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AADE 2009-NTCE-12-06: CONTINUOUS FLOW SEPARATION SYSTEM RECOVERS OIL FROM RESERVE PIT FLUIDS

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Abstract

Lined reserve pits are widely used for storage of drilling discharges during land drilling operations. In the areas where operators predominantly utilize invert-emulsion drilling fluids such pits may contain significant amounts of hydrocarbon, solid material including colloidal particles and some free-water. Weak oil-in-water emulsions might also be present. Recovery of both, the hydrocarbon and aqueous, fractions of this reserve pit fluid can be achieved by demulsifying the fluid and separating fine and colloidal particles from the oil medium. The results are environmentally and economically beneficial. By optimizing reserve pit fluid treatment management practices on location, the volume of waste and the number of reserve pits can be reduced. Reclaimed hydrocarbons from the reserve pit can be recycled and used as a base for new drilling fluids.

A continuous-flow closed-loop process has been developed to treat the reserve pit fluid so as to recover clean oil. The reserve pit material is treated with a demulsifying surfactant and a flocculating polymer which converts the solids and some of the water phase into a flocculated mass which can be separated using a standard oilfield centrifuge. The remaining water and oil phases exit the centrifuge as liquid effluent and are collected. The chemical de-emulsification is sufficient to allow the oil and water phases to separate under gravity and the top oil layer can then be recovered to a separate vessel for recycling or reuse.

This technology has been tested at an operational location in the US and results from this successful operation will be presented. It will be shown that this chemically enhanced separation system significantly improves solids and water removal from the reserve pit fluid compared to centrifugation alone. Chemical treatment at <1 vol % was sufficient to recover clean oil which contains less that 3% by volume water and solids and is suitable for reuse. This new approach provides an innovative solution to reserve pit fluid treatment and management for land drilling operations, allowing effective treatment of oil-containing pit fluids for environmentally responsible waste reduction, pit cleanup and oil recycling.

Introduction

Solids found in used drilling fluids come from two main sources. Some solids, such as barite and bentonite, are added to the fluid as ingredients to provide properties such as viscosity, density, or filtration control. Additional formation solids become suspended in the fluid during the drilling process. Typically, formation solids, drilled and sloughed, are classified as contaminants and need to be removed if present in excessive concentrations.[2] API classifies solids greater than 250 microns as intermediate, from 74 to 250 microns as medium, from 44 to 74 microns as fine, from 2 to 44 microns ultrafine and smaller than 2 microns as colloidal.[3] Ultrafine and larger particles are removed by solids-control equipment routinely used on a drilling rig. Such equipment may include settling pits, shale shakers, desanders, desilters, hydrocyclones and centrifuges providing step-wise removal of progressively finer drill solids. Decanting centrifuges are capable of removing ultrafine particles but not the colloidal solids. Therefore, colloidal solids cannot be removed by standard solids-control equipment and tend to build up in the drilling fluid causing adverse effects on mud properties and stability. The concentration of colloidal particles can usually only be reduced by dilution or disposal. The process and equipment described in this paper involves a unique flocculation process that enables aggregation of colloidal solids to a size that can be removed using standard oilfield centrifuges.

When drilling fluids become unusable during land drilling operations, they are temporarily stored in lined reserved pits on the rig-site locations. Those pits may also be used as receptacles for drilled cuttings with associated fluids, slop fluids, oily discharges, wastewater, spacer fluids, excess cement, and other drilling discharges.

Drilling waste minimization measures, including fluids management strategies and reduction of environmental impacts, have been widely implemented in the industry. Different approaches to treatment of drilling effluent are used depending on the fluid properties. Water-based fluid handling is well developed; different kinds of discharge waters now are processed and reused on the rig, or further cleaned to comply with environmental standards to be safely released into the environment. Oil-based or oily drilling discharges present additional challenges in terms of toxicity, dispersibility, bioaccumulation, and biodegradability. One of the main considerations for land disposal is the type of oil and oil concentration that remains after biodegradation. Some oils are biodegradable and considered to be non-toxic, however, for diesel oil, for example, potential plant toxicity is a major concern.

Whether it originates from natural sources or added as a byproduct of the drilling operations, water is the largest component of pit fluid in terms of volume percent concentration. In the areas where most drilling is conducted with oil-based drilling fluids (OBM) and synthetic-based drilling fluids (SBM), concentrations of oils in reserve pit fluid are large. In areas in Central US, where many wells are drilled with diesel OBM, waste management strategies have to be applied at a different level from aqueous-based fluids. Reclaiming hydrocarbons in general and diesel oil in particular for recycling or reuse offers several advantages in terms of environmental compliance, waste reduction and economic considerations.[5]

The process and equipment package for this continuous flow separation system was developed initially as an invert emulsion flocculation process and equipment that targeted traditional OBM and SBM with an oil-water ratio greater than 50/50. This paper is focused on oil recovery from reserve or cuttings pit fluids, with an oil-water ratio less than 50/50 and include fluids with oil-water ratios of 20/80 or lower using the same equipment. In addition, the continuous flow separation system described not only recovers the oil, but also allows reuse of the recovered water. The water may also be further processed for safe release to the environment. This application, therefore, provides maximum practical benefits by enabling the recycling of oily reserve pit fluids and minimization of liquid haul off.

Pit Fluid Characterization

The reserve pits described here are located on current or old rig locations where OBM are most commonly used for drilling. The content of these pits is complex. During the drilling phase, they receive drill cuttings coated with mud and any oily fluids generated on the rig. The lowest layer of the pit consists of larger solids and associated fluids that settle out during a period of time. Higher layers contain significant amounts of water, a full range of finer solid particles and associated fluids, colloidal solids, and emulsions containing colloidal solids. Determination and characterization of the exact composition or positioning of different layers of fluid is an impossible or very difficult task as it will be unique for every pit and will constantly change due to environmental factors, possible chemical reactions and physical interactions. The top layer is usually a hydrocarbon layer that contains some free or emulsified oil. All the elements of drilling and completion fluids can be present in the fluid of these reserve pits.

During retrieval of the fluid from the pit and transportation to a collection tank for treatment, the different fluid layers are mixed by pumps or vacuum systems. Solids from the bottom of the pit may also be reincorporated in the fluid, and the oil and water fractions may be sheared sufficiently to reform weak or stable emulsions. Every batch of fluid received for processing will vary greatly due to the difference in composition in every pit depending on place of the pit from one particular fluid is extracted, and how it was processed upstream. Therefore, prior to processing, each batch of fluid must be tested to determine the treatment requirements.

Density

The density of the fluid, commonly called mud weight, is measured prior to treatment as a criterion to estimate the solids content and to provide a baseline measurement prior to processing. Measurements are performed with a mud balance of sufficient accuracy to measure within 0.1 lb/gal.[1] These measurements are commonly performed under field conditions and do not require complex laboratory equipment. A temperature of a fluid is measured and recorded at the same time. The density of the recovered fluid after it has been processed is a key factor in determining performance.

Liquid and Solid Content

The pit fluids contain three main easily detectable components – oil, water and solids. Liquid and solid content measurements are performed on a standard mud retort. The mud retort is a distillation apparatus that boils off and collects the liquid fraction of the fluid. Any emulsions contained in the fluid are broken by temperature during this process, and the distilled fluid will separate cleanly into oil and water fractions that can be accurately measured. The liquids and solid content measured prior to treatment gives an estimate of volumes of potential oil and water recovery and information about amounts of solids expected to be removed.

The liquid and solid content of the recovered fluid after processing is again measured to determine the success of solids removal and the remaining oil and water content. Generally, the solids content after adequate treatment is approximately 1% by volume or less.

Gravity Assisted Separation Phenomenon

In some instances the fluid received for processing may exhibit stronger emulsions that prevent separation of the oil and water phases, and maintain solids in suspension. In other cases, an emulsion may be absent or very weak allowing gravity separation to naturally occur in untreated fluid if the fluid is left undisturbed for a prolonged period. Gravity-assisted separation phenomenon indicates presence of free oil, water and weak emulsions in a fluid; some tighter emulsions can also be present at the same time. This process, however, may progress very slowly further inhibited by the amount of fluid contained in a tank or the geometry of the tank. For instance, separation by gravity in the lab of a few ounces in 10-12 hours may correspond to days or even weeks in a large tank. Separated layers are dirty and may be suspended sporadically in a fluid. All fluids should be subjected to mechanical conditioning prior to treatment. Whether the fluid is showing ability to separate under gravity or remains homogeneous, a chemically enhanced separation treatment is needed to optimize oil reclamation.

Process Principles

The process and technology of oil recovery from reserve pit fluid is based on invert fluid flocculation where chemicals are used to weaken any existing emulsions and then flocculate any solids in the fluid, including the colloidal solids. Invert-emulsion flocculation technology has only recently been developed; however, similar technology for aqueous-based fluids including oil-in-water emulsions has existed for decades. For reserve pit fluids, removal of the fine solids presented a new set of challenges due to possible presence of both types of emulsions, but predominantly invert emulsions, free oil, significant amount of loosely emulsified or free water and a number of different contaminants. The newly developed process has resulted in the ability to reclaim the oil fraction and recover a significant proportion of the water.

The flocculation process is driven by adhesion of polymer particles to multiple oil-wet and water-wet solid particles suspended in a fluid and creating larger aggregates. These aggregates, or flocks, become larger than the cut point of a decanting centrifuge, and can then be removed. During the flocculation process demulsifying surfactant and free water are required to weaken invert emulsion and water-wet solids, making these solids available to react with a flocculant.

The exact process parameters required are determined for each fluid before treatment through screening tests and process optimization at the start up of any new treatment. The process is continuously monitored and optimized as fluid parameters change during treatment. In practice, fluids properties tend to change frequently requiring precise control and process management.

The continuous-flow separation process (Figure 1) is started when a fluid is pumped from the feed tank to the processing unit by a variable frequency drive (VFD) controlled pump. Two chemicals, one after the other, are injected and mixed thorough into the feed fluid as it passes though the main flow line. Sufficient mixing is needed to ensure that the chemicals are adequately dispersed in the feed fluid creating optimum conditions for chemical reactions. The chemical injection and mixing equipment is selected and placed to optimize processing capability over a range of feed fluid viscosities and the properties of chemicals used for treatment. The mixing equipment arrangement employs static and dynamic mixing devices. The static mixers work by mixing through an orifice that applies the principles of alternative vortex shedding and intense shearing layers turbulence. The dynamic mixer provides process conditions independent of mixing capabilities and can shear fluids with high viscosities.

Once a fluid is subjected to chemical treatment, the flocculation process takes place while the fluid is delivered through the main line to a decanter centrifuge. The overall process is designed to complete the flocculation reactions before a fluid enters the centrifuge. The decanter centrifuge is a typical piece of oilfield equipment used for separation of solids from liquid under the influence of centrifugal acceleration to increase gravity, or "G" force. Centrifuge settings are adjusted to provide the appropriate "G" force and retention time to maximize solid removal efficiency. The centrifuge overflow is then collected in an effluent tank and pumped to the corresponding separation tank. The centrifuge overflow is practically free of solids and contains an oil and water mixture. The majority of the solids are expelled from a centrifuge as the underflow. If centrifugation of the same fluid is performed without chemical treatment or chemical treatment is insufficient, the centrifuge underflow is semi-liquid, and the colloidal particles will remain in the overflow. Centrifugation of a fluid after the effective flocculation process produces a dry bulky underflow due to the improved liquid/solids separation and the flocculated solids.

Due to a large amount of water in typical pit fluid, the overflow fluid, recovered after chemical treatment and centrifugation, consists of an oil and water mixture. The use of a demulsifier in the process enables the mixture to separate quickly by gravity in a separation tank allowing clean oil and water recovery.

Reclaimed oils after treatment can be returned to the active systems as a diluent or used to prepare new drilling fluids. Several series of tests were performed in-house and by independent laboratories to determine the impact of such drilling fluids on reservoir productivity. Independent permeability plugging tests performed with different types of core show that returned permeability for drilling fluid prepared with reclaimed oil was equal to results for drilling fluids prepared with clean oil.

Equipment

The flow loop and chemical treatment equipment is packaged in a single self-contained skid (Figures 2 and 3). The equipment includes positive displacement pumps for the main feed flow line, chemical injection pumps for surfactant and flocculant delivery, mixing equipment, all piping, valves and controls, with easy access for operation and maintenance. Fixed and removable chemical storage totes and a storage tank for centrifuge effluent to allow sampling and process monitoring are also incorporated into the skid. The control panels are certified according to NEMA standards and are available as NEMA 4 enclosures for land operations which are in compliance with water, dust and hazardous atmosphere presence requirements at different levels. The centrifuge is installed separately from the skid piece of equipment to allow flexibility in use either for the skid or for a centrifuge. Storage tanks and settling tanks are also installed separately. This approach was chosen to allow for more efficient equipment utilization and flexible installation on a rig site or in-field processing area. The skid dimensions are equal to that of a standard 20-foot long shipping container.

Different configurations of process equipment can be set up depending on location needs. A winterized version (Figure 3) of the skid allows operations in winter conditions. A mobile unit can be set up on a trailer to perform shorter jobs on different locations and rig sites and avoid permanent installations. Installed on the same trailer, oilfield centrifuge and diesel power generators are included in mobile unit. (Figure 2)

Treatment Performance

During work in Wyoming, the unit processed a variety of reserve pit fluids containing fluids formulated by different service companies operating in the area. In-field processing plant was set up with storage tanks and ancillary equipment to enable used drilling fluids and discharged fluids from various drilling locations in the area to be processed. The processing plant was originally set up to treat used muds with high levels of colloidal solids, or to adjust the oil-water ratio of water-contaminated mud. However, due to the high drilling activity in the area, the operator had high volumes of discharge being generated in the cuttings reserve pits and requested clean up to recover as much of the base oil as possible.

The technology removed the fine entrained solids at low chemical treatment rates. Most of the brine was retained in the recovered fluid, which kept the volume of solids discharge low. The brine and oil in the effluent separated into clean phases after treatment, allowing recovery of both phases into two streams. The oil phase recovered was re-usable with no further treatment required. It was noted that these fluids have the ability to separate into invert emulsion phase and water phase if left undisturbed for several hours. Evidently, very low surfactant dosage was needed to treat the fluid. When 130 bbl of 8.6-lb/gal fluid with 72% water, 24% oil, and 4% solids content was treated with low levels of surfactant and flocculant, 40 bbl of 7.2-lb/gal oil, which contained 96% of clean oil with less than 4% of residual water and solids, was recovered. In another case, 7.0-lb/gal effluent oil was recovered containing 99% of solid-free clean oil (Figures 4 and 5).

Operations can be continued year round using winterized equipment. Reserve pit fluid properties change during winter due to environmental conditions. Growing drilling activity in the area at that time led to substantial increase of discharge fluids stored in reserve pits. Work requests focused on recovering oil from reserve pit fluids with high water content. The fluids ranged from lightly emulsified fluids to heavier emulsified fractions, all showing no phase separation on standing. The solids content ranged from 12 to 20%.

The winterized unit was installed on location with outside temperatures below 20°F during the day time. The temperature inside the unit was kept satisfactory for the process and chemical storage requirements. All outside lines were isolated and heated. The fluid had to be continuously rolled, in the mud tanks to prevent freezing.

The fluid to be treated was 345 bbl of reserve pit fluid with a density of 9.2 lb/gal (1.1 SG) with 14% solids, 35% oil and 65% water content (Figure 6). The fluid was emulsified with no phase separation on standing. The centrifuge reduced the density of this feed mud to 7.8 lb/gal (0.94 SG) with no chemical treatment. Using a feed rate of 10 gallons per minute, and additions of surfactant and flocculant, the solids were effectively removed. The effluent recovered contained both brine and oil, and these rapidly separated into what appeared to be clean oil and brine phases (Figure 7). The clean oil phase had a density of 7.2 lb/gal (0.86 SG), and contained 99% oil with less than 1% water and solids. No analysis was carried out on the brine phase. The recovered fluid was transferred to a separation tank and allowed to settle under gravity. Recovered oil after separation was transferred in storage tank and later re-used to build mud volume.

Conclusions

Developed on the principle of invert-fluid flocculation, the continuous-flow separation system is an innovative, field-proven solution to waste management for land drilling operations where diesel-, oil-, or synthetic-based drilling fluids are used. The system enables effective treatment of oil-containing pit fluid for environmentally responsible waste reduction, pit cleanup, oil and water recycling. Liquid haul off is minimized in the process. Reclaimed oil and recovered water can be returned to the active system or reused in other ways to minimize waste and reducing the environmental impact.

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Nomenclature

API	= American Petroleum Institute
bbl	= Barrels
G	= Gravitational Acceleration
NEMA	= National Electrical Manufacturers Association
OBM	= Oil-Based Mud
lb/gal	= Pound per Gallon
SBM	= Synthetic-Based Mud
SG	= Specific Gravity
VFD	= Variable Frequency Drive

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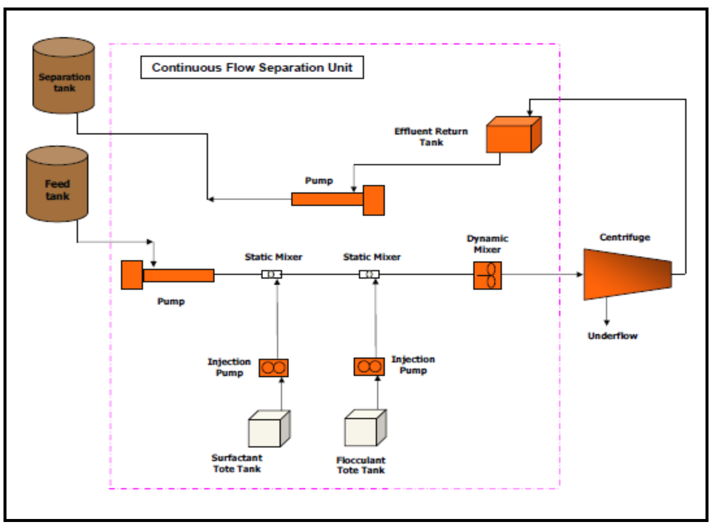

Figure 1 – Reserve Pit Fluid Treatment Process Flow

Figure 2 – Mobile Treatment Unit

Figure 3 – Winterized Treatment Unit

Figure 4 – Recovered Oil Retort Results

Figure 5 – Mud Weight of Recovered Oil

Figure 6 – Reserve Pit Fluid before Treatment

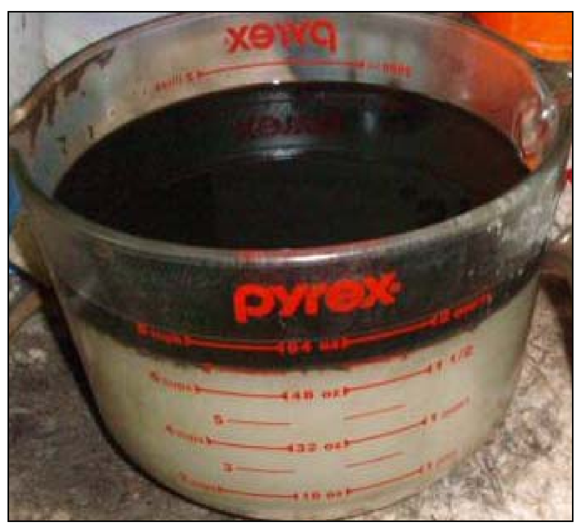

Figure 7 – Effluent after Treatment