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# Bulk Transportation of Drilling Waste

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## Abstract

A concern of any waste management program is the movement of drilling wastes from point-to-point on location, or transfer offsite. Logistics, environmental laws and budget will influence what is practical and effective. Brandt, a division of Varco offers the Brandt Transfer System (BTS™), a patented pump and collection system designed to pump drilling wastes and heavy sludge (see Fig 1).[i] Key features of the system include:

- A variable speed hydraulically driven submersible centrifugal pump with suction-assisted open impeller housing.
- A bypass gate allows partial or total re-circulation of the slurry without the need for extra pipe construction.
- The pump can be supplied as a stand-alone device suitable for attachment to a "boom" apparatus, or more typically is installed on a V-bottomed tank with a traversing rack and pinion system.
- Variable speed, reversible, rotating cutter heads help break up sedimentation that can accumulate in tanks.
- This entire pump assembly also pivots from the top of the rack and pinion system to help dislodge stubborn sediment & compacted solids.

Some typical uses for the system are to fill open top dump trucks, vacuum trucks, transfer sludge to collection barges, evacuate barges, and feed cuttings to centrifugal dryers.

## Introduction

Environmental concerns and regulatory authorities are forcing the offshore drilling industry to modify or eliminate the dumping of drilling wastes overboard. On land rigs, the practice of constructing earthen reserve pits is also declining in favor of "zero-discharge" closed-loop systems. Therefore the effective containment and transportation of drilling wastes is becoming ever more important. The environmental benefits of a well designed waste collection and transportation systems can even be observed directly in many cases. However, there may also be other less obvious environmental impacts and hidden economic costs associated with some practices.

## Problems associated with moving drilling wastes

Simply stated, drilling waste is any solid or liquid generated by the drilling process. It can range from nearly dry solids to pure liquids but is usually somewhere in between. Thus arises the nature of the problem. Technologies exist which easily transport solids in dry form (screw auger conveyors, pneumatic transport systems, or vacuum transport systems). On the other hand, fluids are easily moved with a variety of pump types that are currently used throughout the industry (e.g. centrifugal pumps, piston pumps, and progressive cavity pumps).

However, drilling wastes are usually a combination of solids and liquids. What is worse, there is little control over the proportions. A few factors that can affect the composition and quantity of drilling waste are hole size, penetration rate, drilling fluid type, formation reactivity, and solids removal efficiency. Discharges from solids control equipment range in particle size from a few microns to several inches. Varying amounts of fluids are associated with these drilled solids such that the collected form of them can resemble anything from stackable piles to free-flowing liquids. The larger the drilled solid is, the less fluid there is associated with it.[ii] Characteristically upper hole sections will usually have "drier" drilling wastes than lower hole sections. Ideally, though not currently practical, drilling wastes should be segregated into a solid phase and a liquid phase, thus enabling existing technologies to move them efficiently.

A second preference, also not currently practical, would be to build slurries of controlled density and thixotropic properties to act as carriers for the waste. This would allow traditional pumps and tank systems to move the drilling waste in slurry form. While the viscosity of drilling fluids have been measured and maintained to suit specific purposes for years there is little if any incentive to "build muds" for the specific purpose of transporting drilling waste. The additives needed to perform such a task will add cost to the project. They would probably not be recoverable, and would add extra waste volume thus, additional disposal costs.

One practical technology that is available now is a patented bulk storage and transportation system that has been in use for several years. This system features a submersible centrifugal pump with several unique characteristics. When mounted on a purpose-built, V-bottomed tank, the pump travels on a rack and pinion system the length of the tank to virtually eliminate dead spots. The pump features a suction-assisted impeller and open-throat housing, as well as several other essential features that make it suitable for most conditions.

**Establishing some criteria for evaluation**
A variety of systems is available to move drilling waste in bulk. When evaluating these, some questions to ask are:

1. Can the system match the drilling program requirements for peak solids generated?
2. Can the system accommodate slow drilling conditions efficiently?
3. Is downtime an issue, and are there contingency plans in place to allow drilling operations to continue without disruption?
4. Is the process economical? What is the energy needed to complete the task?
5. Does the system contribute to a balanced environmental goal?

While each installation and each drilling program poses its own unique challenges, some common issues must be addressed in all instances.

**Evaluation of the system**

Criteria number one:

1. *Can it match the drilling program requirements for peak solids generated?*

The process capacity of any drilling waste transportation system must be able to keep up with peak drilling conditions. Hole size and penetration rate as well as other things will dictate these needs. An equation to calculate solids generated per foot drilled can be written.[iii]

$$V_W = [((D^2 \times 0.000971) \times WO) \times SRE] / \%S$$

Where:

| | |
|---|---|
| $V_W$ | = amount of drilling waste (bpf) |
| D | = bit size of (inches) |
| WO | = washout factor of (percent) |
| SRE | = solids removal efficiency |
| %S | = percent solids in waste |

EXAMPLE 1: FAST DRILLING CONDITIONS**:** by assigning some values we can calculate for $V_W$.

| | |
|---|---|
| **D** | = bit size of 20 (inches) |
| **WO** | = washout factor of 10% |
| **SRE** | = solids removal efficiency of 78% (i.e. |

78 percent of the solids that were generated from the hole were removed. This is one of the most difficult factors to calculate, and is purely an assumption.)

**%S** = percent solids in waste (i.e. the waste stream to be stored and transported was 50 percent liquid and 50 percent solids by volume, typically most of the liquid is associated with drilled solids discharge.

Given these values we calculate a waste volume of 0.667 bpf of depth will be generated.

$$V_W = [(( 20^2 \times 0.000971) \times 1.10) \times 0.78] / 0.50$$
$$V_W = 0.667 \text{ bbl/ft}$$

This amount of solids will need to be evacuated at a nearly continuous pace. It would take a screw conveyor of 20-inch diameter, rotating at 36 rpm to perform the same task. This conveyor would require a minimum 15 HP motor with a 20 HP motor providing a better margin of safety.[iv] A negative pressure (vacuum) or positive pressure (pneumatic blower) system could perform the task as well. These systems typically use from 100 to 150 HP to drive the compressors. For this instance, 200 HP would be advisable, and may consist of two independent systems.[v]

The centrifugal pump supplied on the system described has been tested up to 1800 gpm or nearly 43 bpm. This is almost 64 times the rate required. It would not be prudent to have a system operate on a continuous basis under these conditions. Therefore, a collection tank is advisable and is supplied in most instances with a volume of 200 barrels. This purpose-built tank supports the traversing rack and pinion system, which supports and moves the pump assembly.

The tank's main purpose is as a depository for solids control equipment discharges. However, it can also accept drilling wastes from various points on the rig when spot clean-ups are performed. This 200-barrel capacity provides a means of minimizing the impact of large waste volumes during fast drilling situations. A formula to calculate the time (**T**) to fill the tank is simply stated:

$$T = 200 \text{ bbls} / (ROP \times V_W)$$
$$T = 200 \text{ bbls} / (300 \text{ fph} \times 0.667 \text{ bpf})$$
$$T = 200 \text{ bbls} / 200 \text{ bph}$$
$$T = 1 \text{ hour}$$

Under these conditions, it takes about one hour to fill the

tank. During fast drilling, personnel and equipment are stressed to the limit of their abilities. Should a problem arise with any portion of a transportation system, (whether it be mechanical failure, routine maintenance or dealing with the introduction of foreign objects), this built-in volume buys critical time. This extra time (though it may only be a few minutes) may make the difference between normal drilling operations and not drilling. Please note that these equations represent steady state drilling conditions and do not take into account events that can cause surges in return volume.

The collection tank is not the end of the process, but a convenient means for the pump to access the waste. On land rig applications where "zero-discharge" rules are in effect, trucks may be used to haul the waste for certified disposal or treatment. A full tank can be pumped-out in less than five minutes. This fast turnaround time reduces truck idle time. Traditionally the task of cleaning an open top tank is performed with a backhoe and takes many times longer, depending on operator skill. Invariably, spillage occurs with a backhoe. With the pump system, often times locations are as clean at the end of a well as the beginning.

Criteria number two:

- *Can the system accommodate slow drilling conditions efficiently?*

It may seem that once fast drilling conditions have been satisfied, there is no need to consider the ability of a system to move small volumes of waste when drilling rates diminish. However, keep in mind that any transportation system should be able to perform both with equal efficiency. Screw auger conveyors and vacuum transfer systems require the system to operate on a continuous basis. By sizing these systems for maximum capacity conditions, they are greatly oversized for small volumes. This continuing need requires more monitoring and higher maintenance due to the added cycle times of rotational devices like bearings.

EXAMPLE 2:    SLOW DRILLING CONDITIONS
Alternate values are used to signify slow drilling:

$$V_W = [((0.000971 \times 6.5^2) \times 1.05) \times 0.78] / 0.40$$

$$V_W = 0.084 \text{ bpf}$$

We calculate a waste volume of 0.084 bpf of hole drilled will be generated. Note that values have changed and are in line with slow drilling activities. Bit size is reduced, a more stable formation causes only 5% washout, and the collected waste is now only 40% solids by volume (reflecting the smaller size of the drilled cutting). The

78% SRE is assumed to hold true, while ROP slows to 25 fph.

$$T = 200 / (ROP \times V_W)$$
$$T = 200 / (25 \text{ fph} \times 0.084 \text{ bpf})$$
$$T = 200 / 2.10 \text{ bph}$$
$$T = 95 \text{ hrs}$$

The same 200-bbl system now has 95 hours (almost 4 days) of collection time before there is a need to transfer the slurry. Storage of waste over this extended period will undoubtedly cause some separation of solids and liquid through a naturally decanting process. This can be advantageous in that it will allow the opportunity to skim the tank, recovering free liquid. This adds value to the operation by reusing fluid and reducing haulage or treatment costs.

The natural decanting process can pose a problem to simple holding tanks. Sedimentation of solids in the tank will stop most centrifugal pumps from working. The options are limited:

1.  Prevent the solids from settling by continuously moving the slurry
2.  Provide a means to dislodge sediments

The first method would require continuous recirculation of the slurry through centrifugal pumps to prevent settling. Line velocities needed to keep the solids from settling in the tank would require the expenditure of significant amounts of power. The continuous circulation of the high solids laden slurry could cause severe wear on fluid end components. Suspension using mechanical agitators is not feasible given the concentrated nature of the waste streams.

The second method, until now required an external apparatus (such as a shovel or bucket) to dislodge the sediment. One of the features of the described process is the reversible, variable-speed cutter heads attached to the pump, (acting independently of the pump rotation) which can break up the sediment. The pump assembly itself can pivot to free extremely stubborn sediment. The suction-assist blades and open-throat suction housing help scoop material into the pump body. Once the bulk of the solids are dislodged, homogenization is achieved by briefly recirculating the slurry through the bypass gate on the pump. This process takes usually less than 10 minutes to accomplish. Another 5 minutes are required to transfer the 200 bbls at maximum rate. Consider the ratios with the slow drilling example; four days worth of waste can be moved in less than 15 minutes.

Waste collection continues unabated while the slurry is transferred. Minimal user action is needed as the system can be manipulated by one person. Occasional

monitoring and minor housekeeping will ensure continued operation. Thus, personnel are free to perform other duties that require more attention.

Criteria number three:

- *Is downtime an issue? Are there contingency plans in place to allow drilling operations to continue without disruption?*

Any system must be operable at all times while drilling. Thus, the need to eliminate downtime is obvious. When dealing with waste transportation systems, there are two methods to minimize or eliminate the impact of downtime.

- Install additional or alternate back-up systems or
- Add redundancy by increasing storage capacity

Installing a secondary method of transporting or storing waste may keep drilling operations going uninterrupted, but may pose problems that cannot be overcome: e.g. extra space requirements, extra power requirements and added cost.

The second option might be more preferable. One way to build redundancy is by adding storage capacity. This provides a buffer. As seen in the slow-drilling example, 200 bbls capacity provides almost four days of buffer, while the fast drilling scenario buys one hour. Still, one hour can be enough time to perform minor repairs or maintenance. Typically, this is all that is needed to keep the system operational. Systems with minimal capacity or no way to increase capacity (like conveyors) may force operators to choose option one. However, installing duplicate systems or auxiliary apparatus, (like cuttings collection boxes) poses more economic and logistical problems (e.g. standby rental, additional rig space, diversion of crane usage), which may make this choice undesirable.

Criteria number four:

*Is the process economical?*

Most waste management systems are supplied by service companies to the operator. The cost to lease varies on typical market drivers like supply and demand. Other drivers that can influence fair market value include the cost to manufacture, install and operate a system. For example, screw auger conveyors are typically quite inexpensive to manufacture and operate. However, their use in vertical lift applications may make the shear number required more expensive from an engineering standpoint. Vacuum and pneumatic conveying systems may be an alternative, but are more costly to manufacture and operate. While rental price is usually the primary concern, operational costs can have an impact on long-term project economics.

Factors affecting operational cost include personnel requirements, cost of expendables and energy requirements (quite often overlooked),

Maximum power requirement for the system is 100 horsepower, which is roughly equivalent to 74.6 kilowatts. However, this energy is only needed for a short amount of time, so we must determine kilowatt-hours. To convert to kilowatt-hours (kWh), multiply the number of hours used by 74.6 kW. In this case, the system was actually only active for 15 minutes (1/4 of an hour) over the four-day collection span.

$$kWh = HP \times 0.746 \times M^{1}$$
$$kWh = 100 \times 0.746 \times 0.25 \text{ hours}$$
$$kWh = 18.65$$

Where:

| | |
|---|---|
| **kWh** | = kilowatt-hours of energy consumed |
| **HP** | = horsepower (maximum is assumed) |
| **M** | = operational time |

A value that describes the amount of energy needed to move a barrel of waste could then be calculated and used as a benchmark. The term describes a theoretical energy equivalent in kilowatt-hours per barrel of waste moved.

$$kWh/bbl = 18.65 / 200$$
$$kWh/bbl = 0.09$$

Therefore, each barrel of waste moved during this slow drilling scenario costs only 0.09 kWh of electricity. To put this in perspective, a kWh of electricity in the current market is valued at about 8 cents. Some examples of optional transportation methods are given for comparison in table 1. The first three options must run continuously while drilling, therefor the kW/bbl usage is much higher. For convenience' sake, maximum HP requirements are assumed, but actual usage will likely be lower, and could only be determined accurately by installing monitoring equipment. These examples are purely hypothetical and given as examples to illustrate extreme circumstances.

These costs of operation are in addition to other costs that include equipment rental, haulage and disposal cost.

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[1] A more exact method to calculate kW is available but requires more information including: volts, amps, and power factor.

Criteria number five:

*Does the system contribute to a balanced environmental goal?*

Proper project management strives to insure that every part of a system works in harmony with all the other elements towards a common goal. A properly designed and implemented waste management plan revolves around this holistic concept to achieve minimal environmental impact while maintaining economic viability.

An example of this approach in practical terms is embodied in the new regulations governing non-aqueous fluids developed by the US EPA. Environmental impact studies indicated that by setting achievable limits of synthetic fluid retained on cuttings, total pollution from all sources would be minimized. Not only would the impact to marine life be minimized, but also the impact to surface environment would decrease because less energy would be used, which would cause fewer emissions to atmosphere.[vi] This type of investigative research led to the conclusion that achieving goals through short-term solutions (zero-discharge offshore) are not always the most beneficial to the environment, but can cause more pollution and add cost.

Best management practices minimize environmental impact, minimize health and safety risks and enhance system performance. Evaluation of a waste transportation system takes into account the long-term as well as short-term goals. If waste collection and transportation is done at the cost of excess energy use, then there exists the potential for a net detriment to the process.

**Conclusions**

New and more stringent environmental laws are forcing the industry to change ingrained practices, thus creating the need for new technologies. This innovative system addresses these needs and when properly done, can add positively to the goal of minimal impact.

Proper storage and transportation of drilling waste is one component of a successful waste management project. Several technologies exist to perform the task. No one is superior in every circumstance to another. Deciding which equipment to use can be a challenge and hinges upon several factors. Proper execution of or compliance to the five judgment criteria as outlined will aid in making prudent decisions about bulk transportation of drilling waste, as well as other components of a waste management plan.

Thus, a properly implemented waste transportation system should:
- Be able to match the drilling program requirements for peak solids generated.
- Perform the task efficiently, even at slow drilling rates
- Reduce or eliminate the impact of downtime to the drilling operation
- Control operational costs over the life of the project
- Enhance long-term environmental goals

**Nomenclature**
*BPF = barrels per foot*
*BPH = barrels per hour*
*BPM = barrels per minute*
*FPH = feet per hour*
*GPM = gallons per minute*
*ROP = drilling rate of penetration*
*RPM = revolutions per minute*
*SRE = solids removal efficiency*
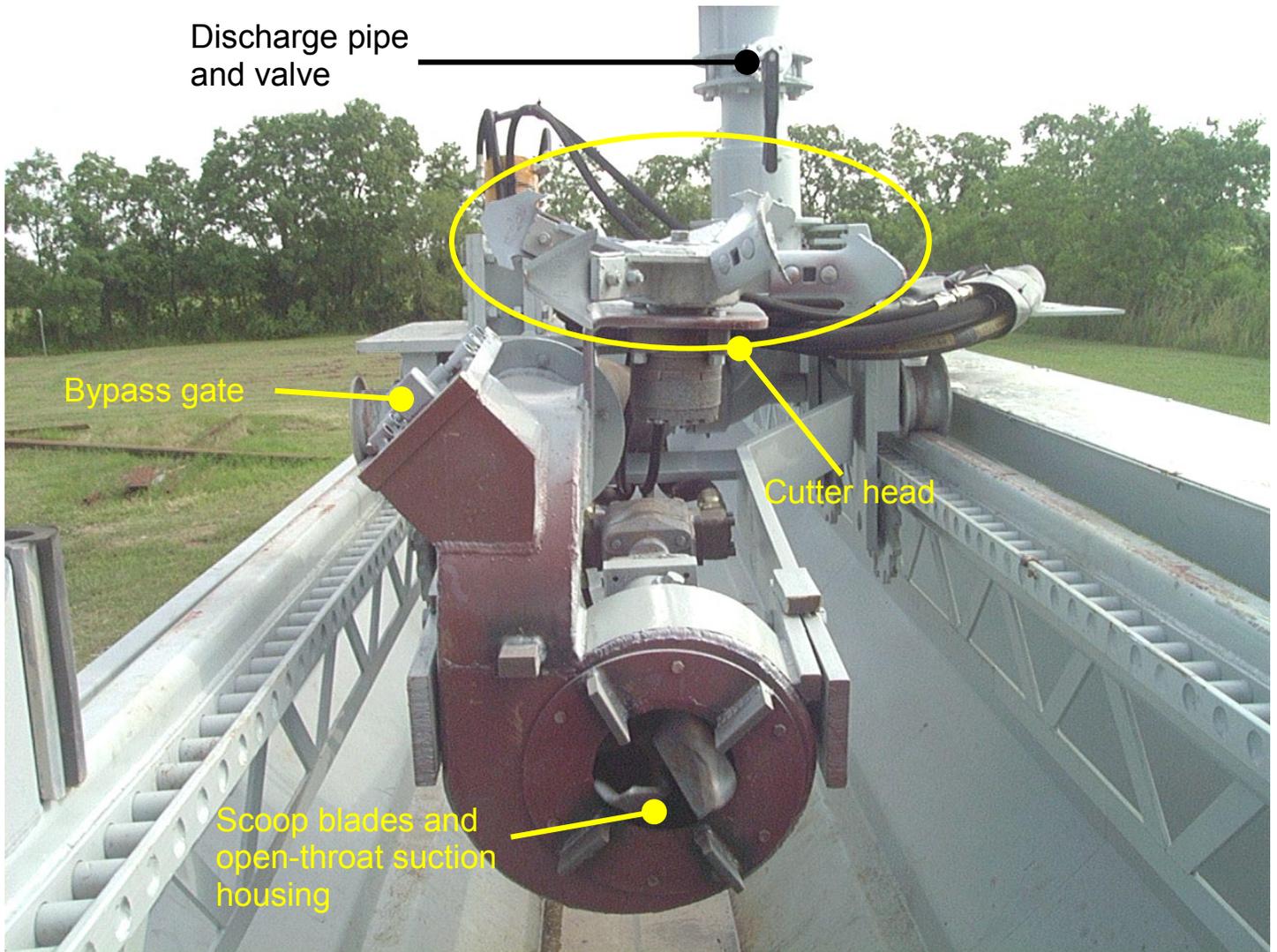*WO = washout factor (percent)*

**Figures**



**Figure 1 View of patented pump and some essential features.**

| Transfer method | HP (max. assumed) | Hours operated | kWh equivalent | KWh per bbl of waste | Energy cost per barrel of waste @ 8¢ / kWh |
|---|---|---|---|---|---|
| Screw auger | 20 HP | 95.20 | 1,420 | 7.10 | $0.57 |
| Vacuum transfer | 100 HP | 95.20 | 7,102 | 35.51 | $2.84 |
| Pneumatic transfer | 150 HP | 95.20 | 10,652 | 53.26 | $4.26 |
| Pump & tank system* | 100 HP | 0.25 | 19 | 0.09 | >$0.01 |

Table 1: Equivalent kWh and energy cost per barrel of differing transfer technologies using slow drilling conditions described in paper. Actual figures would be lower and fractionally proportional to amperage draw. *Calculations for the pump and tank system are based on usage of only 20 minutes over the span of 4 days as discussed in the body of the text.

## References

[i]  See US patent number 5,846,440: Dec. 8, 1998 for full description

[ii] "Solids Control Handbook" Amoco, Dowell/Schlumberger, 1998 edition, **Dowell ITM-1158**, section 300, pg. 30-31

[iii] Modified from "Solids Control Handbook" Amoco, Dowell/Schlumberger, 1998 edition, **Dowell ITM-1158**, section 200, pg. 4

[iv] Martin Engineering "Sprocket and Gear Catalog-1090" Section H (Screw Conveyor): calculations based on 63 TPH, S.G. 1.88, 112 lb/ft$^3$, and trough length of 30 ft.

[v] "Perry's Chemical Engineering's Handbook", Perry and Green; 7$^{th}$ ed: section 21,pg. 20, table 21-12

[vi] "Economic Analysis of Final Effluent Limitations Guideline and Standards for Synthetic-Based Drilling Fluids and other Non-Aqueous Drilling Fluids in the Oil and Gas Extraction Point Source Category", **EPA-821-B-00-012**, December, 2000, Section 7