RETROFITTING MATERIALS HANDLING PLANT TO ALTER FLOW PATTERNS

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1. Introduction

The science of bulk materials flow has developed significantly over the last 40 years through the application of design principles based on test work performed on shear cell testers. The application of advanced technologies in plant design has been well recognised by both major corporations and project houses with defined benefits being achieved in construction and operating costs.

The constant drive in existing materials handling plant to improve efficiencies, increase throughput and reduce operating costs whilst handling lower grade materials with higher moisture contents has necessitated a review of possible applications of material flow technology in retrofit installations.

Some examples of the of typical flow problems encountered are [1]:

- The need to handle lower grade, "difficult-to-flow" materials resulting in erratic flow or when stoppages due to the formation of either stable arches or ratholes
- Limited live or useable capacity of storage silos often the result of a ratholing problem
- The inability to achieve required discharge flow rates
- Dusting, spillage and high wear at transfer points
- Segregation
- Erratic flow often occurring when ratholes collapse
- Flushing and flooding of fine powders (uncontrolled flow)
- Excessive power consumption on feeders
- Material degradation (caking, spontaneous combustion, spoilage)
- Vibration in structures
- Accelerated wear profiles

The impact of flow problems are direct and measurable being, manpower to keep material flowing, damage to structures from hammering or vibration, reduced product quality, spoilage, uncontrollable processes and even fire damage to downstream feeders, conveyors and equipment in the case of spontaneous combustion.

The alternatives available to plant management under these circumstances are limited:

1. Live with the problem and accept the costs

2. Replace the bin, its feeder and other associated equipment

3. Make retrofits which can minimise and possibly eliminate the flow problems.

Of these equally unattractive options bin retrofits are often the most cost effective alternative. The selection of the equipment employed however must be based on a sound understanding of the flow properties of the material being handled. The reasons for the flow problems should be properly understood so as to address the cause of the problem as opposed to masking the symptoms. Equally important as the theory is the physical modification which should be designed and performed by engineers with a solid grasp of the intricacies of material flow, able to demonstrate an appreciation for the fine details that affect the performance of the system as a whole.

2. Retrofit Options

Numerous types of retrofits can be considered however they can broadly categorised into five main types [1]:

- Hopper Modifications
- Inserts
- Flow Aid Devices
- Feeder Modification
- Aeration

The selection of the best alternative able to provide the most cost effective solution is dependant upon the type of problem experienced, the flow properties of the material being handled and the physical constraints of the application such as headroom, bin size, feeder type etc.

Although each of these options is discussed in more detail hereunder and a reference table provided to assess the viability of each alternative against the physical problems being experienced it is pertinent to review the theory of bulk material flow as detailed by W. Deijs [3] prior to analysing the alternatives available to retrofit existing materials handling installations.

3. Theory of Bulk Material Flow

The three categories of material flow in storage applications are described below and these discussions are extended to include factors affecting material flow patterns.

3.1 Mass Flow (Fig 1)

Mass flow occurs in bins or silos when the hopper is steep enough and smooth enough to allow material to flow along its surface. As such all the material in the bin is in motion during discharge.

Mass flow bins are particularly suitable for cohesive materials, materials that degrade over time, and materials where segregation should be kept to a minimum.

Typical examples of a bulk material storage applications requiring mass flow patterns are in a power stations where segregation will effect mill efficiencies, the materials are generally cohesive and prolonged storage can lead to degradation or even spontaneous combustion with dire consequences and in food silos where material may rot and contaminate the entire batch.

Characteristics of mass flow are as follows:

- First in first out
- There are no dead or inactive regions
- Fine powders are allowed to de-aerate
- Segregation is minimised due to re-mixing of the material in the hopper during discharge.
- Materials are fed uniformly at constant density

3.2 Funnel Flow (Fig 2)

Funnel flow occurs in bins and silos when the hopper angle is not steep enough or the walls not smooth enough to allow material to flow along their surface. A channel is created above the opening and material will flow from the top of the channel.

Funnel flow bins are suitable for coarse free flowing materials that do not degrade over time and where segregation is not a problem. Funnel flow has the advantage of providing wear protection for the bin walls as material always flows on top of stored material. Controlled feed rates are however almost impossible to achieve as feeders are often subjected to flooding. Fine materials are prone to flushing where they become aerated and these varying densities prevent accurate feed rate measurement. Since funnel flow bins are prone to ratholing they often require the use of flow promotion devices to initiate and maintain flow.

Typical funnel flow characteristics are:

- First in last out
- Low headroom due to shallow hoppers
- Material in the channel is in motion whilst the remainder is stagnant
- Ratholes may form is the opening size is too small
- Flow may be erratic - difficult to control and measure
- Segregation is amplified.

3.3 Expanded Flow (Fig 3)

Expanded flow is best described as a combination between mass and funnel flow in different parts of the bin. Expanded flow patterns combine the storage efficiency of funnel flow bins with the reliable discharge characteristics of mass flow hoppers.

Steep, smooth hopper sections facilitate mass flow discharge and the hopper which then expands upwards to the region where the critical rathole dimensions are exceeded then begins to operate in a funnel flow pattern. This flow pattern design is common in bins with multiple outlets and in stockpiles.

3.4 Factors Affecting Flow Patterns

Although a very detailed topic in itself the primary factors affecting flow, or the lack thereof, in storage bins can be summarised as follows:

a) Opening Size

Opening sizes are determined to provide not only the required feed rate but to ensure that the critical arching dimensions are exceeded. In the case of larger particles, mechanical arches occur due to an interlocking of solid particles across the outlet. To overcome mechanical arching opening sizes should be designed at a minimum of four times maximum lump size.

Cohesive arches occur across outlets under the action of consolidation of the bulk solids and this is particularly prevalent under time storage conditions.

b) Opening Geometry

Bin openings are classified as either conical/square or plane where plane flow hoppers are defined as having slot type openings with a length to width aspect ratio greater than 3.

The influence of plane flow hoppers practically translates to provide an allowable hopper half angle (wall angle measured from vertical) of 8 - 12 degrees more than that of conical hoppers.

c) Wall and Friction Angle

Hopper and chute wall angles can be considered the single biggest influence on the flow pattern that will be achieved. Simply put hopper walls that are not steep or smooth enough will not permit mass flow to occur.

d) Time Conditions

Many bulk materials experience an increase in cohesive stress during undisturbed storage. The effect of this consolidation is to require larger openings to initiate flow following prolonged storage.

e) Feeder Interfaces

Feeder interfaces are the most commonly neglected design aspect often left to feeder suppliers to specify in designs. In practical terms, a properly constructed mass flow bin will not achieve mass flow unless fitted with an appropriate feeder interface.

The concepts of mass flow feeding are simply to allow discharge of material uniformly across the bin outlet and are best described practically when considering a screw feeder. It is important to note that these concepts apply to all feeder types from aprons to belts, rotary valves and table feeders.

When considering a conventional screw conveyor with a screw having constant pitch and flight fitted below a bin the screw turns to propel material forwards. As the screw turns the first (back) chamber is emptied and material flows from the bin to fill this cavity. As the material is propelled forwards into the second and subsequent cavities these are in fact filled by the material being pushed forward in the screw and not by the material descending from the bin. The shear plane in these sections of the flight is now horizontal and the only path available for material to enter the feeder is from the rear establishing an uneven discharge of material from the bin. To overcome these problems in screw feeders they are generally constructed with varying pitch and flight to allow material to enter over the full length.

Aside from even discharge across the complete opening, mass flow feeder interfaces also generate substantially lower loads on the feeders than conventional interfaces due to various secondary effects and other conditions, offering design engineers substantial capital cost savings.

4. Retrofit Categories [2]

4.1 Hopper Modifications

Hopper modifications are employed in instances where funnel flow patterns result in reduced live capacity, ratholing, arching, degradation of stored materials such as foodstuffs, spontaneous combustion and the like, where it is desirable to covert to a mass or expanded flow pattern.

There are a number of hopper modifications that could be considered and these include:

4.2 Liners

As detailed above the component having the single biggest influence on flow patterns can be considered to be the wall angle of the hopper. The use of liners having lower friction coefficients serves to simulate steeper wall angles or conversely permits flow to occur at shallower angles.

The application of shear testing technology permits a scientific approach to liner selection as opposed to the traditional hit and miss approach of installing new liners to see if they work.

The following factors should be considered when selecting the most appropriate liner [6]:

- Surface friction and adhesion
- Resistance to abrasive wear
- Resistance to impact (if appropriate)
- Resistance to corrosion
- Method of attachment
- Initial Cost
- Installation cost and maintenance

Whilst cost remains the primary decision making criteria for most liner applications it is important that the lining material be selected on the basis of service life and performance to provide the most economical solution that is commonly confused with the cheapest alternative.

4.3 Transition Hoppers

The factors affecting flow patterns as described in section 3.4 are all interlinked and there are limits to the application of cone and bin inserts where the use of transition hoppers becomes necessary.

As in the case of the cone inserts transition hoppers are designed to capitalise on the 8 - 12° benefit afforded by slot openings and in effect require the removal of a portion of the cone which is then replaced with a transition hopper that terminates in a slot opening. Most commonly transition hoppers are employed to convert funnel to expanded flow patterns.

Full flow testing is required to determine the required geometry of the cone, allowable wall angle, liner selection and transition hopper top diameter (when designing for expanded flow) to ensure that stable ratholes are not formed in the funnel flow section. Properly designed feeder interfaces are also essential to the successful operation of a transition hopper.

The implementation of a transition hopper retrofit solutions generally require the replacement of feeders and on the whole are not as cost effective as insert technologies.

4.4 Wall Angle Modifications

When sufficient headroom exists within a bin the creation of false internal walls or, the casting of steeper internal concrete walls, can create mass or expanded flow patterns provided the outlet size is sufficiently large.

It is often more economical to employ minor wall angle modifications together with low friction liner selections to achieve the same result however each design should be evaluated on its own merits. This retrofit method has been used very successfully in the cement industry in South Africa on various hoppers employing hand packed concrete with void formers and has proven to be very economical.

4.5 Enlarged Outlets

When flow problems are of the arching, ratholing and limited flow type it is possible, although not always practical, to enlarge the opening and feeder to achieve more desirable flow patterns.

Once again detailed material flow testing is employed to determine the critical outlet dimensions.

5. Inserts

The concept of installing inserts performs two important functions. Firstly by being positioned above the outlet it relieves pressure on the opening exerted by the head of material stored that consolidates the material to form a stable arch and disrupt flow.

The second objective achieved by installing an insert cone is visible in the top view of the bunker where the opening around the insert when cut and folded out is in fact nothing less than a slot. Inserts can thus simply be categorised as devices employed to simulate slot openings in conical or square hoppers. Technically defined inserts expand the size of the funnel flow channel to approach a mass flow pattern [2]

By positioning the cone correctly the slot width can be determined in accordance with the required design parameters and the section below the cone encompassing the existing opening operates merely as a chute

Two of the more commonly known inserts are the inverted cone or pyramid and the patented Binsert® cone within a cone.

6. Flow Aid Devices

Flow aid devices have traditionally not been selected based on scientific principles as their selection and specification is derived from very low level decision making structures within operating plants desperate to overcome daily operational problems. Although they can be very effective in resolving flow problems they are typically active devices generating operating costs and employed to treat the symptoms of poor flow rather than the causes.

The purpose of flow aid devices is to assist gravity flow by applying external mechanical forces. The effect of this energy input on bin structures is often overlooked when flow aid devices are employed.

The more common flow aid devices employed are:

6.1 Air Cannons

Rapidly expanding gas in the form of compressed air is used to generate a shock wave that can be very effective in breaking arches or collapsing ratholes. The effective range of air canons is typically limited to 2m and it is often necessary to employ a number of canons that are discharged simultaneously.

In the case of air canons and vibrators the bin structures need to be suitably designed to withstand the shock and mechanical forces.

Air canons are not suitable for use on pressure sensitive materials that have not formed stable arches and may have the opposite effect of compacting the material and aggravating flow problems under certain conditions.

6.2 Vibrators

Vibration technology is the most commonly misunderstood retrofit technique whereby its application is limited to coarse materials experiencing arching problems (typically mechanical). In applications handling moist products with high compressibility they serve to compact these types of solids increasing the cohesive stresses.

Operation and maintenance costs are high when considering the effects of metal fatigue and shock loading when arches collapse.

6.3 Agitators

When considering the forces and power requirements of paddles and moving arms inside bins the application of agitators is immediately limited to smaller vessels where they can be very effective in overcoming arching and ratholing, increasing live capacity and mixing the material to reduce segregation.

The only significant drawbacks of agitators are their high operating costs and wear on moving components.

7. Feeder Modifications

As described in section 3.4, feeder interfaces are the most commonly neglected design aspect often left to feeder suppliers to specify. The interface between the bin and feeder is critical to its success and the solution to many flow problems is often found in the feeder interface modification.

Solutions may be as simple as venting a rotary valve or as complex as increasing the size or altering the type of feeder employed. The most common feeder retrofit entails changing conveying equipment used in feeder applications to proper feeding equipment.

8. Aeration

Fluidising materials through the introduction of low pressure air within the hopper section of a bin can be effective in achieving higher flow rates and eliminating flow problems.

In the majority of cases air must be of a high quality and dry to avoid moisture contamination. Air supply should be constant to avoid deaeration and material flow may be irregular due to varying levels of fluidisation.

9. Retrofit Guide

The following table derived and modified from [2] provides a reference relating to each of the bin retrofits above, evaluating the combinations in terms of their likelihood of solving each of the typical flow problems described. The ratings are indicated on a scale of 1 – 4 where 1 indicates extremely likely to be effective and 4 implies little likelihood of having any positive effect, selections rated 4 may have the potential to aggravate the problem.

TABLE 1 : MATRIX RELATING BIN RETROFITS TO FLOW PROBLEMS

	NO FLOW		Erratic flow	Flooding	Limited discharge rate	Segregation	Limited live capacity	Degra-dation	Bin Vibrations	Excessive power
	Arch	Rothole								
A. Modify Hopper										
i. Liner	1	1	1	1	4	1	1	1	1	1
ii. Transition hopper to replace cone	1	1	1	1	4	1	1	1	1	1
iii. Expanded flow	1	1	2	1	4	3	2	2	3	1
iv. Enlarge outlet	1	2	2	3	1	3	3	3	3	4
B. Inserts										
i. Inverted cone or pyramid	1	1	1	1	3	1	1	1	2	1
ii. BINSERT®	1	1	1	1	4	1	1	1	2	1
C. Flow Aid Devices										
i. Air cannon	1	2	3	4	4	4	3	3	4	4
ii. Vibrator (bin discharger, external, etc.)	1	2	3	4	3	4	3	3	4	4
iii. Agitator	1	1	2	2	3	2	1	1	3	4
D. Modify Feeder										
i. Screw	1	1	1	1	1	2	2	2	2	1
ii. Belt interface	1	1	1	1	1	2	2	2	2	1
iii. Rotary valve venting	1	4	2	4	1	3	4	4	4	4
E. Aeration										
i. Air permeation	3	4	1	3	1	4	4	4	4	4

ii. Fluidization	1	2	3	1	1	4	2	2	4	4

Note: **1** = high potential in overcoming flow problems; **4** = unlikely to have much benefit, may be detrimental.

10. Case Study - Effecting Mass Flow In Power Station Coal Bunkers

A recent project completed on the modification of a power station's coal bunkers employed the concepts of material flow described above to overcome the effects of arching and ratholing.

The financial implications of poor flow were significant with bunkers requiring constant lashing to maintain flow. Each of the 60 bunkers averaged 3 incidents of coal hang up per day that cost the entire power station between R 500 000 and R 1m per month in fuel oil, labour and load losses.

The existing design is illustrated in fig 4 where the existing wall angle is 36° from the vertical. Flow tests detailed showed that the existing lining would require a wall angle of 7 degrees and an opening size of 1.5m to produce mass flow.

Tests were conducted on various lining materials and it was determined that for the square opening a glass lining, which offered the lowest friction coefficient on this particular coal would require 23 degrees to produce mass flow but with an existing 36° wall angle lining on its own was not a solution that would overcome the problem.

It is evident from Table 1 that for "No Flow" problems the most likely source of a retrofit option could be found in hopper modifications, inserts and feeder modifications and as described hereunder all three of these concepts were employed.

As detailed in section 3b a plane flow or slot hopper produces an allowable wall angle of up to 12 degrees shallower than that of a square or conical outlet and the design centered on simulating a slot opening in order to achieve mass flow with a glass lining on the hopper with an existing 36° half angle.

An insert cone was selected to simulate a slot opening which together with the glass FLOWTILE lining produced an allowable hopper half angle of 33°. In order to overcome the 3 degree difference between the hopper half angle required to produce mass flow, the angle of the insert cone was increased to produce an overall hopper angle of 66 degrees.

The table feeders were modified to create a mass flow interface and although the flow rate was initially lower than required subsequent modifications created a positive plough to increase the discharge rate.

The structural analysis showed very high point loads being created at the cone's support beam attachments and additional stiffening was added to the bunker.

Through a combination of modern design techniques and low friction linings the bunkers were successfully modified and since commissioning in January 2002 have not experienced a single incident of coal hang up.

This design concept has also recently been successfully implemented in power station coal staiths.

The glass FLOWTILES employed in this application are not well known and further details are provided as an appendix to this publication where the liner selection criteria detailed above are evaluated. [4]

11. Wear Patterns in Storage Bins [5]

Very little research has been performed in the area of comparative wear testing with the only known wear testers being in Australia and the US. Research conducted by A.W. Roberts [5] reveals interesting data on the wear patterns in bins having conical and slot outlets as well as in funnel flow bins traditionally selected due to their flow patterns being typically material over material.

The research compared the wear profile of conical and plane flow bins having identical hopper half angles and opening dimensions and the typical results have been approximated in figure 5.

In the case of the conical outlet (axi-symetric bin) the maximum relative wear occurs at the outlet whilst the plane flow or slot hopper experiences its highest wear at the transition point between the hopper and vertical wall. The wear index at this switchover point on axi-symetric bins is however still very high and typically when retrofitting or designing new bins the common practice is to provide wear protection only up until this transition point. It can be concluded that for optimum life the wear protection in the vertical bin should be extended to a height of approximately 70 – 75% of the height of the hopper section.

Another phenomenon observed by Roberts in the operation of funnel flow bins which typically experience low wear in the hopper sections due to the flow of material always being on itself was that the material loading into the bin caused impact wear on the side walls weakening the structures.

This same phenomenon has been experienced in eccentric discharge coal mill bunkers in local power stations where the bins have only delivered 12 years of useful life as opposed to lined vessels in the UK and Botswana which have been in operation for over 50 years. Two local power stations have demonstrated the consequences of this wear profile with one of the bins experiencing critical and catastrophic failure. The cycling of the coal during loading as well as the uneven flow induced by poorly designed feeders led to a concentrated wear on the vertical walls of the hopper in the area directly behind the feeders. The outcome of the decision to limit lining to the hopper alone and not protect the vertical bin walls has resulted in a significantly reduced life and a repair cost higher that the initial cost of the bins.

12. Fundamentals of Chute Design and Modification.

The theory of chute design has been presented in various forms for many years yet chute blockages and high wear areas remain a very real problem in South African industry. There are many papers available on design principles for chutes and this is considered outside of the scope of this paper however as a result of numerous chute design audits it can safely be concluded that the single biggest contributing factor in chute design failures in South Africa is a direct result of a lack of appreciation for the effect of impact pressure on friction.

Stuart-Dick and Royal [7] illustrate in their paper that the first principle of chute design is to prevent plugging where after plotting the trajectory of material the impact pressure of the stream is calculated. This impact pressure has a direct effect on the internal angle of friction of the material as well as its measured friction angle on any particular liner. The equation for velocity after impact provided by Stuart-Dick and Royal [7] illustrates the effect whereby:

$$V_2=V_1\{\cos\theta - \sin\theta * \tan\Phi\}$$

Φ represents the friction angle derived from measured results on the shear cell as illustrated in fig 7 and θ represents the angle between the chute and the incoming stream.

It stands to reason that there exists combinations of Φ and θ that will reduce V_2 to zero and cause the material to build up to the point where it is steep enough to permit gravity flow once θ is sufficiently low. Very often if the chute's cross sectional area is too small to accommodate this build up and the volume of the stream the chute will plug completely.

When retrofitting chutes exhibiting this type of problem two primary methods are employed. Firstly liners are changed to obtain a lower friction characteristic (Φ) and in more extreme cases bash plates are used to alter the path of the trajectory in order to lower the impact angle (θ).

An example of a successful retrofit of this nature is again available from a local power station where the low friction ceramic tile (Line-OX SF) was developed specifically to overcome blockages. The bash plates or bonnets were themselves building up with ash to the degree that the chutes plugged completely. Following the commissioning of this retrofit the throughput was increased from its design 600 tph to a staggering 1 200 tph and has run blockage free for over 18 months now at this increased rate.

The theory provided by Stuart-Dick and Royal [7] can be further extended to include the combination of various lining materials in different areas of chutes to control velocities more accurately and construct chutes more economically employing these liner combinations in the areas in which they are most suitable. Fig 6 illustrates a velocity controlled chute designed for ROM coal using dead boxes in high impact points, 500 BHN liners and low friction ceramics in the lower impact and sliding zones in order to control the stream velocity and match it as closely as possible to that of the receiving belt, whilst minimising impact and kinetic energy on the belt.

13. Conclusion

The case studies and examples clearly illustrate that the application of material flow technology in chute and vessel design is not limited to greenfields development but can be applied with tremendous benefit to existing plant. In the South African context however the responsibility for implementing modifications of this nature generally lies with newly qualified project engineers or operating personnel without the exposure to available technologies that then generally results in the selection of a flow aid device that on the rare occasion when successful merely mask the symptoms whilst incurring large operating costs.

14. References

[1] Marinelli, J. and J.W. Carson: Preventing solids flow problem; Powder and Bulk Solids 1986

[2] J.W. Carson and D Stuart-Dick: Retrofits can correct Flow Problems: Bulk Solids Handling 1992

[3] W. Deijs: Plant Design Using Advanced Technologies, Bulk Solids Handling 2001

[4] A. Bresler: Glass and Glass Composites for use as Liner Materials, Composites Conference RSA, 2002.

[5] A.W. Roberts: Tribology in Bulk Solids Handling 1991

[6] Tunra course notes 6.1 – 6.16: Influence of surface friction and adhesionon chute design and handling plant performance.

[7] D. Stuart-Dick and T.A. Royal: Design Principles for Chutes to Handle Bulk Solids, Bulk Solids Handling 1992.

15. Author's CV

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Work History

Engineer AECI Modderforntein 1991 - 1997, various positions from projects to plant engineering and new business development

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Member – Material Flow Solutions cc 2003 - formed in association with Bulk Solids Flow SA performing materials handling functional design and consulting whilst aiming to ensure the long term availability of material flow technology in South Africa.

Major achievement in field – Winner of Institute of Tribology Technical Achievement Award for composite glass and alumina ceramic low friction tile lining May 2002

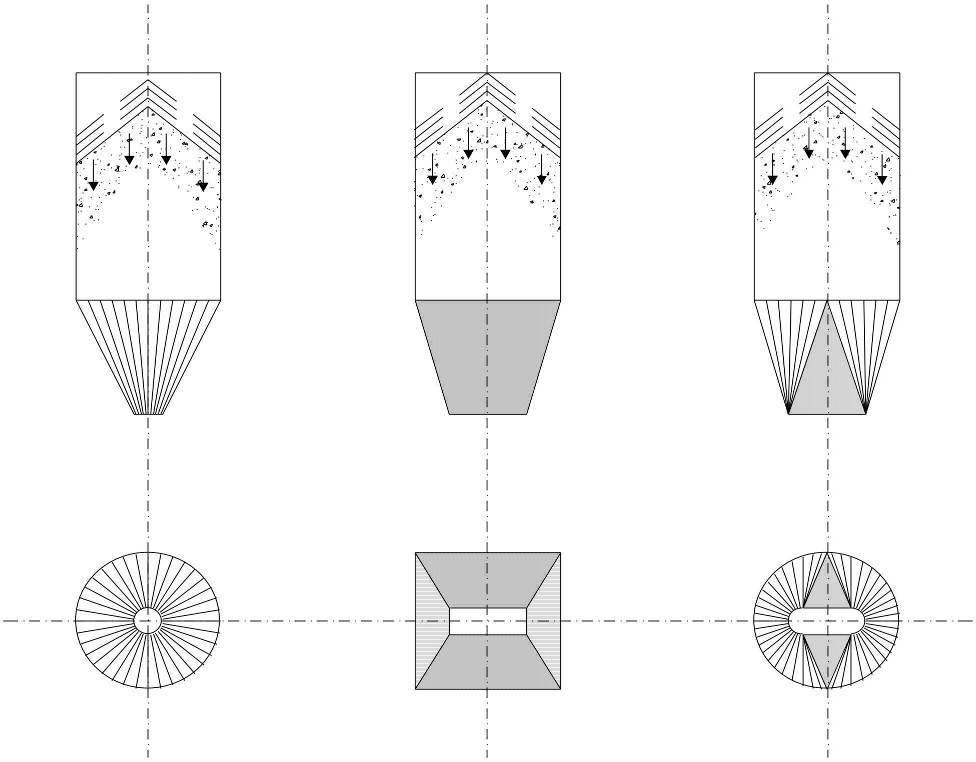

Fig. 1: Mass Flow Bin & Silo Arrangements

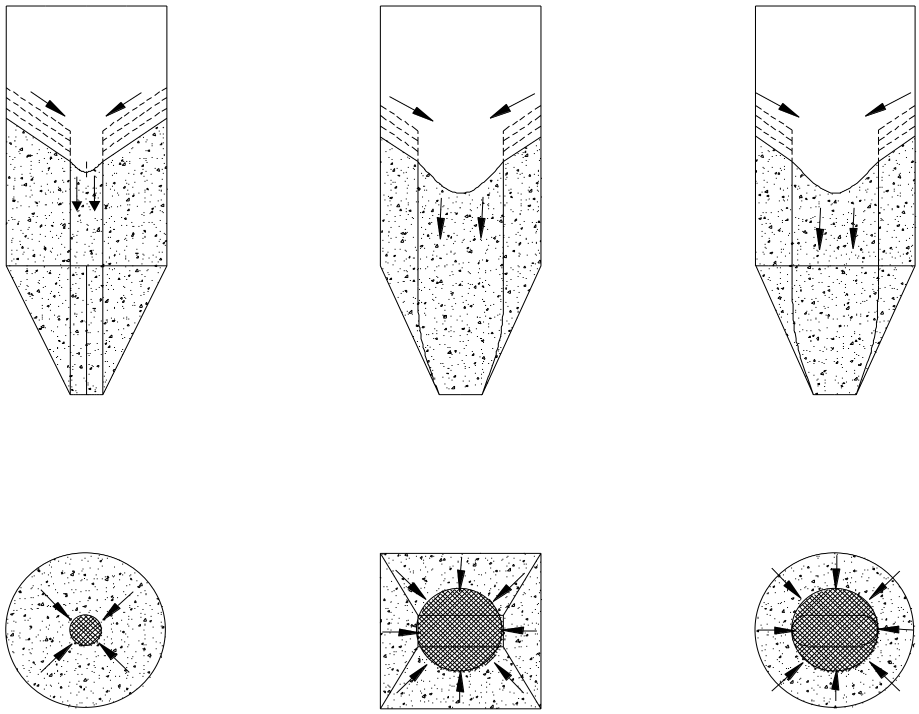

Fig. 2: Funnel Flow Bin & Silo Arrangements

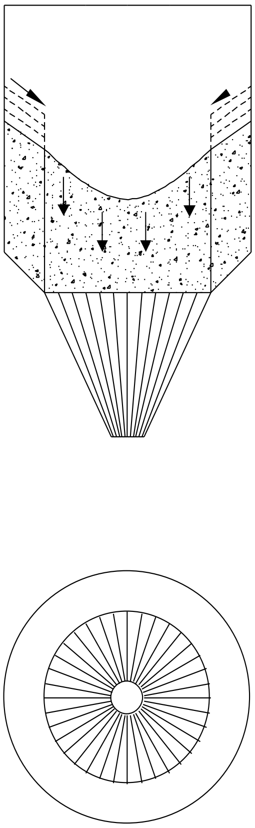

Fig. 3: Expanded Flow Silo Arrangement

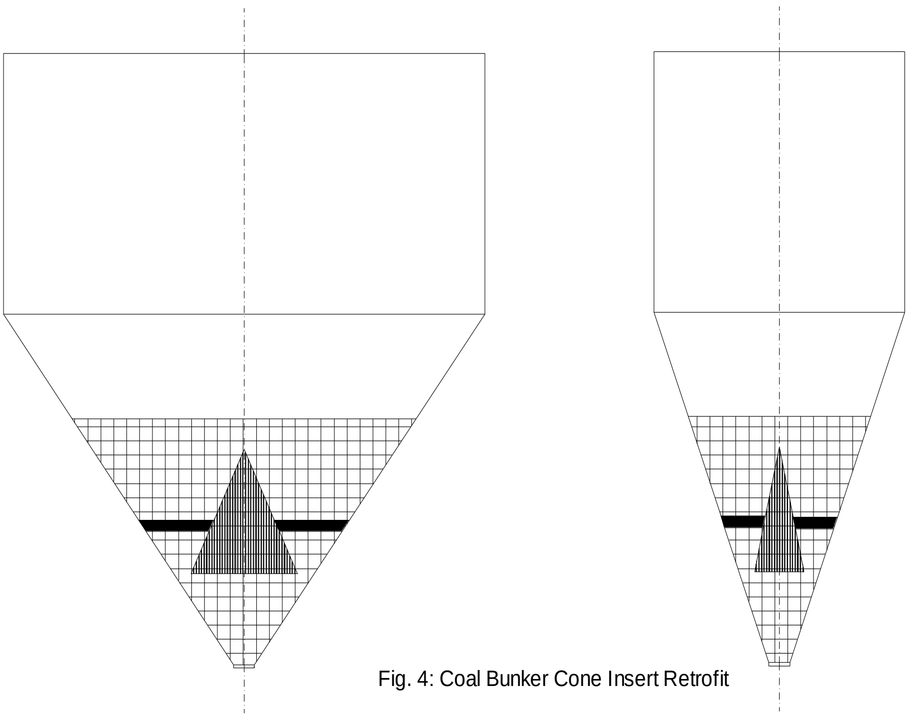

Fig. 4: Coal Bunker Cone Insert Retrofit

Moisture Content	8%	8%	17%	17%
Time Condition	0hrs	48hrs	0	48 hrs
Opening Size Reqd – **Conical** **Slot**	 1.15m 0.58m	 1.56m 0.78m	 1.24m 0.62m	 1.47m 0.73m
Wall Angles Steel – **Conical** **Slot**	 12° 22°	 14° 24°	 12° 22°	 13° 23°
Wall Angles UHMWPE – **Conical** **Slot**	 15° 25°	 18° 28°	 14° 24°	 15° 25°
Wall Angles Glass – **Conical** **Slot**	 20° 30°	 21° 31°	 21° 31°	 23° 33°

Table 2: Power Station Coal Test Results

Liner	**Coal**	**Char**	**Concentrate**
Ceramic	18°	16°	11°
Glass FLOWTILE	25°	27°	16°
Line-OX SF™ (new)	25°	27°	16°
Line-OX SF™ (Worn)	21°	23°	13°
Polished Steel	18°	16°	16°
Carbon Steel (400BHN)	19°	23°	11°

Table 3: Comparative Hopper Half Angles

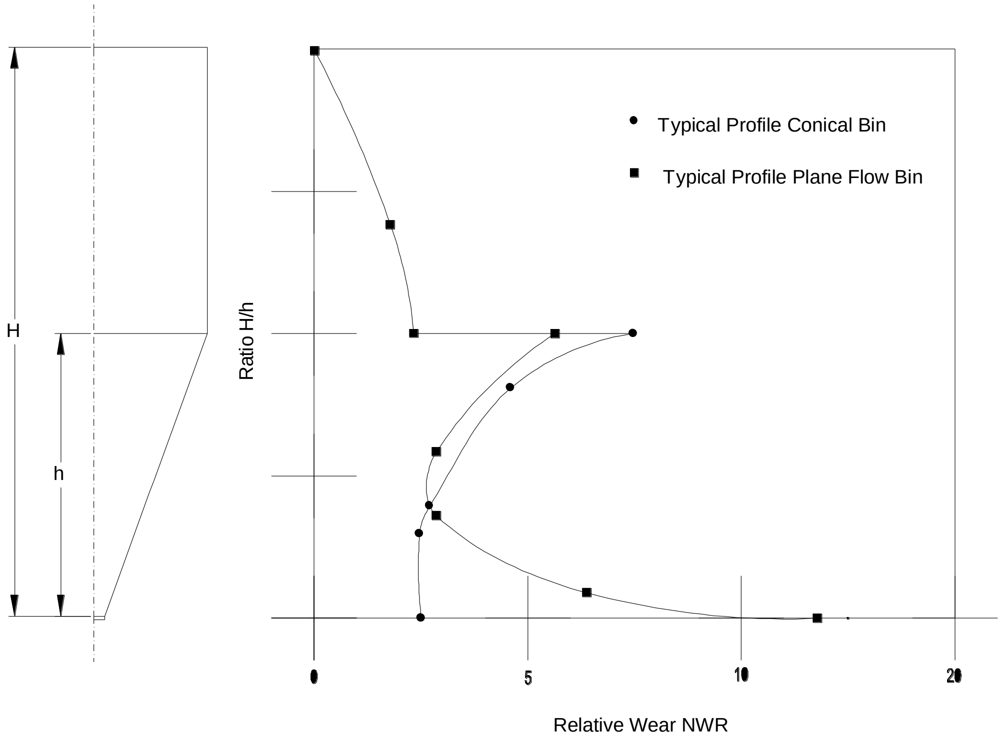

Fig. 5: Comparison of Typical Relative Wear Profile
for Conical and Plane Flow Bins

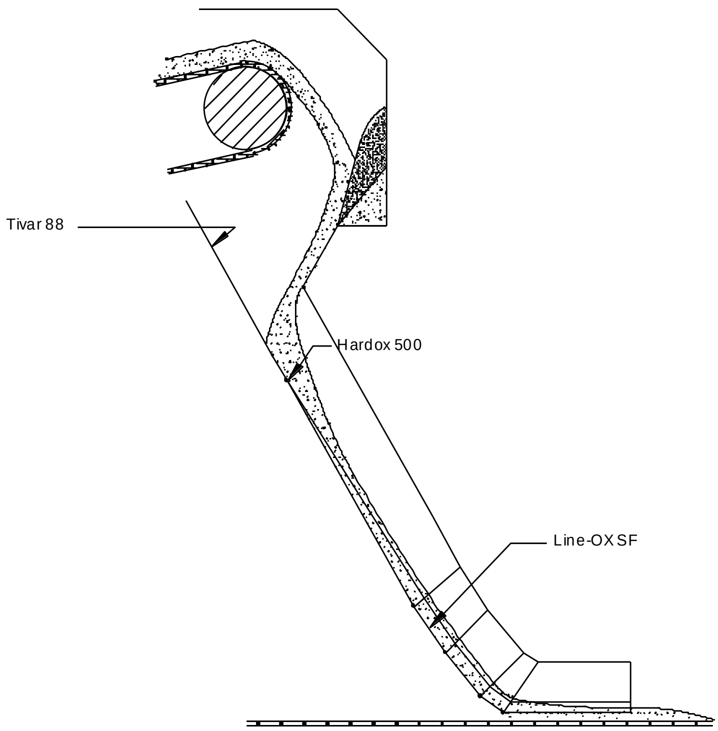

Fig: 6 Complimentary Chute Liners

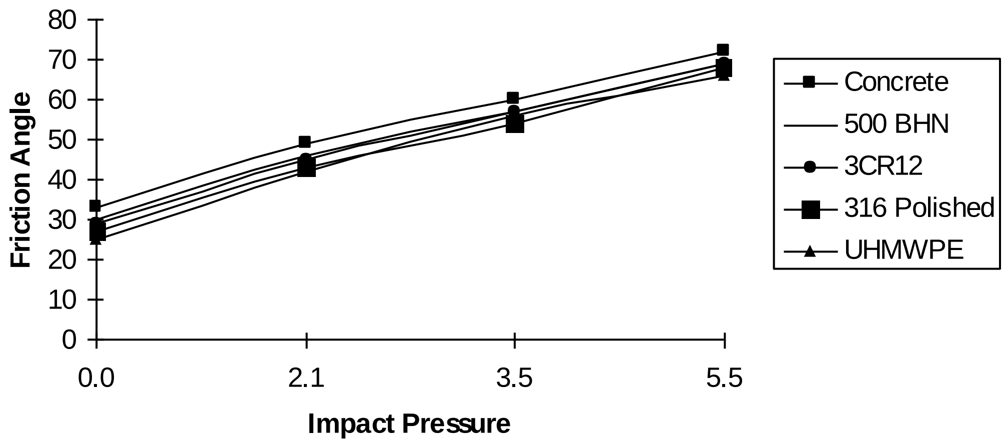

Fig 7: Effect of Impact Pressure on Chute Friction Angle

Appendix 1: Glass Linings in Bulk Storage Applications [4]

Glass tile linings better known as Ashlars™ or FLOWTILES™ have been employed in bulk storage applications for over 60 years. For many years inferior adhesives and installation practices resulted in failures that naturally impacted on the demand for glass linings on a global scale.

In 1996 new adhesives were developed in conjunction with the CSIR that have dramatically improved the application of glass linings in South Africa and the product has successfully found new applications ranging from coal to slag, lime, gypsum and many other cohesive materials that have historically proven to be difficult to handle.

Like all lining materials the appropriate design considerations are essential to its successful application. With a typically low co-efficient of friction, low cost and good durability glass Flowtile linings have proven to be a viable alternative to traditional lining materials.

When considering the factors outlined in section 4.1 glass tile linings in industrial bulk storage applications do offer certain defined benefits. As a practical example considering the specific case of power station coal bunkers constructed from steel glass can be evaluated as follows:

5.1 Surface friction and adhesion

Although friction coefficients are very specific to the bulk material being tested together with parameters such as consolidation pressures etc table 3 illustrates the hopper half angles required to produce flow on various liner materials. It is important to highlight that these figures are indicative only as large variations are evident even between coals from different sources.

Typically in new mass flow hopper designs, low friction liners such as glass facilitate a wall angle of up to 10° shallower than that of unlined steel. This enables an overall saving in bin height and hence the mass of steel required for an identical live capacity. In addition every meter of height that is saved translates to between 4 and 5 meters of conveyor required to load the silo.

5.2 Resistance to Abrasive Wear

Little work has been completed on the measurement of abrasive wear in South Africa and the only two known abrasion testers are in Australia and the US. Practical experience however provides some indication of the resistance of various liners to abrasive wear.

It is interesting to note that wear itself is influenced by friction characteristics and surface roughness as shear forces are lower and wear is directly proportional to boundary pressure.

As detailed above when comparing unlined coal bins in South Africa with glass lined bins both in Botswana and the UK, the useful working life of South African coal bunkers was limited to 12 years as opposed to 50 years on lined bunkers. In addition there remain bunkers in service in South Africa that have in other applications delivered over 50 years of active service with glass linings.

When considering abrasive wear the advantage of employing a sacrificial wear surface that is replaceable is significant when considering the maintenance cost of fabricating a new bin where the structures have been designed without liners. A local power stations recently experienced critical thickness problems on their bin walls as once the steel has worn to 30% of its original gauge it is no longer capable of carrying the loads imposed by stored coal. Liners were installed following repairs as they are capable of providing a wear life equal to 100% of their thickness with no impact on the structural integrity of the bins.

5.3 Resistance to Impact

Contrary to popular perceptions, glass liners are capable of withstanding a fairly high degree of impact. They have to date delivered over five years of active service in train tippler hoppers that offload 80 ton coal wagons. Minor aesthetic damage has been caused by tramp iron however the liners continue to perform unaffected.

The impact resistance of the glass lining is achieved through the uniform bonding of the liners to the substrate whereby all impact forces are absorbed by the backing with the glass linings merely experiencing a compressive force.

5.4 Resistance to Corrosion

When considering the use of glass in laboratory and domestic applications it is evident that glass is inert to most forms of chemical attack making it a popular selection for lining leach and concentrate type bulk storage vessels.

In the case of the power station bunkers corrosion resistance was not considered in the decision to eliminate liners in the original design and corrosion induced wear has accelerated the attack on the steel bin walls reducing their useful life dramatically.

5.5 Method of Attachment

The two most significant advantages offered by glass through its method of attachment are the speed of installation and the fact that the liner provides an impermeable barrier to resist corrosion of the structures.

By way of practical example a recent major platinum project saved over nine weeks of total project duration by employing glass linings over alternatives. When considering the impact of daily production gains the revenue generated was substantial.

In the case of the coal bunkers had the decision been taken to line the coal bins initially the method of attachment would have been an important factor so as to select a liner that seals the bin walls to prevent moisture and fine coal build up behind the liners that has the potential to erode the structures.

5.6 Costs

The capital cost of liners is not high when considering the overall effects as detailed above. These translate to direct savings in other capital cost areas and reduce maintenance costs accordingly.

In the case of the coal bunkers the decision not to install liners in these particular power station bins resulted in a 75% reduction in useful life, maintenance costs exceeding the original capital cost and a disruption to the flow patterns that influenced operating costs where bunkers required intermittent lashing to maintain flow.