A Review of Hopper Discharge Aids

A. R. Reed and C. H. Duffell, England

Summary

If a hopper is performing unsatisfactorily it is not uncommon for engineers to look to a proprietary discharge aid to help solve their problems. However, without any previous experience to fall back on he is faced with the problem of which device, from the wide range of proprietary aids currently available, will best suit his needs? Therefore, the purpose of this paper is not only to introduce some of the more commonly used devices but also to give the reader an indication as to their advantages and limitations. Hopefully, this will give the engineer a better basis for the selection of such aids.

1. Introduction

The hopper is one of the most important items of equipment in any bulk materials installation, since the repercussions of a poorly flowing hopper can be widespread throughout the rest of the plant as a whole. If a hopper is performing unsatisfactorily it is not uncommon for engineers to look to a proprietary discharge aid to help solve their problems. However, without any previous experience to fall back on he is faced with the problem of which device, from the bewildering range of proprietary aids currently available [1], will best suit his needs? Unfortunately, whilst gravity flow hoppers can be designed on a scientific basis, insufficient research has been carried out to date to say the same for hoppers incorporating discharge aids. The present situation is that whilst research at the Bulk Solids Handling Unit at Thames Polytechnic, Materials Handling Division of Warren Spring Laboratory and other institutions throughout the world have provided an improved understanding of the operating mechanism of various proprietary devices, a unified approach to the design of hoppers incorporating discharge aids has still to be developed. Under such circumstances it is then clear that the use of such aids is, at present, a matter of selection based on good judgement rather than design. Consequently, the purpose of this paper is not only to introduce some of the more commonly used devices but also to give the reader an indication as to their advantages and limitations. Hopefully, this will then give the reader a better basis for the selection of such aids.

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2. Design and Discharge Aids

As implied in the Introduction, discharge devices are all too often looked upon as the only solution for a badly designed and poorly flowing hopper. This reasoning is only too understandable since selection and installation of the 'correct' device can provide a quick, practical solution to the problem of a poorly flowing hopper. Obviously, this is not the best approach for using discharge aids since selection is then limited to those devices which satisfy the constraints of the existing system. It is evident that under such circumstances the selected device may not lead to the best solution to the problem. Indeed, selection of the 'wrong' device may have the reverse effect and lead to more problems that it solves.

It should always be borne in mind that although discharge aids serve a useful purpose, they should not be used as a substitute for good hopper design. Consequently, it is proposed that a more logical approach to any situation involving the flow of bulk solids from hoppers would be to:

i) Determine the configuration of the 'ideal' gravity flow hopper that would discharge the product satisfactorily. Gravity flow is the cheapest and most reliable method of discharging from hoppers and so it is not unreasonable that it should be considered first. This is achieved by undertaking tests on a representative sample of the product and utilising the design procedure developed by Jenike [2, 3]. The outcome may be that it is impractical to install such a hopper. If this is the case then:
ii) Consider what modifications can be made to the ideal gravity flow hopper to meet the constraints of the system. If under no circumstances a gravity flow hopper can be accommodated then, and only then:
iii) Select an appropriate discharge aid and design/redesign the hopper accordingly.

It is the authors' opinion that a sound policy towards any hopper flow problem is to undertake tests with a view to determining the 'ideal' gravity flow configuration as mentioned in (i), since this then yields the engineer an indication of the magnitude of his problems. The outcome of such tests have often shown that a comparatively trivial change to the hopper and feeding arrangements can overcome existing problems. However, another frequent outcome is that the orifice diameter and wall angle of the ideal hopper are too great to be accommodated within the constraints of the system. Principal reason for this are:

i) Insufficient headroom to accommodate the required storage volume,
ii) The orifice is too large for the feeder situated beneath the hopper,
iii) The flow rate through the orifice is too large and therefore incompatible with the requirements of the system or process.

Modifications to hopper geometry, by using stationary conical inserts and long slot outlets, can assist both the insufficient headroom and large orifice problems whilst still retaining a simple gravity flow configuration. However, with many cohesive materials, gravity flow is impractical or even impossible and a discharge device is then required.

Discharge aids are an effective means of overcoming the problems mentioned above. However, despite the claims of manufacturers of these devices, no one device is effective in handling all materials and this again emphasises the importance of making the right selection for a given installation. The most primitive discharge methods of rods, hammers and even explosives are familiar. They are, however, dangerous, unpredictable, of limited effectiveness, do not promote steady flow, can cause damage to equipment, and are actually expensive since they require frequent intervention by staff. Consequently, automatic methods are much more satisfactory. Generally these fall into three broad categories:

i) Those types which rely on the application of air to the product for their operation,
ii) Those types which rely on the application of mechanical vibrations being applied to the hopper and/or the material, and
iii) Those types which rely on mechanical means of discharging/extracting the product from the hopper.

For the sake of brevity these categories will, from now on, be referred to as pneumatic, vibrational and mechanical respectively.

The next three sections are intended to promote an awareness of the advantages and limitations of the more commonly used discharge aids which fall within these groups.

3. Pneumatic Methods

3.1 Aeration

Aeration of the product within the hopper is the simplest and often the most effective method of promoting discharge. This technique basically relies on controlled quantities of low pressure air being supplied to the bulk so as to reduce its strength and improve its flow characteristics. However, there are two schools of thought regarding the quantity of air that should be used with this approach. The first approach advocates the addition of air in sufficient quantities so that the wall friction is reduced and the bulk in the region of the orifice takes on 'liquid-like' properties. Under such circumstances the product is more free-flowing and consequently it can be induced to flow down shallower wall angles and through smaller orifices than would be possible with a simple gravity flow hopper. The air can be introduced via porous aeration pads mounted on the internal surfaces or porous membrane mounted in the base of the hopper, see Fig. 1.

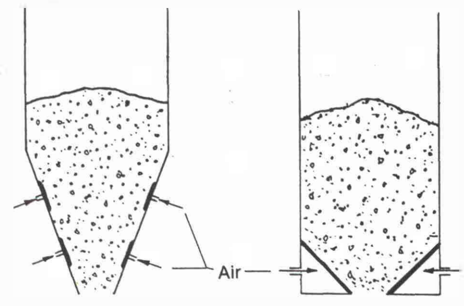

Fig. 1: Aeration methods

Porous ceramic tiles, plastics, sintered metals and woven steel laminates have been used successfully for this purpose. The success of this approach largely depends on an even distribution of the air to the product and a high resistance (i. e. high pressure drop) membrane should help here. However, care must be taken when selecting the membrane material since the fines content of some products can 'blind' them. It is difficult to be specific about the types of product to which this approach is best suited but experience has shown that dry or very low moisture content materials, less than about 300 μm in size, are suitable. The major criticism regarding this approach is that it can lead to uncontrollable flow or flooding of the product at the outlet.

The other approach to aeration mentioned at the beginning of this section has been developed to overcome the criticism regarding uncontrollable flow with the first technique. It is based on the observation that when a powder is introduced into a hopper it has a relatively low strength due to the air naturally entrained within the bulk. Under these circumstances many powders are relatively free flowing. Initially the air serves to 'lubricate' the particles by keeping them apart from each other. As time progresses this air gradually diffuses through the bulk, the particles move closer together, the forces of attraction increase and the bulk gets stronger. This is the principal reason for powders gaining strength and decreasing their ability to flow over a period of time. The approach to aeration under consideration here is to continuously replace the air, which would otherwise diffuse from the material, so as to maintain the bulk in a 'weak' state. Since the naturally entrained air diffuses quite slowly from fine powders it is only necessary to introduce the replacement air at low rates. Rates of 0.1 $m^3/min/m^2$ of hopper cross-section (1/3 $ft^3/min/ft^2$) have been shown to be sufficient. The air may be introduced by aeration pads of the type shown in Fig. 1 or by a ring distribution system shown in Fig. 2. It should be emphasised that with this approach the air must be continuously supplied and not only when discharge is required. If the air supply is turned off for any period of time the bulk will gain strength and it is then un-

Fig. 2: Ring distribution system

likely that the air flow will be sufficient to promote product flow. Experience has shown that aeration of this kind is best suited for fine, dry powders of a size less than 70 μm. However, care must be taken when using this approach for submicron powders. With such products it is unlikely that the air will have a significant effect on reducing the very high interparticle forces.

3.2 Air Expansion Methods

With this method a small quantity of high pressure air is introduced into the bulk in sudden bursts, with a view to the kinetic energy of expanding air initiating flow of a material that is static as a result of arching or rat-holing. Air is introduced at pressures up to 7 bar (100 lbf/in^2) to the required points through the side of the hopper via charged reservoirs, see Fig. 3. Proprietary devices go by such names

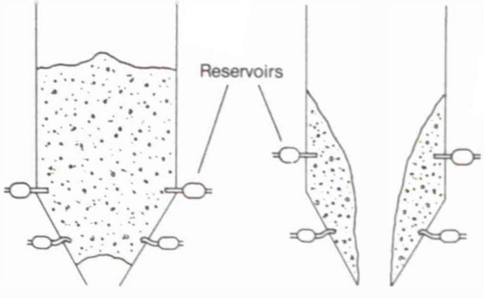

Fig. 3: Air expansion methods

as AIR GUN, AIR CANNON, BLAST AERATOR and BIG BLASTER etc. The number of reservoirs and the frequency at which they can be operated obviously depends on the situation. It may be sufficient to operate a couple of times per working day or, if required, they can be used as often as every four seconds. It is important to realise that since time is required to recharge them from a main air supply, they cannot be operated on a continuous basis. It is likely that they will give an uncontrolled flow and great care should be exercised when using them with fine products since the rapid expansion of the air may cause an air-borne dust problem.

Their use is, however, a 'brute-force' approach to the basic problem of badly designed and poorly flowing hopper. Consequently, they should only be looked upon strictly as an emergency measure when all other techniques have failed. A final thought with regard to this approach is that if these devices fail to dislodge the product and initiate flow, how does the air then dissipate its energy? In such circumstances damage to hopper walls has been known.

3.3 Air Operated Devices

The principal type of air-operated device takes the form of elastic pads mounted on the internal surfaces of the hopper, see Fig. 4. The pads are inflated at regular intervals by com-

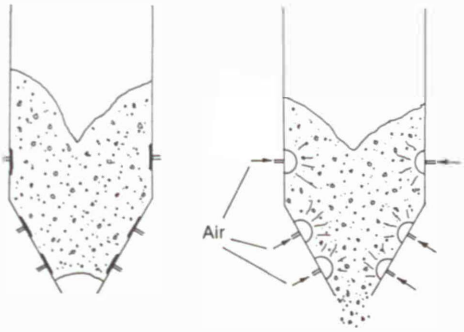

Fig. 4: Inflatable pads

pressed air to form a half balloon shape. This pushes the stored material, destroys arches and rat-holes such that flow is promoted or maintained. After the flow has been re-established the pads return to the deflated position. Automatic control of the whole system may be achieved by means of sensors near the outlet. If there is no flow, the pads will then be inflated. It is not unreasonable to expect that the most effective position for the pads is near the region of arching and experience has shown this to be the case. This can lead to problems since this position may not be known with any certainty and, indeed, it may be variable. It has been shown that these devices are particularly useful for products which form 'brittle arches', that is those products where flow-no-flow is marginal. With materials which form 'strong' arches, their use may only succeed in compacting the product yet further and thereby compound the no-flow problem.

4. Vibrational Methods

The application of vibrations to hoppers and bulk materials is one of the most commonly used methods of discharging the contents of hoppers [4]. Means of supplying such vibrations can vary from simple blows on the side of the hopper with a hammer or rapper to comparatively sophisticated live bottom shaking devices.

The success of vibrational discharge lies in the ability of materials to transmit vibrations and, in doing so, to reduce the strength of the bulk. The main function of the vibrations is to reduce the inter-particulate forces and allow slippage of one particle with respect to its neighbours. Inevitably this will lead to a densification of the product and while the vibrations are being applied, to a reduction in material strength. If the source of vibrations is then removed, the bulk comes to rest at a higher bulk density and greater strength. For this reason vibratory devices should never be operated whilst the outlet of the hopper is closed since this will only compact the product. The vibratory device will then be faced with the problem of initiating the flow of a product which is inherently stronger than before the vibrations were applied. It then follows that vibrations should only be applied when the outlet of the hopper is open and flow is required. There are basically three ways of effecting the vibrations. The first is vibrating the hopper walls with respect to the stored material and the second imparts vibrations to the stored material itself. The third is a combination of the first two but since it is seldom used it will not be considered here.

4.1 Vibration of Hopper Walls

Vibration of the hopper walls is normally achieved by the addition of air or electrically operated limpet vibrators which are externally mounted on to the walls. This is essentially little more than a refinement of the simple hammer approach. Their addition is intended to promote flow at or near the hopper outlet, thereby weakening the material up to its highest stable arch and at the same time reducing its adhesion to the walls. It then follows that the position of the vibrator(s) is critical. It is evident that the amplitude and frequency of vibration must be sufficient to break the arch. Unfortunately the complexity of the situation does not permit a mathematical calculation of these and, consequently, they are normally determined by trial. However, experience has shown that suitable positions for vibrators with various hopper geometries are as shown in Fig. 5, [5]. Although

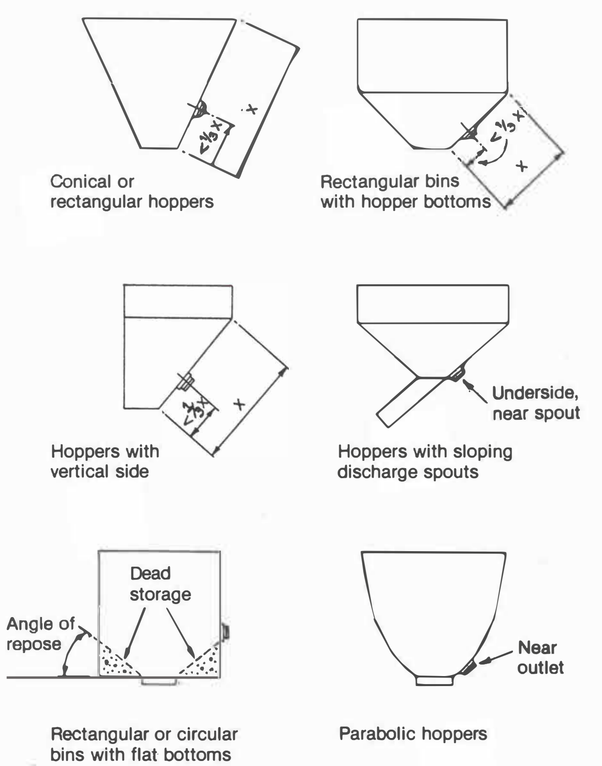

Fig. 5: Recommended positions for vibrators

these examples are for single vibrators, several vibrators can, of course, be used on opposite faces at different elevations. There are basically four types of vibrators which can be used:

i) Electromagnetic
ii) Air Piston
iii) Out of Balance Rotary Electric Motor
iv) Air Operated Ball or Roller

Types (i) and (ii) produce vibrations perpendicular to the hopper wall and are generally capable of frequencies in the range 20—120 Hz. Types (iii) and (iv) impart a radial impulse so that the hopper is also subjected to stresses parallel to the wall. They generally operate at frequencies in the ranges 15—50 and 100—500 Hz respectively. All of these types are, of course, available in a range of impacting forces. Reisner [5] gives some criteria which should be used in their selection.

The particular advantage of these vibrators is that they are relatively cheap and can be easily attached to a hopper without the need for extensive modifications. Consequently, this approach is commonly used when flow problems are present in existing installations. It is also a useful approach for situations where flow or no-flow is marginal, for example, to initiate flow after a product has been static for a weekend. Their principal disadvantage is that it is difficult to introduce uniform vibration to the walls and hence to the product. Consequently, to overcome this, several devices have been developed in recent years which apply vibrations directly to the product itself and these will be dealt with in the next section.

4.2 Vibration of the Stored Product

The majority of proprietary discharge aids that have come on to the market in recent years are of the type which impart vibrations directly to the stored material. The most established device that falls into this category is the BIN ACTIVATOR. This consists of a steel dish, suspended across the outlet cone of a storage hopper via a number of rods, see Fig. 6. A cone or baffle is supported from cross

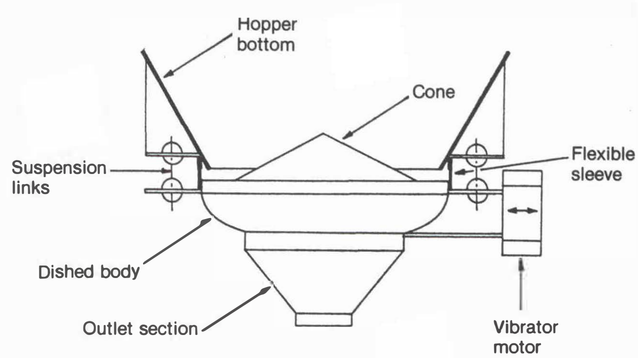

Fig. 6: BIN ACTIVATOR discharge aid

members spanning the mouth of the dish and the gap between the dish and the hopper is closed by a flexible sleeve. The cone is vibrated in an elliptical path in the horizontal plane at frequencies of 25 or 50 Hz via an externally mounted rotary vibrator motor of the type mentioned in the previous section. The vibrations imparted to the material by the cone cause it to move down the walls of the hopper and the cone itself, out through the annulus between the cone and the casing and into the converging outlet section. In this section, the material is in a dilated, flowing state and therefore of low mechanical strength. It is thus able to pass through a relatively small orifice at the base. A certain degree of control can be exercised over the discharge rate by altering the size of the cone, and therefore the flow area of the annulus, together with adjustment of the out-of-balance setting of the motor. With a correctly sized activator the stored product can be discharged apparently in a mass flow pattern at a fairly constant rate.

The method used by manufacturers to size an activator for an application is largely based on their experience together with a knowledge of the diameter of the parallel sided section of the hopper/silo and the characteristics of the product to be discharged, see Table 1.

PRODUCT CATEGORY	DESCRIPTIONS	ACTIVATOR/BIN DIAMETER RATIO
A	Granular, free flowing	$^1/_4 \rightarrow {}^1/_3$
B	'Sluggish' e. g. Starch, flour.	$^1/_3 \rightarrow {}^1/_2$
C	'Fine adhesive' and 'light flaky', e. g. Bran, Wheatings.	$^1/_2 \rightarrow {}^2/_3$
D	'Sticky' or 'Fibrous'	$^2/_3 \rightarrow 1$

Table 1: Guidance for the Selection of Bin Activators

Research by manufacturers and at Warren Spring Laboratory [6, 7] has shown that this simple classification correlates well with the product's ability to transmit vibrations. Obviously category A respresents the good transmitters. Experience has shown that most dry and semi-dry materials can be discharged. However, flooding may be a problem with fine, dry products and poor transmitters of vibration, i. e. category D (Table 1), may also present problems.

The SILLETA, like the BIN ACTIVATOR, is also a device which is attached to the bottom of the hopper. It consists of a stationary frame enclosing an inner frame which is made to vibrate in the horizontal plane by an externally mounted electromagnetic vibrator, see Fig. 7. In this inner frame a

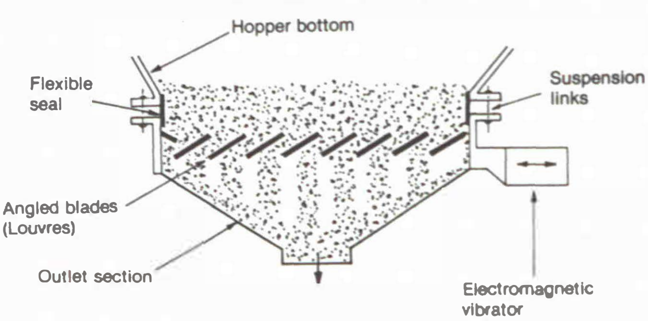

Fig. 7: SILLETA discharge aid

number of angled blades are fitted so that they take the form of louvres. This effectively divides the discharge area into a series of narrow slots. In the stationary condition the product will naturally arch over these slots. However, when the blades are vibrated these arches will be broken and the product then flows down the sloping blades. Again, like the BIN ACTIVATOR, in the outlet section the dilated material is of low strength and therefore can be discharged through a relatively small orifice. The blade/slot dimensions and inclination are pre-set by the manufacturers to suit the particular handling characteristics of the product in question. The manufacturers claim that the discharge rate of a wide range of products varies linearly with the amplitude of vibration. If this is so and since control over the amplitude can be readily exercised by the electromagnetic vibrator, it is then possible for this device to also be used as a feeder.

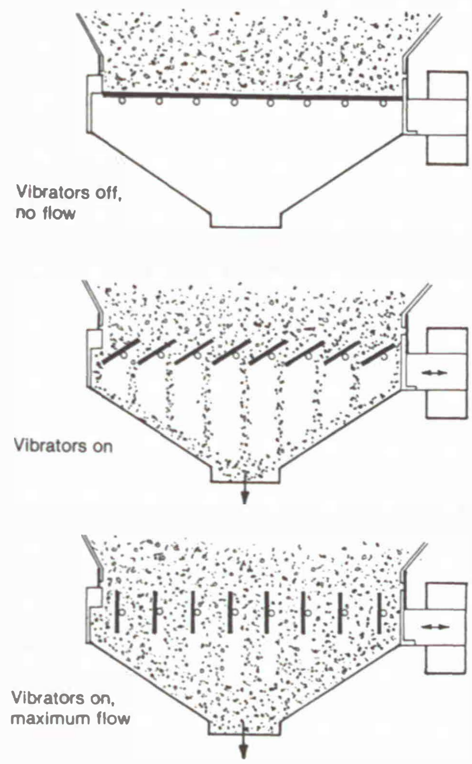

Fig. 8: HOGAN discharge aid

The HOGAN discharge aid, Fig. 8, is of a similar construction to the SILLETA but differs in the respect that the vibrations are generated by two fixed amplitude and frequency rotary vibrator motors [8]. Control over the discharge rate is then exercised by external adjustment of the angle of the vibratory blades, much as the flow of a fluid in a pipe can be controlled by a butterfly valve. Since both the SILLETA and HOGAN are relatively new, little is known about the range of products they are capable of discharging. However, since they both rely on the ability of the product to transmit vibrations and therefore reduce its strength, then, like the BIN ACTIVATOR, it is reasonable to doubt their effectiveness at handling sticky, flaky and fibrous materials.

Unlike the three devices discussed so far, which effectively provide live bottoms to the hoppers to which they are fitted, the last two devices in this section consist of vibratory screens or cages which are inserted into the converging section of the storage container. The more established of these is the BRIDGE BREAKER, which has been developed to break the arch of material as it attempts to bridge across the converging section of the hopper. It consists of one or more expanded metal screens which are mounted parallel to

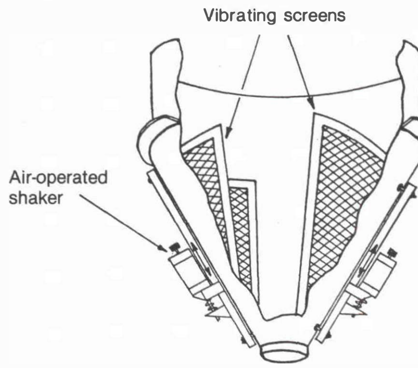

Fig. 9: BRIDGE BREAKER discharge aid

the inner walls of the hopper, as shown in Fig. 9. Each screen has its own externally mounted air operated reciprocating shaker which, via a mounting bracket and studs, transmits a low frequency (approximately 20 Hz), high amplitude (2—4 mm) motion to the screens in a direction parallel to the hopper walls. Research at Thames Polytechnic [9] has shown that this leads to a shearing of the material in the vicinity of the screens and thereby assists in moving the product towards the orifice. Experience has shown that this approach is most effective when the screens are operated for thirty seconds in every minute and then only when the system beneath the outlet, i. e. feeder, conveyor etc., is in operation. Some ingenuity on behalf of the manufacturers may also be necessary in sizing, positioning and shaping the screens if this approach is to be used to its best advantage. This system has proved capable of handling a wide range of products but, like the other proprietary devices mentioned in this section, it is not too effective at discharging fibrous, flaky, damp or sticky products. Apart from operating the screens on an intermittent basis little control over discharge rate can be exercised. This is not suprising since, as previously mentioned, the device was conceived solely to overcome the problem of bridging and arching and thus aid discharge of what otherwise would be troublesome products. The particular advantage of this device is that since the screens can be formed to a wide variety of shapes, it is possible for it to be readily incorporated into existing, troublesome hoppers without the need for extensive modifications.

The VIBRO-BI-PLAN [10] basically consists of a shaking motor suspended centrally in a hopper which transmits vibrations to a fabricated cage which is mounted parallel to the hopper walls, see Fig. 10. The position of the obliquely

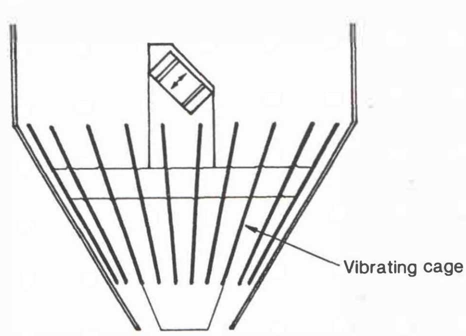

Fig. 10: VIBRO-BI-PLAN discharge aid

mounted motor is adjusted to give the required degree of horizontal and vertical vibrational forces to effect discharge. It is not known how this device affects discharge but it is not unreasonable to assume that, like the BRIDGE BREAKER, it prevents a stable arch from being formed. As it has only been marketed in the U. K. for a short time, not too much is known about its performance or the range of products it is capable of discharging. However, with regard to its design, doubt must be expressed about the wisdom of mounting an electrically operated motor inside the hopper which, at some stage, is likely to be covered with product.

5. Mechanical Methods

The simplest mechanical devices consist of chains suspended in the hopper or paddles within the material which rotate in the horizontal or vertical axis. The suspended chains have proved a successful approach with large sized materials such as crushed rocks or ore. If the material arches, an upward pull on the chains breaks the arch and flow restarts. Paddles are intended to maintain the product in continuous movement and so prevent arching. However, for hard, coarse materials, wear can be significant. The vertical types can suffer from shaft deflection in the absence of bottom bearings and the horizontal types require good sealing at the hopper walls to protect the bearings.

Screw feeders are probably the most commonly used mechanical method of discharging/extracting and feeding products from storage containers. Their advantage is that they can discharge at a reliable rate whilst providing a suitable choke to what would otherwise be an unacceptably high discharge rate in a gravity flow situation. Their principal disadvantages are that they can be expensive and can be subject to high wear rates. Installation takes many forms but the simplest is the single screw, Fig. 11. With this, and all

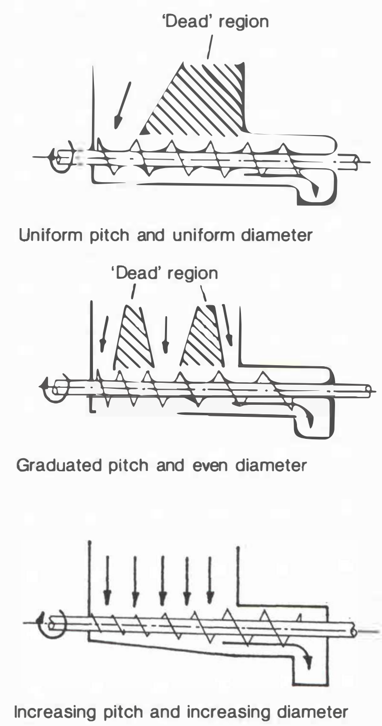

Fig. 11: Screw dischargers

other screw type equipment, care must be taken with the design of the screw if the required flow pattern in the hopper is to be retained. Besides the conventional application of the single screw, several screws parallel to each other may be used to discharge very awkward products from containers with parallel sides. In this way, the material in the hopper is kept live and the hopper outlet can then be large enough to prevent arching without the attendant high feed rate.

The types of screw devices mentioned so far tend to be manufactured on a '*one-off*' basis to suit a particular installation. Of the proprietary screw type devices the BOWER-HILL-PARCEY and STORALL are probably the most well known. With the BOWERHILL-PARCEY [11], Fig. 12, a

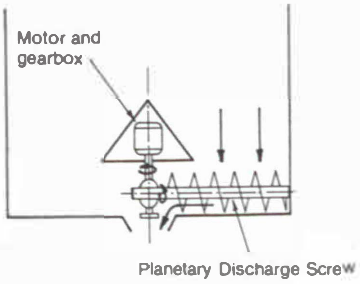

Fig. 12: BOWERHILL-PARCEY Planetary discharge aid

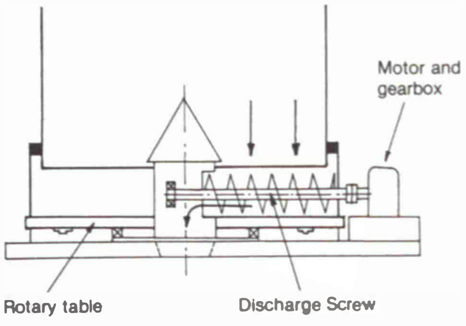

Fig. 13: STORALL discharge aid

single screw circles slowly around the base of the silo. Through the rotation of the screw the product is cut away and discharged through the outlet at the centre of the silo. The STORALL, Fig. 13, is also a single screw device but the screw rotates in a fixed position and it is the base of the silo which rotates so as to present the product to the screw. Although both of these devices are expensive it is claimed that they are capable of handling products that cannot be satisfactorily discharged by other means, for example, wet, sticky products. Consequently, they represent a valuable addition to the range of discharge aids.

The CIRCULAR BIN DISCHARGER is one of the most successful of the proprietary mechanical discharge aids, see Fig. 14. It consists of an arch breaker arm which is driven positively through a universal joint and is free to work anywhere in the conical bin. Hopper angles of 50° can be accommodated by the universal joint but with shallower angles wear can be considerable. A seal below the joint protects the bearings and drive shaft. When the arch breaker arm rotates, material is fed into the discharge section by the rota-

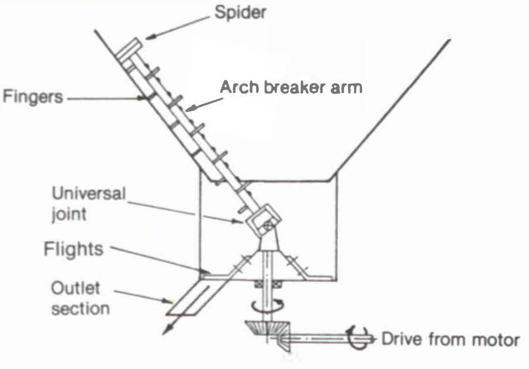

Fig. 14: CIRCULAR BIN DISCHARGER

tion of the flights and this will continue until the hopper is empty. This device has proved to be robust and reliable and particularly useful for awkward, fibrous products which do not respond to aeration or vibration. It can also be used as a volumetric feeder since the flow rate can be controlled within fairly close tolerances for many materials.

The final device in this section, the rotary table, is not really a discharge aid. It is, nevertheless, a useful approach for overcoming the basic problem of high flow rates that are associated with he large outlets necessary to avoid bridging/arching with poorly flowing products. It basically consists of a table that rotates under the outlet of a gravity flow hopper such that a fixed blade ploughs off the emerging column of material, see Fig. 15. Obviously, the outlet should be

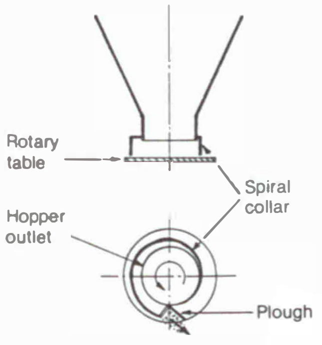

Fig. 15: Rotary table feeder

large enough to prevent arching in the supply hopper and this dimension can be readily determined by laboratory tests [2, 3]. If the outlet collar is a spiral then a fairly uniform flow can be expected, but it should be remembered that a dead, conical region will remain in the centre of the table. Since table speeds are normally in the range 1—10 rev/min, relatively low discharge rates are possible. However, this approach is generally confined to diameters of less than 2 m because of the high pressures and high forces needed to operate under larger outlets.

6. Concluding Remarks

As mentioned earlier in this paper, discharge aids should not be looked upon as the only solution to the problem of a poorly or potentially poorly flowing hopper. It may subsequently transpire that a discharge aid is required but this should be only after the possibilities of installing the cheaper, more reliable gravity flow hopper have been thoroughly exhausted. Under such circumstances there are no general rules regarding the selection of a particular type of device for a given installation. Obviously the devices described here vary considerably in cost and for the majority of engineers cost is an important criteria in any selection process. Indeed, cost should be examined closely since it is possible that what would appear initially to be a high capital cost device may, in fact, be capable of controlling the discharge rate with sufficient accuracy so as to eliminate the need for ancillary feeders. However, because of the wide variation in the handling characteristics of bulk solids together with the knowledge that no one discharge device is capable of handling all products, the over-riding factor in the selection process is whether the device will discharge the product in question. This, of course, requires a knowledge of the advantages and limitations of the discharge aids currently available to the potential user, and it has been the principal objective of this paper to contribute towards providing this. The advice of independent and experienced organisations such as Thames Polytechnic, Warren Spring Laboratory and others may also prove valuable at this stage. Once the engineer has selected the device with the greatest potential for his installation, it should be his responsibility, as far as possible, to ensure that it is capable of discharging his product under the worst conditions that will be experienced in practice, e. g. highest moisture content, highest state of compaction etc. Many companies, in fact, have test facilities where, by supplying a representative sample of product, the potential user can witness the ability of the aid in question to handle his product. It is clear that, until hoppers incorporating discharge aids can be designed on a quantitative basis, such facilities should be fully utilised. Only if the outcome is favourable can the user then proceed to install the device with confidence that it will serve the purpose for which it was selected.

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