



## Design and Testing of Bulk Storage Tanks for Drill Cuttings Offers Operators Safer Solution in Zero Discharge Operations

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### Abstract

Since the introduction of environmental regulations limiting or banning the discharge of various types of drilling fluids and associated drill cuttings globally, there has been considerable growth in “zero discharge” or “ship to shore” operations.

In these operations drill cuttings and associated waste fluids are collected on the rig in cuttings boxes, then sent to shore for disposal or treatment prior to disposal. These types of operations typically create operating challenges and costs associated with the required additional equipment, manpower, rig space and even rig modifications.

Certain safety and environmental risks are associated with “ship to shore” operations and the use of cuttings boxes. These include significantly increased crane operations, housekeeping and deck space issues, transfer of wastes to boats or barges, the use of screw conveyors or high-pressure pumping equipment, and increases in the waste volumes generated and disposed of.

A new process for handling drilling waste in zero discharge operations is described and the advantages of this system from an environmental and safety perspective are highlighted and supported by data from field operations and testing.

### Cuttings Containment and Transportation

In the oil drilling industry a growing problem is the storage and transportation of oil contaminated drill cuttings that are required to be removed from a drilling installation and transported to a disposal facility<sup>1,2,3</sup> both in onshore and offshore operations. In addition, there is legislation in some areas that prevents the discharge of water-based cuttings. In recent years various methods have been developed to address this problem. One method requires the use of cuttings containers, typically with capacity in range of four to eight tones. These are also known as cuttings boxes or skips, which require multiple crane handling, resulting in significant risk factors, both to the environment and to the safety of workers on the rig.

A typical offshore well can generate in excess of

1000 tonnes of cuttings and require several hundred cuttings boxes. In a typical offshore operation, all these boxes have to be lifted onto a boat, transported to the rig, lifted up onto the rig, and lifted to the filling station on the rig. Once filled with cuttings, the box is lifted away from the filling station, lifted down onto the boat, and finally lifted off the boat when it returns to the shore base. This means six or more crane lifts are required for each cuttings box filled, and at 200 boxes per well this amounts to 1200 individual crane lifts per well. This represents a significant safety risk to workers at the rigsite, on boats and at the shore base. In addition, these boxes can take up considerable deck space on a rig, many of which were never designed for these types of operations. See photograph below.



**Cuttings boxes on North Sea drilling rig**

One way to reduce crane lifts is to utilize larger boxes, which is applied occasionally. However, larger boxes create different operational problems for handling as they typically can not be handled by forklifts. When full, they may also require higher crane ratings than may be available.

The use of bulk storage tanks for cuttings can considerably reduce the risks involved in the handling of multiple cuttings boxes. The same bulk handling

techniques for cuttings and drilling waste can be used as is commonly done for handling of bulk materials such as barite, cement and liquids.

Both of these techniques eliminate the need for cuttings boxes and allow the operator to transport the cuttings from bulk storage tanks on a drilling rig to storage tanks on a supply ship. The tanks on the rig can be linked with the tanks on a ship by hoses and use either pneumatic techniques or pumps to transfer the material. This eliminates the use of cuttings boxes and cranes, which offers the operator fully enclosed zero discharge systems.

### **Current Bulk Storage and Transportation Systems**

Bulk material storage tanks and techniques have been around for a considerable period of time. However, the ability to store and transport drill cuttings in bulk has been a difficult concept to develop and achieve due to the constantly changing nature of drill cuttings in size, shape, consistency, and the drilling fluids associated with the cuttings<sup>4</sup>. Cuttings generated in the Gulf of Mexico are different in nature than cuttings generated in the North Sea due to different formations drilled. Even within the same geographical area, cuttings generated can be substantially different in consistency, making it very difficult to design an effective bulk storage and transportation system suitable for all locations and all cuttings types. This is in contrast to other commonly used bulk materials, such as barite, which are very consistent in their physical properties.

There are a number of bulk cuttings systems currently in use in the drilling industry today and these can be categorized as:

- Single Centre Discharge Point Tanks
- Mechanically Assisted Tanks
- Cuttings Slurry Tanks

#### **Single Centre Discharge Point Tank**

Some systems currently in use today are fitted with a single outlet at the base of the pneumatic tank for the cuttings to flow through during discharge when pneumatic pressure is applied. The cuttings are generally loaded into the top of the tank and the cuttings are discharged via a single cone arrangement at the bottom of the tank. Compressed air is introduced to the top of the tank to push the cuttings out. These tanks are very similar to the conical bottom tanks used to transfer bulk powders such as barite. They have the advantage of being relatively simple to construct and have few moving or mechanical parts.

However, due to the nature of drill cuttings, this single discharge outlet can become bridged off or blocked during discharge, requiring the tank to be shut down to clear the blockage. Further problems can occur

with single discharge tanks with what is known as “rat holing”. This is caused by cuttings creating their own plastic cone within the mass of cuttings in the tank as they attempt to seek the path of least resistance (i.e., the single discharge point) during discharge operations. This “rat holing”, effectively a cone of cuttings within the tank, leaves a considerable amount of material in the tank, reducing the effective storage and transfer capacity by as much as 60%. One solution to this has been to develop tanks with high angle conical bottoms, specifically designed to establish mass flow when pneumatic pressure is applied to the cuttings to ensure as much material as possible is removed from the tank. However these high angle cones do reduce the relative capacity of a tank in a given footprint.

#### **Mechanically Assisted Tanks**

One solution to some of the problems associated with a single center discharge point tank was to add mechanical agitation systems to the base of the tank. This assists the cuttings in exiting the tank, thus reducing the chances of bridging off or rat holing. These mechanical systems may include internal agitators, screw type augers or sliding tank bases that break up cuttings at the base of the tank to ensure that they do not bridge off, but are pneumatically discharged.

Of course, the downside to this approach is that it adds complexity, cost and the risk of mechanical failure to the bulk system.

#### **Cuttings Slurry Tanks**

Unlike the previous two methods that use pneumatic techniques to empty the tanks and move the cuttings, cuttings slurry tanks slurrify cuttings, generally with water, then pump the slurry with centrifugal pumps to storage tanks on the rig and down to storage tanks on the boat.

While in some cases this may be a good solution, for example if the cuttings are to be injected downhole and would be slurrified anyway, the down side of this system is that it considerably increases the volume of waste material, cuttings and contaminated water to be disposed of, increasing transportation costs, treatment and disposal costs, and overall liabilities resulting from the increased volume of waste being handled.

Further disadvantages with this type of system include the need to prevent settling during storage transportation by constantly having to circulate or agitate the cuttings slurry in the tank or add expensive suspension additives to the slurry.

#### **Honey Comb Base (HCB) Tank Design**

After analysis of the problems encountered with current bulk storage and transportation systems, a solution to the “rat holing” and blocking of single discharge tanks was developed utilizing a multiple outlet

discharge system design based on a Honey Comb Base (HCB) tank. This tank design was developed specifically for the reliable discharge of bulk materials from pneumatic silos. It was originally designed for industrial bulk materials, including dry powders such as fly ash and cement, through to high moisture, viscous type materials such as sewage sludge. The HCB tank can be designed to store capacities from 20 m<sup>3</sup> to 2000 m<sup>3</sup>.

The HCB tank design includes a multiple discharge point arrangement where typically six outlets are arranged in a honey comb design at the discharge base of the tank. Internally there is also a large inverted hexagonal spike stretching up into the tank around which the multiple hexagonal discharge outlets are arranged. This design is shown in **Figure 1** and **Figure 2** at the end of the paper. This inverted spike acts as a breaking device to ensure the material is broken up as it passes down the tank, directing the cuttings to the discharge outlets, ensuring total flow of the material out of the tank and eliminating rat holing down the center of the tank.

The tank discharges cuttings by applying compressed air to the top of the cuttings as with traditional pneumatic tanks. The air on top pushes the cuttings down and out of the outlets in the base. In addition, air is also injected into the base of HCB tank to mechanically break up and fluidize the cuttings as they pass toward the hexagonal outlet, eliminating the need for additional mechanical agitation.

Cuttings are discharged on a timed basis by each discharge point to ensure even flow of cuttings out of each outlet. The discharge valves are opened and closed in a pre-determined sequence for a specific period of time rotating around each discharge point. This ensures the discharge of cuttings is evenly spread around the base of the cuttings in the tank, in effect removing the base of cuttings in the tank and allowing the cuttings to constantly fall down into each outlet.

The inverted spike in the centre of the tank ensures that "rat holing" cannot take place within the tank as there is no single center discharge point and all cuttings are diverted to the individual HCB outlets.

The HCB base has also been designed to fit into a standard ISO frame tank to simplify the design and certification of the tank itself. By maintaining the integrity of the tank through a standard "dished end" design, the cost and certification of this tank has been kept to a minimum. The nominal capacity of each tank is 18 m<sup>3</sup> or approximately 41 tonnes of cuttings per tank at a bulk density of 2.3 SG. However, for fixed system built into platforms or new build rigs, the size and capacity of the tanks can be greater.

### Testing of HCB Tanks

In summer 2005, the HCB system was ready for testing. The primary goals of the tests were to store cuttings in the HCB tank and then pneumatically discharge them completely from the tank to a receiving

location with no slurrification or addition of the cuttings required.

An area of particular interest for the use of HCB tank systems is in the intra- and inter- field transfer of cuttings. The ability to recover cuttings generated at one offshore location and transfer them to a second offshore location for disposal, either through cuttings injection or through offshore thermal processing systems is rapidly becoming an important topic of development in a number of areas around the world. A significant aspect of offshore cuttings transfer will be the ability to transfer cuttings from a rig to a boat, then from the boat back up to a second rig or platform for disposal at that site. In some cases this could require transferring the cuttings from the storage tank up over 150 ft.

The testing of the HCB system was conducted from June 2005 to October 2005 initially at the fabricators yard in the UK and later at an onshore oil supply base in Peterhead where all tests were witnessed by UK based operator staff. The oil-based mud cuttings were supplied by a major UK operator as representative of North Sea cuttings. The HCB system was set up on the base and all interconnecting pipe work, air lines, cuttings handing lines, etc. were rigged up within a banded test area. The HCB tank built for these tests is shown in the photograph below.



**HCB Tank built for Tests**

The main test objectives for the HCB system are:

- Determine horizontal distance cuttings can be transferred pneumatically from the HCB Tank
- Determine the rate (tonnes per hour) at which cuttings can be transferred from the HCB
- Confirm that cuttings can be transferred 55 meter (180 feet) vertically - the height from a boat to rig or platform
- Leave cuttings for extended period of time (> 1 week) in HCB Tanks and then re-establish discharge of tank without blockages
- Ensure HCB tank can be discharged completely with no blockages.

The results of the initial tests conducted are detailed in Table 1.

Discharge line diameter	125 mm (5 inch)
Horizontal distance of loop	102 meters (334 feet)
90 degree bends in loop	6 (1.5 meter radius)
Air pressure inside HCB tank	4 bar (60 psi)
Conveying line pressure	3 – 4 bar (40 – 60 psi)
<b>Transfer Rate Achieved</b>	<b>48 tons per hour</b>

**Table 1. Horizontal Pump Tests**

A second set of tests were conducted to demonstrate that cuttings could be transferred vertically from an HCB tank on a boat up to a platform or rig, a height of 55 meters. A crane was used to simulate the height pumped from the boat up to the platform deck. A photograph of this arrangement is shown below.



The results of the second tests are detailed in Table 2.

Discharge line diameter	125 mm (5 inch)
Vertical height pumped	55 meters (180 feet)
Total distance pumped	120 meters (393 feet)
90 degree bends in loop	6 (1.5 meter radius)
Air pressure inside HCB tank	5 bar (75 psi)
Conveying line pressure	4 – 6 bar (60 – 88 psi)
<b>Transfer Rate Achieved</b>	<b>30 tons per hour</b>

**Table 2. Vertical Pump Tests**

Upon completion of the horizontal and vertical pump trials, the cuttings were pumped back into the HCB tank and left in place for seven days without agitation or movement. After seven days, the same set of tests were conducted, pumping the cuttings horizontally and vertically with the same results achieved.

### Conclusions

After completion of all the tests, it was possible to reach the following conclusions regarding the performance of the HCB tank system.

- All cuttings in all transfer operations were pneumatically discharged from the tank with no “rat holing” or material left in the tank giving full storage and discharge capability from the tank.
- The HCB system handled cuttings of varying consistency from dry to wet and showed no signs of blocking the discharge ports of the HCB tank.
- Cuttings were discharged horizontally at distances in excess of 100 meters through 5” line at a rate of 48 tph.
- Cuttings were discharged vertically at heights in excess of 50 meters through 5” line at a rate of 30 tph.
- All objectives of the tests were met with no need to slurrify cuttings and no blockages of the discharge ports of the HCB tank.

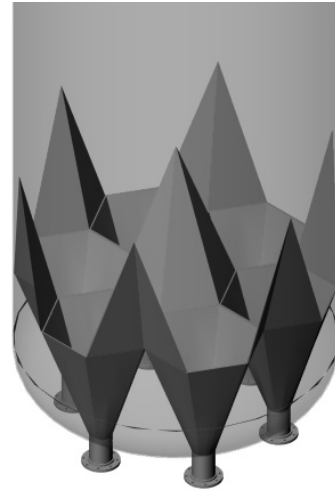
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### References

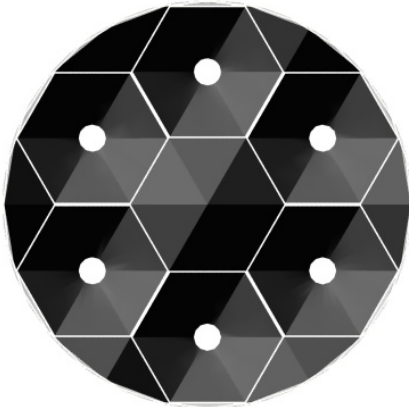
1. Holt, C.A. Jr., Prewett, H., and Mansour, S.: “Oily Drill Cuttings – A Positive Approach to Protecting the Environment,” SPE 29794, SPE Middle East Oil Show, Bahrain, 11 – 14 March, 1995.

2. Veil, J. A.: "Drilling Waste Management – Past, Present and Future," SPE 77388, SPE Annual Technical Conference, San Antonio, Texas, 29 September – 2 October, 2002.
3. Paulson, J.E., Omland, H.I., Aas, N., Solvang, S.A.: "Drill Cuttings Disposal, Balancing Zero Discharge and Use of Best Available Technology," SPE 85296, SPE/IADC Middle East Drilling Technology Conference and Exhibition, Abu Dhabi, UAE, 20 – 22 October, 2003.
4. Morris, R., Seaton, S.: "Unique Drilling Waste Handling and Transport System Offers Advantages to Drilling Operations and Assists Operators in Achieving Safety and Environmental Compliance," SPE 94194, SPE/EPA/DOE Exploration and Production Environmental Conference, Galveston, Texas, 7 – 9 March 2005.



**Figure 2. HCB Tank – Isometric View**

**Figures 1 and 2**



**Figure 1. Honey Comb Base (HCB) Design**