A Radical Approach to the Vertical Conveyance of Bulk Materials: the Olds Elevator

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1. Abstract

Totally new concepts rarely arise in the mature field of solids handling. Until recently, the vertical transportation of bulk materials has been by bucket elevators, special belt conveyors, chain and flight machines, screw elevators, aero-mechanical conveyors (disc and wire) and various types of pneumatic systems. A new development that exploits a fundamentally different elevating mechanism by rotating a tubular casing around a static helical screw, is establishing itself as an advantageous alternative to some of these devices. This innovative concept enlarges the scope of selection for those involved with bulk solids handling by overcoming many of the operational, installation and product-related drawbacks and limitations of conventional machines. It equips Industry with a new versatile tool, a vertical elevator for bulk materials that has various unique characteristics, including the ability to be used directly as a variable rate feeder.

Figure 1 (left) Rice Propulsion, a large propeller manufacturer in Mazatlan, Mexico, was seeking an efficient method to elevate foundry sand to a height of 6.4 m (21 feet) to feed their sand mixing machine. The foundry had been using a crane to hoist bags of sand up to workers who emptied the bags into the mixer's hopper. The foundry owners considered purchasing a pneumatic conveyor to elevate their sand. A 100 mm (4-inch) diameter Olds elevator™ vertical conveyor was supplied at a fraction of the cost of the pneumatic conveyor. It delivers sand at a rate of 6 tons per hour. No maintenance has been necessary since installation in January 2004.

2. Introduction

Perhaps new ideas are best developed without the cluttered backdrop of established techniques clouding one's thoughts. When Peter Olds an Australian engineer faced the task of elevating sand for metal casting moulds five metres above his foundry floor, he found that traditional devices fell well short of his objectives for economy, compact size, quietness and maintenance free operation. Olds returned to first principles and reversed the normal screw conveyor design, driving the outer casing to rotate around a stationary inner screw. Following the successful testing of a small prototype, a full size machine was soon installed and performing well in his foundry and an application granted for Patent protection. Demonstration and tests astounded many visitors who witnessed the elevation of peas, beans, bread crumbs, coal fines, dried capsicum, dog biscuits, flour, plastic powder, wet and dry sand, rice, coffee beans, granulated coffee, macadamia nuts, steel shot, peanut kernels, various grains and seeds, sugar, wet sulphur slurry, dry sulphur and even molasses.

Word spread quickly and an Olds Elevator was soon working at the foundry of the Rice Propeller Co. in Mexico (figure 1). A second machine was employed locally for elevating of macadamia nuts (figure 2), another for lifting sand in Singapore (figure 3), and two larger machines installed at Bean Growers Australia, Kingaroy, followed by a further order for two more (figures 4, 5). Olds Elevators are now made under license and can be found working in USA, England, Mexico and Singapore with the key components supplied from Australia.

This paper reviews the development of the Olds Elevator since its beginnings in December 2002. It discusses the operating principle and examines the many benefits of this new elevation mechanism, in contrast with traditional methods of elevating bulk materials. The paper will review case studies of applications, showing the versatility and capability of the elevator. Finally, it will examine the research and development currently underway, on three continents, for the wide applications that are emerging for this new technology.

Figure 2 (left) – Macadamia nuts are gently elevated with this 100 mm (4") diameter Olds Elevator.

Figure 3 (right) – The elevator being used for lifting sand in a foundry in Singapore.

Figure 4 – Completed 100 mm (4") diameter by 7 meters and 152 mm (6") diameter by 10.7 metres lift Olds Elevators for Bean Growers Australia at Olds Engineering, Maryborough.

Figure 5 – 150 mm (6”) by 7.5m and 7 m lift Olds Elevators at Bean Growers Australia.

3. New vertical elevator design: the Olds Elevator

Operating Principle

The new vertical elevator design has only one moving part in contact with the bulk material, a tubular casing with its attached in-feed scoops and delivery slinger, that rotates around a static screw. Generous clearance is provided between the static screw’s diameter and the tube (figure 6). This clearance is an important design feature that prevents damage to the bulk material, casing wear, metal-on-metal contact and improves energy efficiency. In-feed pick up scoops at the lower end of the rotating casing gather the bulk material from the feed supply into the rotating casing. The elevator is therefore self-feeding at a controlled rate as it rotates. The top of the casing has an overlapping ‘slinger’ seal that prevents material leaking from the surrounding discharge chute. Bulk material in the feed hopper typically covers the pick-up scoops (figure 7). As the casing rotates, material is directed into the rotating casing by the pick up scoops that rotate with the casing. Friction against the inner wall of the casing rotates the material and causes product resting on the screw flight to be driven gently up the inclined face of the screw. Back leakage of materials down the screw clearance is prevented by the rotating boundary layer of material that forms on the inside wall of the casings and seals the annular clearance between the casing and the static screw diameter. The bulk material itself forms an effective dynamic seal and stabilizes the central position of the screw to inhibit casing contact (figure 8). This contrasts dramatically with the dynamic leakage that takes place in a conventional screw elevator that offers little resistance to the whirling potential of the rotating screw (figure 9).

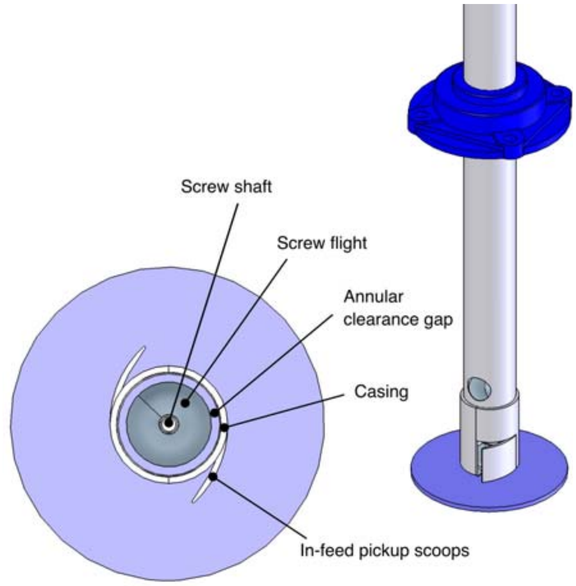


Figure 6 – In-feed pick up scoops are attached at the bottom of the elevator.

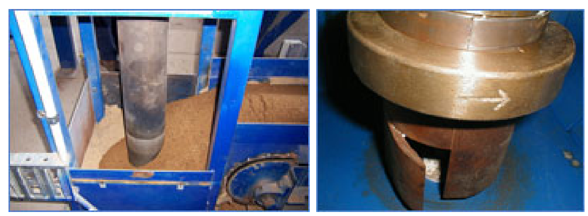


Figure 7 – The bulk material can be easily picked up near ground level (left), being fed by the two rotating in-feed pickup scoops at the base of the casing (right).

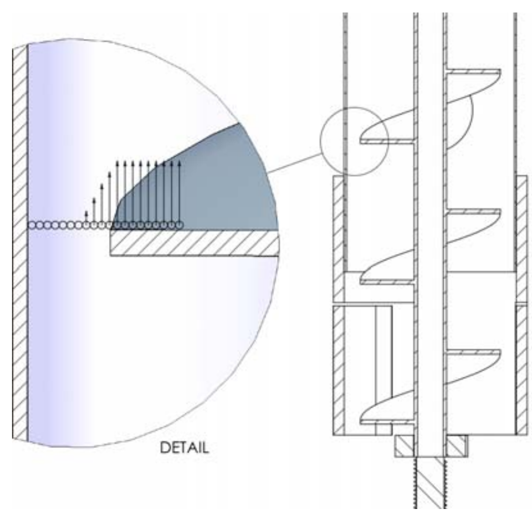


Figure 8 – Enlarged view of the boundary layer that dynamically seals the annular clearance gap between the screw and rotating casing.

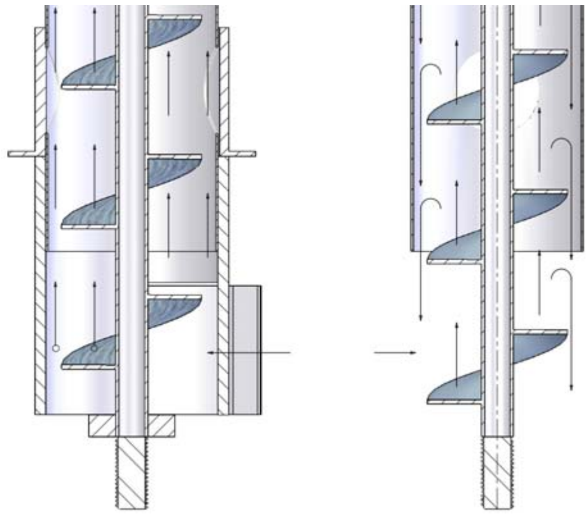


Figure 9 – Comparison of elevation mechanisms of (left) the Olds Elevator where fall back is prevented by the sealing boundary layer of rotating product and (right) the conventional rotating screw conveyor showing product fall back in the screw clearance gap.

The bulk material flows smoothly and continuously up the screw, to discharge evenly over the 'slinger' into the surrounding discharge chute (figure 10). The delivery rate is directly related to the rate of rotation of the casing. Therefore consistent control of the product delivery rate is possible – in fact from any rotational speed above 0 RPM.

Figure 10 – Top of the 7.9m (26 foot) elevator being tested at Olds Engineering, showing discharge hopper, drive pulley, bearing, and Stainless steel 100mm (4”) O.D. rotating tube.

Further explanation and comments

The in-feed scoops control the rate of handling and deliver material into the casing with a pressure that initiates motion up the lower portion of the screw flight. The internal mechanism then takes over to move the material along the inclined face of the screw flight by frictional drag of the product on the rotating boundary layer. This sealing and elevating motion of the product is reinforced at the inlet region by further material entering the in-feed scoops. The collection and transfer of material takes place in settled conditions, rather than the dilated turbulence of a dynamic vortex. The density difference and quiescent movement allows a greater mass of material to be elevated.

The effectiveness of the mechanical extraction of material from the feed hopper by the rotating scoops contrasts sharply with the resisting pressure offered by prior contents in the rotating screw of a conventional screw elevator. Instead of needing a steep inlet chute at one side of the casing to generate the horizontal pressure to overcome the centrifugal force of rotating product, the new elevator offers a flow-gathering dimension larger than the casing diameter virtually at floor level. This enables difficult flow materials to be offered to the machine at low level via a mass flow inlet section on the feed hopper, whereas the bottom bearing and seal of a standard screw elevator, followed by a steep inlet chute on one side of the casing that extends some distance up the length of the casing inevitably means a high rim height and/or low holding capacity of a conventional feed hopper, even for free flowing products. Difficult flow materials usually require a separate feed screw to deliver the bulk material into a standard form of screw elevator.

It was initially thought the casing speed would need to generate sufficient centrifugal force to maintain the annular boundary layer to create an effective seal against back-leakage. In reality, the elevator delivers product at any rotational speed above zero RPM in a flooded condition, similar to a horizontal screw feeder operating in flooded mode. The machine capacity is determined by the mechanics of in-feed scoops, but is ultimately limited by the ability of the subsequent conveying screw section to transfer the product along the screw face. A key design feature is therefore to optimize the relationship of these features. A crucial feature of screw helix angle is that the frictional drag imposed by shearing contact between the product resting on the screw flight surface and the rotating boundary layer must exceed the frictional resistance and lifting effort of the product sliding up the flight surface. In practice, slippery and spherical products such as beans, steel shot and round macadamia nuts elevate easily by this method. As internal friction is normally considerably higher than sliding friction on a smooth metal surface, a ratio of screw pitch equal to the screw diameter can normally be employed.

Most machines made to date utilize twin in-feed scoops on the rotating casing. This is superficially attractive as a symmetrical feature to avoid out-of-balance forces on the casing. A single in-feed scoop version (with an opposite balance weight) is beneficial for delicate handling, sensitive feed control and to enlarge the swept pick-up area for difficult flow or larger particle size products. It is essential to ensure that the elevating capacity is not exceeded by the collecting mechanism otherwise some material in the flow path of the scoop will move around or over the scoop instead of into the casing. Optimization needs to be tempered with a margin of safety to deal with variable product conditions. A feature of the elevator is that, as with a normal screw elevator, it remains full of product unless the machine is run on for a while after the feed hopper empties, and even then will not completely self-clear. This means that a free flowing product will tend to run back down the casing when the elevator stops and the machine has to re-start with a section of the casing full. Long elevators may have a slightly shorter pitch in the lower section of the screw, to give a better wedging action and allows material to accelerate away when it reaches the longer pitch section.

4. Contrasting the Olds Elevator with conventional screw elevators

Prototype testing of a 100 mm diameter elevator indicated this new method has at least twice the flow capacity of a conventional vertical screw elevator (figure 11), uses less energy, creates less dust and has lower noise levels.

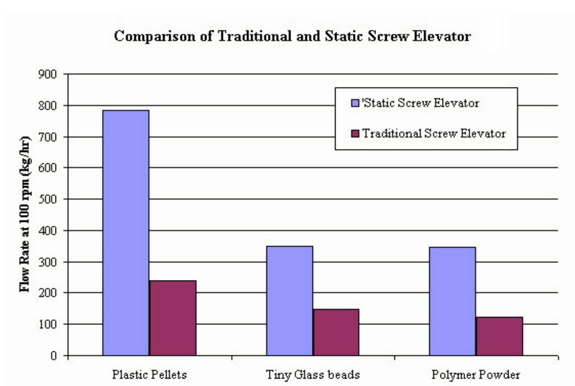


Figure 11 – Flow rate comparison for Olds Elevator and traditional screw-driven elevator.

With the obvious similarities between the Olds Elevator and vertical screw conveyors (both employ the use of screws and cylindrical casings) it is important to identify the differences in how they handle bulk materials. Screw conveyors are ubiquitous in the field of bulk material handling. Their operation has developed little over the 2,200 years since Archimedes discovered the utility of elevating water with an inclined screw. Screws are effective horizontal conveyors and metering feeders for a broad range of bulk materials. However, as screw conveyors are inclined their handling capacity deteriorates and the limit of gravity sliding down the face of the screw flight is quickly reached. At inclinations steeper than 30º more than half of the spectrum of bulk materials requires an alternate elevating technology, as screw conveyors are no longer practical. Where a screw conveyor's performance is best when horizontal, the Olds Elevator's perform best at 90º. Olds Elevator can also be tilted and tests at 45 degrees recorded no reduction in delivery rate. Combined with metering capabilities, this provides a powerful new tool for the process engineer.

CEMA's *Screw Conveyors for Bulk Materials* (Book No. 350) lists 433 different bulk materials that are suitable for conveying via screw. Less than 37% (160 of 433) of these bulk materials are indicated to be suitable for handling by vertical screw elevators. A partial list of bulk materials is shown in the following table that have been successfully elevated by Olds elevators, although they are specifically identified as unsuitable for elevation via a vertical screw elevator by CEMA, the Conveyor Equipment Manufacturers Association.

Material deemed unsuitable for conventional screw elevators by CEMA	**Elevated by Olds Elevator**
Barite	Yes
Beans - Navy, Dry	Yes
Bread Crumbs	Yes
Carbon Black – Pelletized	Yes
Casein	Yes
Cocoa Beans – Whole	Yes
Cocoa Beans – Nibs	Yes
Corn – Seed	Yes
Gypsum - Calcined, Powdered	Yes
Gypsum – Calcined	Yes
Plastic powder	Yes
Sand - Dry Bank, Damp	Yes
Sand - Dry Bank, Dry	Yes
Sand - Foundry, Shake-Out	Yes
Sand – Silica	Yes
Soap - Beads or Granules	Yes
Soap - Detergent	Yes
Soap - Powder	Yes
Soybean - Whole	Yes
Sulphur	Yes

Initial tests demonstrated one machine handled a wide range of materials from wet and dry silica sand to shredded rubber tyres without modification.

5. Performance and features summary

Feeding and pick-up performance

- Pick up is at the lowest point of the rotating tubular casing, and can be at virtually floor level.

- The in-feed scoops give a positive, controlled input of material that is volumetrically proportional to casing speed, so the machine can be used as a self-regulating variable rate feeder, whereas other elevators generally need to be fed by another piece of equipment that has to be matched with the loading of the elevator.

- Flow rate accuracy and repeatability trials conducted on dry silica sand indicate a percentage error of +1.3% of sample average at 2 Sigma based on 15 consecutive samples of 100 seconds and 175 lbs. sample weight. For sulphur pastilles an error of +0.83% of sample average at 2 Sigma based on 20 consecutive samples of 45 seconds and 100 lbs. of sample weight

- The active collection area extends to the swept tip diameter of the scoop(s), to provide a large effective flow channel to a mechanically extracted region. The feed hopper can diverge from the scoop tips as a mass flow, expanded flow or a non-mass flow channel, to suit the nature of the bulk material being handled, thereby maximizing the hopper holding capacity. Feed material can be entered from any or all sectors of the machine's periphery.

- No leakage can take place at the base of the elevator, whereas bottom screw elevator seals are a notorious source of leakage and maintenance due to the proximity of the agitated product.

Discharge

- The discharge of material is always a smooth, steady stream, without pulsations experienced with screws and bucket elevators.

- The material exits from the casing over a full 360° spread, so the discharge can be divided into two or more sectors, with the discharge rate to each being directly proportional to the percentage of the casing periphery taken by the respective chutes.

- As the discharge end on smaller machines has no bearings, seals or drive, discharge can be close to the ultimate headroom. With no seals or bearings at the discharge the elevator is well suited to handling difficult hot, abrasive or corrosive bulk materials. Vanes can be attached to the top of the rotating casing to accelerate poor flow materials from the discharge head and away from the machine.

- The machine can also to be tilted to suit application and plant design without any reduction in delivery rate.

Dust minimization

- The risk of dust explosions within the elevator is virtually eliminated. Metallic contact is inhibited by the boundary layer of material. The bulk material slides coherently upward on the inclined face of the stationary screw with little relative motion between individual particles. Air intake is limited to that existing in the voids of the feed material.

- Discharge from the rotating casing is a smooth, continuous action, thereby minimizing the creation of dust.

- No dust escapes from the feed point as the intakes are located below a head of product in the hopper or sump and the head of material acts as a seal.

Drive, seals and bearings

- The bottom bearing and shaft seal (necessary in a screw elevator) are eliminated. Bearings are hence not in close proximity with the agitated product and dust, and valuable headspace is saved. At all points, bearings are totally external to the product flow and accessible for maintenance, if required (figure 12).

Figure 12 – bearing fitted to elevator, and bearing housing.

- There are no seals or components requiring lubrication adjacent to the product. Leakage is eliminated and product contamination totally avoided.

- The drive can be located at any position along or around the casing, above the discharge head assembly and even located below the feed hopper* to suit application restraints, easy mounting, wiring and access. (* seals would then be necessary)

- The static screw allows the stiff casing tube to rotate without generating internal rotational forces on the screw or the product other than transfer by contact friction, so shear and dilated vortex motion in the conveyed product is reduced, allowing delicate products to be handled with little damage.

- A single overhead bearing configuration above the discharge head allows deep immersion in special applications. Suitable guide rollers or liquid lubricated rubber bearings on the lower end of the rotating casing can be fitted if required.

6. Combined feeder/elevator

The facility to use a single machine with a low pick-up as an elevator and volumetric feeder could have dramatic implications in future plant design and the layout of bulk materials handling equipment (figures 13, 14). Currently, plants that feed a process via volumetric screw feeders often need to use overhead hoppers to gravity feed the screw feeders. These hoppers, in turn, must be filled by yet a third piece of equipment like a bucket elevator or pneumatic conveyor. The ability to take material from floor level and feed a process directly as a controlled volumetric feeder/elevator offers significant saving in cost, floor space, headroom and maintenance.

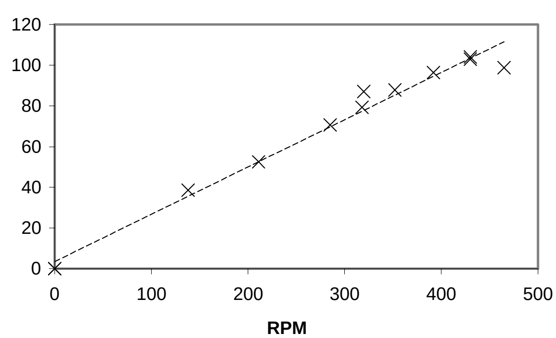
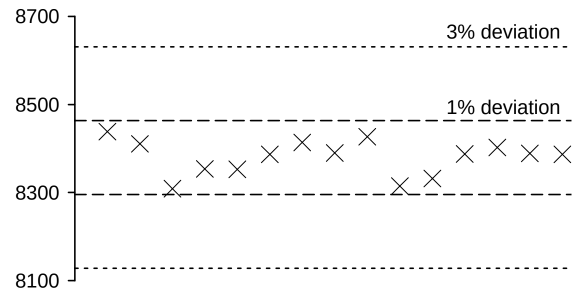


Figure 13 – The flow rate (CFH) for the Olds Elevator is directly proportional to the rate of rotation of the outer casing. Therefore, it can be used as combined elevator and feeder.



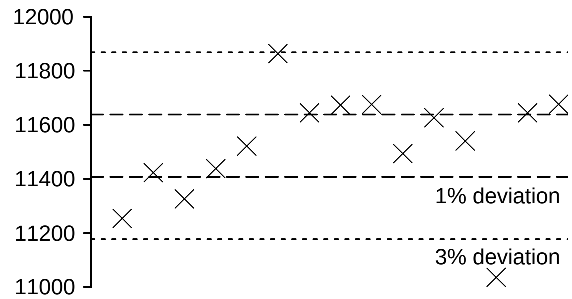


Figure 14 – In preliminary tests the Olds Elevator was shown to be a reliable feeder over 15 trials of foundry sand elevation, with flow rates ±5% of the average. Furthermore, 96.6% of the tests had less than 3% variability and 70% of the tests showed variation of <1%. Better results are anticipated using more accurate measuring and testing equipment and tighter controls. The elevator used for the test is a basic machine without the ideal feed hopper or features that enhance performance.

7. Case Studies

Beans and Grains

In 2004 Bean Growers Australia (BGA), Australia's largest bean processors sought to replace three bucket elevators that were deployed to feed various sorting, grading and packaging units with five inclined belt conveyors with U-shaped belts. Prior to installing the inclined belt conveyors, BGA learned about the Olds Elevator.

The Kingaroy facility ultimately replaced their three bucket elevators with two Olds Elevators, saving thousands of dollars in capital costs and recovering significant floor space at their plant (figure 15). The elevators are fitted with variable speed drives to control the flow rate. A large reduction in the ambient noise level of the plant was also realized. Recently, BGA placed a repeat order for two further elevators to upgrade their bagging section. The two initial Olds Elevators were both 152mm (6") diameter, one 7 m high and the other 7.5 m high. The two further are 152mm (6") diameter by 10.7 m high, and a small unit with a 101.6 mm (4") diameter by 8 m high.

Figure 15 – 152 mm (6”) by 10.7 metres lift Olds Elevator is lowered into position at Bean Growers Australia, Kingaroy plant April 2006.

Gypsum

A leading American gypsum company processes gypsum powder by feeding the gypsum into a calciner to drive off water. Currently, their calciner is fed by a horizontal volumetric screw feeder 6m (20 feet) above floor level and filled by gravity from an overhead hopper fed by a 12m (40-foot) tall bucket elevator. A 100mm (4 inch) diameter by 4,5m (15 foot) tall Olds elevator was purchased for evaluation by their R & D group. Extended trials confirmed that the flow rate of the elevator was precise enough to act as a volumetric feeder, indicating that a machine scaled up to the necessary could use a single 7.6 m (25 foot) Olds Elevator in the place of a 12m (40 foot) bucket elevator, an overhead storage hopper and separate volumetric screw feeder to free up the third and fourth stories of the plant. These plants are currently operated at maximum capacity. Converting to Olds Elevators could increase production capacity within existing floor space.

Sanding of Rail Locomotives

The Olds Elevator has been adapted into the '*Sand-piper'*, a portable unit, featuring a built-in sand hopper with a 1.25 tonnes capacity (figure 16). Rail locomotives carry sand in boxes, which is dispensed onto the railway tracks to aid traction in slippery conditions. The Sandpiper refills a locomotive's sand boxes in minutes, often saving a time-consuming trip to the service yard. Various models are in use in Queensland and New South Wales including a self-propelled version with wheels and Olds Elevator electrically driven from an onboard diesel generator (figure 17).

Figure 16 – The Sandpiper uses an Olds Elevator for refilling sand boxes in locomotives.

Figure 17 – The Sandpiper is self-contained and self-driven.

8. Research and development

Larger diameter units

An important step is to establish the limits of height and diameter of this new technology. There seems virtually no limit to the height of the machine, although a practical limit of 10 metres is currently recommended. The cost per unit volume of material handled reduces with increasing elevator diameter. To date 63, 76, 101 and 152 mm (2 ½", 3", 4" and 6") diameter elevators are in use. A 203mm (8") diameter elevator is under construction in the U.S to elevate ceramic beads to a height of 6m (20 feet) at a rate of 25 tonnes per hour. A 254mm (10") diameter elevator section was recently tested in Australia for R & D.

Tests with the 254 mm (10”) diameter machine indicate the Olds Elevator can be successfully scaled up to handle larger industrial applications. This will require solids handling engineers to rethink their plant designs to take advantage of the elevation and metering capabilities of this unique tool. This will require larger licensed manufacturing partners to be selected, as well as redesigning of bearings and drive systems (figures 18, 19).

Figure 18 – Empty 254 mm (10”) diameter test elevator.

Figure 19 – 254 mm test Olds Elevator being rotated by hand delivers fine sand without any fall back through the 12.7 mm annular clearance gap.

Documenting volumetric feeding accuracy

Early trials documenting the Olds Elevator's accuracy and repeatability as a volumetric feeder were conducted with silica sand. Although initial testing and measurement methods were relatively crude, the accuracy and repeatability of the flow rate control of the Olds Elevator was evident. Improved measurement techniques are to be employed to secure more accurate measurement data. A database of flow rate accuracy and repeatability is to be compiled to cover a broad range of bulk material types. This database will guide the direction of industrial applications that may benefit by the simplicity of this innovation.

Predicting and controlling component wear

To date, the only wear items on these elevators have been the screw and the intake scoops. Intake scoops are inexpensive and readily replaceable parts. Screw wear is greatest at the lower end, where material enters the elevator and changes direction. Recent designs employ screws made in multiple segments so the bottom segment can be removed and replaced independently. Tests with various abrasion resistant materials, variable screw configurations, including the double helix, will allow wear rates to be predicted and countered by specifying the most suitable materials and configurations for specific applications.

Purging the elevator for product changeovers

All mechanical elevators leave residue in the machine at the end of a run. Reversing the casing to empty residual product back into the hopper may purge short Olds Elevators up to 152mm (6") diameter. As elevators grow in diameter and height this residual volume will become several times the volume of the feed hopper. However, whereas it is difficult to empty other mechanical elevators, removing the bottom flange allows the contents of an Olds elevator to be discharged into a collecting tray.

Power Consumption

For high lifts at large diameter the power requirements may become prohibitive for a single elevator, in which case two or more elevators might be better used. The power requirements and efficiency of large elevators need to be investigated.

In-feed Pick-up scoop optimisation

Currently, research is being undertaken to optimise the in-feed scoop inlet geometry to improve the gentleness of handling and maximise the delivery rate.

9. Potential applications

As Heat Exchanger

Since the screw or helical auger is stationary and its shaft can be hollow, it can be plumbed to circulate heating or cooling fluids through its centre shaft. For larger elevators (228 mm/9inch diameter and larger), hollow flights may be constructed to utilize the full working surface of for heat transfer. The pitch of the screw may be optimized to ensure maximum residence time. This creates the prospect of a single piece of equipment serving as an Elevator, Volumetric Feeder and Heat Exchanger within a small footprint of plant space.

Other Applications

Industry professionals who, after observing the Olds Elevator in operation, have suggested several possible applications for this new technology, such as: -

- Ship Unloading
- Dredging
- Application of coatings to drug tablets
- Agglomerating of fine powders
- Feeding, top - down
- Separation of mixtures

10. Conclusions

The Olds Elevator is an important innovation that allows process engineers to use a single piece of mechanical equipment to elevate a broad spectrum of bulk materials at 90º, while simultaneously volumetrically feeding with a high degree of accuracy. In combination with the many convenient features of geometry and minimum maintenance requirements, the machine is expected to find many applications because it offers performance benefits and simplified equipment layouts.

Users of this emerging technology have found that, for their applications, the machine does a better job than any existing alternative and its simple design reduces maintenance costs dramatically as there are so few moving parts and no seals or bearings adjacent to the product. **The Olds Elevator will become a game changing technology!**

11. References

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- CEMA Book. "Screw Conveyors for Bulk Materials" Third Edition No. 350. Publisher: Conveyor Equipment Manufacturers Association.
- http://www.oldselevator.com
- http://www.oldsusa.com

12. Appendices

Biography of inventor – Peter Olds

Figure 20 – Lyn Bates of Ajax Equipment, England (left) with inventor of the Olds Elevator, Peter Olds, in Maryborough, Queensland, 2005.

Peter Olds (figure 20, left) is Managing Director of Olds Engineering and is very much a “hands-on” engineer. His hobby is also engineering, building 5” gauge model live steam locomotives. With a lifetime of practical engineering experience, he has earned a high profile amoungst his peers for the many designs and diverse range of products manufactured, including various special care hospital beds. In 1994 a special Tilting Hospital bed was supplied to Pope John Paul II. Peter was invited to the Vatican and stayed as guest where Pope John Paul II personally thanked him for his wonder gift.

Olds Engineering has been serving a wide range of industries since 1918, including mining, maritime, sand and gravel extraction, sawmills, sugar and flour milling industries. Early experience in designing and manufacturing coal, wheat and flour conveyors and other machines is now being applied to an exciting new method for the vertical conveyance of bulk materials. A fit 76 year old, he continues to work full time, involved in the R & D of the Olds Elevator.

Historical account: inventor, Peter Olds, describes the original concept

When the inventor awoke suddenly at about 3 a.m. from a seemingly peaceful sleep on the morning of 5th December 2002, he had clear concept on his mind of how an elevator for the small foundry in Maryborough, Queensland could work. This concept was shown in the sketch he made on the kitchen table when he quietly sneaked out of bed and put his ideas roughly on paper to take to work later that morning. Quite satisfied he went back to bed without waking family and was asleep again by about 3.30 a.m.

Those ideas, shown clearly with notes, describe the rotating tube or casing carried in bearings not affected by the fine sand to be elevated. The tube carrying the in-feed pickup unit beneath the sand to be elevated from the base of the machine would rotate fast enough to cause the sand entering the tube to be thrown out with sufficient centrifugal force to line the inside of the rotating tube.

The volume of rotating sand would then engage with the stationary screw, stretched under tension from the top to the bottom of the machine, thus keeping it straight and clear of the inside of the tube. Only that sand engaging with the screw would be elevated, leaving a boundary layer rotating with the tube, the thickness of which would be equivalent to the clearance between the outside diameter of the screw and the inside diameter of the tube. This boundary layer would drive the inner core of rising, rotating sand like a long continuous nut up a long thread.

To gauge the effect of the speed of rotation and the centrifugal force generated, a test device was made up. A short section of 3 inch diameter (76 mm) tube was closed by welding in a disc at one end to which was welded a short stub shaft located centrally on the disc. This then was simply machined so that the whole assembly would run true.

A test was then carried out using a ½ inch (13mm) variable speed electric drill, which gripped the stub shaft of the tube assembly. The test rig was then held over a sand bin and run at full speed with the open end of the rotating tube upwards. Sand was then carefully poured into the rotating tube where it immediately leveled out evenly while rotating with the tube.

With the drill still running, the whole arrangement was inverted so that the open ended tube carrying the sand was now upside down. The sand still naturally clung to the inside of the tube and continued to do so until the speed of the drill diminished to a surprisingly low rate.

This simple demonstration proved the effectiveness of creating a rotating body of sand, the inside of which could be sheared off upwards by any suitable spiral or screw.

When a prototype test machine was built it worked immediately. A fully operational machine was then made and installed in the foundry. This has only a 2 1/2 inch diameter (63mm OD) tube rotating at 500 RPM delivering just over 1 tonne of sand per hour. It has continued to run ever since with no trouble whatsoever, being driven by only a 1KW motor.

Further test machines were then built in larger diameters and fitted with variable speed drives. This led to the discovery that the device would also work very effectively at very low speeds and with a very large range of products. It was also found that surprisingly large clearances could be used between the inside of the rotating tube and the screw, thus avoiding damage to fragile products.

From these findings it was realized that the device worked in two distinct modes and that, at very slow speeds, centrifugal force and the boundary layer theory did not count.

These two very distinct modes in which the elevator worked were named the “Open Mode” and the “Full Flow Mode”. The speed at which the mode changes, due to centrifugal force forming the Boundary Layer, has been called the Critical Speed. The Critical Speed varies with the diameter of the rotating casing and the properties of the product being elevated. Both modes of operation have their own distinct advantages.