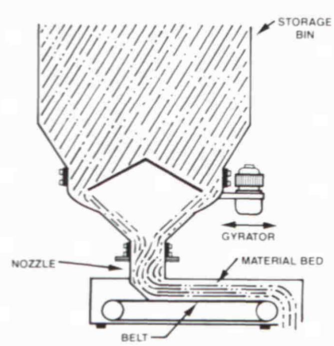

Fig. 7: Dished head discharger, vibrated nozzle and belt feeder

4. Vibrating Pan Feeder

A vibrating pan feeder is similar in many ways to a belt feeder, although it is usually used in less accurate feeding applications. It consists of a flat trough with vibration applied in a manner so as to convey or feed bulk materials along the trough. As with a belt, material is prone to fluctuation and flooding unless deposited on the trough with a continuously operated Bin Activator. Also, the accuracy of a pan feeder can usually be greatly enhanced when prefed from a continuously operated Bin Activator.

5. Rotary Feeder

A rotary feeder derives its feed accuracy from uniform filling of its pockets or vanes, much like a screw feeder (Fig. 8).

Any significant variation in the flow of material from storage will cause the same pulsating pattern of feed rates as we saw with the screw feeder. In many cases, the rotary feeder is used to feed a positive pressure pneumatic conveying line. The pressure seal is maintained by a tight fit between the vane and housing and, to a certain extent, by a full vane of material. A variation in the filling of the vanes can cause an increase in blow back air and, most significantly, loss of conveying pressure.

6. Bag Filling Equipment

Bag Filling operations also require a uniform prefeed in order to assure a consistent quantity. A continuous discharger maintains a constant density head of material which, with a volumetric filler, is critical (Fig. 9). The self-throttling feature of the dished head discharger is particularly valuable in this application because it operates continuously, and has the ability to throttle itself during each brief lag in output rates. Additionally, since typical fill cycle rates are quite low, anything but a self-throttling discharger will cause packing. Also, rate changes may be quite frequent; a dished head discharger will self adjust to the rate, while a cycled unit will require retuning.

7. Continuous Blenders

Such devices are normally filled or charged with various component ingredients by individual screw, belt or pan feeders (Fig. 10).

Since accurate introduction of materials is critical to proper blending, any inaccuracy of the feed device due to poor prefeed from the storage hopper will have adverse effects on quality. A continuous bin discharger will, therefore, greatly improve blender operation.

8. Conclusions

Above we have discussed how a Bin Activator enhances the performance of downstream process equipment such as feeders and blending, and why continuous operation is more desirable than cycling. Continuous operation also provides certain advantages in assuring proper bin emptying.

Bin Activators are sized for a given application based on the diameter of the bin to be discharged and the type of material being handled with the ideal objective of mass flow.

Mass flow is desirable because it avoids *rathole flow* which leads to material segregation and stagnation. Segregation begins when the bin is first filled. Larger particles migrate toward the bin periphery while finer particles tend toward the center. With rathole flow during discharge, the fine particles flow out first and the larger ones last. Stagnation also occurs when the bin is refilled before it completely empties. With rathole *core flow,* this means that material around the bin periphery never gets a chance to discharge.

However, a properly sized Bin Activator along with its integral vibrated baffle, encourages flow from the entire bin cross-section and therefore solves these problems.

Material that has segregated during the loading process has the opportunity to remix at the outlet due to *mass flow* drawdown. Stagnation cannot occur because the entire bin cross-section moves downward toward the outlet.

With a cycled discharger, however, *mass flow* only occurs during the brief *on* cycle when the unit is vibrating. When *off* and with material flowing strictly by gravity, *rathole flow* quickly forms with subsequent segregation and stagnation.

9. Final Comments

The vibrated bin discharger was developed in direct response to the need for reliable prefeed to processing equipment. The early cone design was found to require precise setup and cycled operation in order to avoid inherent design problems. Cycling itself was, as a result, a necessity that did not provide good performance for all processing equipment or over a range of rates.

Further research and experimentation brought about the continuously operated, self-throttling, dished head Bin Activator which has proven to be the answer to these problems in well over 75.000 installations worldwide.

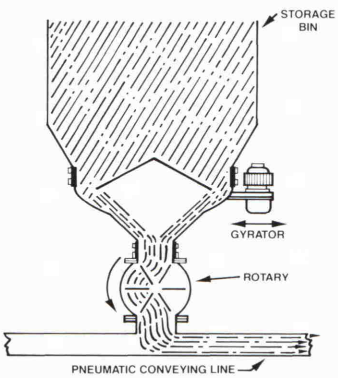

Fig. 8: Dished head discharger, rotary feeder

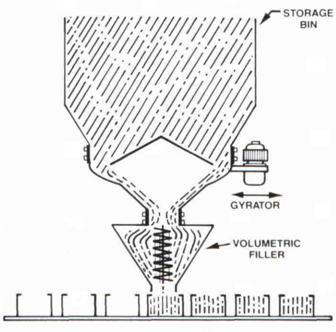

Fig. 9: Dished head discharger and volumetric filler

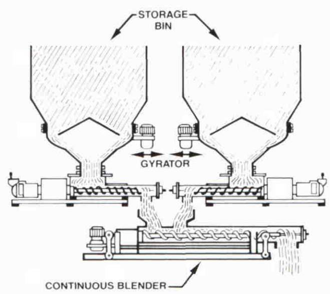

Fig. 10: Dished head dischargers, feeders and continuous blender