



Successful Optimization Of Advances In Disposal And Treatment Technologies, To Cost Effectively Meet New Oil-Based Cuttings Environmental Regulations

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Abstract

Drilling wells safely, economically, and successfully, in the new era, generally requires drilling fluids, which significantly reduce drilling days, and eliminates gas hydrates. While these fluids accomplish these tasks, recent environmental pressures are causing operators to minimize synthetic on cuttings discharge to the sea. In the U.S., the EPA is setting the discharge limit to 6.9% by weight for IO synthetics and 9.4% by weight for esters. This paper addresses methods for synthetic reduction on drill cuttings processes, bulk shipment of drill cuttings, and cuttings re-injection.

Introduction

Drilling operations in the new era faces challenges with emphasis on environmental issues, pressuring operators into major decisions with regard to drilled cuttings disposal. New drilling techniques, which allow the driller to increase drilling efficiency, raises concerns regarding the zero discharge of drilled cuttings and the minimization of synthetics on discharged cuttings.

Four solutions to cuttings handling and disposal are presented here for the minimization of the cost associated with oil-based cuttings.

- Skip and Ship
 - Bulk Shipment
 - Cuttings Re-Injection
- Synthetics with dryer technology in reducing oil on cuttings to less than 3%.

1. SKIP & SHIP

Apollo Services provides screw conveyors or vacuum units for the provision of transportation of drilled cuttings

from the solids control equipment, directly into cuttings containers.

a.) Screw conveyors have been the most widely used method for transportation of drilled cuttings, for several years in the oil industry. Based on the screw conveyor field track record of breakdowns, high maintenance requirements, failures, and injuries resulting from exposed moving parts, they are no longer the preferred method for cuttings conveyance. In addition, screw conveyor installations require costly hot work, extensive labour and may require deck or wall penetrations to route the units. The industry now considers it to be a potentially hazardous and a costly method of conveying drilled cuttings. The focus is on the use of new technology for cuttings conveyance.

b.) Vacuum Directly into Containers.(Fig. 1) Apollo Services' vacuum equipment is completely enclosed with no exposed moving parts, eliminating the possibility of injury to personnel. Apollo vacuum equipment meets and exceeds European design standards. The vacuum equipment is very safe and easy to mobilize and demobilize. Bulkhead penetrations are installed requiring no hot work. The vacuum line routing is simple and quick to install, as well. By installing the necessary bends along with horizontal/vertical runs of hose or PVC pipe, provides simple to install conduits for cuttings and air flow for cuttings movement from the rig shaker collection point to its end destination in the containers. Apollo Services has been using this method as its primary means to convey drill cuttings since 1994.

Vacuum Equipment Installation: The ditch would be examined to determine if the arm angle is adequate to allow drilled cuttings to fall by gravity means into the centre exit pipe. The exit pipe would be plugged and

used as a central collection point for the vacuum pick up hose. Investigation into a false temporary ditch may be required to ensure the cuttings would, by gravity means, flow into the centre ditch exit point. Seawater flush system should not be used in flushing the cuttings to the ditch centre as this adds to haul-off volumes in containment operations.

In order to maintain 100% equipment redundancy, two vacuum units would be the ideal solution for ship-to-shore operations. This would avoid any potential for rig downtime. The units are 75 kW rated with an air throughput of 1600 CFM's, which moves the air/cuttings at 105 mph through the 6" conduit pipe. This rapid movement through the conduit avoids any potential for line plugging in gumbo sections during the drilling operation.

The vacuum unit can transport all types of material including dry, wet, and sticky, gumbo, rock, clay-stone and sand. A purpose built vacuum lid would be supplied to suit the proposed containers. The lid is constructed of either fiberglass or steel, which will keep the handling weight to a minimum. The lid is fitted with a large seal to ensure an airtight fit. The lid is fitted/sealed to the box during filling operations.

To retrieve the drilled cuttings, the vacuum system uses a hose from the cuttings ditch collection point. The solids/liquids phase would be transported from the ditch to the mud boxes using vacuum means. The solids/liquids will travel through the hose conduit and the solids phase would fall out of suspension in the container while the air phase will continue through the vacuum unit and exhaust into the atmosphere. The system can process up to 25 tons/hour of drilled cuttings per vacuum unit.

Four to six containers (engineered at 1 bar 14.7 psi) are positioned in a suitable envelope during filling operations and used as a vacuum vessel. There are many suppliers who state their boxes are vacuum rated and have been used in vacuum applications. However, investigations routinely suggest that in fact the boxes are not properly engineered for full vacuum loading and may be used in an unsafe manner.

c.) Vacuum directly into containers via hopper system (Fig. 2). It is the view of many that skips are not adequately vacuum rated requiring the supply of cuttings vacuum hoppers. Typical Vacuum hoppers cannot discharge and vacuum simultaneously. Thus, two gravity vacuum hoppers are required to handle 100% of the drill rate, with no redundancy resulting from equipment faulting. Additional problems result from drill cuttings being sticky and not flowing freely from the gravity hoppers resulting in compromising the drill rate. Apollo's patented continuous duty vacuum hopper system eliminates these concerns. The Apollo system

has a mechanical screw within the vessel, which pushes the cuttings out of the hopper, not depending on gravity. Each continuous vacuum discharge hopper can handle 100 % of the drill rate (**Fig 3**). The unit is equipped with an articulating arm, which can be positioned over the containers during filling operations.

The Apollo vacuum hopper system consists of 2 x 10bbl hoppers mounted in a frame, which are approximately 4 meters above the deck. The hopper is equipped with a choke plate device at the lower end of the pod with an articulating arm, which can be positioned over the containers during filling operations. At a predetermined weight, the choke plate will offset, allowing the cuttings to gravity fall from the pod lower end into the containers via the chute arrangement. This system provides 100% equipment redundancy, preventing the possibility of rig downtime during containment operations.

A flexible hose connects to the pod inlet via the ditch collection point conduit line. Attached to the pod is an " exit hose connected to the vacuum unit to allow for airflow through the unit.

The vacuum unit includes the air volume box and is equipped with acoustic paneling to reduce noise emissions locally to <84dB (**Fig. 4**).

Among the advantages achieved with the Apollo patented Continuous Vacuum Discharge hopper vacuum system are significant improvement in Health And Safety, by elimination of manhandling vacuum lids, reduction of skips to be handled because we can fill the containers to the top, elimination of putting a vacuum load on cuttings boxes, the ability to put four to six boxes under the Apollo Continuous Vacuum pods, and minimizes crane usage. Investigating the Apollo hopper system from a safety perspective, operator handling is kept to a minimum reducing the potential for injury. Another feature is that the operator has a visual view into the box, which allows him to ensure each box is filled to its maximum capacity. We believe this visual view means the boxes have 1/3 more filling capacity over lid fillings operations.

The system is capable of transporting cuttings of 100 meters/hour in a 12 ¼ " hole section. Operators have drilled as fast as one mile in 24 hours, utilizing this system (**Fig. 5**).

Container operations: Containers can be stacked two high on the drilling deck and are easily maneuverable around the rig. Four to Six containers can be placed under the hopper system at any one time. A complete replacement of two full containers with two empty is recommended. This operation is coordinated with the crane operator.

2. BULK SHIPMENT

During bulk containment operations (**Fig. 6**), large boxes of variable capacity (230 bbl capacity) are used to collect cuttings on the rig as opposed to small 6-ton (15Bbl) skips. A standby vessel arrives on a logistics schedule to collect the cuttings bulk containers; the cuttings are transferred to the vessel by blowing the dry material directly to the rig. This eliminates crane handling of skips, reduces equipment-handling requirements during containment operations, reduces potential injury hazards and allows the rig to continue drilling during poor weather conditions.

The Apollo Bulk Handling system has been developed to eliminate the need for adding drilling mud or running shale shakers wet to provide pumpable cuttings slurry to the boat.

This proprietary system is protected under worldwide patents applied for. Among the benefits achieved by the Apollo Bulk System are reduced amounts of cuttings to be stored, hauled and treated; reduction of oil/water on the cuttings which also minimizes the cost of onshore treatment and disposal; allows for more hole to be drilled and stored before a boat is required for cuttings transfer; recycles good mud on the rig that would normally be disposed of at high costs; improve solids removal efficiencies; eliminates the need to add mud to the cuttings that increases disposal costs, etc.

BULK CONTAINMENT SYSTEM OBJECTIVES

- 1. Eliminate Skip Transfers/Rentals**
- 2. Improve Health and Safety**
- 3. Dry Cuttings to OOC<3%, Avg. 1.8%**
- 4. Stores More Cuttings per Hole Drilled**
- 5. Recovers/Recycles Mud from Cuttings**
- 5. Decrease Dilution Costs**
- 6. Reduces Haul Off Volumes and Disposal & Treatment Costs**
- 7. Improves Cuttings Transfer Systems/Reduces Space Requirements**

Bulk Containment Process Description:

Drill cuttings are discharged from the rigs vibrating shakers and transferred by auger or vacuum means to the vertical centrifuge (**Fig. 7**). The cuttings enter the upper cavity of the vertical centrifuge by gravity means, flowing into the internal bowl of the Typhoon, where the solids and liquids are separated by centrifugal force. During the separation phase of the process, the bowl rotates at 230 G-Force. In order to facilitate separation of the liquids and solids, a fine mesh screen is fitted in the internal bowl of the rotating vertical centrifuge.

The liquid mud recovered resulting from centrifugal force flows from the dryer via a 4" conduit through a high-speed centrifuge at 3100 G's in removing low gravity solids from the liquid phase of the mud. A mono pump fitted onto the centrifuge unit to the mud pits then transfers the cleaned mud.

The solids phase, will gravity fall into large containers, designed to fit on the rig's available envelope and have enough capacity to store the hole sizes planned. Cuttings are stored, usually at about 2 times hole volume, as opposed to competitive systems reporting 6 to 7 times hole volume. This allows for more hole to be drilled and stored awaiting the vessels arrival.

Apollo's blower system will be positioned adjacent to the bulk containers on the rig for transporting the dry cuttings to the bulk container positioned and manifold on the vessel during filling operations from the rig to the vessel.

On arrival to the port, the cuttings transportation vessel will be secured to a bulk docking facility near the Thermal Desorption facility. The blower unit fitted on the vessel will retrieve the dry drill cuttings from the bulk containers and transport them via the flexible conduit line to the thermal facility-receiving facilities (**Fig. 8**).

3. CUTTINGS RE-INJECTION (CRI)

Apollo Services CRI Philosophy:

When Apollo introduced CRI in 1988, complex modeling techniques used to determine fracturing parameters for increased hydrocarbon production, in tight, porous, brittle and ductile formations were used for CRI. Although a good start, these models differ significantly from models required to simulate cuttings injection of drill cuttings (**Fig. 9**).

Slurry injection consists of a different set of parameters in relation to typical fracture models. Fracture models for hydrocarbon stimulation are designed to create large fractures, and are noted as follows: High injection rates to prevent sand screen out, Injection with specific brittle particles that are large when compared to cuttings slurry particles, no distribution of particle size, high fluid horsepower at the formation face, short duration pumping, slurry rheologies that have low fluid loss and are ultimately designed to maximize the fracture (**Fig. 10**).

Apollo Services philosophy is to minimize fractures as follows: cuttings slurry particles are small in size, soft/ductile in nature, pumped at low rates for long periods of time, sometimes for over a year, purposely designed to keep the fluid horsepower low, and generally have poor fluid properties. Slurry injection

dictates a minimal impact to the formation. The intent is not to propagate large fractures.

Having identified the differences, we have modified fracture programs based upon what has actually happened on over 360 Apollo CRI disposal projects around the world in many types and strengths of formation rocks. Based on our injection well database, coupled with our cuttings injection experience, models of worst-case scenarios have formed our basis of design modeling. Our analytical method in designing the injection subsurface programme through our modeling has been very successful and allows for large volumes of slurry to be injected in the subsurface regime. Based upon this experience, we have proven that we can inject drill cuttings successfully, anywhere in the world.

Newly developed monitoring and acquisition systems allow for real-time data gathering of the formation affects from injecting cuttings slurry injection and assist in plotting this effect over time. We are currently using continuous data logging to record and analyze the formation reaction over time, as well. This same equipment is also programmed to control parts of the injection process and enables the system to provide automation capabilities.

Quality control of the slurry prosperities, and site-specific rheological/physical property adjustments are crucial for maintaining zonal isolation and for maintaining long-term injectivity. Many formations change its injection characteristics over time, especially after large volumes of slurry have been injected.

Operating Considerations:

A variety of operational details must be dealt with to properly plan the project. Successful operations dictate that the majority of the work is completed in the planning stages. Some of the details include:

- Identifying suitable cuttings disposal/sealing formations.
- Selecting surface equipment.
- Designing the casing program.
- Design of the injection program/contingency planning
- Plug prevention in the annulus and the formation.
- Preventing cuttings slurries from breaching to the surface or contaminating the water table
- The impact on existing producing wells or future wells to drill.
- Quality control/monitoring of injection procedures.

- Abandonment of waste disposed to permanently entomb the waste.
- Obtaining regulatory approval.
- Addressing environmental and safety concerns

Characteristics of the subsurface environment, sealing formations, injection zone, slurry properties, drilling plans, subsurface slurry disposal dimensions and other elements, directly impact each of these operational considerations. Of the various technical details that must be evaluated, the least understood but equally as important, are those questions associated with down-hole considerations: -

- Into what formation can the cuttings slurry be injected?
- How will the cuttings slurry be contained?
- In what direction will the cuttings slurry propagate? And how far?
- How significant of an impact will cuttings slurry have on nearby well bores/formations?
- How will the cuttings slurry affect existing wells and future drilling plans?
- What volume of cuttings slurry can be safely disposed of?
- What forces will be put on well casing?
- How are slurries injected to minimize formation impact?
- How are the annulus and the formation protected?
- When the formation changes - how does the CRI operator vary the slurry specifications?
- Particle Size < 100 micron (**Fig. 11**)

Surface Equipment Requirements:

Proven equipment reliability, manpower requirements, utilities, ease of installation and contingency plans must all be considered when designing the surface equipment system. Proper system design is crucial since any downtime for repairs or maintenance directly impacts on drilling progress. In zero discharge operations, it is important that the CRI surface equipment is adequately sized to process the cuttings ahead of the drill rate/surge conditions. Contingency plans should be developed for each specific project. (**Fig. 12**)

4. CUTTINGS DRYERS to Reduce Synthetic on Cuttings Discharge

Different styles of cuttings dryers have been developed over the years, with increasing success. Today, with

some of the tools available, Synthetic on cuttings discharge levels are less than 3%. Resulting in a biodegradable product on the seabed. Apollo has aligned with various operators since 1995, drying drill cuttings, in order to reduce the environmental impact that these fluids entail.

Dryers are positioned down stream of the rig solids control system allowing the rig shakers to be fitted with finer screens, resulting in increased drill solids removal efficiency. The additional mud lost over the shakers is collected in the cuttings dryer and returned to the mud active system, after centrifuging the drill solids.

MUD RECOVERY OBJECTIVES

1. **Dry Cuttings to OOC<3%, Avg. 1.8%**
2. **Recovers/Recycles all Mud from cuttings**
3. **Reduces Dilution Costs**
4. **Improves Cuttings Transfer Systems/Reduces Space Requirements**
5. **Reduces Haul Off Volumes and Disposal & Treatment Costs**

The Apollo Typhoon (**Fig. 13**) is a centrifugal, cone-shaped, vertical centrifuge that “dries” the cuttings with a 300 G centrifugal force. The effluent of the centrifugal dryer is processed thru a high-speed centrifuge for optimum cleaning of recovered mud. The process rate for the cuttings dryer is 40 tons of cuttings per hour. With this system, synthetic discharge to less than 3% synthetic by weight has been achieved and in some cases, averaging 1.85% synthetic discharge by weight. (**fig. 14**).

Screening-up improves cleaning of the mud and separates the undesired fine solids before they are re-run down hole. The results would be the drill solids would degrade into millions of ultra fines. There are only two solutions for ultra fine drill solids: Mechanical removal (Centrifuges), or by dilution with very expensive Synthetic Base Fluid or Mud.

The Apollo cuttings dryer process allows the optimization of the rig's solids control system; thereby reducing substantially expensive dilution requirements of the active mud system. (**Fig. 15**)

More importantly, the reduction of drill solids in the drilling mud system has proved to reduce drilling days, allows for better hole conditions; reduces mud costs by improving mud properties resulting in less chemical treatment costs.

Another dryer product by Apollo is the squeeze press technology. (**Fig. 16**) The squeeze press does not depend on centrifugal "G" force to strip the liquid through a screen while grinding the cuttings. The squeeze press works on a gentle squeeze and aerospace, vibrating, wedge wire screen process, which squeezes the maximum amount of liquid phase available. The primary advantage of the squeeze press is that the unit can be fitted in confined envelopes as opposed to the vertical Typhoon dryer and can position two units side by side for increased through put capacity in faster drilling applications.

During drilling operations, the drill cuttings will retain a ratio between 1.0 and 1.5 barrels of mud to 1 barrel of cuttings, if the rig shakers are optimized for maximum efficiency. As the hole size or penetration rate decreases, rig shale shakers are screened up, resulting in finer solids separation and more fluids retained with the cuttings. In these circumstances, mud recovered ranged from 40-200bbls per each day of drilling.

The discharge of the cuttings to the ocean will be much lower in Base Fluid retention than experienced with other technologies. Tests have confirmed that fewer than 3% by weight Synthetic on cuttings can be achieved. The cuttings can also be ground and discharged with cuttings grinders designed by Apollo. The results lowers the impact to the environment, less discoloration to the ocean, increased biodegradability of the cuttings, and a possible risk of having to retrieve and remove any overly contaminated cuttings bed from the sea floor. Environmental regulatory bodies are tightening regulation in regard to reducing or eliminating synthetic base cuttings discharged to the sea. (**Fig. 17**)

Additional use for cuttings dryers are to reduce the amount of cuttings hauled off and disposed of by recycling the drilling mud from the drill cuttings. Depending on the quantity of cuttings to be processed and the liquid ratio of mud to cuttings, rates of reduction up to 39.6% have been achieved.

Conclusion

Drilling performances are being optimized by the use of oil based or synthetic based mud. Solutions to cuttings handling are assisting operators in drilling wells at a lower cost.

The Apollo patented vacuum/hopper system, provides a safe and efficient method of cuttings conveyance that improves operational system safety.

Our Bulk Shipment process reduces haul-off volumes by 30 to 50%.

Our Cuttings Re-injection success has improved the popularity of CRI and is being used globally, on a much larger scale.

Cuttings Dryers are being utilized to improve the ability to drill faster in large hole sections. Both for reduced synthetic on cuttings discharge to the sea and/or for decreasing the amount of cuttings to be stored and transferred directly to boats.

KW = kilowatt

CFM = cubic feet per minute

bbl = barrels

dB = decibels

OOC = oil on cuttings

CRI = cuttings re-injection

psi = pressure per square inch

Nomenclature

Vacuum Conveyance System

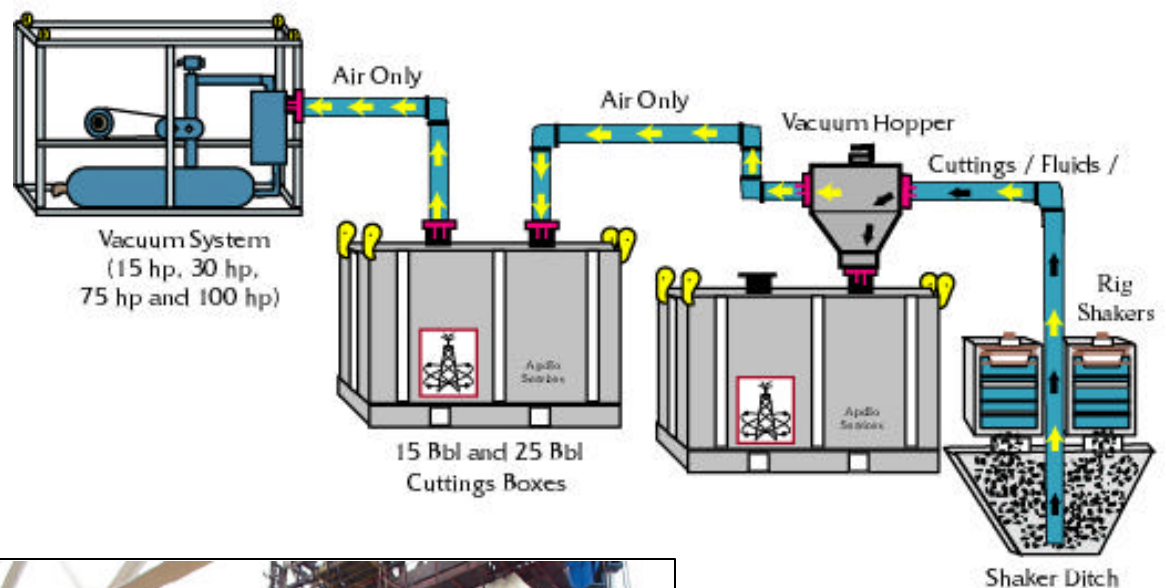
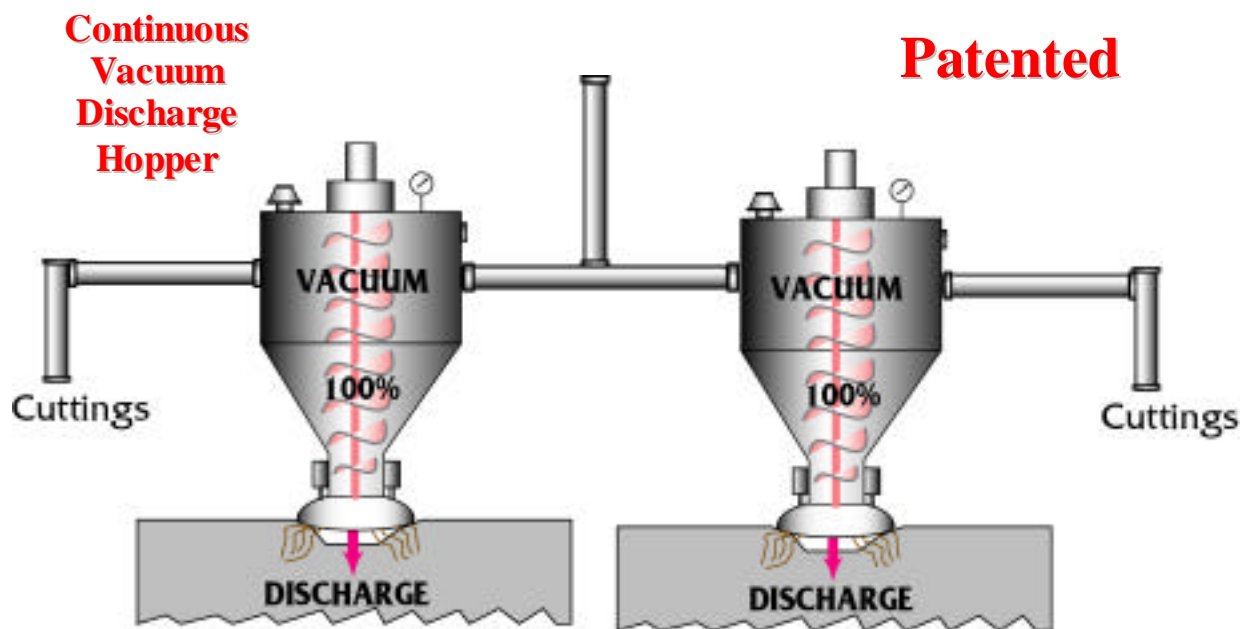


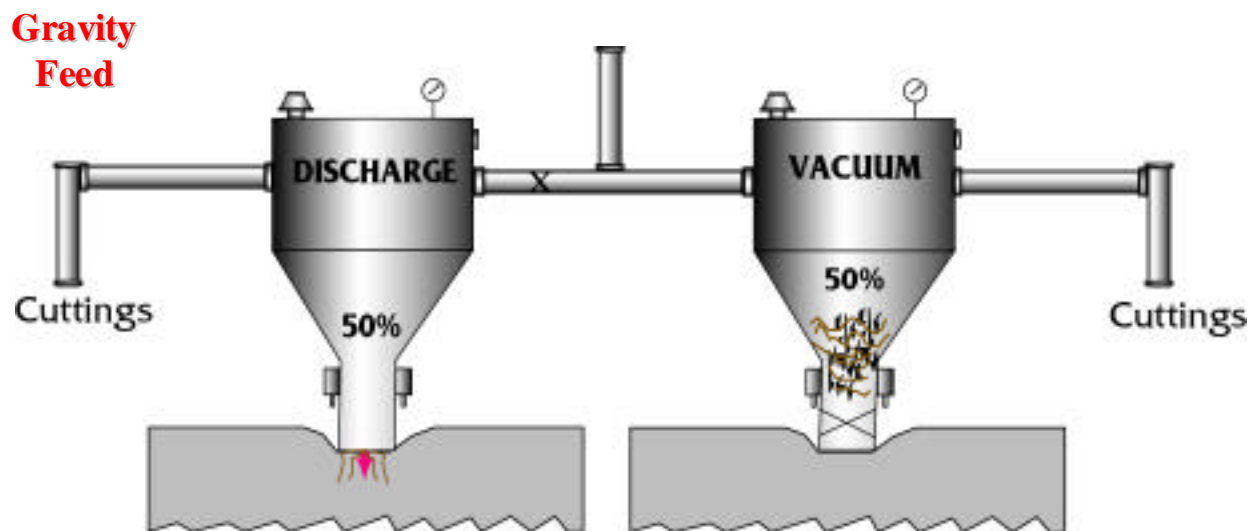
Fig.1



Fig.2



Apollo Services



Others

Fig.3



Fig. 4

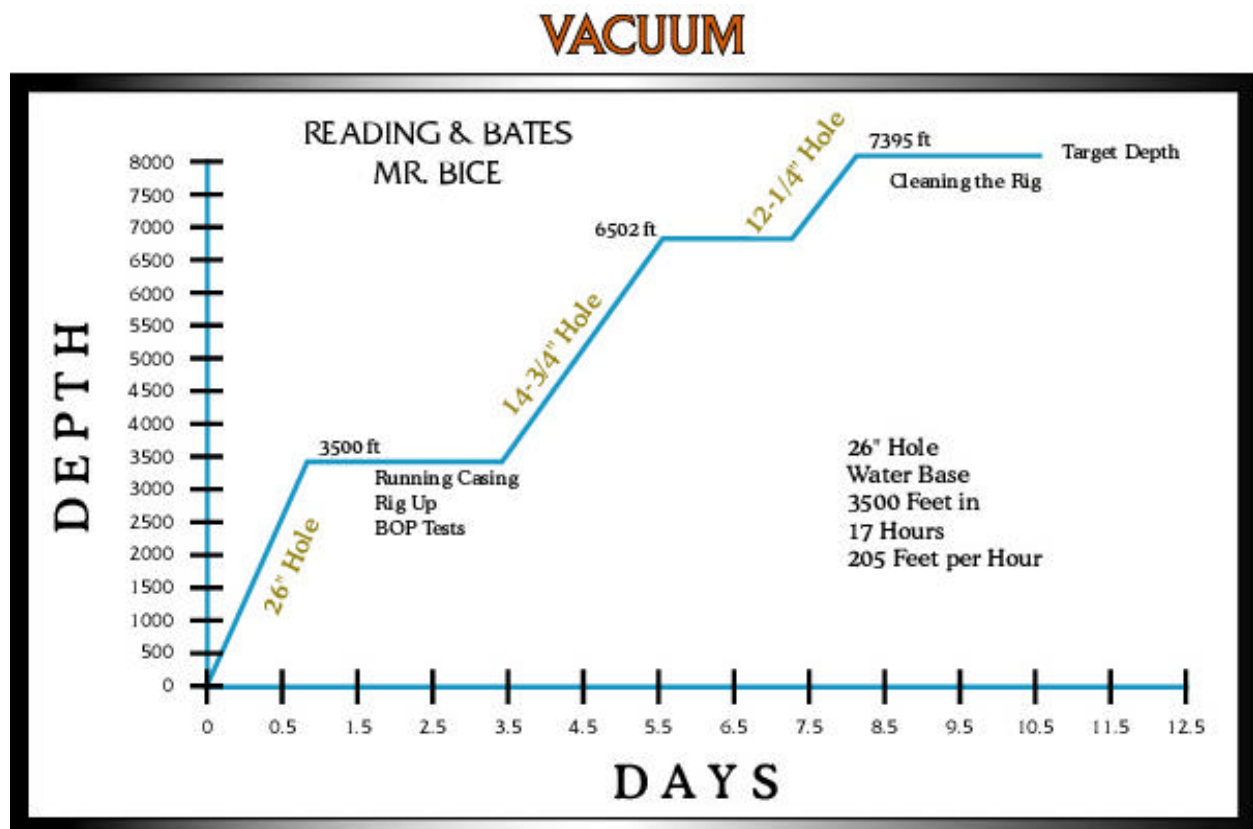


Fig.5

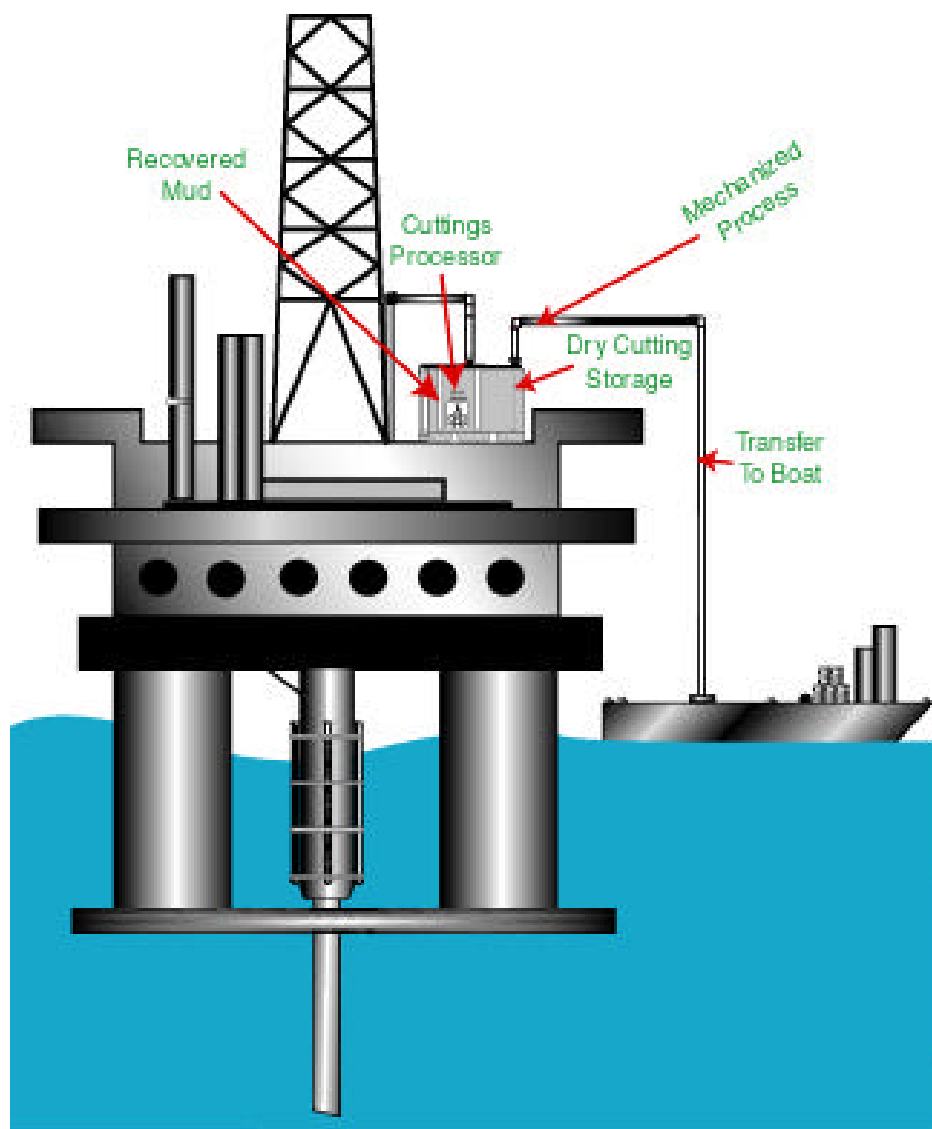


Fig.6

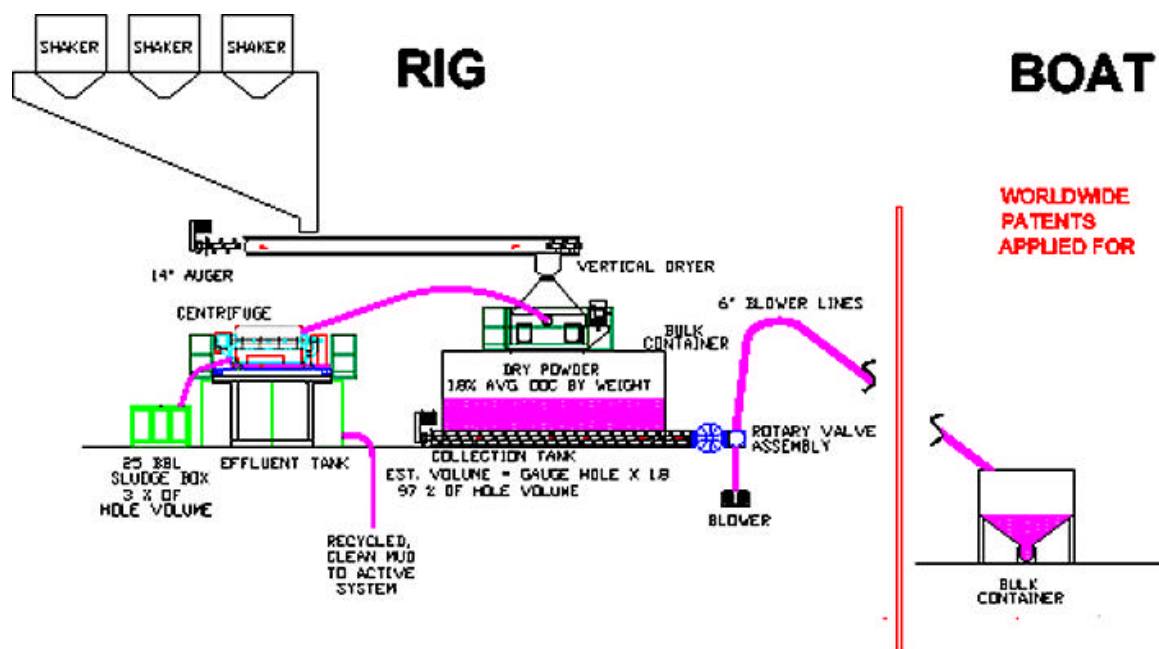


Fig.7

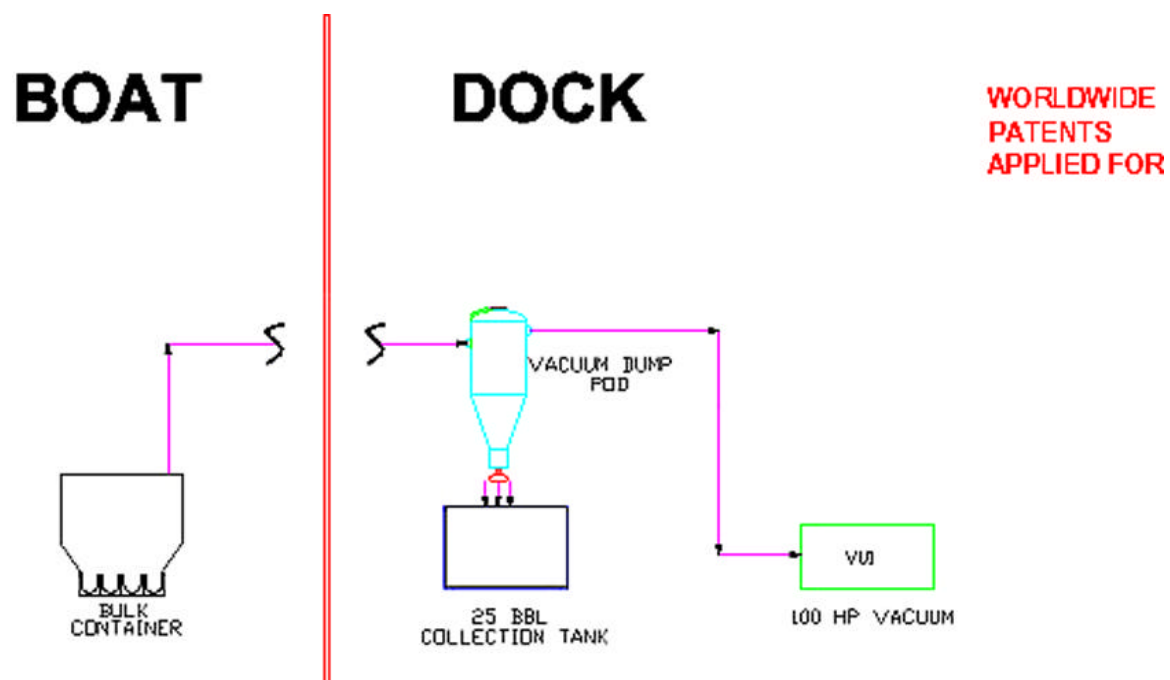


Fig.8

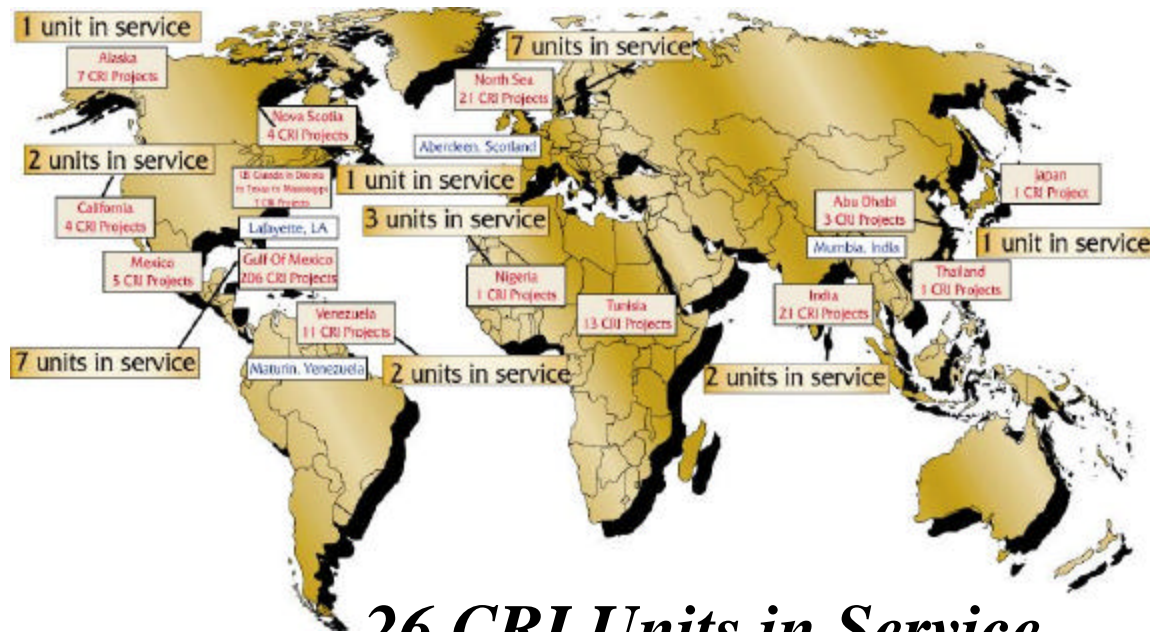


Fig.9

APOLLO HAS DEVELOPED ITS OWN FRACTURE MODELS

- ◆ Significant theoretical differences exist between fracture programs used for production and those successful for re-injection.

Characteristics of Production Fracture Models

- ◆ Design to stimulate production
- ◆ High injection rates
- ◆ Uses brittle large particles
- ◆ One particle size
- ◆ High fluid horsepower
- ◆ Short in duration - 3-4 hours
- ◆ Excellent fluid properties

Characteristics of Apollo Fracture Models

- ◆ Design for maximum Injection volume
- ◆ Low Injection rates
- ◆ Ductile particles
- ◆ Particle size varies
- ◆ Low fluid horsepower
- ◆ Long in duration - 3 years
- ◆ Poor fluid properties

360 Well Data Base

Fig.10

SLURRY PARTICLE SIZE ANALYSIS

System number 5226 Diode DR473 Limestone Formation
Malvern Instruments Easy Particle Sizer M6.1M Date 28-02-89 Time 09:58

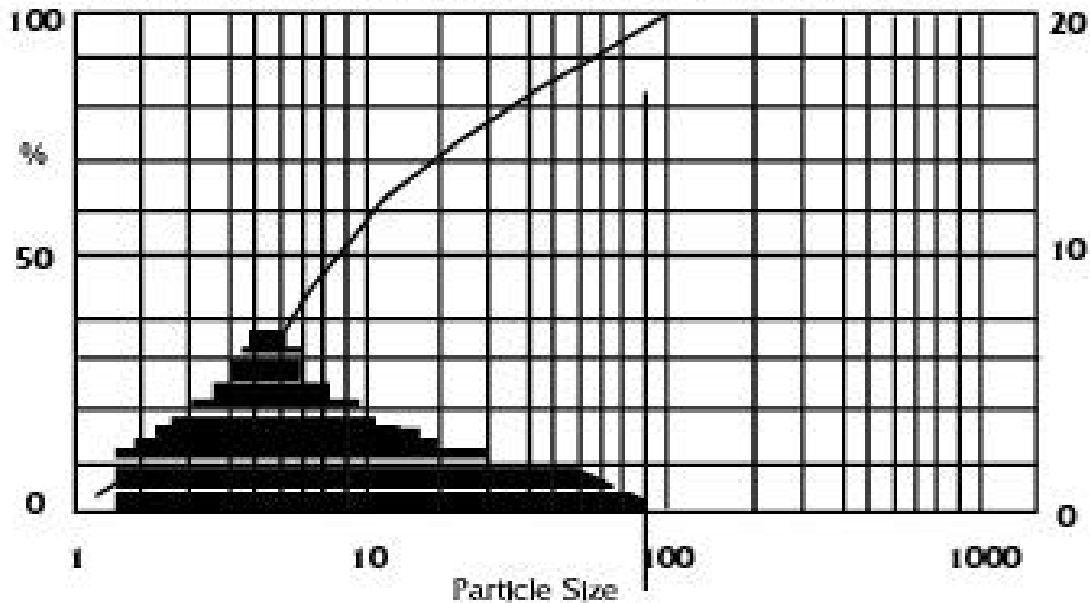


Fig.11

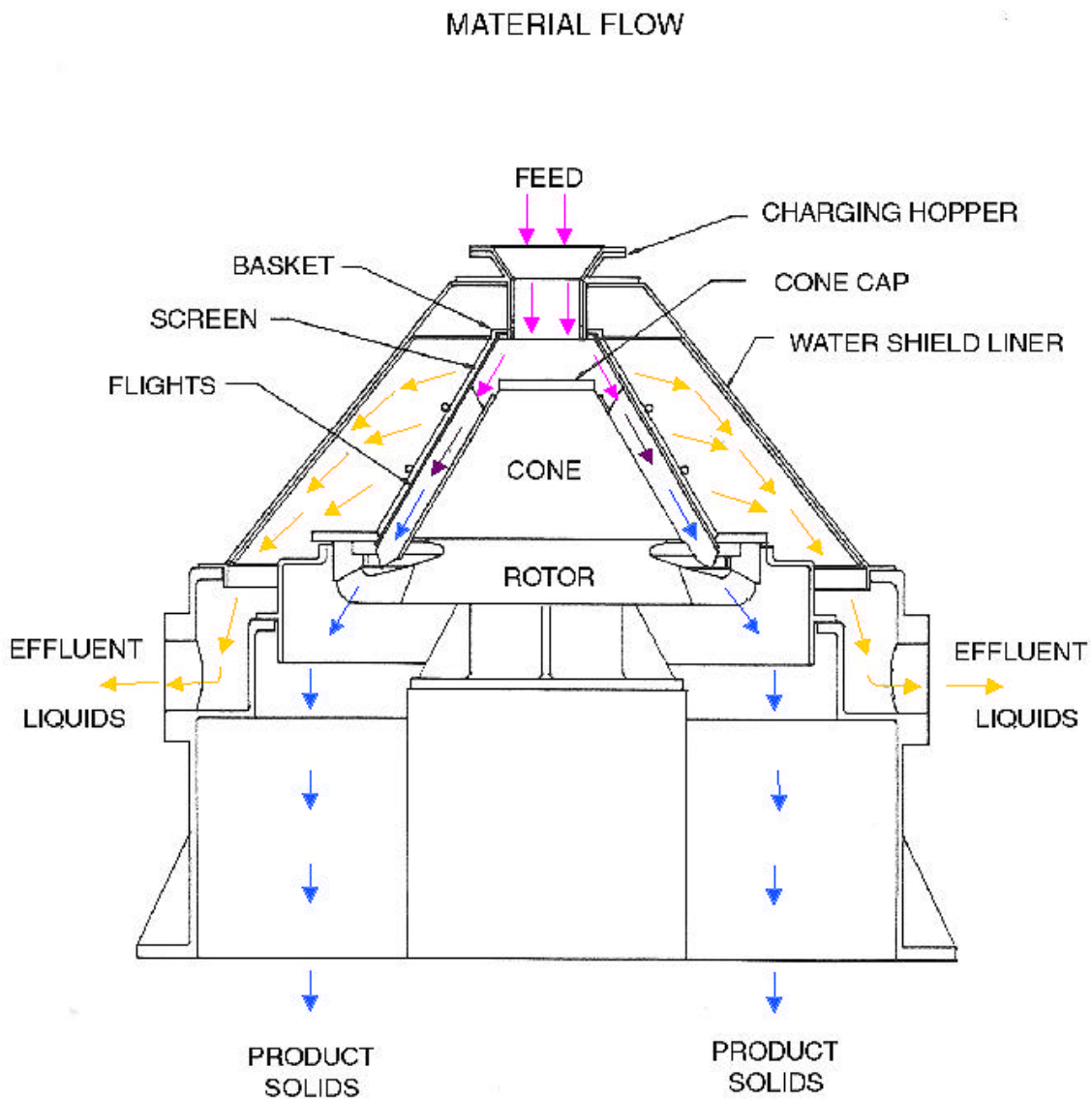
APOLLO'S CASE HISTORY HIGHLIGHTS

OPERATOR	LOCATION	INJECTION FORMATION	BBL'S INJ.	INJECT SYSTEM	HOLE SIZE	DRILL RATE	# OF WELLS
British Gas (7)	Offshore Tunisia	Imperable Claystone	162,476	Mud Line Suspension (Subsea Template)	12-1/4	400 FPH	13
Hunt Oil	West Texas, Land	Chalk	178,426	tbg/perf	Pk	3000 B/d	N/A
Amerada Hess	North Dakota, Land	Tight Sandstone	48,452	tbg/perf	Pk	2700 B/d	1
Hunt Oil	South Louisiana, Land	Loose Sandstone	675,000	tbg/perf	Pk	3500 B/d	10
Numerous Operators (1, 7)	Gulf of Mexico (offshore)	Sand/Shale Intervals	1,200,000	tbg/perf/annular, MLS, depleted zones	12-1/4	280 FPH	95 - Ongoing
Shell U.K. (6, 7)	Brent Bravo North Sea	Clay/Sandstone	132,476	Annular	12-1/4	200 FPH	7-ongoing
BP U.K. (5, 7)	BP Andrew North Sea	Sand/Shale	137,476	tbg/perf/annular	16	250 FPH	9-ongoing
BP Venezuela	Venezuelan Jungle	Claystone/Geologic Upthrust	56,000	Annular	16	1500 B/d	N/A
Phillips Alaska (4, 7)	Cook Inlet Alaska	Sand/Coal/Shale	48,279	Injection String	12-1/4	150 FPH	4-ongoing
Unocal/Spirit Energy (7, 1)	Gulf of Mexico	Sand/Shale	12,724	Annular	12-1/4	1 Mile/24 Hrs.	10-ongoing
Enron India - Two (7)	Offshore India	Imperable Claystone	32,472	tbg/perf/annular	12-1/4	400 FPH	6-ongoing
PanCanadian/Nova Scotia (7, 2, 1)	North Atlantic	Imperable Shale/Clay	24,274	tbg/perf	12-1/4	200 FPH	3-ongoing
Conoco (7)	Gulf of Mexico	Sand/Shale	18,275	Mud Line Suspension	6-1/2	Rig Trash	1
Unocal/Thailand	Gulf of Thailand	Tight Sandstone	4,671	depleted zone tbg/perf	N/A	Hg Prod Slud	1
Numerous Operators	Gulf of Mexico	Sand/Shale	78,460	tbg/perf	N/A	NORM/LSA	16
BP Wyth Farm (3, 7)	South of England, Land	Sand	12,476	3000 ft Horizontal tbg/perf	17-1/2	200 FPH	2-ongoing
Mobil (1, 7)	Gulf of Mexico	Sand/Shale	8,732	tubing/gravel pack	12-1/2	350 FPH	1-ongoing

1-Vacuum Assist 2-Monitoring Pkg, fully automated, Single Lift Pkg 3-Cominge Production and Slurry 4-Tbg Injection String on Site Surface Csg allowed injection of Drill Cuttings immediately after drilling out from under surface 5-North Sea record of 2200 Barrels of cutting slum processed and injected 6-Best Mechanical Engineering Award 1997-OTC 7-Inject while drilling - real time

New Methods Further the Use of Technology

Fig.12



Apollo's Typhoon

Fig.13

Apollo Services
Reduction of SBM Discharge

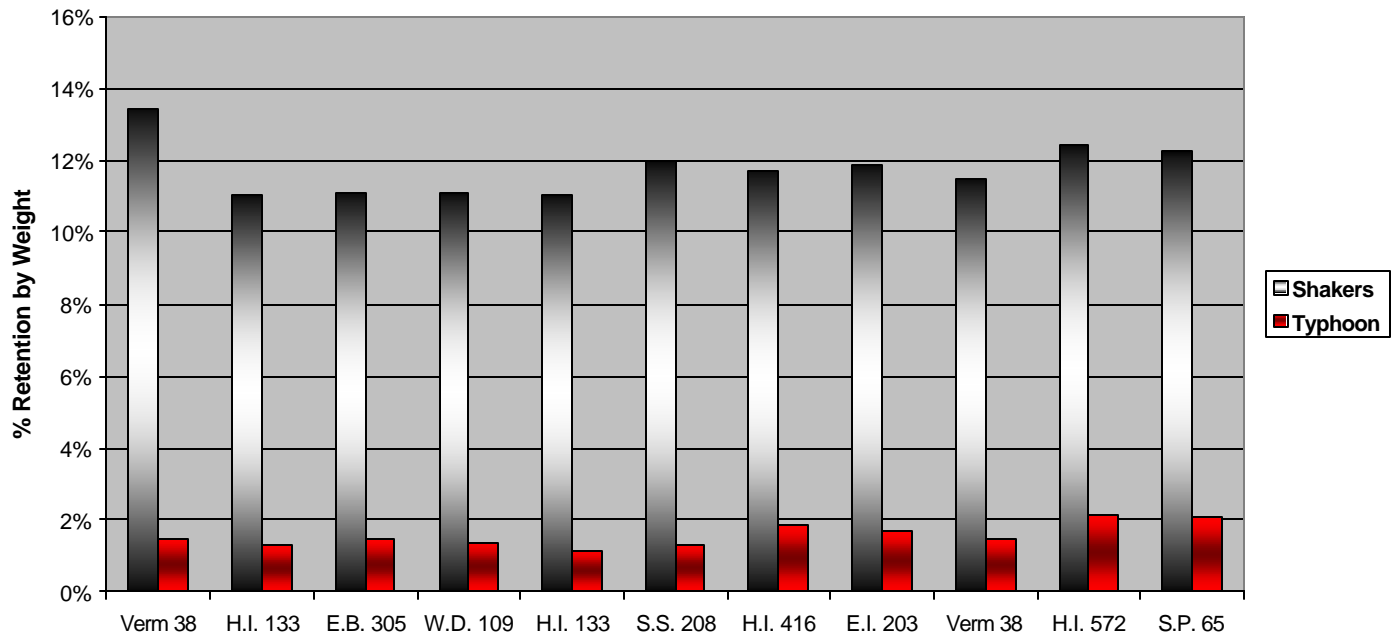


Fig.14

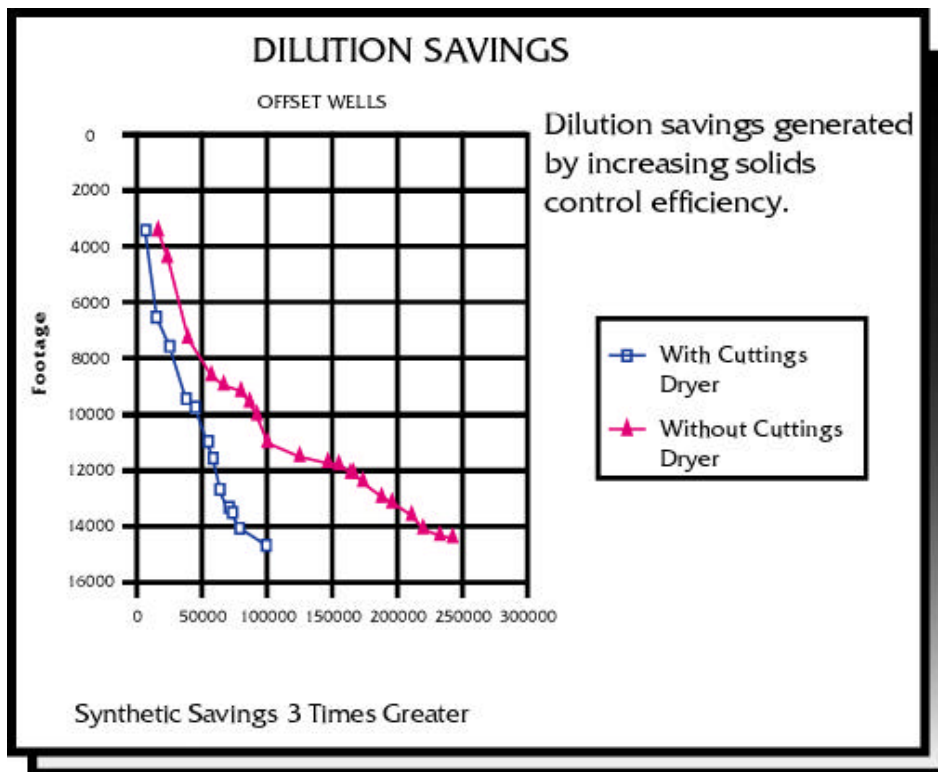


Fig.15

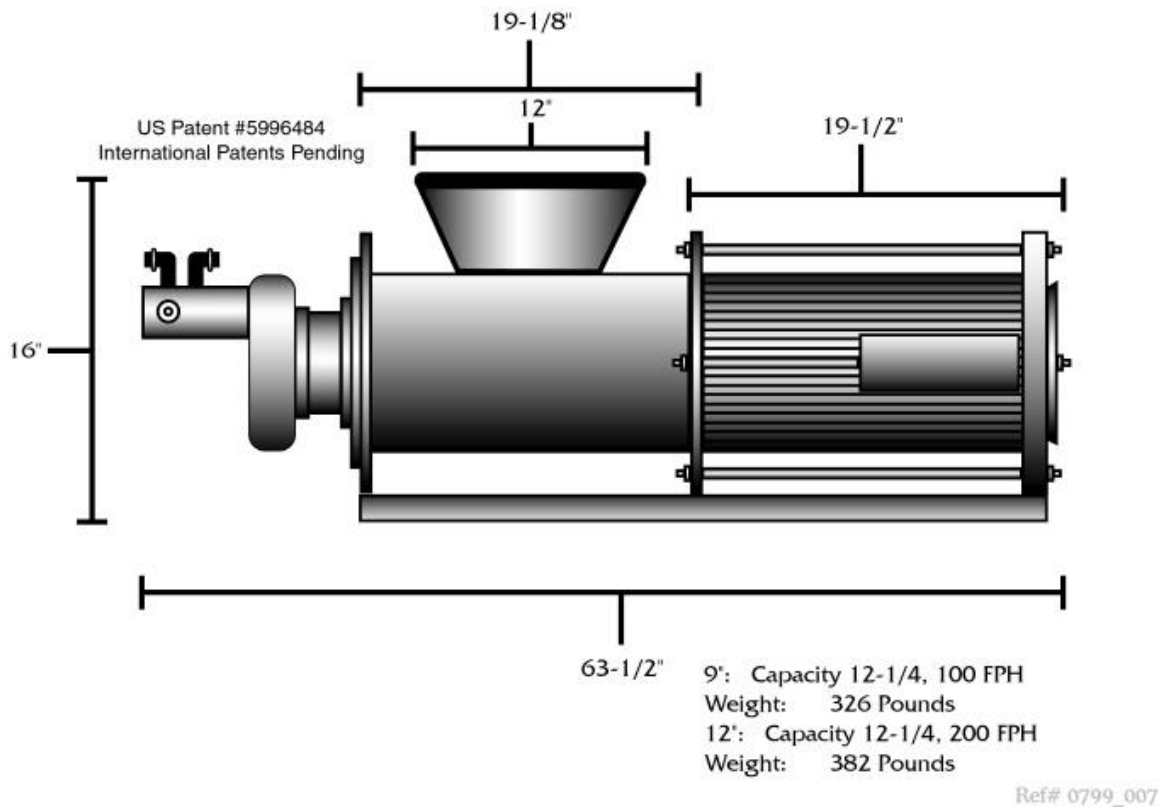


Fig.16

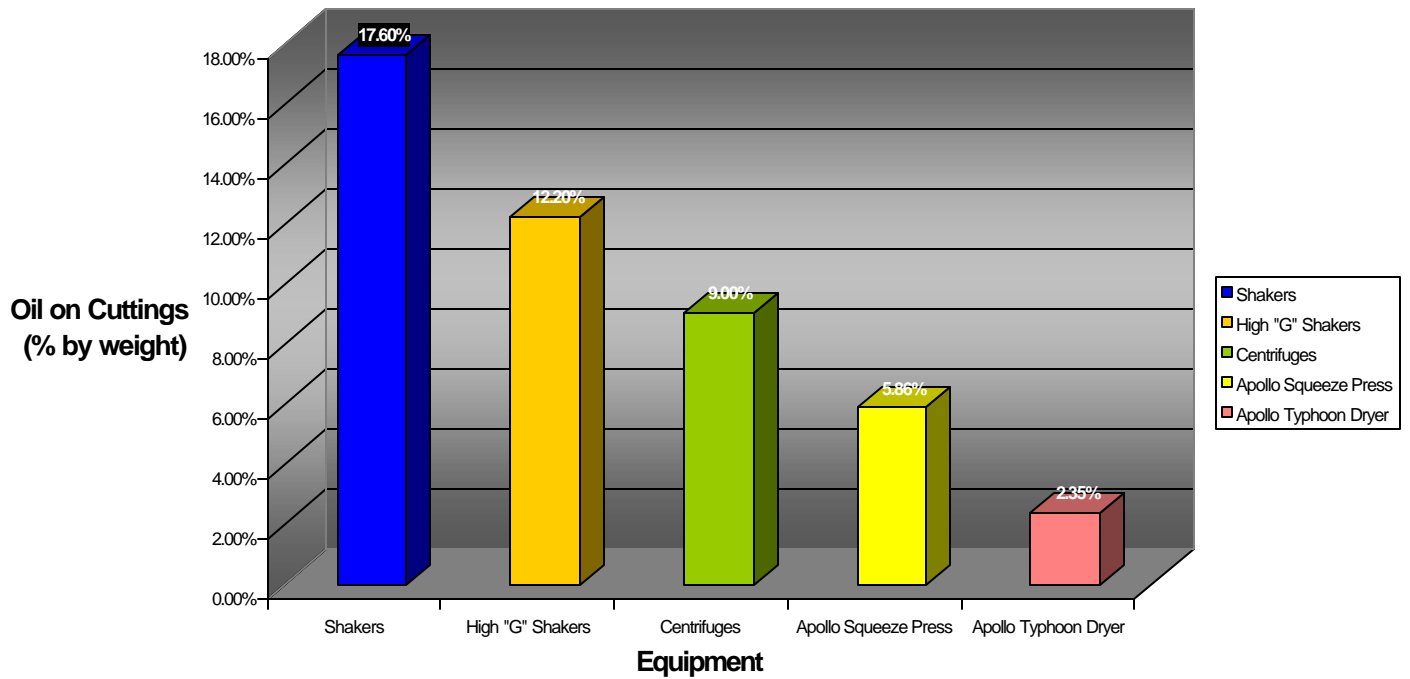


Fig. 17