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Treatment of Nonaqueous-Fluid-Contaminated Drill Cuttings—Raising Environmental and Safety Standards

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Abstract

Drill cuttings and other hydrocarbon contaminated wastes generated in offshore drilling operations have been processed onshore for many years, in part to comply with the regulatory restrictions governing offshore disposal and in part to conform to sound environmental practice. However the transporting (“skip & ship”) of large tonnages of hydrocarbon contaminated cuttings from offshore installations to shore based processing facilities carries with it considerable environmental and safety implications for the industry.

The concept of processing these hydrocarbon contaminated cuttings offshore and the recycling of both the recovered oil and water back into the drilling fluid provides a unique solution to the inherent problems of “skip & ship”, both in the North Sea and elsewhere. The development of this concept into a practical, field proven technology commenced in 2001 and was satisfactorily concluded, following a series of offshore trials in the UK sector of the North Sea, in the latter part of 2002. Since this time the application of this technology has gained wider use and greater acceptance by the industry, allowing for a thorough evaluation of its application in resolving many of the more intransigent problems associated with drilling waste management in offshore operations.

This paper reviews the work completed to date and how it might best be applied in the future. For the work completed, field data will be provided on all aspects of the process and also evaluate the benefits, both in terms of the environment and safety, on a project specific basis.

With regard to the future, the paper will look at ways in which offshore treatment may be better applied to optimize all of the advantages obtained.

Introduction

The environmental impact of exploring for oil and gas is of increasing concern to the industry. With drilling activity extending to evermore remote and environmentally sensitive areas these concerns have been compounded. One of the more critical issues the industry faces today and has for a number of years is how to effectively minimize the detrimental effects the disposal of drilling waste may have on the environment in both offshore and onshore locations. This drilling waste includes the lightly contaminated oily slops and the more contaminated higher solids tank cleaning sludge, centrifuge underflow and drill cuttings. These high solids materials will, if non-aqueous based fluids are being used as the drilling mud, be hydrocarbon contaminated. The disposal of these solid materials without treatment will have both a negative impact on the environment and result in a loss of valuable base oil that could, if recovered, be reused either in the drilling mud or in a number of other applications.

The use of these NABF has more than doubled between 2000 and 2005 as more complex wells are drilled with more demanding geometries where the more traditionally used water based muds perform less well. This, in combination with increasing rig day rates, has stimulated the demand for these higher performance fluids which provide more stable wells regardless of temperatures, pressures and geology while optimising drilling time. The types of oils used as the external phase of these NABFs include low toxicity mineral oils with a low aromatic content (<5%) synthetic fluids, which are normally linear paraffin's and, to a decreasing extent, diesel (Page *et al* 2003). However, regardless of base oil type it is now a widely accepted practice to treat the cuttings contaminated with NABF prior to disposal in compliance with regulation and best environmental practice while recovering a valuable asset, the oil itself.

Given the increased use of NABF for the reasons described above the tonnages of NABF contaminated cuttings around the world has also increased. In the UKCS, for example, as much as 80,000 tonnes of NABF cuttings are generated offshore each year. These cuttings will typically come off the shakers with a hydrocarbon content of between 15% and 20% by volume. The volume of recoverable base oil from this 80,000 tonnes of material equates to between 37,500 and 50,000 barrels of low toxicity mineral oil. With the UKCS making up only a very small part of the world's drilling activity the volume of oil that can be recovered on a worldwide basis will be considerable. The factors that drive which of the various options are likely to be used for the treatment of these drill cuttings are:

- Government legislation
- Operator environmental standards
- Cost
- Safety
- Logistics

Drivers for treatment

The five treatment drivers defined above will vary in importance from one country to another and from region to region depending on a number of variables, which include numbers of wells drilled, depth of water, prevailing currents and others. In many, government legislation will override them all while in some individual operators may put in place their own standards. Whichever the driver, what is actually done in each location does often differ widely.

Government legislation.

Regulations governing the disposal of NABF cuttings and the permitted levels of hydrocarbon contamination vary from the most stringent "zero discharge" policy, which is applied in Kazakhstan's Caspian Sea, Nigeria and elsewhere to the UKCS' less onerous 1% by weight (dry) introduced in implementation of OSPAR Decision 92. There are other variations which include the 6.9% upper limit in the GOM and the 10% which is applied in many parts of South East Asia. To further complicate the issue these "headline" permissible oil content figures are not necessarily comparable with one another as the percentages for each country may have a different baseline and there may be different restrictions on the types of oils that may be used.

Operator environmental standards.

Oil companies have become increasingly pro-active in setting environmental standards themselves. In countries or regions where there may be no government regulations that control the disposal of NABF contaminated solids, operators have put in place their own upper limits on acceptable hydrocarbon contamination levels to ensure that they are in full compliance with the very highest of environmental standards.

Cost.

With the high cost of NABF the recovery of all or part of this fluid, which might otherwise be disposed of with the cuttings, is of economic value (Ivan and Dixit, 2006). Given that the cuttings may contain as much as 20% of base oil the recovery and reuse of this material can, in many instances, recover a significant part of the cost of treatment.

Safety.

The movement of large tonnages of drill cuttings can have serious safety implications. Depending on the treatment process chosen and if drilling operations are taking place either in a remote location on land or offshore, cuttings may have to be transferred to a central treatment facility prior to disposal. This is likely to require the use of cuttings boxes (purpose built steel containers with a typical capacity of 4 metric tonnes) which in turn creates a number of negative safety factors given the large number of crane lifts required to do this. If for example the 80,000 tonnes of cuttings generated in the UKCS have to be taken ashore for treatment using these cuttings boxes there will be at least 20,000 bins used. For each bin transported to the rig, filled and returned to a shore based processing facility there are likely to be as many as 15 crane lifts, which over the year would total 300,000 lifts. This number of lifts, often in cramped spaces, will increase risk of injury to those involved in the process.

Logistics.

Much like the safety issues described above the need to transfer large tonnages of cuttings to a central processing facility will create logistics problems. This especially true when drilling operations are taking place offshore in winter months, when weather conditions may make it difficult to transfer cuttings ashore as well as getting empty cuttings bins to the rig. Similarly in remote locations onshore the transfer of these cuttings to a central processing facility may be difficult if the road infrastructure is poor. As a result any failure in getting bins to or from the rig could result in a temporary shutdown of drilling operations.

Treatment Options

With restrictions in force on cuttings disposal in many countries and in those where there are none the operators taking the lead with their own, the industry has had a number of disposal / treatment options available. Onshore these have included thermal desorption, fixation and bio-remediation. Offshore the re-injection of cuttings has been one option. In other locations, where legislation is less restrictive, various methods of “mechanical” separation have been used to meet discharge limits. The driers widely used in the GOM are one such example.

If cuttings generated from offshore operations are to be treated onshore this will, of necessity, involve the transportation (“skip and ship”) of large tonnages of NABF contaminated cuttings from these offshore installations to whatever shore based processing facilities are available (see Fig 1 for schematic of skip and ship). This practice, widely used in the North Sea and elsewhere, carries with it considerable cost, logistics and HSE implications as described above. Whichever onshore treatment option is taken this impact on cost and HSE is significant and that is before the liability issues relating to the disposal of processed powder are taken into account.

Clearly the movement of large tonnages of invert emulsion contaminated cuttings from offshore installations to shore based processing facilities is not the perfect solution to one of the industry’s more important environmental problems. If the highest standards are to be met the best options would, for the reasons described before, require the removal of “skip and ship” from the equation but to do this a technology for processing cuttings offshore would need to be found.

Various types of direct and indirect thermal desorption have been used by the industry for a number of years to process cuttings onshore. The process which uses thermal energy to evaporate the fluid phases from the cuttings before recovering them separately as oil and water could in theory be used to treat cuttings offshore. Although size, processing capacity and safety issues rule many of the various types available as unfit for purpose. One of these indirect thermal desorption technologies - based on a hammermill (See Fig 2) - could feasibly be used to meet the more stringent demands of working in an offshore environment. The hammermill type of thermal desorption uses a series of hammer arms mounted on a central drive shaft rotating at high speed in a process chamber to create friction with the cuttings which in turn generates the necessary temperatures required to flash evaporate the fluid phases of water and oil, the vapours of which are then passed first through an oil condenser to recover the oil and then a steam condenser to recover the water.

However before this technology could be trialled certain criteria had first to be met. Safety issues are clearly paramount and therefore how the thermal energy is generated for desorption to occur is a vital component. Equally, great emphasis needs to be placed on equipment reliability when operating offshore and effectively “online” with drilling operations, while at the same time ensuring that sufficient processing capacity is available to keep pace with the rate of cuttings generation. Other issues of importance are footprint, weight, mobility and, of course, cost. Meeting these and other criteria would be the challenge.

Technological Development

In the mid 1990s work commenced in the UK sector of the North Sea on the evaluation of hammermill technology for use in offshore applications for the treatment of NABF cuttings. The key elements addressed during this development programme, apart from meeting or exceeding regulatory requirements, included modularisation of the plant, reducing weight and footprint, meeting zoning specifications and getting processing throughput high enough to cope with cuttings generation rates, even in the larger hole sizes. Individual module weights had to be kept to a minimum to meet crane lift restrictions and footprints reduced to fit within the limited space available on most offshore installations. The zoning specifications were designed to meet Zone 2 requirements. Some of the safety features included using enclosed containers with a CO_2 purge system, tying the equipment into the rigs emergency shutdown and computer controlling all operations. Processing rates were increased to keep pace with cuttings generation at typical rates of penetration not only in the 8½” but also the 12¼” and 17½” hole sections.

The prototype cuttings treatment plant based on this hammermill technology, specifically designed for offshore use operated on a continuous process basis governed by a computerised control system. Temperature (typically 260ºC) was generated to flash evaporate the fluid phase (water and oil). These evaporated fluids would then be condensed and recovered separately.

Most importantly during the process there would be no emissions to the atmosphere and both the recovered water and oil would be suitable for recycling back into the drilling fluid. During initial onshore trials, analysis of this recovered base oil showed that the process had little or no effect on the oil or its performance in the drilling fluid. The level of retained hydrocarbons in the recovered water was typically <20 ppm and the suspended solids between 5 and 15 mg/litre. The inert processed powder had a retained hydrocarbon content of less than 0.1%.

Field Trials.

To ensure all elements were operating effectively and that recovered materials met or exceeded specifications, once the initial modifications where completed, field trials had to be carried out to prove the concept and the process. This included confirming that the recovered oil would be suitable for reuse in the mud system and that both the water and powder properties were in compliance with the regulations governing offshore discharge. The company was fortunate that throughout this development phase an operator had been actively involved and an offshore installation was made available through all stages for these trials.

- The first system, capable of operating in a zone 2 area, on an offshore installation was commissioned in April 2001.

- The first offshore proving trial was initiated in June 2001 on board the rig Glomar Arctic III (now GSF Arctic 111).

- A further two (2) trials were undertaken to allow regulatory bodies such as the Dti and various environmental organisations the opportunity to audit of the efficiencies of the technology, again on the Skene field

- Upon completion of the third (3) trial period the unit was accepted by the Dti as an alternative method for the processing and disposing of drill cuttings from an offshore installation.

- The first 950kW process plant was built and then mobilised to the Ocean Guardian in early August 2003.

Offshore Operations

With the early trials completed and the technology meeting regulatory requirements for offshore discharge the process was fully commercialized in 2003. Since that time more than 30,000 tonnes of cuttings have been processed offshore UKCS by a total of eight operators. The wells on which the technology has been used have included HTHP wells, 17½” hole sections and combinations of both. In those hole sections where high rates of penetration and large hole sizes have combined to produce cuttings at rates that have for brief periods of time exceeded the processing capacity of the plant some purpose built storage tanks have been used to provide some buffer storage to level off these peaks allowing the process to continue partly “offline” from drilling operations on 24 hours per day basis (see figure 3 for schematic of offshore layout). The recovered oil from the process has been routinely used back in the NABF and the powder discharged overboard with a hydrocarbon content typically of less than 0.1% and well within the regulatory upper limit of 1%. In most cases the recovered water has also been discharged overboard to wet the treated powder to avoid any dust that may result from the offshore disposal.

This 30,000 tonnes of cuttings that have been processed to date offshore have saved 112,500 crane lifts and reduced the number of bins used by 7,500. In addition there has been no need to dispose of about 18,000 tonnes of recovered powder to landfill as it was possible to discharge it all to the sea. The oil recovered from the process has been suitable for reuse and totaled as much as 18,000 barrels.

Case History

In July 2006 the first of two hammermill type thermal desorption units were mobilized to a semi-submersible in the UKCS along with the necessary handling equipment in readiness for the drilling of a series of wells with NABF. The 950 kW machine was installed on the starboard aft deck. The unit, in four module format, has a footprint of 64 square metres and a deck loading of 1.5 tonnes per square metre. Since the installation a total of 8 wells have been drilled and 9,000 tonnes of cuttings processed offshore saving the mobilization of 2250 cuttings bins and as many as 33,750 crane lifts, reducing risk and improving safety. All of the base oil recovered was reused back in the mud system, the processed powder, which had a hydrocarbon content of <0.1% by weight, was discharged overboard down an existing cuttings discharge line. With the processed powder being discharged overboard there was no need to dispose of the powder in to landfill so reducing environmental impact.

The second offshore thermal desorption unit was mobilized to a second semi-submersible working for the same operator in the UKCS in May 2007. A total of 3 wells have been drilled since then and 6,000 tonnes of cuttings processed offshore and, much like the thermal process on the other rig, this saved the mobilization of 1500 cuttings bins and 22,500 crane lifts.

Similarly all the base oil recovered was reused and the processed powder discharged overboard.

With 2 thermal plants operating on two rigs a total of 15,000 tonnes of cuttings have been processed offshore to date. This has saved the mobilization of 2750 cuttings bins and 56,250 crane lifts, all of which have contributed to safer working environment with over 46,000 man hours worked LTI free. With regard to the environmental impact all of the solids were treated and the hydrocarbon content reduced to <0.1% and all were discharged overboard rather than being disposed of to landfill, which would have been the case if the cuttings had been processed onshore.

Conclusion
The treatment of drill cuttings offshore has proved to be a viable option to improve safety, reduce environmental impact while simplifying logistics. The hammermill type of thermal desorption has been effective in reducing oil content to levels that meet all but the most restrictive "zero discharge" regulatory frameworks.

With operating temperatures of between 240º and 260º C the recovered base oil is unaffected by the process and may be reused in the mud system. The average processing capacity of 6 metric tonnes per hour is sufficient for most drilling operations, particularly if some buffer storage is available to take the treatment process "offline" while leveling level off the peaks in the rates of cuttings generation from the larger hole sizes. The machine's relatively small footprint of 64 square metres will allow it to be installed on most mobile offshore units. In those circumstances where this may not be possible the process can be carried out on a boat or barge, which will allow offshore treatment to be carried out without the need for "skip & ship". This option could also allow cuttings to be processed from a number of rigs with only 1 thermal plant, thereby fully optimizing its processing capability.

With the use of NABF likely to increase and environmental regulations tightening around the world the treatment of cuttings offshore using thermal desorption will add to the options available to the industry to meet some of the challenges of the future.

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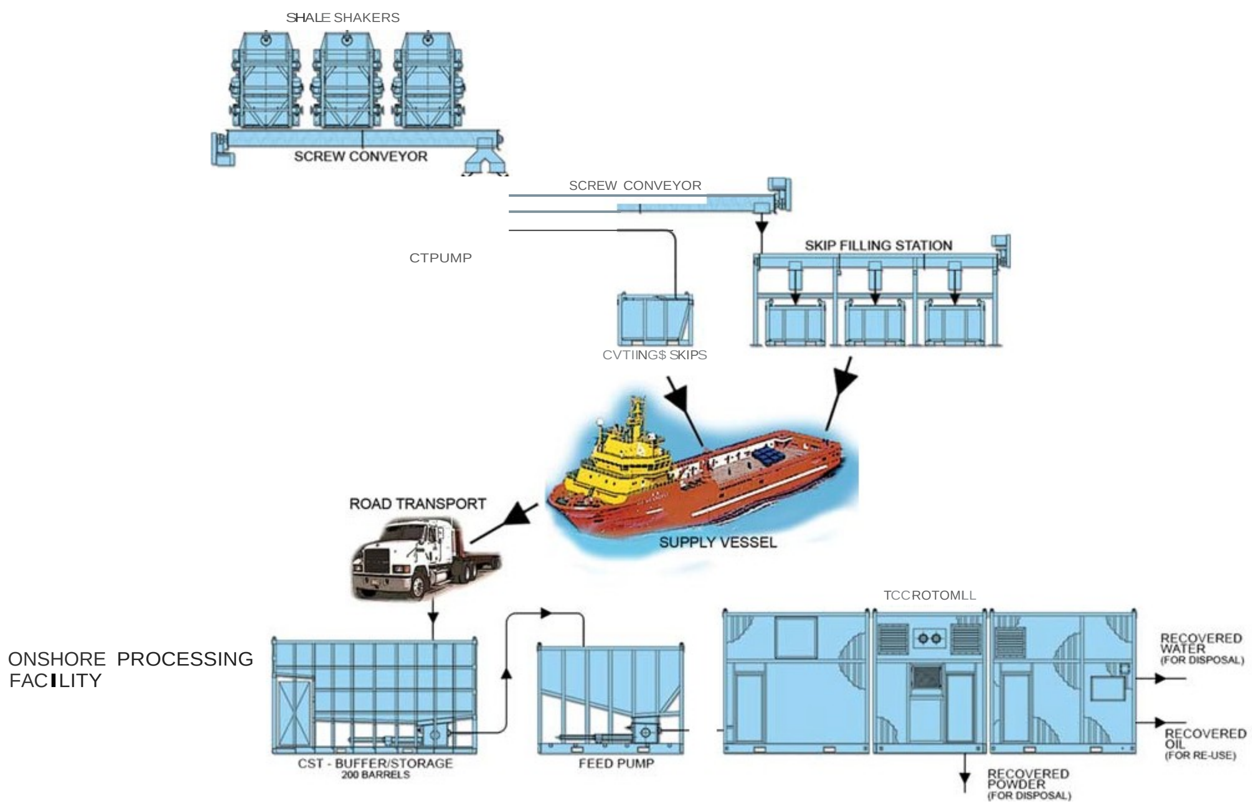
Figure 1



SKIP AND SHIP OPERATION

Figure 2

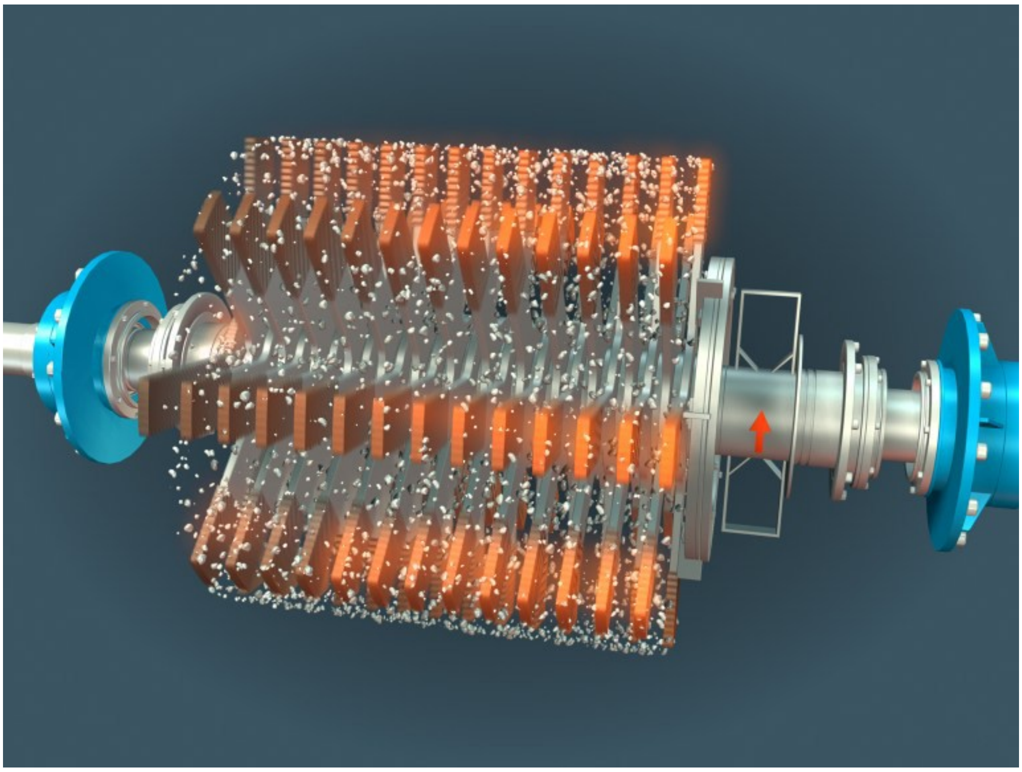
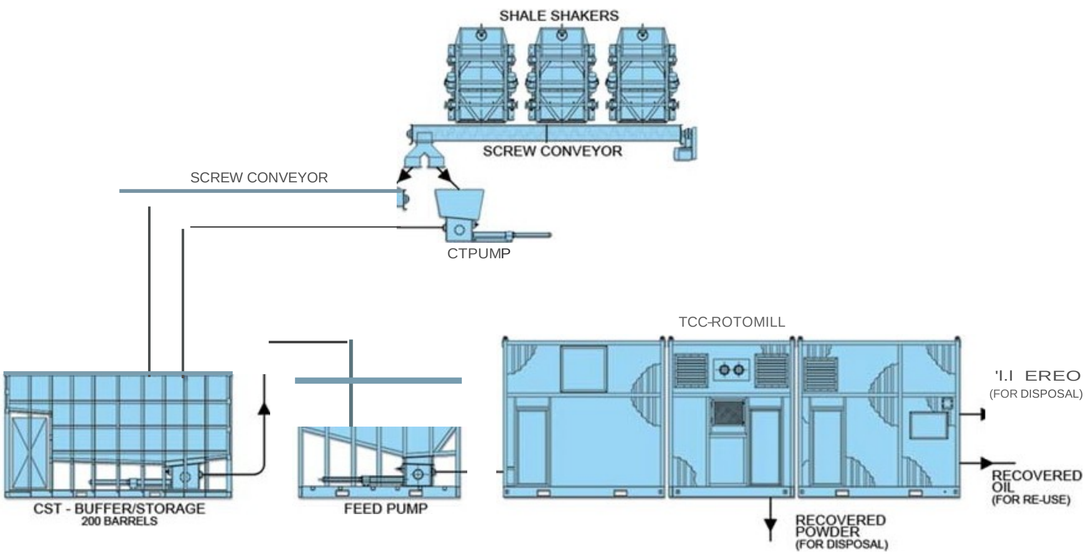


Figure 3



OFFSHORE PROCESSING