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Abstract

This paper highlights the value associated with the thermal processing of drill cuttings offshore, at source, on an operational and economic basis for a single well drilling campaign.

Treating materials at source eliminates the requirement to transport drilling wastes long distances onshore for treatment and/or disposal, significantly reducing logistics costs and the likelihood of safety and environmental incidents.

The paper outlines a safe, efficient and reliable at source drilling waste management solution that increases operational efficiency, supports well cost reduction initiatives and exceeds regulatory requirements.

It also demonstrates that mobilizing this solution as an onboard drill cuttings processing spread for a one-well drilling campaign is cost-effective.

The paper draws on a detailed case study in which thermal drill cuttings processing technology was mobilized for a one-well drilling campaign on the Orlando field in the UK North Sea, under a contract between TWMA and the Licence Operator but managed by the Well Operator AGR Well Management (AGR).

Using a process of thermal desorption, the solution allows the recovery of three elements from the drill cuttings: oil, water and solids. Recovered base oil, which retains its full original quality, can be reintroduced to the drilling mud system, and recovered water and solids can be safely dispersed on location as they are processed to well within UK environmental tolerances and regulatory requirements. Using the technology on the Orlando development well enabled a reduction in drilling waste handling and reduced downtime, due to the elimination of wait on weather, reducing rig non-productive time by allowing continuous drilling during adverse weather conditions. It also reduced handling, storage, offshore lifting and skip to shore vessel requirements, for the 17 ½" and 12 ¼" sections, saving an estimated $640,000 in vessel costs alone (based on the market rates at that time).

Thorough planning meant initial challenges relating to delivery of equipment was quickly mitigated and support from TWMA, in close co-operation with AGR and the operator, helped to reduce the operational time-table and costs.

The drilling waste management operation was completed within time and on budget with zero Lost Time Incidents and zero loss of containment to the environment during operations.

Introduction

The North Sea is in a mature phase of development with an increasingly diverse range of operators, including newer entrants and small independent developers looking to monetise the basin's remaining resources.

The Orlando Field was discovered by well 3/3-11, by Chevron, in 1988-89, more than 380km northeast of Aberdeen in the Northern North Sea. In 2011 and 2012, the field was appraised by MPX North Sea via wells 3/3b-13 and 13Z (sidetrack).

The development plan for the Orlando Field is a single subsea well, tied back 11km into the CNR International-operated Ninian Central Platform. AGR was appointed the Well Operator to drill and complete the well starting in early 2018, using the Ocean Guardian semi-submersible drilling rig.

Key challenges for AGR were that the well had to be delivered within the scheduled window, by July 2018, due to the subsea infrastructure being installed shortly after the well was completed and suspended. Due to its location, more than 380km from Aberdeen, and more than a 24-hour sailing time from the shore base facilities, limiting downtime due to wait-on-weather was a key priority. With a total depth of 18,266ft to be drilled, more than 1,600Mt of drill cuttings were expected to be generated from the three sections.

Basis of Design

As part of the basis of design, the TWMA engineering and operational team analysed the anticipated drill cuttings return from the well. It is this initial volume along with the projected rate of penetrations (ROPs) that allow TWMA to dictate equipment requirements, ensuring drilling targets are at a minimum met, and exceeded. Table 1 below references the well profile supplied by AGR.

Table 1. Well Profile for Thermal Processed Sections

Section	Anticipated Interval Lengths (ft)	Fluid Type	Anticipated ROP	Estimated Drill Cuttings Generated (MT)
17 ½"	4814	OBM	30ft/hr	907
12 ¼"	6737	OBM	85 ft/hr	740

Thermal Processing Technology

Traditionally, operators have used a skip-and-ship system to deal with drill cuttings waste during drilling campaigns offshore. Drill cuttings waste, including drilling mud, water and solids, are put in skips and then shipped to shore. This involves significant and costly logistics operations which increases the risk of safety incidents and loss of containment to the environment. Skip-and-ship can cause drilling downtime, due to a requirement to wait on weather for lifting operations, causing logistical delays.

TWMA is the first organisation globally to successfully deliver rig-based thermal processing of drill cuttings, which eliminates the need to ship drilling waste to shore. TWMA's thermal desorption solution allows the recovery of three elements from drill cuttings: oil, water, and solids. Recovered base oil, which retains its full original quality, can be reintroduced to the drilling mud system, representing significant cost savings for operators. Recovered water and solids can be safely dispersed on location as they are well within UK environmental tolerances and regulatory requirements.

The technology uses, as a basis, a cylindrical mill that grinds a bed of solids within the mill chamber, causing kinetic energy, creating heat through friction. Once the mill reaches a pre-determined temperature, set to suit the evaporation properties of the particular base oil in use, the drill cuttings are fed into the chamber, causing the liquids (oil and water) to flash evaporate from the solids. The resulting gases then exit the mill and pass through a cyclone, where any fine solids particles are removed prior to the gases travelling to the oil and steam condensers, respectively. The oil condensers goal is to recover the oil from the gasses without condensing the water, with this in mind the temperature of the gasses are cooled to approximately 105.C, this allow the oil (only) to condense whilst the remaining gasses contain on water and will pass through to the steam condenser. The steam condenser will further reduce the gases temperature down to 40.C, fully condensing the remaining gasses, should there be any light oil fractions carried over into the steam condenser a gravity separator has been integrated to the offshore thermal processing unit to ensure any oil is removed from the recovered water phase.

The three recoverable phases from the thermal processing unit is solids, oil and water, the quality of each is highlighted in the below table.

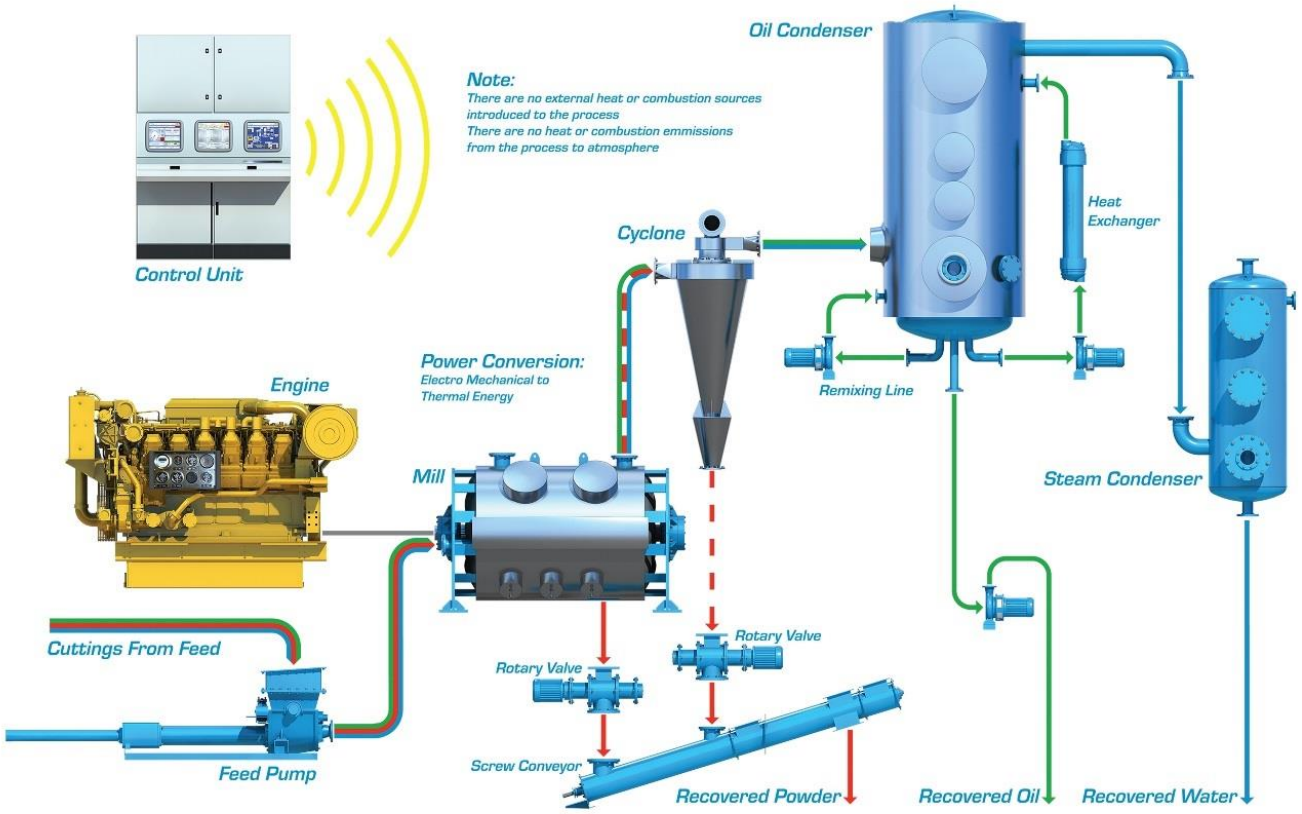
Table 2. Output Stream Quality

Output Stream	Design Specification	Orlando Well Results	Comments
Solids	<1% Oil on Cuttings (OOC)	0.058%	These solids are classed as inert and suitable for disposal.
Oil	Recovered oil retains the physical properties found in the drilling fluid's base oil	208.04m³ base oil recovered	Due to the pre-determined temperature within the mill chamber, recovered oil retains the physical properties found in the drilling fluid's base oil. The base oil is then made available for reuse in the subsequent sections.
Water	<30PPM	2PPM	Recovered water is slurrified with the recovered solids and disposed overboard, inline with discharge requirements.

In each case when solids and water are dispersed overboard, this is inline with standards outlined in the Chemical Usage and Discharge permits issued by the Department of Business, Energy & industrial Strategy and the Scottish Environmental Protection Agency (SEPA).

Below (Figure 1) shows an overall offshore thermal processing unit process flow diagram.

Figure 1. Offshore Thermal Processing Unit Process Flow Diagram



Thermal Process vs Skip and Ship

There has been a perception that mobilising thermal drill cuttings processing equipment offshore on a one-well basis would entail high installation costs and involve installation and demobilising around other drilling related activities.

AGR performed an evaluation of using the themal processing technology verses the more conventional approach of skip and ship and found HSE and operational benefits. The key HSE benefits of processing drilling waste offshore, according to the company's assessment, were: a reduction in skip handling; a reduction in waste handling; and reduced weather exposure, i.e. limiting movement of skips on deck and to a dedicated vessel. The key operational benefits were: a reduction in the requirement for crane use; no requirement for a dedicated vessel to be at the rig site during drilling; the ability to re-use base oil in the drilling fluid. The downsides were increased daily rental costs of equipment and personnel and greater mobilisation cost, however these were largely offset by some of the cost savings and reduced weather risk exposure outlined above

AGR also undertook a commercial evaluation taking into account the reduction in time waiting on weather, removing the dedicated vessel requirement, and the reduction in logistics costs. It found that, even with the increased rental and mobilization costs, the overall costs could be 36% lower.

AGR's conclusion, based on the circumstances around the Orlando well, namely sailing time, weather exposure and ability to install equipment on location ahead without impacting operations was that mobilisation of the technology could in fact be cost effective, as well as reduce HSE exposure, and

awarded a contract to TWMA for drilling waste management services using offshore thermal desorption during the 17 ½" and 12 ¼" Orlando production well drilling. The contract also included skip and ship services for during the 8 ½" section, due to a need to demobilise the thermal processing unit to create space for a well-test package.

Total Cost of Ownership

TWMA's goal is to reduce the total cost of ownership for its client. When evaluating a project, all factors associated with the treatment must be identified to understand all spend relating to the management of drill cuttings from source to disposal.

A key driver for offshore processing being the most cost-effective solution is the sailing distance to ship drill cuttings onshore and base fluid recovery and reuse. With the Orlando field located approximately 380km from the shore (Aberdeen), it was important that the drilling waste solution minimized the requirement to transport wastes onshore for treatment or disposal. The offshore thermal processing solution saved up to 120 hours of sailing for the well and associated logistics costs. In addition, the solution minimizes the risks associated with the unloading and offloading of skips at the rig site, quayside and ultimately the processing facility. This project recorded 3,000 skip lifts per well which were eliminated.

Table 3 below highlights the savings of utilising the thermal processing solution over skip and ship operations.

Table 3. Skip and Ship vs Thermal Processing Total Cost of Ownership

	Skip & Ship	**Offshore Thermal Processing**	**Comments**
Installation (Materials)	$0	$175,698	Provision for skip and ship services already on rig
Equipment Costs	$56,378	$372,861	Thermal processing equipment vs skip station and ancillary
Personnel Costs	$183,820	$337,642	
Vessel Costs	$637,000	Eliminated	Based on estimated section times and vessel market conditions in the North Sea at that time
Onshore Logistics	$32116	Eliminated	
Processing	$246,226	$23,227	
Fuel for Processing Technology	Not required	$72,000	
Waiting on Weather	$390,000	Eliminated	Based on a rig and spread rate for an assumed amount of weather downtime
Total Cost	$1,545,540	$981,428	36% reduction in cost

*Source TWMA and AGR operational reports

TWMA was awarded the contract in mid-December 2017. Due to space limitations on the Ocean Guardian, the thermal processing equipment configuration and layout design was the most compact installation performed to date. Equipment is often required to be spread around different areas of the rig to fit available space, however this can lead to issues for example, blockages as the material has further

to travel. Having all the equipment within the same area in a smaller footprint allowed TWMA achieve the most efficient processing.

TWMA initially planned to install the bulk of the equipment while the rig was moored at Invergordon, in the Scottish Highlands. However, due to weight limitations on the rig, for the tow, installation was carried out while offshore.

The Ocean Guardian mobilised on 1 March 2018. TWMA's equipment package was mobilized to the Orland location from Aberdeen on 28 February and then lifted on board the Ocean Guardian on 6 March.

Despite reduced crane availability, due to weather and other rig mobilisation requirements, the offshore thermal processing package was fully installed within nine days, half a day ahead of schedule. On March 13, the TWMA operational crew replaced the installation team onboard the Ocean Guardian and the 17 ½ inch section processing started.

At the end of the 17 ½" and 12 ¼" sections, the themal processing unit was demobilised to create space for a well test package, and operations reverted to skip and ship for the 8 ½" section, as planned, filling 32 skips with 160Mt of drill cuttings.

Presentation of Data and Results

A total of 1,647.91 Mt drill cuttings were processed at source with the thermal processing unit working to an average throughput of 6.87Mt/hr with a high of 8.66Mt/hr. No drilling waste was returned to shore for the 17 ½" or 12 ¼" sections, which would have been equivalent to 300 skips.

A total of 1255.19Mt of recovered solids were diverted from landfill and discharged overboard with an average total petroleum hydrocarbon organics (TPH) of 0.058%, which is well below the North Sea allowable discharge of <1%.

A total of 223.37m^3 of recovered water was discharged overboard with an average oil on water of 2ppm, also well below the North Sea allowable discharge of <30ppm.

There were no incidents or accidents associated with the TWMA operation throughout the duration of the drilling campaign.

By processing drill cuttings offshore at source, it was estimated that approximately 26 hours of weather down time was eliminated during drilling operations, which would have resulted in an associated spread rate cost of approximately $380,000.

Based on the market conditions at the time it is envisaged that a saving in excess of $640,000 was achieved by not using a dedicated vessel for a period of approximately 50 days. Handling, storage and removal of more than 300 skips was avoided, including more than 3000 crane lifts, significantly reducing HSE risk to personnel. There was also zero loss of containment to the environment.

Utilising the thermal processing technology enabled an increase in solids control efficiency and a reduction in waste handling, offshore and onshore, with use of less equipment and services compared to alternative solutions.

An additional benefit of TWMA's close involvement with AGR was that it was agreed that the cutting storage tanks (CST) would be kept on board as a buffer for additional storage for oil-based mud (OBM) breaker fluid at the end of the 12 ¼" section. This opportunity arose during a drilling well on paper (DWOP) meeting, which highlighted storage limitations at critical stages of the well and TWMA's team offered use of the CST.

The use of the CSTs for the storage of the completion breaker fluid assisted with the the rig system being displaced to completion brine, thus assisting with operational efficiency. While this is not normal procedure for TWMA, it helped AGR complete well operations ahead of time and showed the benefit of AGR and TWMA working closely together.

Highlights

The close interaction and detailed planning that went into the mobilisation and demobilisation of the themal processing unit during well operations contributed to the success of the Orlando well. Despite the significant volume of equipment movements, no HSE incidents or accidents were encountered at any stage of this process – mobilisation, operations or demobilisation – and this is testament to the professionalism of the TWMA team.

AGR Well Team Leader stated: “The TWMA crew worked effectively, installing the equipment ahead of schedule before successfully delivering the operational phase of the project. The thermal processing technology was effective, allowing AGR to drill continuously and avoid any down time relating to waiting on weather in both the long 17 ½’’ and 12 ¼’’ hole sections. The solution proved that the total cost of waste ownership for offshore processing versus skip and ship can be cost effective even in a one well campaign. The TWMA operations team fully embraced the culture on board the rig with their positive approach to safety, teamwork and operations therefore delivering on the value promised.”

The team were also commended by the AGR Drilling Supervisor for a “one team” ethos after completing pit cleaning, removing solids from the pits, which was not part of the scope of work that TWMA were initially contracted to provide. Because this was done, the operations could move on to the next stage faster.

Lessons Learned

TWMA has proven that an offshore thermal processing unit can be safely and efficiently rigged up and installed during operations in a confined space. There is a perception that utilising offshore thermal processing equipment across a short drilling campaign is not cost effective, however, this project demonstrates the significant cost savings that can be made even across a one well drilling programme.

By engaging with AGR early in the planning process, TWMA was able to provide an effective drilling waste management solution to overcome the challenges of the project and reduce the company’s total cost of ownership for drilling waste management.

Summary

Using TWMA’s thermal processing technology on the Orlando development well reduced rig non-productive time by allowing continuous drilling during adverse weather conditions and ultimately reduced costs to AGR and the operator during drilling. Having the package onboard also gave the client flexibility and schedule compression opportunities. Close co-operation with AGR and the operator also meant schedules were compressed.

TWMA’s first one-well project has proven that mobilisation of thermal processing technology is cost-effective for any operator to use on a one-well basis.

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