# THE IMPORTANCE OF VIBRATED BIN DISCHARGERS AND FEEDERS TO THE PHOSPHATE INDUSTRY

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## INTRODUCTION

Florida's phosphate industry, like other industries around the world, has looked to vibrated bin dischargers and volumetric feeders for solutions to many of its dry bulk material handling problems. Vibra Screw Incorporated, as the first company to apply the principle of controlled vibration to bin dischargers and volumetric feeders, has pioneered the most effective solutions to these problems. Some of the materials presently being handled in the phosphate industry by the Vibra Screw Bin Activators and Volumetric Feeders include lime, wet unground phosphate rock, diatomaceous earth, dry ground rock, run of pile and granulated triple super phosphates, phosphate rock clay, potassium chloride, soda ash, M.A.P. and D.A.P. fertilizer, defluorinated phosphates, and ammonia sulfate crystals. We will take a closer look at some of these applications later in the talk.

During the past two decades, a wealth of data has been developed on the broad subject of bulk handling. Both theoretical and practical concepts have been put forth in technical papers, at workshop seminars, in the form of professional design services, and by bin and equipment manufacturers. Extensive mathematical analyses have been developed to support some of the concepts. Generally, only those who are closely associated with bin design and operation, and the manufacture of material handling equipment and its operation, are aware of the limitations of some of these concepts. The basic requirement for a way to remove bulk materials from storage bins and silos, without resort to manpower, brought forth a host of devices aimed at overcoming jamming and bridging of material within the storage structures.

There evolved two dominant approaches to solving the problem of material flow stoppages from bins. One involved bin design to promote unassisted gravity flow, generally based on mathematical analysis of solids flow. The other, and more empirical approach to the problem, involved enlarging the bin discharge opening and flexibly attaching a vibrated bin bottom. Both approaches found practical application in industry and achieved an improvement over other existing techniques.

Further engineering developed the present-day version of the vibrated bin bottom to the extent that it does not require special or empirical design of the bin to achieve continuous solids flow. The application of this device in the Chemical Industry, especially as pertaining to the Phosphate Industry, will be discussed in this paper.

## THE BIN ACTIVATOR

The ideal situation would permit withdrawal of the material from bins and other containers in a controlled flow without resorting to the use of manual labor or auxiliary equipment. For some materials, this can be accomplished. The area of concern with many materials, however, is where the material becomes very difficult to handle because of changes in its flow characteristics brought about during processing or storage.

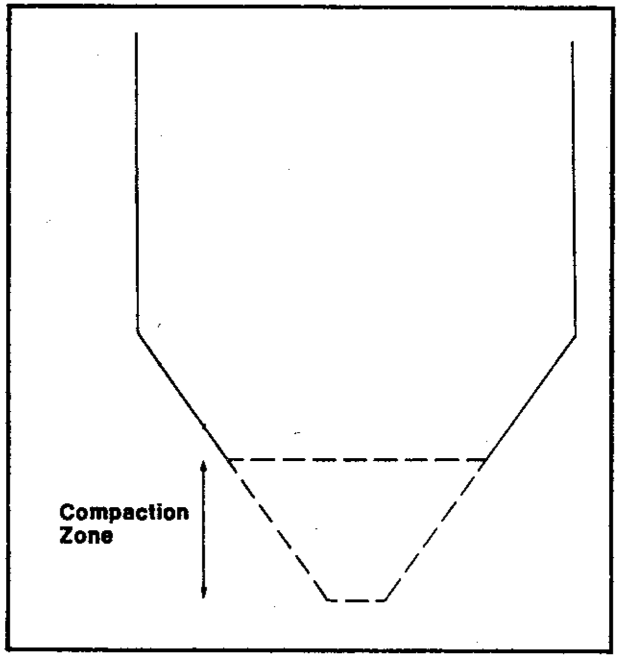
Most flow problems are caused by materials compacting in the converging bottom of a bin. The problem is overcome by removing the compaction zone and substituting a vibrated bin bottom.

The bin activator developed by Vibra Screw Incorporated was patented and became a state-of-the-art advance in bin discharge technology. Since it is the original and is available commercially, the working principles are discussed in some detail in Figure 1.

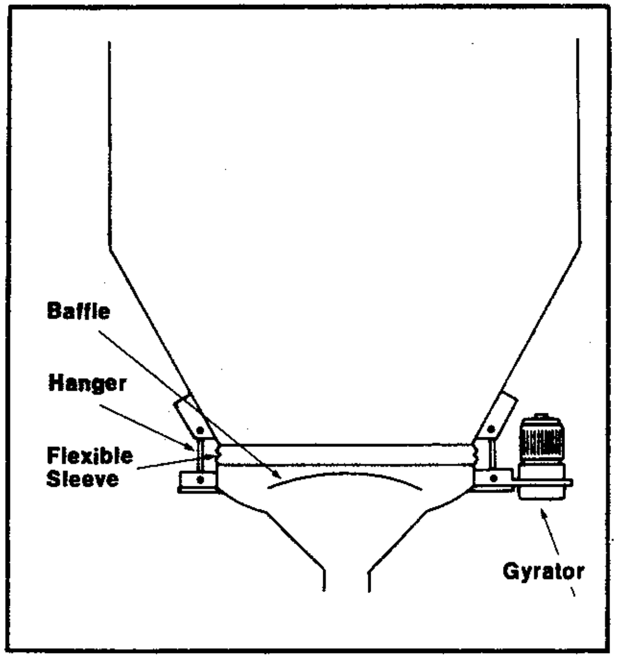
The bin activator is shaped like a shallow dish with a conical outlet centrally located. In application, it is suspended from the bin or from the conical hopper by means of hangers. These hangers, fitted with rubber bushings to isolate vibration, permit free horizontal motion. The gap between the hopper and the bin activator is bridged by an elastomer sleeve. The gyrator, mounted at the edge, produces an elliptical motion restricted to the horizontal plane.

In practice, the diameter of the dish ranges from one-third the diameter of the bin to its full diameter, depending on the materials contained in the bin, Table 1. The chosen diameter must be sufficient to eliminate the compaction zone over the outlet of the cone. It has been observed that materials seldom bridge or pack over a 12 ft. diameter.

The bin activator has an integral baffle of the same diameter as the major diameter of the gathering cone. This supports the headload of material and prevents packing the gathering cone above the outlet. The shape of the baffle is either domelike or conical, with the apex protruding into the hopper above. When the gyrator is in operation, the bin activator vibrates at 1,740 cycles/min. in the horizontal plane, vigorously agitating the material within the dish and gathering cone to keep it in flowing condition. Since the baffle protrudes into the mass of material stored above, the multi-directional thrusts

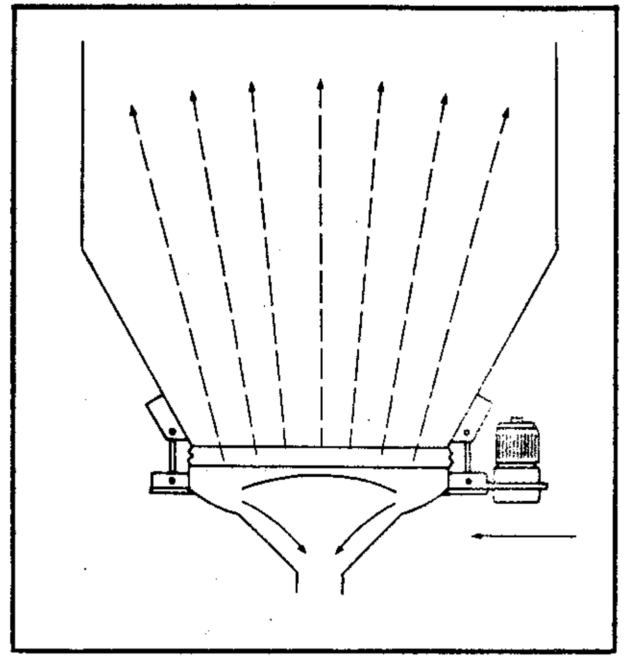



Conventional storage bins have large cross sections which converge to small outlets at the bottom. Most flow problems are caused by materials wedging and compacting into the converging part of the bin. When the bins are full, the enormous weight above compresses the underlying material into the cone section below, resulting in severe packing in this part of the bin. Accidental vibrations by trucks, trains, machinery, etc., greatly aggravate this problem, which worsens if the converging sides are made steeper.




Vibra Screw solved the difficulty by cutting off the lower cone section of the bin and replacing it with a Bin Activator consisting of a relatively flat dished head and baffle. There flat support surfaces carry the overhead load without permitting the additional compression that occurs in a conical bottom

The Bin Activator is flexibly hung from the upper bin by rubber-bushed forged steel hangers. An elastic sleeve of reinforced rubber seals the small gap between the main bin and movable bottom. An integral baffle relieves headload over the outlet Mounted to the Bin Activator and riding with it is a sealed, oil lubricated gyrator.



In operation, the gyrator produces powerful horizontal thrusts which vibrate the Bin Activator, its baffle and the contained material but not the bin. The material lying unpacked on the dish, is thrown horizontally toward the free-running outlet beneath the baffle where it falls away easily by gravity. This two-stage discharge principle eliminates conical compression of material during discharge and avoids packing it into the bottom during storage. The curved baffle resolves the horizontal thrusts into the main bin. This discourages overhead bridging.

FIGURE 1

of the gyrator send pressure waves upwards, breaking down the arches and preventing rathole flow.

The distance of the baffle above the dish defines the height of the circumferential orifice. The curvature of the dish leads to an almost flat bottom.

Thus, the flow of material is horizontal and is fully acted upon by the horizontal thrust of the gyrator, which pushes the material over the lip of the gathering cone, from whence it falls away by gravity. The vigorous vibration of the shallow gathering cone prevents compaction of material in that section. This was clearly demonstrated in separate experiments using shallow cones packed with difficult material vigorously vibrated in the horizontal plane.

The effectiveness of horizontal vibration, discharging a flat-bottom container through a vertical side opening, was preserved by making the vertical opening peripheral and facing centrally inward. The shallow container, converging to a small outlet that can easily discharge packed material under horizontal vibration, became the gathering cone. The baffle served the dual purpose of supporting the mass of material in the bin above, and by thrusting and wedging action, sending waves of vibration upward throughout the bin. The hangers with resilient rubber bushings allowed the bin activator to be vibrated vigorously, without vibrating or shaking the stationary sidewalls of the bin. And, finally, the elastomer sleeve permitted free horizontal movement of the bin activator while containing the material.

By applying the vibration only to the contained material, and not to the structural mass of the bin, and by applying it horizontally, so that the gyrator thrust was in the same direction as the discharge flow through the orifice, a high efficiency of energy application was obtained. This enabled great masses of material to be moved by an electric motor of relatively small horsepower.

For the strain and fatigue resistance required by the contoured-dish bin activator, the ASME code dished head was selected. Careful manufacturing processes used in this head, and its strength under fluid pressure loading assured its suitability for this service. Strongly agitated granular materials in flow have properties approaching fluid conditions. The number of hanger bars supporting the device is determined by the density of the substance and the diameter of the dish. Bars are made of steel forgings of suitable strength and proportions. The usual bin activator is 3 to 12 ft. in diameter, and has 4 to 16 supporting hangers.

## CLASSIFICATION OF MATERIALS

The flow characteristics of bulk solids vary widely and must be taken into account when specifying equipment for a dry materials handling system. With precise classification of materials is possible, for most requirements comparison with thousands of other materials and past experience afford a good, practical guide. In the more unusual situation, direct tests on pilot scale equipment, either at the factory or in the customer's plant, provide an accurate guide.

Further use of material classification to determine flow rates is shown in

Table 1 Material Classification

| Material Class | Description | Average Flow Rates in Ft.³/Hr. Under Free Fall Conditions. Always use largest possible outlet diameter compatible with downstream equipment. Outlet Size 8" | 10" | 12" | 20" | 30" |
|---|---|---|---|---|---|---|
| I | Material is granular and free-flowing. Would normally flow unassisted but temperature and moisture changes may cause it to bridge occasionaly. EXAMPLE: Granular salt, sugar, plastic pellets. Slide angle 30°. | 2600 | 4000 | 6000 | 16000 | 36000 |
| II | Material is a sluggish powder 100 to 300 mesh. Would not normally flow by gravity alone EXAMPLE: Flour, starch. Slide angle 35° to 55° | 1250 | 2000 | 3000 | 8000 | 18000 |
| III | Material is a powder that tends to be readily adhesive or becomes easily fluidized (—325 mesh). EXAMPLE — Adhesive Materials: $TiO_2$, and pigments in general. Fluidizing Materials: Hydrated lime cement, talcum powder, confectionery sugar. | 1000 | 1700 | 2500 | 7000 | 15000 |
| IV | Material is fibrous or flaky with a relatively low bulk density of 3 to 20 lbs./ft.³. Particles sizes are from ⅛" strands to 1" or larger chips. Has tendency to interlock and absorb vibration. EXAMPLE: Woodchips, slivers, shavings, asbestos fibres, flaked grain. | 330 | 500 | 750 | 2000 | 4500 |

Table 1. Flow rate is given in cubic feet per hour, based on bin activator outlet sizes ranging from 8 to 30 in. in diameter. This information can be used to determine sizing of downstream equipment.

## AERATION AND DENSIFICATION

With some materials, it is necessary to guard against flushing, which can be as upsetting to system function and stability as flow stoppage. Flushing may occur when a material becomes aerated and then flows like water. A typical example of this would be ground phosphate rock, silica, and ground or pulverized lime. The entrained air must be removed to restore the material to its normal condition. A bin activator accomplishes this by imparting vibration to the stored material, thus releasing entrained air which, in closed bins, is vented to atmosphere. When discharge from a bin is to a feeder, it is necessary to deaerate material before it reaches the feeder if good feeder accuracy is to be achieved.

## SEGREGATION

Segregation may occur when a material is composed of a variety of particle sizes, or particle weights. During the loading of a bin, the larger, or heavier particles tend to collect around the periphery of the bin, thus segregating part of the material. Unless something is done to prevent it, the smaller, lighter particles will discharge preferentially down the center of the bin followed by the coarser material from the outer edge.

Some remixing of material particles occurs as material is discharged from any bin, but, to remix for optimum particle distribution, the material particles must become mobile. The baffle, which is an integral part of the bin activator, vibrates with the bin bottom and imparts vibration into the material above it, causing the material to flow about equally from the center of the bin as from the outer region. In the process, material particles are widely distributed and mixed.

## FLOW CONTROL DEVICES

The type of flow control used will depend on the material use rate and may be selected for a consistent flow in a continuous process, or for intermittent flow, as in a batching operation. Frequently, it is at this stage in system design that projected costs for control equipment become significant in relation to total system cost. Second thoughts on the degree of feed accuracy required and extent of automatic controls employed arise. Economic considerations usually dictate the cost guidelines. For some systems, a simple slide gate may suffice to control the flow of material from the storage bin to feeding device. Not always, however, will a material immediately flow when a slide gate is opened at the discharge outlet of an unassisted gravity flow bin. To cope with this possibility, additional auxiliary equipment, such as external vibrators, ports for the insertion of an air lance, or the use of pulsed air pads, or other devices must be added to the system cost.

The flow of highly aerated materials may be controlled by a rotary-vane to, in effect, meter the material out of storage. For large flow rates, these devices become expensive.

While the bin activator is primarily a flow-promoting device and not a feeding device, it can serve both functions in many applications. Since flow rate is normally specified, the bin activator design parameters can be varied. Dependent on the flow characteristics of the material, bin activator diameter, outlet diameter, baffle size, shape, and location above the outlet, transition cone angle, and materials of construction are all taken into account. Fine adjustment of flow rate is accomplished by increasing or decreasing the amplitude of vibrations. With many materials, flow starts or stops as the gyrator is turned on or off, without the use of a gate or valve. This characteristic greatly simplifies system control.

Highly aerated materials can be densified in the bin by the vibratory forces developed by the bin activator. Entrained air is released and the redensified material may be discharged into process without the use of a rotary-vane, except where a pressure differential exists. To accomplish redensification, there must be enough retention time in the bin, usually about 20 min., to achieve uniform density. In recharging the bin with fluidizable material, a baffle plate is used to prevent the impact of new material onto the reserve in the bin.

Where feed accuracy is not important, discharge from the bin activator may be directly to the take-away belt or screw conveyor, or flow can be controlled by a bin gate, manually or remotely operated. For greater feed accuracy, a screw or belt feeder is usually required.

FEEDERS

The efficiency of both belt feeders and screw feeders can be greatly improved by providing a constant supply of uniform bulk density material at the input. For belt feeders, this is readily accomplished when a bin activator equipped with vibrated nozzle and adjustable gate is employed. This method assures a constant volumetric deposit of material on the belt and permits uniform belt loading for pre-determined throughput. Feed accuracy within $\pm$ 1 to 2 percent can be achieved for most materials.

The same technique is equally effective with screw feeders. A constant head of uniform bulk density material is maintained in the feeder hopper by the bin activator. The hopper, screw, and tube are vibrated to prevent bridging in the trough and ensure that each flight of the feed screw is filled to its maximum in the filling area and completely emptied at the discharge point.

This method of supplying material to belt and screw feeders overcomes material segregation. Both bin activator and feeder may be remotely controlled for continuous or batch operation.

## APPLICATIONS IN THE PHOSPHATE INDUSTRY

LIME (Hydrated, Pulverized, Ground): These three forms of lime are all used in the Phosphate Industry, both in manufacture of products and for environmental purposes. Fine lime materials have two basic flow characteristics. (1) They are hydroscopic, tending to bridge and compact in silos, and (2) once flow is induced, they tend to "fluidize" and flow like water.

With the percent cost of lime, ($30. to $50. per ton), controlled feed is extremely important for both economic and process control reasons.

One way in which lime is used extensively is in pH control of acid ponds, particularly with the coming requirement for "zero" discharge.

In one plant, Electro-Phos Corporation, producing elemental phospherous, the use of bin activators and heavy duty SCR controlled feeders reduced the lime consumption by approximately 50%. This was accomplished by close and uniform rate control achieved by coupling automated Vibra Screw equipment with a downstream pH meter.

The result was a continuous closely controlled pH versus a previous irratic pH in the pond water. This eliminated the necessity for overliming to ensure not to have too low of a pH at the discharge or reuse point.

DIATOMACEOUS EARTH (Silica): This material is typically used in the production of phosphate products and in Uranium Recovery. It has the characteristics of being light in density, and tends to aerate, but at the same time the particle characteristics are such that it will pack and bridge even in large diameter silos.

The Vibra Screw Bin Activator can prevent bridging and compaction in the discharge cone, and provide a continuous uniform deareated controlled flow to process. We presently have approximately 10 Bin Activators in operation or being installed in the Florida Phosphate Industry on this service.

PHOSPHATE ROCK: While we presently have a number of installations handling dry ground phosphate rock, the general trend of the industry is towards the wet rock process.

Vibra Screw has demonstrated it's ability in discharging wet unground phosphate rock containing up to 12% moisture from silos up to 2500 ton capacity.

One interesting developement in silo design came from our work with wet unground rock. Thru Davy Powergas, the concept of flat bottom concrete silos was developed. This achieved the following: (1) Less expensive silo construction, (2) A lower height silo requirement for a given capacity.

By using a single Bin Activator in the center of the concrete silo bottom and allowing the material to build it's own material cone inside the silo, the expense of a steel conical bottom and its inherent head room requirements were eliminated.

CONCLUSION:

One of the first Vibra Screw Bin Activators to be installed in the Florida

Phosphate Industry was in 1971. This unit was for Run-of-Pile T.S.P., one of the most difficult materials to be handled. This unit is still in operation today along with approximately 45 Vibra Screw Bin Activators installed since that time.

Vibra Screw has also supplied Heavy Duty Vibrating, Volumetric Screw Feeders, both in conjunction with the Bin Activator and as separate metering devices. These vary from 1/4" screw size for laboratory research work to 8" production models.

These vibrated screw feeders provide volumetric accuracies down to plus or minus 1% when used in conjunction with the Bin Activator. Controlled discharge is from .0037 to 1200 cu.ft. per hour. Screw feeders are available up to 16" diameter offering even higher discharge rates.

In addition Vibra Screw now has available a non-vibrating metering screw conveyor and a complete line of vibrated pan feeders to 6,000 cu.ft. per hour capacity.

Before joining Vibra Screw, Gus Formicola was superintendent of engineering at Johnson & Johnson with previous responsibilities in plant engineering, product and equipment design, research and development, etc. Prior to Johnson & Johnson, he was with RCA.

Gus earned his Bachelors degree in Mechanical Engineering at C.C.N.Y. in 1953, his Masters in Mechanical Engineering in 1957, and took additional graduate engineering courses at Columbia University. He is also a Licensed Professional Engineer.

# NOTES