Fluid monitoring service raises bar in HTHP wells

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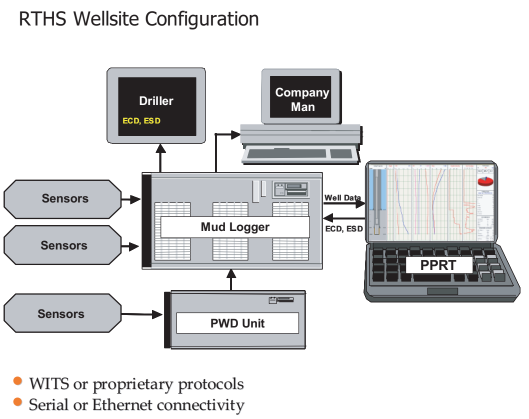
A SPECIALLY ENGINEERED oil-base drilling fluid system applied in conjunction with a unique real-time hydraulic monitoring service has established a new benchmark in the drilling of high-temperature and high-pressure (HTHP) wells.

The combination was employed in an exploratory HTHP well in the Norwegian North Sea where it reduced drilling days more than three fold, saving a conservative $3 million in total project costs.

Generally, HTHP wells are defined as those with an expected static bottom hole temperature (BHT) anywhere from 300º to 500ºF and an expected shut-in pressure from 10,000 to 25,000 psi. Such abnormally harsh environments place



An advanced real-time hydraulics system (RTHS) at the wellsite monitors and measures data wherever available, making it a perfect addition to real-time onshore drilling and operations centers.

distinct technical demands on a drilling fluid as they present the potential to radically alter its behavior compared to more conventional applications.

Under conditions of very high temperature and pressure the rheological parameters of drilling fluids are difficult to predict without considerable field experience supported by laboratory data from a Fann 75 HTHP rheometer. The rheology is particularly important in the deeper sections of HTHP wells where the annulus is smaller in diameter, thereby creating erratic fluid behavior that can have a profoundly negative impact on equivalent circulating density (ECD) management. While the abnormal pressures experienced in these wells required higher mud weight to control formation fluids, the fracture gradient of the pressured formations does not increase at the same rate as the pressure. Consequently, the so-called drilling window between the pore pressure and the fracture gradient can be very small on HTHP wells. Hence, if the rheology of the drilling fluid is too high, the circulating pressure could break down the formation, resulting in lost circulation and increasing the risks of well control issues.

Furthermore, the risk of becoming differentially stuck is magnified on an HTHP well. The weight of the drilling fluid required to control the abnormally pressured zone is much higher than the pressure requirement in nearby formations. This condition results in differential pressures between the drilling fluid and pressured formations in excess of 3,000 psi. If the zones contain permeable formations, the risk of becoming differentially stuck is elevated. Filtration must be tightly controlled, whereby a lubricious filter cake is deposited, which is a critically important factor in avoiding stuck pipe, especially in extended reach and high-angle wells. Since invert emulsion drilling fluids exhibit excellent filtration characteristics and a low coefficient of friction they provide a practical solution for wells with a BHT of 400ºF or more.

ENGINEERING AN HTHP FLUID

A number of factors must be taken into consideration when designing or selecting a drilling fluid for an HTHP well. The rheological profile and filtration stability of the fluid at elevated BHT is critical, along with its drilling performance at very high densities. The fluid also must possess good hole cleaning, lubricity and corrosion characteristics and be resistant to contamination, including H2S and CO2 contamination.

For kick detection, the compressibility and solubility of gas in the mud must be considered and understood. The selected fluid must pass environmental and toxicity evaluations where applicable, while also being cost-effective. These factors were taken into consideration when designing a new fluid system for HTHP applications.

The new HTHP fluid system can be formulated using either linear paraffin or low-toxicity mineral oil as the base fluid. The lower kinematic viscosity of both these base oils delivers low to flat rheological profiles that make them effective under a wide range of downhole temperatures and pressures. Drilling fluids designed with flat to low rheological parameters are expected to drill a well at lower ECD, encounter fewer problems and successfully avoid instances of lost circulation, all critical issues in the drilling of an HTHP well.

An essential component of the newly developed system is a new thermally stable organophilic clay, which is used as the primary viscosifier. While similar to that used in conventional invert emulsion systems, the new clay incorporates a new type of quaternary amine group that is thermally stable, thereby making it oil soluble and increases its temperature stability. The clay used in earlier systems began to thermally degrade at 347ºF, while the new product is stable to temperatures in excess of 400ºF.

The exclusive package also contains primary and secondary emulsifiers that deliver a temperature-stable emulsion, high-temperature, high-pressure fluid-loss control and preferential oil-wetting of solids.

A specially developed HTHP fluid-loss control agent is employed when temperatures are expected to exceed 300ºF. Owing to a melting point that exceeds 400ºF, the new fluid-loss control agent can be used effectively in high-temperature applications with no adverse effects on rheology.

The end result is a system that remains stable at high temperatures, is suitable for narrow hydraulic window applications and reduces ECD while maintaining stable low shear rate viscosity. The reduction in high shear rate viscosity, in turn, reduces total system pressure loss. Further, the new system is not only easy to engineer, but displays the behavior and accepts chemical treatment similar to conventional invert emulsion fluids. The system also has proven effective in reducing barite sag.

REAL-TIME MONITORING

In HTHP applications, proper management of ECD is vital in avoiding well control problems, poor hole cleaning, lost circulation, ineffective drilling performance and cost over-runs. For HTHP and other narrow-pressure margin wells reaching their objectives safely and economically requires accurate knowledge of downhole hydraulics in real-time. Accordingly, pressure-while-drilling (PWD) tools satisfy many of the needs of ECD management in critical wells, however, the very nature of this technology limits its use in certain critical operations and wells. Ironically, the temperature limitations of these tools often make them unavailable when pore and fracture pressures converge, resulting in narrow operating windows, which is a critical element of an HTHP well. Serious real-time information gaps also exist while running pipe or casing, or making connections where downhole pressure data is not available in real-time at the surface.

An advanced real-time hydraulics system (RTHS) has been developed to complement, and, in special cases, to substitute for PWD tools when they are not available. The RTHS models complex downhole hydraulics in real-time based on conventional surface-measured input data. The software provides ECD predictions if a downhole tool is not installed or has failed, or when measured data is not available at the surface in real-time. If both data sets are available in real-time, the "what is" provided by the downhole tool and the "what should be" provided by the RTHS can be compared and successfully used to avoid drilling problems. "True" real-time is achieved by providing results fast enough to affect changes in a dynamic process before their completion.

The RTHS relies on a continuous stream of surface measured data wherever available, making it a perfect addition to real-time onshore drilling and operations centers increasingly being used to monitor drilling operations. The system is monitored onshore by connecting to the real-time data stream from the rig and transmitting calculated data back to the data provider on the rig and displayed in front of the driller as virtual or simulated sensors.

The RTHS employs sophisticated engineering models and a specially trained hydraulics engineer to provide complete surface-to-TD downhole pressure profiles. The system utilizes two fundamental concepts verified in a wide range of drilling applications. The first concept subdivides the entire well into short segments, each with their own set of properties and parameters that is continually updated in real-time. The second concept uses the best available rheological data for the drilling fluid by combining data from various measurements. The system relies heavily on a sophisticated transient temperature simulator to predict downhole temperature profiles and adjusts drilling fluid density and rheology based on temperature and pressure.

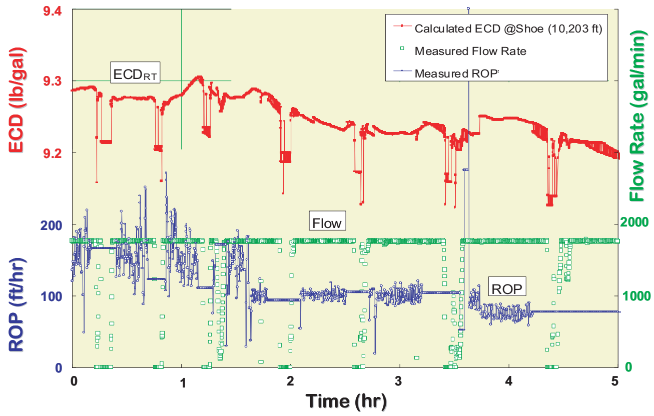
The system has substituted for downhole tools in HTHP applications where downhole temperatures exceeded tool limitations and helped reduce well observation time while avoiding well-control and lost-circulation incidents.

The RTHS is uniquely available for ECD management while drilling, tripping and running casing in narrow operating windows where operations would normally be suspended in the absence of downhole pressure tools.

The RTHS has been successfully used on HTHP and other exploratory wells to prevent hydraulics related drilling problems. The system has complemented and substituted for downhole pressure tools while drilling, tripping and other operations in the Gulf of Mexico, North Sea, West Africa and South America, among others.

FIELD RESULTS

The new HTHP fluid system, formulated with low-toxicity mineral oil as the base fluid, was used in tandem with the well-site hydraulics monitoring service to successfully drill an exploratory well in the Norwegian North Sea with bottom-hole temperature and pressure exceeding 350°F and 14,000 psi, respectively. The combination was used in the critical 12 ¼-in. and 8 ½-in. sections, which the best available offset required 156 days to drill. The maximum required equivalent static density (ESD) was 18 lb/gal, among the heaviest ever recorded in the Norwegian North Sea, with a fracture gradient of 18.5 lb/gal.



The RTHS can substitute for downhole tools if they become inoperable due to tool mechanical failure. The RTHS has been used to guide drilling operation and prevent an extra trip and wasted rig time to replace non-functional tool.

Since the well exceeded the temperature limitations of the PWD tool, the RTHS was used and consistently calculated ECDs within 0.1 lb/gal of measured values. Correcting downhole mud density (ESD) for fluctuations in temperature and pressure was crucial in maintaining well stability and integrity. The accurate prediction of pressures while drilling and tripping dramatically reduced well observation time while avoiding well control and lost-circulation incidents. Consequently, the sections were drilled in 46 days, saving a conservative $3 million when compared to offset wells.

More recently, the combination was used successfully in a deep shelf well in the Gulf of Mexico where the temperatures were beyond the limits of the PWD tool.