IMPROVED DOME STORAGE SYSTEMS FOR CEMENT

Figure 2. Artist's impression of a cement terminal with two domes of 30 000 t each. The domes are equipped with a full fluidised floor with side outlet. The ring line and valves to the fluidised floor sections can clearly be seen. (courtesy Fuller Bulk Handling).

Ad Ligthart, Partner, Cement Distribution Consultants, the Netherlands, and Fred Wuertele, General Manager Distribution Systems, Fuller Bulk Handling, USA, consider the advantages offered by fluidised floor systems in dome storage applications.

Introduction

Dome storage is becoming increasingly popular in the cement industry. This is especially so for cement distribution terminals where the combination of investment and operational costs of domes often offers the most suitable alternative. Previously, such terminals used mostly mechanical dome reclaim systems; however, these have a number of disadvantages. They represent a relatively high investment cost, the requirement of a tunnel under the dome and the limitation that only spherical domes can be used. Moreover, to achieve sufficient redundancy, two domes are recommended, each to handle half of the storage capacity, rather than one large dome. The fact that the mechanical reclaim system is located inside the dome, with many moving parts located in the cement, has operational and maintenance consequences. Moreover, the reclaim rate under certain conditions is uneven and it is not possible to load and discharge a dome at the same time.

Fluidised floors have the ability to overcome these disadvantages, and therefore enable new possible dome configurations. Due to the advantages of these floors, it is likely that the use of domes for cement terminals will increase substantially.

Figure 1. Full fluidised floor with side outlet. The inclined bottom slopes both to the centreline and to one side of the dome where the outlets are located. The sections of the floor are clearly visible.

Fluidised floors by themselves are not new: since the 1960s all kinds of airslide applications have been used for conveying systems, inside storage facilities and in the holds of self-discharging ships. Shore based facilities such as silos and even a number of domes have been equipped with partial fluidisation systems such as open top airslides. Although these systems have a low cost and are very effective, they have the disadvantage that they leave part of the floor unfluidised, creating a volume of dead stock that over time will accumulate and hamper the cement flow. Clean-up of this dead stock can be very troublesome and even dangerous. Therefore, for domes which have a large floor area, partial fluidisation has a substantial disadvantage.

The current development of the full fluidised floor system for domes finds its origin in the fluidisation system for self-discharging ships. The key feature of this system is a 100% fluidisation of the floor area. The qualifications of this fluidisation system are extremely good: as an example, self-discharging ships of 20 000 dwt, discharging 50 times a year, leave less than 20 t in their holds after each discharge. The key to bring this system 'to shore' was to find a cost effective method to put the system onto a concrete floor and to find the best possible combination between dome design and floor configurations.

Concept and operation of the full fluidised floor

Everybody in the cement industry will be aware of the airslide principle, in which cement rests on fluidising fabric with an airchamber below it. When pressured air enters the airchamber, it escapes through the permeable fabric and enters the cement. The injected air gives the cement fluid particulars. The airslide is put under an angle of approximately 8°, forcing the fluidised cement flow by gravity to the lowest point. In this way, large quantities of cement can be conveyed using very little energy. The full fluidised floor also works on this principle. However, because of the very large floor area necessary, the height of the cement load on the floor, and civil construction constraints, a special design is required.

A typical cement dome will store between 10 000 t and 60 000 t. This large quantity of cement has to be extracted in a controlled way in order to prevent large mass flows from damaging the dome. Moreover, a good turnaround of the cement without the build-up of dead stock has to be created. This is achieved by dividing the fluidised floor in sections that are individually activated.

The number and size of these sections depends upon the size of the dome and size of the fluidisation blowers. This selection is determined by finding the optimal ratio between required energy consumption, required flow control, and required clean-out capability.

The height of the cement in the dome is an important factor in the design of the full fluidised floor. In principle, when the height of the cement is higher than approximately 6 m, fluidisation is ineffective, as the material pressure prevents the fluidising air from entering the material. The result is that when the dome is full, extraction is largely by tunnel flow. This means that the cement flows through a narrow tunnel from the top vertically down to the outlet. Only when the level in the dome falls does the fluidisation start to have an effect, working from the tunnel flow outwards.

From this moment the sequence of activation of the fluidised floor sections can be used to control the material flow. A PLC takes care of full automated operation.

The full fluidised floor has proven its excellent capabilities in self discharging ships, however, to make the system suitable for domes, where it has to be placed on a concrete bottom, a number of design modifications were required. To fix the fluidisation fabric to the concrete floor, steel strips with studbolts have to be anchored into the concrete. The steel air chambers also have to be positioned into the inclined floor before the concrete is poured. A full fluidised floor is shown in Figure 1, with the individual sections and the method of fastening clearly visible.

To keep the civil construction costs as low as possible, the number of planes of the floor also has to be limited. In general, the floor will be sloped downwards towards a centre trench, which can slope down either towards the side of the dome or to outlet points in the centre of the trench depending on the type of conveying equipment. Figure 2 depicts a cement terminal

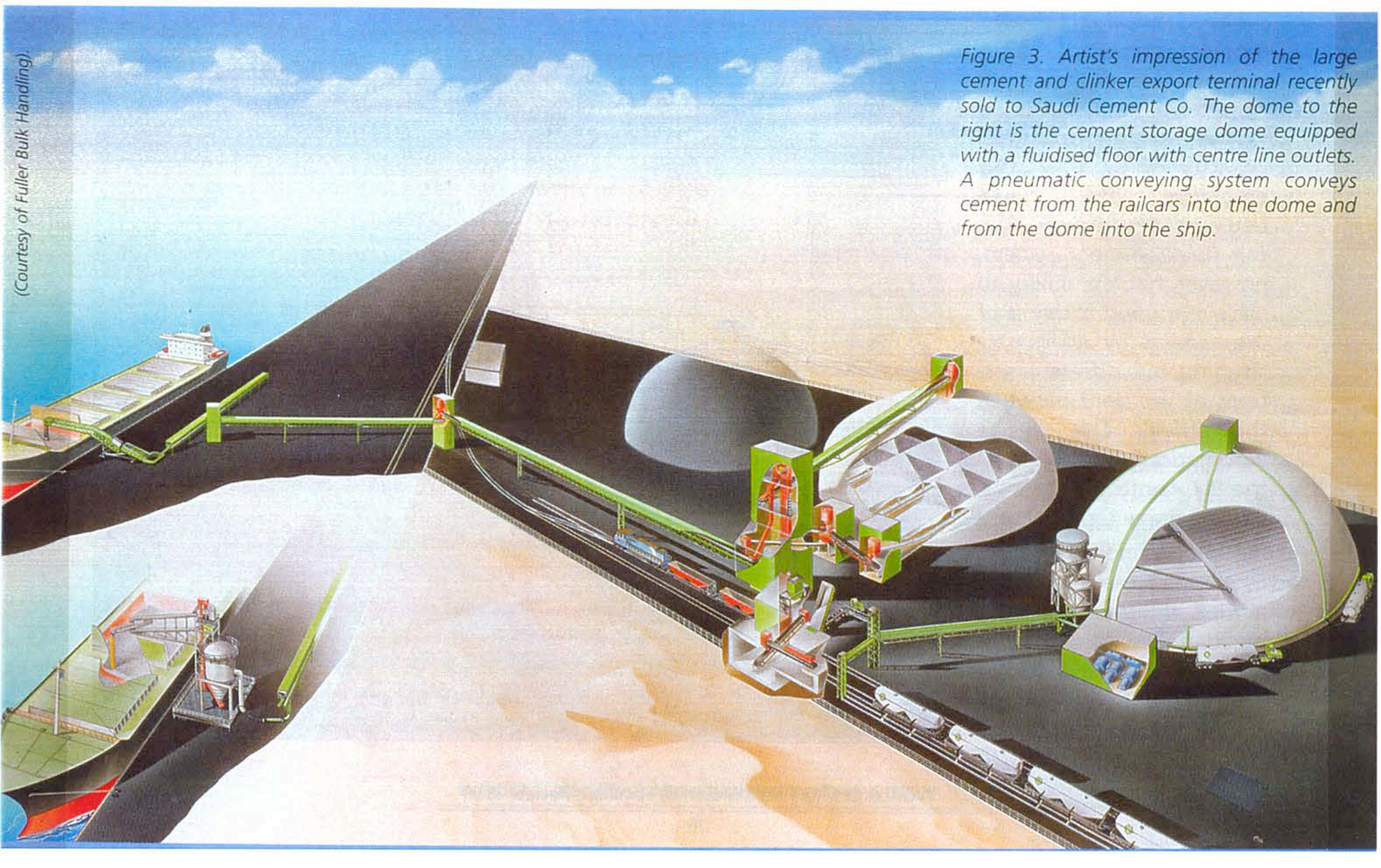


Figure 3. Artist's impression of the large cement and clinker export terminal recently sold to Saudi Cement Co. The dome to the right is the cement storage dome equipped with a fluidised floor with centre line outlets. A pneumatic conveying system conveys cement from the railcars into the dome and from the dome into the ship.

with two domes with a full fluidised floor sloping to centre and side, with the ringline around the dome, feeding air to the individual floor sections, visible. Figure 3 shows the cement and clinker export terminal for Saudi Cement in Saudi Arabia which has just been ordered from Dome Technology. The cement storage dome incorporates a full fluidised floor sloping to a centre trench. The centre trench declines towards two outlet points where a pneumatic system picks up the cement. The pneumatic system is used for all cement conveying; from train to dome, from train to ship and dome to ship.

The shape of the fluidised floor is adaptable to meet many different equipment and silo layout configurations.

Advantages of full fluidised floors

The full fluidised floor has a number of advantages, as follows:

Operational advantages

- *No moving parts:* The full fluidised floor does not have any moving parts inside the dome: all valves, blowers, etc. are easy accessible. This makes maintenance extremely simple compared to mechanical systems, where the equipment is located inside the dome and largely in the cement.
- *Consecutive filling and discharge:* A dome with a full fluidised floor has the advantage that it can be filled and discharged at the same time, which is of importance during ship-unloading operations. Domes with a mechanical reclaim system cannot be filled whilst the reclaim system is in operation. This is one of the reasons that two domes are required when a mechanical reclaim system is used. This is also because the mechanical reclaim system is largely a last-in first-out system. With a two dome configuration a good rotation of the cement can be achieved by alternately emptying the dome between ship arrivals. The full fluidised floor system, however, has the ability to achieve a good rotation of the cement by alternately cleaning out different sections of the floor between ship arrivals. This can be automatically controlled by the PLC control and allows a single dome terminal configuration.
- *Excellent clean-out capability:* a well designed full fluidised floor will leave less than 0.5% of its storage volume behind after the operation is finished.
- *Minimal risk of breakdowns:* the full fluidised floor consists of multiple floor sections, multiple control valves, multiple blowers and multiple material outlets, and therefore no single item is critical to the operation of the dome extraction system. The system as a whole is so reliable, that it is not necessary to have two domes, as one dome, with the full fluidised floor system, provides sufficient redundancy to continue terminal operations.

Cost effectiveness

It is very difficult to make a direct cost comparison between the mechanical reclaim system and the full fluidised floor reclaim system. Terminals with domes using mechanical reclaim systems have a traditional configuration of two spherical domes with tunnels underneath them. The cost of this configuration will change with the level of the water-table as the tunnel (and with that the dome) has to be above this level.

The full fluidised floor does not have such a fixed configuration. A large range of configurations is possible; single or dual domes, spherical or non spherical domes, tunnel or no tunnel, centre or side outlets, gravity or vacuum extraction, and so on. The particulars of the site and the logistics of the operation will determine the best possible configuration. Tailor-made solutions are possible to create maximum cost effectiveness.

To provide an indication of cost competitiveness in respect to price, it is of course possible to compare a typical two dome terminal configuration using mechanical reclaim systems with a two dome configuration with fluidised floors. To do this, the following

Table 1. Review of full fluidised floor characteristics

Technical configuration	• Floor fully covered with fluidisation fabric. • Floor subdivided in many sections that can be individually fluidised for full flow control and clean-out control. • Sections individually supplied with air from ringline around dome. • All equipment components are multiple (ensuring redundancy). • Automatic operation by PLC control.
Characteristics	• No moving parts in the cement. • Better than 99.5% clean-out capability. • Loading and discharging of dome possible at same moment. • Rotation of cement stock possible within one dome. • Suitable for any size and any shape dome.
Cost effectiveness	• Due to loss of volume of inclined floor the dome needs to be larger (various options possible) and therefore has higher cost. • Lower overall equipment and installation cost. • No tunnels required. • More cost effective terminal concepts possible.
Advantages	• Single dome configuration possible where other reclaim systems need two domes for operational and redundancy reasons. • High reliability. • No moving parts in cement. • High clean-out (> 99.5%). • Flexibility in design allows for cost effective terminal concepts even for difficult port sites.
Design flexibility	• Any dome shape possible. • Any type of onward conveying equipment possible. • Multiple compartment domes possible. • Other systems can be put inside the dome, such as truckloadouts, bagging plants, trucks, offices, machine rooms.

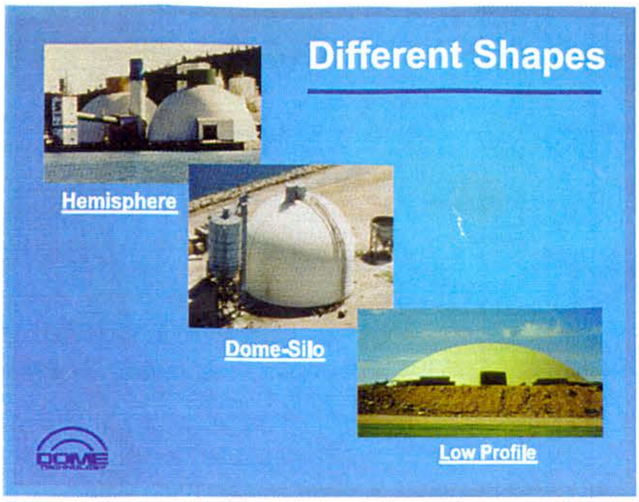


Figure 4. Review of different dome shapes (courtesy of Dome Technology).

Figure 5. Comparison of different dome configurations (courtesy of Dome Technology).

factors have to be taken into account:

- *Equal dome volume*: the mechanical reclaim system is used in combination with spherical domes and flat floors. This is the configuration that has the lowest dome cost per ton of storage. Fluidised floors are inclined, and the floor occupies volume. The dome therefore needs to be larger to accommodate this additional volume. Depending on the situation this can be a dome with a larger radius, a dome with equal radius but placed on a low stem wall, or a highrise dome with a smaller diameter, but on a high stemwall. These dome configurations have a higher cost of dome construction. In addition to this there are the extra costs of constructing the inclined floor and the fill underneath it.
- *Equipment cost and installation:* the mechanical reclaim system is manufactured in several large pieces, which are shipped to the project site. Installation work is relatively limited and is only a minor portion of the combined equipment and installation cost. The full fluidised floor reclaim system consists of many small components, a substantial number of which are integrated into the concrete floor. The equipment cost is considerably lower than the mechanical reclaim system; however, the installation cost is higher. The overall cost of the full fluidised floor is lower than the mechanical reclaim system. Whereas the cost of the mechanical reclaim system will be fairly equal worldwide, the cost of the fluidised floor will vary (substantially) depending on steel construction and labour costs in various countries.
- *Tunnels:* whereas the mechanical reclaim system is typically equipped with tunnels under the domes, these are not typically required for fluidised floor as it can be equipped with either a side outlet, vacuum extraction or a vertical trunk inside the dome. In general, this is a substantial cost advantage for fluidised floor applications.

Cement Distribution Consultants has been involved in several comparisons for dome reclaim systems. Although it is never possible to give an answer that covers all situations, the general conclusion is that the fluidised floor system is cost competitive with mechanical reclaim systems.

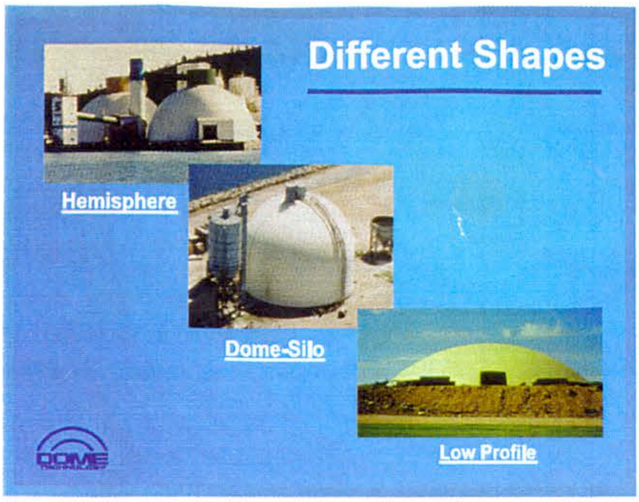
The key issue, however, is that the fluidised floor allows for a larger flexibility in terminal design, offering substantial cost savings over the whole terminal, and allowing the use of domes on sites that would not allow the typical two spherical dome configuration.

Flexibility of the full fluidised floor concept

The flexibility of the fluidised floor is apparent in various ways:

- *The flexibility to use different dome shapes:* instead of being limited to spherical domes, the fluidised floor allows for different dome shapes. Figure 4 shows the most common dome shapes: the hemisphere, the high rise dome (or dome-silo) and the low profile dome. The high rise dome is suitable for small port sites, using approximately half the floor area of the hemisphere dome (as shown in the comparison presented in Figure 5).

  The low profile dome is expensive and requires a substantial area, but provides a solution to create a large storage volume when a height restriction applies to the site. Further configurations are possible by combining the hemisphere or low profile dome with a stem wall.
- *The flexibility to use a range of conveying equipment:* The full fluidised floor is extremely flexible in design: it can feed to any number of outlets at any given location in or at the side of the dome. From these outlets either bucket-elevators, screw-conveyors, belt-conveyors, Fuller Kinyon pumps or vacuum-pressure convey systems can be used to convey the cement to truck loadout station, bagging plant, bargeloader or other destinations. The simplest system is a fluidised floor with side outlet feeding a bucket-elevator or screw-conveyor. For many terminals this will be the most economical alternative (Figure 2). For terminals where the cement has to be conveyed to several destinations located a distance away from each other, a pneumatic system offers the best alternative (Figure 3). The flexibility of the fluidised floor allows that the most favourable equipment configuration can be selected.



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Cement Distribution Consultants

A new alliance between independent experts in the field of cement trade, transportation and terminals, the goal of Cement Distribution Consultants is to make this specialised knowledge and experience available to companies that want to set up cement import, export or domestic distribution operations.

Cement distribution operations consist of far more than just the physical terminal facilities of course. The strategy behind the operation, the possible partnerships and supplier relationships, the local conditions, the globalisation in the industry, the world shipping situation, all have a considerable impact on the set up of a distribution project. Cement Distribution Consultants can advise its customers taking into account all these aspects, while providing a strong focus on overall profitability and return on investment for a complete operation. With the flexibility to tackle small or large assignments, Cement Distribution Consultants emphasises its independence and availability to all.

Figure 6. Single dome suitable for multiple products storage (courtesy Dome Technology).

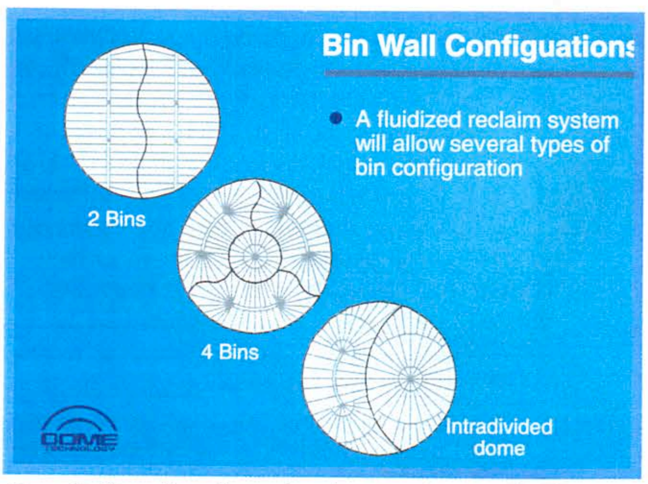

Figure 7. Bin wall configurations (courtesy Dome Technology).

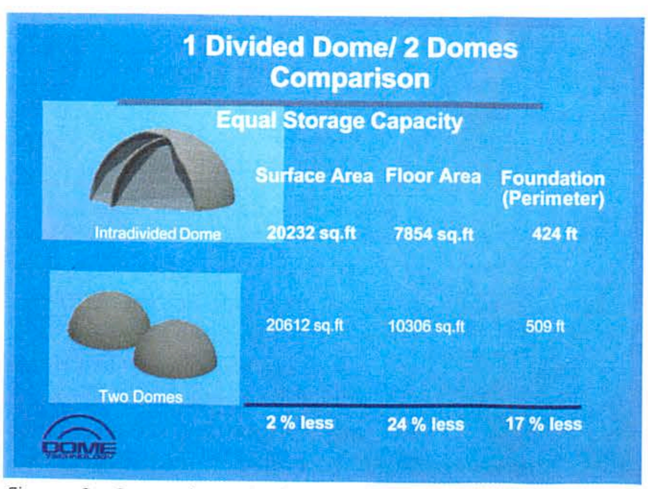

Figure 8. Comparison single intra divided dome as against 2 domes (illustration courtesy of Dome Technology).

- *The flexibility to use only one dome:* with a fluidised floor, it is possible to use only one dome, even for multiple material storage requirements, allowing the dome to be subdivided.

  These subdivision walls can either be partial height or full height. Partial height walls ensure that one side of the dome can be cleaned out completely whilst a substantial quantity of cement (30 - 35%) can be stored on the other side of the dome. This means that a good rotation of cement is possible without the risk of accumulating dead stock. Full height internal walls (Figures 6, 7 and 8) can be used for multiple material storage. Dome Technology has developed curved walls that can be constructed very cost effectively, using shotcrete.

  The capability to subdivide domes is important as it is giving domes the same capabilities as multicell silos but at a much lower cost. The full fluidised floor has made this development possible.
- *The flexibility to install other systems inside the dome:* fluidised floors can be shaped around or over obstructions, making it possible, for example, to run tunnels through the dome for truckloading inside the dome. Vertical trunks for bucket-elevators or screw-conveyors can also be located inside the dome without problems.

  Taken to an extreme this means that a whole cement terminal could be fitted into a single dome including storage-facility, truckloadout, bagging plant, offices and machineroom. For congested ports where space is very limited this might be a viable option.

Conclusion

Full fluidised floors are a valuable addition to existing dome reclaim systems. Not only is the system cost effective and reliable, but its flexibility allows for highly effective terminal designs even for port sites that face restrictions such as area size, building height and high water table. The potential of internal walls in domes in combination with the full fluidised floor allows new uses of domes storage. In combination with the full fluidised floor, this enables dome storage to become an even more important storage facility in the cement industry than ever.

Acknowledgements

The authors would like to thank Linden Fielding of Dome Technology for his co-operation and support.

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