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Upgrade of Spar Topsides with Comprehensive Facilities Sand Management System

Y. Loong, Murphy Sabah Oil Co. Ltd.; H. Rawlins, PhD, and D. Goo, eProcess Technologies

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Abstract

A deepwater field located offshore Sabah, East Malaysia, with an average water depth of approximately 1300 m and operated by Murphy Sabah Oil Co. Ltd., features a spar dry tree unit and multiple subsea hub tie-backs to an FPSO. In early 2011, several of the wells on the spar began producing solid fines that affected production. In order to sustain and maximize production, Murphy Sabah initiated three separate measures to control the solids. It was decided that a long term solution would be to re-complete the affected wells with enhanced downhole sand control on the lower completions, such as open-hole gravel pack and cased-hole frac packs. The short term solution consisted of installing a topside Sand Management System on the spar to remove solids at the wellhead prior to the choke and sand sparging equipment on the FPSO separators to remove buildup of sand that was produced by the subsea wells and any solids that bypassed the spar. This paper focuses on the spar topsides sand management system that is unique in its size and scope. It includes ten wellhead desanders, a common slurry transportation system, a dewatering and bagging station, and a skip removal system to process up to 10 tons per day of solids. Current work is underway to upgrade the system to include an integrated sand cleaning package that will allow the overboard discharge of the solids, which will be a first for Malaysian waters.

The solids separation part of the system is integrated into the wellbay with dedicated wellhead desander and accumulator units installed on ten wells, which are designed to remove solids upstream of the choke. The sand management system and the first wellhead desander were commissioned in October 2011, and by April 2012, a total of six wellhead desanders were on-line. Upgrading the spar with topsides sand management system has effectively controlled the production of solids and maximized hydrocarbon production during the same period. A detailed process review of the Sand Management System is provided, along with a system integration timeline, solids analysis, and lessons learned.

Project Overview

The Kikeh Field is located 120 km northwest off the island of Labuan, offshore Sabah, at approximately 1300 m water depth. The field was developed using a stand-alone facility with hydrocarbons being produced from both subsea and dry tree wells from a SPAR/Dry Tree Unit (DTU) facility. The oil is processed, stored, and exported from a Floating Production Storage and Offloading (FPSO) vessel, with initial production in August 2007. Figure 1 shows the layout of the field.

In December 2008, the Kikeh Field started to produce solids at varying rates. This initially caused erosion damage on facility control valves, but did not present serious problems to process piping or vessels. In January 2010, after the failure of a sand-screen completion on one of the wells, the process facilities on the FPSO started to receive approximately one metric ton of sand on a daily basis.

Although the sand-screen failure was considered to be an unusual and extreme case and solids production was expected to be addressed downhole, it became apparent that solids production would be experienced throughout the life of the field. Due to this, it was considered necessary to provide sand erosion protection for the choke valves and the downstream piping and equipment, and to prevent accumulation of sand in the FPSO process vessels.

The project goal was to install wellhead desanders on the DTU immediately downstream of the wellheads, which provide protection for the DTU choke valves, production headers, fluid transfer lines (FTL), and FPSO swivel and manifolds, as well as lessen the accumulation of solids in the FPSO process vessels. The objective was to remove, to the highest possible degree, the produced solids that reached the surface as soon as practicable in the process flow lines.

By March 2011 the solids production problems became worse, resulting in some of the wells being shut in, which resulted in production deferment. The situation led to the proposal to install five individual wellhead desander units on the DTU solids

producing wells. The fast track project took 14 weeks to complete with an additional five wellhead desanders installed at a subsequent stage.



Figure 1. Photograph of Kikeh Field surface layout showing the Seadrill West Menang semi-tender in foreground left contracted for well workover, Murphy Kikeh spar dry tree unit (DTU) in foreground right, and Kikeh FPSO in background.

Once the solids have been separated from the wellhead desander and collected from the accumulator unit, subsequent solids handling is required for further processing. This project was executed in two phases. Phase 1 initially consisted of a rudimentary solids handling system for onshore disposal, and Phase 2 included the installation of a sand cleaning system for overboard disposal.

In Phase 1 the first five wellhead desanders were initially coupled with the solids handling system due to the urgency of the situation. The solids handling system in this initial phase took collected solids from the accumulator units, which were periodically dumped into pipe headers with continuous flow of water, and transferred the slurry to a liquid decanted container and solids bag. This specially designed permeable solids bag drains off the liquid, and a diaphragm pump transfers the decanted liquid to the open drain sump tank. The permeable bag and liquid decant container are located at the lay down area where it is accessible by platform crane, and the solids are transferred to shore in containers for disposal.

The solids handling system included a low pressure desilting solid-liquid cyclone (a desander with open underflow) to handle the additional produced solids from the five additional wells. The desilting cyclone was installed downstream of slurry headers to process the solids and liquids discharged from the accumulator vessels. The cyclone removed most of the flushing water volume while concentrating the produced solids.

The operating principle of the desilting cyclone is the same as the wellhead desander, where centrifugal forces are used to separate the heavier solid particles from lighter liquid fluid. The solids discharge through the cyclone apex (underflow stream) and into the permeable solids bag, which is sent to shore for disposal. The solids-free water exits through the overflow stream and transfers to the open drain sump tank.

KIKEH Sand Production

Solids production from the Kikeh Field presents substantial challenges. Once the sand reaches the DTU topsides, it creates erosion problems on the flow line, choke valves, production headers, fluid transfer lines (FTL), FPSO swivel, and various valves downstream of the FPSO separators. The sand also fills up the separators, slop tanks, and cargo tanks on the FPSO. The DTU topsides and FPSO are not designed for sand service, and subsequently, a comprehensive risk based inspection program has been set up to frequently check the flow lines and FTL pipe wall thickness to predict the life spans.

Without treatment, the sand producing wells are also required to be choked back to minimize the sand quantity until they can be worked over. The wells are shut in regularly for choke valve change-out due to erosion problems as shown in Figure 2. Due to these various issues, production deferral is incurred along with substantial maintenance costs associated with choke valve changeouts and pipe wall thickness inspection activity. The produced sand that accumulates in FPSO separators reduces the retention time of these vessels. This requires the separators to be taken offline for frequent clean-outs. The accumulated sand reduces production rates and cleaning of the separators is very labor-intensive.

Sand Control Options.

The conventional approach to sand control focuses on sand exclusion from the wellbore either through production limits or completion hardware. When a detrimental rate of solids appears at the facility, usually due to a step-change event such as water breakthrough or completion failure, the initial response is to impose production limits. Maintaining sand inflow at a level below the damaging threshold can be rapidly applied with no capital expenditure; however, the net effect is often significant reduction of maximum hydrocarbon production. Most wells in sand-prone reservoirs are completed with inflow hardware, such as expandable screens or gravel packs, to prevent sand from flowing into the well string. Completion tools are widely studied and applied;

however, in some instances maximum inflow is reduced due to skin buildup. A more detrimental event is when the completion fails, resulting in catastrophic sand production. The inrush of sand overwhelms the surface facilities, often resulting in maintenance shutdown. Reinstallation of the completion is a common workover task; however, well downtime and intervention costs can be substantial.



Figure 2. Photographs showing effects of sand production: choke valve erosion (top left), sand in HP-A swivel (top right).

Facilities sand management is tasked with the goal of ensuring sustained hydrocarbon production when sand is present in well fluids while minimizing the impact of these produced solids on surface equipment. Co-production of fluids and solids, with subsequent sand handling at surface facilities, is an inclusion paradigm that may allow sustained hydrocarbon production (Rawlins, 2013). Produced solids are removed at the wellhead upstream of the choke using fit-for-purpose equipment or modification of existing facilities with a sand handling focus. This methodology often allows for increased or recovered hydrocarbon production, whereas removal of sand upstream of the choke protects facilities operations. Incorporating solids management into surface facility design requires more than just installing a separating device. The separated solids may require central collection, cleaning, measurement and monitoring, storage, transport to a disposal site, overboard discharge, or injection disposal. Surface facilities sand handling can be segmented into five unit process areas: separation, collection, cleaning, dewatering, and transportation (Rawlins & Wang, 2000), and each area is integrated to provide a unified system to maximize uptime.

The recommended location for surface solids removal is prior to the choke (Rawlins, 2013). Pre-choke removal protects all downstream equipment, including the choke orifice, flow lines and piping, production separators and treaters, heat exchangers, control valves, and produced water treating equipment. Solids upstream of the choke are at the highest temperature of the facility and uncontaminated by most production chemicals, rendering these solids easiest to clean once separated prior to the choke. With specific regard to compact separation devices, solids are most easily removed from multiphase streams as the increased gas void fraction (GVF) reduces the continuous phase viscosity and density, permitting increased separating velocity of the solids. A separating device upstream of the choke also relieves the pressure drop burden on the choke bean, lessening erosion and converting that pressure into useable separation energy.

Cyclonic Technology for Multiphase Flow.

Cyclonic technology covers a class of unit process devices designed for compact phase separation. Each device converts the potential, or pressure, energy of a fluid into rotating kinetic energy using only the shape of the device in order to partition two or more phases in that fluid into the respective number of concentrated outlet streams (Svarovsky, 1984). Cyclones are used throughout the upstream oil and gas industry, including separator inlet cyclones and swirl tubes (gas-liquid) as well as produced water deoilers (liquid-liquid) and desanders (solid-liquid). The advantage of cyclone technology is that it has the highest throughput-to-size ratio of any partitioning device. Thus, for a given flow rate, cyclonic technology will have the smallest size and weight of any device available. Because cyclones use swirling flow and generate from 100-5000 g-forces on the treated fluids, they are unaffected by platform motion.

The wellhead, or multiphase, desander is a cyclonic device applied upstream of the choke to remove solids from raw well flow. The driving factor for development of the wellhead desander (WHD) was to extend the operability of hydraulic cyclonic technology to the multiphase flow regime. Since the 1960s, desanding hydrocyclones have been used to remove sand from produced water prior to injection, but their operability in mixed gas-liquid streams was unknown. In 1995, the first wellhead desanding hydrocyclone was tested at the BP Wytch Farm production facility. This test culminated the work of a joint industry project (JIP) to develop a multiphase version of a liquid desanding hydrocyclone for continuous removal of solids prior to the choke and resulted in an understanding of the design and operation of the wellhead desander.

Multiphase desanders operate based on a combination of hydraulic and pneumatic cyclonic principles (Rawlins, 2002). As with all cyclonic devices, pressure energy is converted to radial and tangential acceleration to impart centrifugal forces on the contained fluids. The increased forces accelerate the separation of phases with different densities. In the case of a multiphase desander, solids are separated from the gas-liquid mixture. The separated solids collect into an accumulator chamber (external or integral) for periodic isolation and batch discharge while the well fluids maintain continuous flow. Wellhead desanders find use as a service tool during well testing or workover operations and as a production tool for ongoing facilities sand management.

Figure 3 shows a schematic of the typical production wellhead desander design. The wellhead desander system is comprised of a primary vessel with cyclonic insert, an external or secondary accumulator vessel, and a valve set. The primary vessel inlet is

attached off the wellhead to the wing valve with discharge directed to the choke. Well flow exits the wellhead and is directed to the primary vessel where vortex flow is created by the shape of the cyclonic insert. The cyclonic insert is a replaceable component designed to contain all erosion, whereas the wellhead desander vessel contains the operating pressure. Cleaned fluids discharge from the top of the wellhead desander to report to downstream facilities. The separated solids discharge from the bottom of the cyclonic insert to collect in the secondary accumulator vessel. Periodically, the accumulator vessel is isolated from production, vented, and flushed of sand. During this discharge cycle, solids collect in the integral accumulation section of the primary vessel just below the cyclonic insert. Thus, separation of solids is not interrupted. Once emptied, the accumulator vessel is filled with clean water and brought back on-line. Filling the accumulator with water aids in solids cleaning and minimizes slurry flow across the valve set.

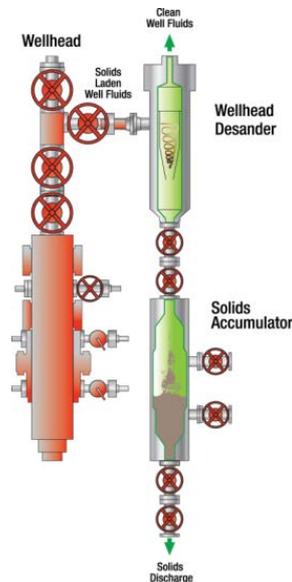


Figure 3. Schematic of wellhead desander installation showing primary vessels and valves.

Wellhead Desander System Design.

Each wellhead desander system is designed for full shut-in and flowing conditions of the producing wells. For the Kikeh Field, the wellhead desander and accumulator vessels are fabricated from carbon steel to ASME, Section VIII, Div. 2 design with 1500# rated ANSI flanges. Inlet and fluid outlet flanges on the wellhead desander are 6" NPS, while the sand outlet flange connecting to the double block and bleed (DBB) arrangement is 3" NPS. Slurry discharge from the accumulator is through 2" NPS flange, and vent and flush connection flanges are 2" NPS as well. The wellhead desander vessel houses a cyclonic insert that is fabricated from duplex stainless steel with internal tungsten carbide coating or is made from bulk silicon carbide with a stainless steel shell. This insert can be removed for inspection and replacement and has interchangeable sizes of 100 mm, 150 mm, 200 mm, and 250 mm with the designation based on the nominal cylindrical diameter.

The primary valves are in the DBB arrangement. These are manual valves with expanding gate design built to full shut-in pressure rating. The gate and seals are made from 410 stainless steel with an AISI 4130 body. All other valves in the wellhead desander system are manually operated.

The wellhead desander has a 2.5 m overall height (flange-flange) with a square footprint of 0.8 m per side. The unit operating weight is 1.5 T. The secondary accumulator vessel has a 3.9 m overall height (flange-flange) with a square footprint of 0.9 m per side. The operating weight is 3.6 T. The wellhead desander integral hold-up volume is 15-30 liters, depending on the insert size, while the secondary accumulator has a 590 liter hold-volume. Overall install height (top of wellhead desander to discharge of accumulator) is approximately 7.5 m including the valve set in between. Access to the cyclonic insert is through the wellhead desander vessel top flange, and the inserts weigh 30-100 kg, depending on the diameter and material of construction.

During operation, the fluids from each well flow into the corresponding wellhead desander system. The incoming fluids are directed to the inlet nozzle of the wellhead desander vessel, then into the cyclonic insert. The insert geometry and design, as well as inlet pressure, accelerate the flow to spin within the cyclonic insert. The vortex flow pattern accelerates the heavier sand particles to the insert inner wall where they spin down and out of the insert apex opening. The solids fall through the apex, through the wellhead desander vessel integral accumulation chamber, through the DBB valves, and into the accumulator vessel. The water in the accumulator vessel is displaced back up to the wellhead desander vessel to report to the clean fluid outlet. The incoming fluids (e.g., gas, oil, and water) discharge through the insert vortex finder and then the wellhead desander vessel outlet. These fluids are then directed to the choke valve and subsequent downstream production separators.

Once the accumulator vessel becomes full of sand, the DBB valves are closed. The accumulator is vented to atmospheric pressure and then the slurry discharge valve is opened. Clean water is introduced into the top of the accumulator at 5-8 bar pressure and 30 m³/hr flow rate to push the slurry from the accumulator and into the slurry transport header. Once the accumulator is flushed,

the slurry discharge is closed and the accumulator is filled with clean water. Filling with clean water minimizes both the re-pressurization time and effect and creates a clean bath into which the separated sand can settle, which provides an initial cleaning effect. The accumulator is first re-pressurized with a 25 mm line connected from the top of the accumulator to the side of the wellhead desander vessel. This re-pressurization minimizes wear on the DBB valves. The DBB valves are then opened to reintroduce the accumulator to the process flow. During the accumulator isolation-vent-flush-fill cycle, which takes an average of 15-20 minutes to complete, the wellhead desander vessel has sufficient hold-up volume beneath the insert to hold the separated sand. In this manner the separation is continuous with batch discharge of the solids.

Project Detail Engineering

Installation of Desanders in Wellbay.

The DTU platform had very little space in the wellbay area, and the challenge was to install not only up to ten separate wellhead desander assemblies, but to do so upstream of the chokes. By utilizing the existing 3D model of the facility, careful planning, designing, and subsequent integration of the equipment allowed for a feasible and flexible solution.

The wellhead desander was installed into the flow line immediately downstream of the flexible jumper as shown in Figures 4 and 5. This location minimized the flow line portion vulnerable to sand erosion and had sufficient footprint area for the customized desander components. The flow line was cut and connected to the wellhead desanders with a removable spool and bypass line that was installed once the equipment was no longer required for production.

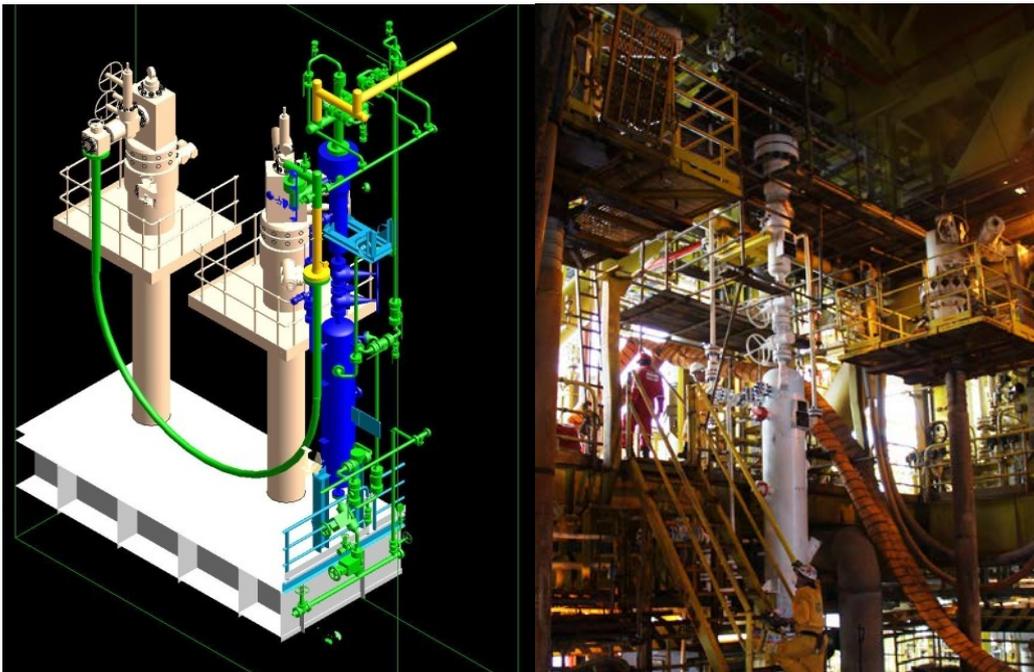


Figure 4. Schematic (left) showing wellhead desander and accumulator installed in wellbay and photograph (right) of installed unit.

The wellhead desander system is made up of three main components: desander unit, double block and bleed gate valves, and accumulator unit. The accumulator is supported by a foundation and bracing, while a structural side support is installed to secure the desander vessel. A number of piping headers connect the individual wellhead desander units together. These are the closed drain line for desander and accumulator depressurization, flushing water line for sand flushing of the accumulator, and slurry line for transferring collected solids through the associated pipework. The piping headers are installed at the wellbay area and integrated with each desander system.

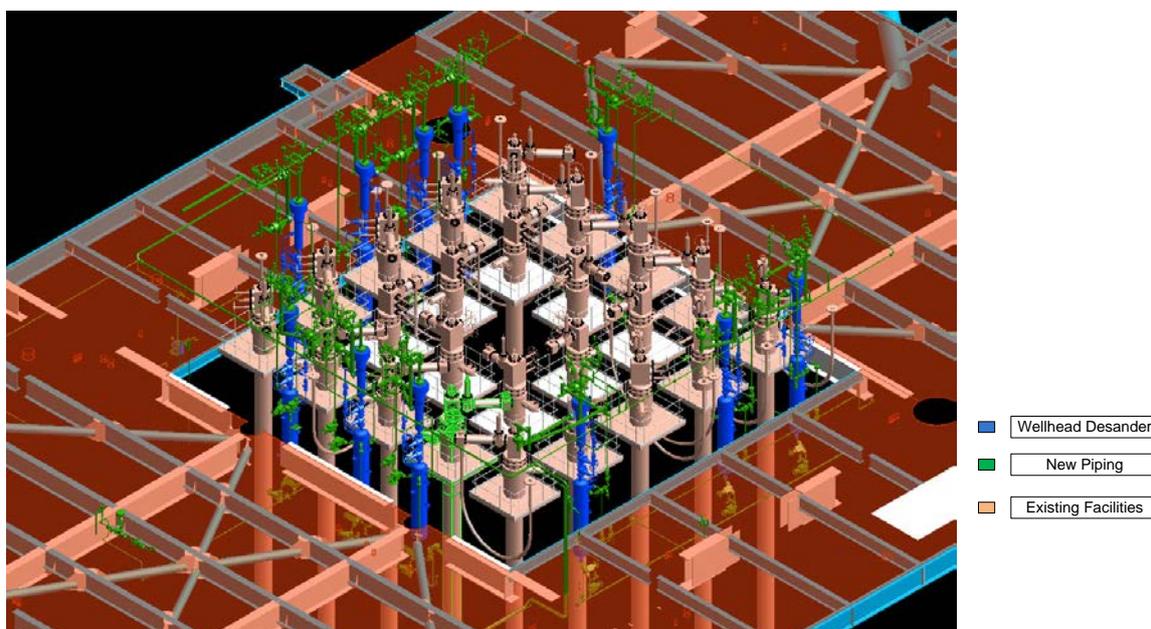


Figure 5. Drawings showing location of multiple wellhead desander systems installed at various positions in wellbay.

Cyclonic Insert Size Selection.

The cyclonic insert inside each wellhead desander vessel provides the separation duty of the system. Each insert is designed to balance separation efficiency and pressure drop. In general, the separation size decreases with insert diameter; however, so does the throughput for a specific pressure drop. The recommended pressure drop range is 5-50 psi, measured from cyclone inlet to overflow. Below the lower value there is insufficient energy to provide suitable vortex spin and separate the solids (however, for gas wells, the lower value can be 1-2 psid). The upper value of 50 psid is artificially set to balance wear life. Separation will take place very efficiently at hundreds of psi pressure drop; however, the insert wear life will decrease dramatically. The recommended upper value lowers for high gas void fraction wells or high solids content, but will increase with low solids content or solids with low abrasion factors.

Separation size is defined as the D_{98} value, which is the particle size at which 98% of the particles are captured. The separation size is fixed by the cyclone geometry, fluid-solid properties, and pressure drop. The separation efficiency is then measured by how many of the particles are captured. Separation efficiency is determined by D_{98} and incoming particle size distribution. For example, a hydrocyclone with a 20 micron separation size will have a 99% efficiency if the incoming particles average >100 microns, but <50% efficiency if the inlet particles average <10 microns.

At the onset of this project, five wells were determined as initial candidates for installation of a wellhead desander system. The flow conditions (gas, oil, and water flows), operating pressure, fluid properties (density and viscosity), and solids properties (density and particle size) were all used in a multiphase desander simulation program to determine the suitable insert size for operation. Table 1 lists the well conditions, insert size selected, and wellhead desander operating conditions. For each well condition, the insert size was selected that fit within the recommended pressure drop range. By maintaining the pressure drop near 40 psid in most cases, the resulting separation size (D_{98}) averaged 15-20 microns. The given solids particle size distribution was bi-modal, as it contained a silica quartz sand fraction (erosive phase) and high amount of clay. The resulting solids recovery averages 92-94%, with the majority of the non-separated fraction as the clay phase.

Table 1 – Cyclone Insert Sizing for First Five Wellhead Desanders

	Units	Well A	Well B	Well C	Well D	Well E
Pressure	psig	1349	1010	1396	1541	1389
Liquid Flow	BPD	16173	12068	7458	3917	3476
Gas Flow	MMSCFD	9.8	5.5	4.5	3.9	3.4
Gas Void Fraction	%	56%	36%	55%	62%	65%
Insert Size	inch	10	10	8	6	6
Pressure Drop	psi	41	23	37	46	37
Separation Size	micron	19	23	16	14	14
Solids Recovery	%	93%	92%	94%	94%	94%

The specific well conditions were different for the next five wellhead desanders, but fit within the same boundaries as Table 1 to allow use of the standard cyclonic inserts (150 mm-250 mm) for each individual well. All wells were targeted to have a design pressure drop in the 25-40 psi range, which allows for maintenance of performance during natural flow variations. If an event happens such that the pressure drop drops below 10 psid or increases above 50 psid, the flow conditions are checked against the

model and a new insert is installed to bring the pressure drop back into recommended operating range. Change-out of the insert does require shut-in of the well and opening of the vessel, and is normally accomplished by two to three operators in one day.

Collected Solid Handling System.

Each sand accumulator is designed to store approximately 1000 kg of sand. The accumulated sand is discharged at approximately 4-6 hour intervals into a common slurry header, which transports the slurry to a central dewatering and bagging station, as shown in Figure 6. Primary dewatering is accomplished using urethane desilting hydrocyclones with the removed water captured to the open drain system. The concentrated slurry receives final dewatering through reusable 1.0 m³ oleophobic rapid-weep sand filter bags, with the filtrate sent to the closed drain system. There are four individual sand bagging stations, and each station handles 500 kg of collected sand. The dewatered sand is transported in the filter bags to a transport skip, and the skip is used to send the sand onshore for landfill disposal.



Figure 6. Photographs showing the overall solids handling system (left) and top view of the four filter bag stations (right).

Operation and Maintenance

Operational requirements of a wellhead desander system are the same as most other topsides facilities. Instruments monitor the performance of the unit, while a maintenance and inspection plan is in place to ensure satisfactory mechanical integrity. Due to the manual design of the system, the wellhead desander operation is relatively labor-intensive and requires dedicated manpower to flush the unit frequently due to the high solids loadings. The accumulator is usually flushed one to four times in a shift and before the vessel is half filled to prevent solids packing at the bottom of the unit. The flushing frequency depends on the rate of produced solids, while back flushing is undertaken if the vessel is tightly packed. This is an issue here due to the high concentration of clay-like particles in the solids load.

Concurrently, personnel monitor the differential pressure across the desander and check the base sediment and water at the outlet of the unit with standard sampling. They also monitor and handle the lift and transfer operations of the collected solids in the sand bags, to the sand skip at upper deck, for transfer back to shore. Trained technicians maintain the efficiency and performance of the system.

Unexpected high sand concentration, in the 2-5% range, at some wells led to premature insert failures. At one well, the insert was eroded in less than two weeks due to very high sand concentrations. The sudden reduction in differential pressure across wellhead desander and increase in sand concentration in the overflow indicated the insert failure. Different types of high wear insert material are commonly available, and these are being utilized to overcome this issue to prolong the life of the insert in these unusual conditions. After a short shut-in period, an insert is easily replaced. A well can also be choked back to reduce flow, and subsequently, reduce the sand volume. The well flow rate, differential pressure across desander, and sand concentration are three parameters that are optimized for each well with each wellhead desander system. The vessel body can be subjected to sand erosion, and to ensure the vessel body remains in good condition, the vessel body thickness is monitored periodically if solids production occurs that is significantly higher than design prediction.

Equipment Performance

Three aspects of equipment performance were analyzed to determine the efficiency of the system. The first was measurement of separation size through sampling; the second was net effect on hydrocarbon production; and the third was lifetime of cyclonic inserts in regard to material selection. Of these three criteria, the net effect on production is the most critical, as it determines the return on investment for the facilities modification work. The primary goal of each wellhead desander system is to reduce the incoming solids loading to <0.05% solids content as determined through a BS&W shakeout. Figure 7 shows wellhead desander inlet and outlet solids shakeout samples. After a wellhead desander is installed, the choke is slowly opened until a <0.05% solids content is reached. Since each well has dynamic, non-steady state operation, periodic samples are taken to monitor the output as necessary.

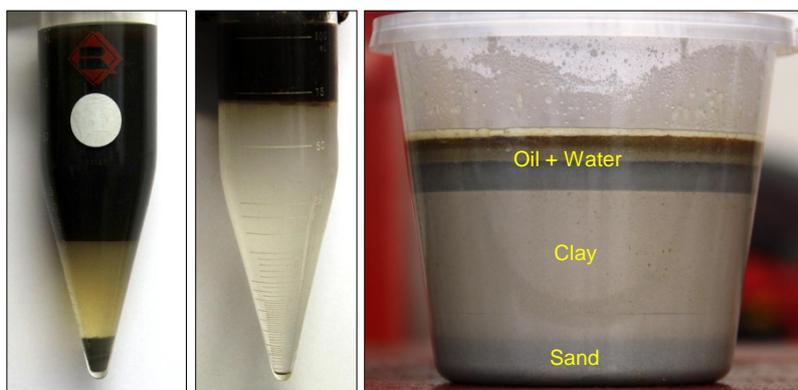


Figure 7. Photographs of wellhead desander inlet with 0.5% sediment (left), wellhead desander overflow outlet with trace sediment (middle), and grab sample from underflow (right) showing amount of clay and sand separated by the unit.

Particle Size Distribution and Desander Performance.

Samples were taken from the wellhead desander underflow and overflow in order to assess the specific separation performance of each operating unit. The underflow samples were taken from the solids handling bin, whereas the overflow samples were taken from the producing stream. Samples were taken through a multi-hour time period and combined to average out fluctuations. Multiple samples were taken and analyzed at local and U.S. laboratories. Underflow samples were analyzed using sieve analysis, while overflow samples, which were dilute and had very small particle sizes, were analyzed using laser analysis. Figure 8 shows the underflow and overflow particle size distributions from one sample campaign on a single well. The underflow stream represents the particles that are being removed from the well flow. While 98.6% of the particles passed 600 microns, there were a small fraction of particles up to 3.0 mm diameter. In general the >600 micron fraction represented fossils and shells, the 38-600 micron fraction was silica sand and corrosion product, and the <38 micron fraction (16.5%) was fine clay. Particles >38 micron had a specific gravity of 2.55-2.65, which is indicative of quartz, and particles <38 micron had a 1.88 specific gravity. The overflow stream consists entirely of clay particles. The larger particles in the overflow sample (30-50 micron) were clay agglomerates that could not be broken up even with ultrasonic agitation.

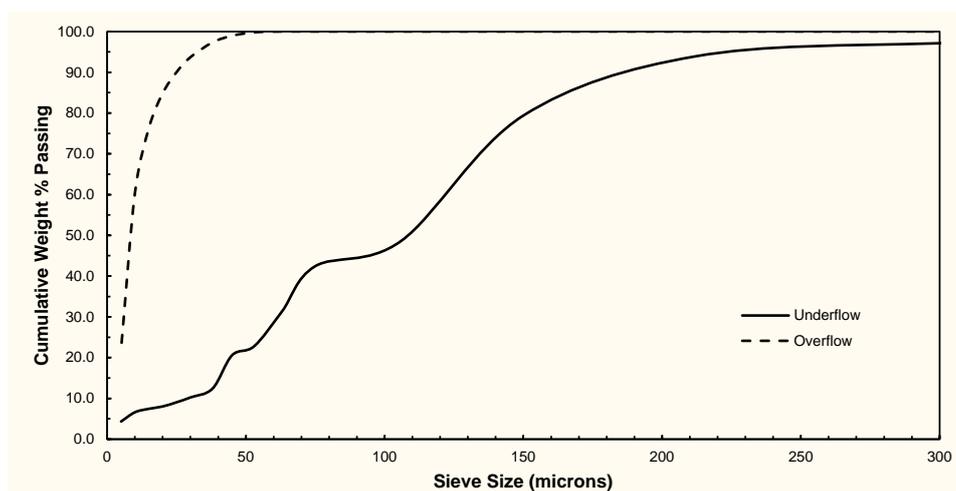


Figure 8. Particle size distribution of wellhead desander underflow and overflow samples. Underflow sample distribution by sieve analysis and overflow analysis by laser scattering.

Based on a mass balance performance, which takes into account both the amount of solids reporting to each outlet stream (underflow and overflow) and the individual streams particle size distribution, a separation size can be calculated. The separation size is defined as the 98% passing size that is recovered by the hydrocyclone from the mass balance performance. The wellhead desanders that were samples exhibited a separation size in the 15-20 micron range, which is in line with the data in Table 1.

Table 2 shows the net operating effect of installing wellhead desanders on six of the wells. The install and decommissioning date is shown for each well. A wellhead desander is decommissioned if the well is re-completed (which negates the need for the wellhead desander) or shut-in. The oil production, before and after installation of the wellhead desander, along with the estimated oil gains are shown in this table. Hydrocarbon production is increased because the wellhead desander allows for opening of the choke until the 0.05% sediment value is reached. The total net oil increase is an average of 1000 barrels per day (BPD) per well. The amount of

sand produced by each well has a wide range both within a single well and across multiple wells. These values range from 130 kg/d to 1137 kg/d with a total sand production from 400-2741 kg/d for these six wells.

Table 2 – Net Operating Effect of Wellhead Desander Installation on Six Wells

Well	Date Installed	Date Decomissioned	Liner size Inch	Oil Production (Bopd)			Est. Oil Gain BOPD	Avg. Vol. Sand Into WHD (kg/d)	Sand Vol. After WHD
				Before	After	Watercut			
1	14-Oct-11	-	8	970	1871	69%	901	130 - 290	0.05% - 0.1%
2	15-Nov-11	19-Oct-12	10	6560	9850	1%	3290	350 - 1137	0.05% - 0.15%
3	09-Mar-12	-	8	2450	2450	73%	0	130 - 495	Trace
4	12-Apr-12	10-Feb-13	10	3550	4650	17%	1100	180 - 559	0.15% - 0.5% (avg 0.25% mud)
5	02-Apr-12	28-Aug-12	8	2550	2550	45%	0	140 - 260	0.2% - 0.8% (mud & sand)
6	02-Feb-13	-	6	3500	4500	20%	1000	300-600	
Total =							6291	400 - 2741	

Cyclonic Insert Material Selection.

Due to the high and variable solids loading in the various wells on the DTU, material selection for the cyclonic insert has been a challenge. During the early phase of the project, the supplied cyclone inserts were made of duplex stainless steel (UNS 31803) internally coated with tungsten carbide high velocity thermal spray. One DTU well using this material has been in operation for more than two years without exhibiting significant signs of erosion. When the solid loading significantly exceeds the design parameters, the duplex/WC insert is not able to cope with the choking of the cyclone apex with solids. One insert failed after two weeks of operation. In response, silicon carbide (SiC) inserts were supplied and installed for this extreme service duty. Periodic inspection on the SiC insert was conducted, and this material shows exceptional erosion resistance. However, SiC material can be susceptible to mechanical cracking due to poor handling and requires extra care during installation. Figure 9 shows an eroded duplex insert and corresponding SiC insert in good condition.



Figure 9. Photographs of a damaged duplex stainless steel insert (left) and corresponding silicon carbide insert (right) showing no sign of erosion.

High abrasion resistant materials, such as 410 stainless steel for the base material or hard facing with Stellite® 6, are being investigated. These options should provide exceptional wear resistance combined with less stringent handling requirements. A hardness comparison of these materials is shown in Figure 10.

Summary

The Kikeh DTU operated by Murphy Sabah in East Malaysia experienced high levels of solids production starting in 2011 that resulted in production interference from several of the wells. Murphy initiated an interim fast track solution consisting of wellhead desanders installed on the highest sand producing wells in order to maximize production while the wells were reworked. The facilities sand management system installed, believed to be the largest offshore system of its type in the world, includes 10 wellhead desanders, common slurry transport system, dewatering and bagging station, and skip removal to process up to 10 tons per day of sand. Figure 11 shows sand from the filter-bagging station being unloaded into the transport skip. There have been several operational challenges including fluctuating sand production, higher than expected sand volumes, rapid erosion of some of the inserts, and labor requirements to operate the equipment. However, upgrading the spar with topsides sand management has effectively controlled the production of sand and maximized hydrocarbon production during the period between the advent of sand and long-term control by upgraded lower completions.

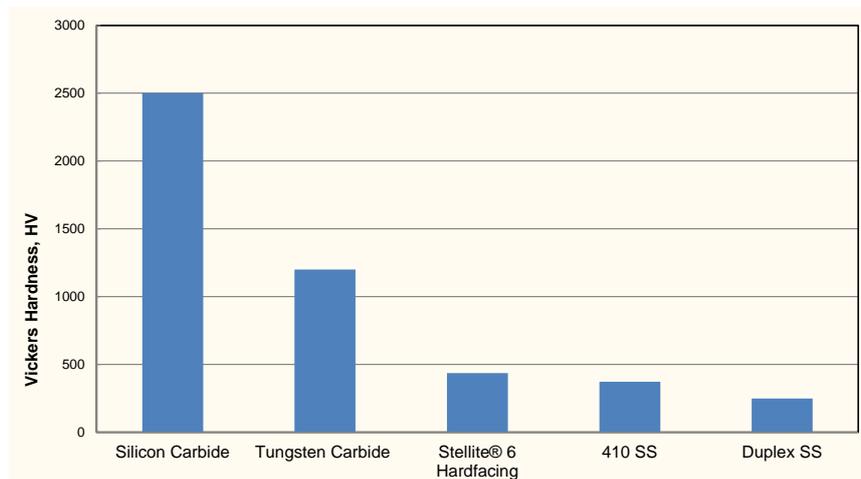


Figure 10. Hardness comparison of various wear resistant materials used for the base inserts material and hard facing. Data from Goodfellow Cambridge, TACA, Polymet, Stal & Matweb and converted to Vickers hardness value for comparison.



Figure 11. Photograph of full filter and lift bag being unloaded into transport bin (left) and dewatered solids in bin before shipment to shore for landfill disposal (right).

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