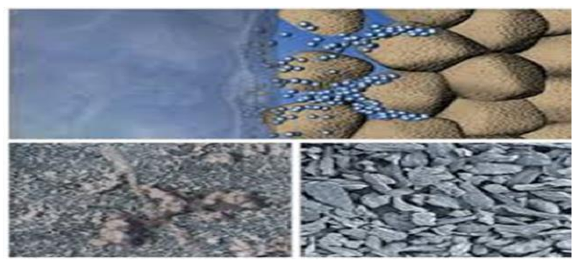
DRILLING FLUIDS TECHNOLOGY



APHRON SYSTEM

Field Lessons from Successful Application in Drilling Depleted

Reservoirs

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The APHRON fluid system changes the way fluid works. It is the only fluid that provides a variable density fluid downhole, and is able to create an automatic "at-balance" condition between the annular and formation pressures to stop invasion and movement of the fluid into the rock. The system has been used worldwide in high permeability sands, fractured sandstone, fractured limestone and dolomite, as well as fractured granite. It has proven highly effective in stopping losses and invasion while providing rapid cleanup and enhanced production.

Introduction

The drilling problems associated with the depleted reservoirs intrinsic to many of the mature fields throughout the world often make further development uneconomical. Uncontrollable drilling fluid losses frequently are unavoidable in the often large fractures characteristic of these formations. Furthermore, the typical laminated sand and shale sequences create conditions that can make drilling unduly expensive and dangerous when using conventional rig equipment. Consequently, these and a host of associated problems have led some operators to forgo continued development of these promising, yet problematic, reservoirs.

The overbalance pressure generated when using conventional drilling fluids is to blame for the majority of the loss circulation and differential sticking problems encountered when drilling these wells. The equipment required when using aerated muds or drilling underbalanced is often prohibitively expensive and meeting safety requirements can be an exhaustive effort. Furthermore, these techniques may fail to provide the hydrostatic pressure necessary to safely stabilize normally pressured formations above the reservoir.

Mr Sebba (1987) found a kind of special biliquid foams called Aphron. It was Brookey This microbubble technology has been employed effectively worldwide, and especially in Latin America, to seal problematic formations that have very high permeability and micro fractures.

BACKGROUND

Mr. Sebba (1987) found a kind of special biliquid foams called Aphron as unique microspheres with unusual properties. Much of his work was done with micro bubbles consisting of air encapsulated in a multi-layer shell created and maintained via chemical equilibrium with various components in the base fluid.

Brookey (1998) described the first use of Aphron and introduced aphron into petroleum drilling industry and renamed aphrons as “micro-bubbles”. In this case, the micro bubbles (as they were then called), were created as a minor phase in a water-based fluid. This system was used as a means of controlling lost circulation and minimizing formation damage in a low-pressure vugular dolomite reef zone. The micro bubbles allowed the zone to be drilled to required TD, logged and drill stem-tested; this had not been possible previously. How did the fluid system work? Many at that time thought that density reduction was responsible, since the application resulted in a lower mud weight on surface. The next application was in a fractured dolomite horizontal well, where the bit dropped only a foot and all returns were being lost. In this application, full returns were resumed as soon as the micro bubbles reached the bit. Obviously density reduction was not the reason these losses were controlled. This experience led to further research in the area of foams and aerated fluids and to the discovery of Sebba’s work with aphrons.

WHAT IS AN APHRON?

Basically, an aphron is nothing more than a bubble containing a gas core and multiple micelle-like shells comprising various components. The purpose of these shells is to provide enhanced stability to the bubble by ensuring greater strength of containment for the gas core. This feature enables different performance benefits than single-shell bubbles in aerated fluids or foams.

Aphrons contain a gas nucleus of encapsulated air and compress when circulated down the hole. The internal pressure of these microbubbles increases at a rate proportional to the extreme pressure being applied. The combination of increasing pressure and temperature serve to energize the individual aphrons. Once the bit exposes a depleted formation, the aphrons immediately aggregate within the pores of low-pressure zones. There, a portion of the energy stored within each aphron is released, causing it to expand. The expansion continues until the internal and external pressures on the wall of the aphron are in balance.

As the now-energized microbubbles enter the formation openings, they carry energy equal to that in the annulus. Once they crowd into an opening, external Laplace forces increase substantially, causing both aggregation and an increase in the internal low- shear-rate viscosity (LSRV) of the fluid system. The microenvironment created by this phenomenon assists in reducing fluid invasion.

Not only does the aphron technology draw upon the traditional benefits of high LSRV fluids, it further optimizes their performance capabilities. This enhancement is accomplished by lowering the high-end shear rate properties, and this translates into a significant reduction of frictional pressure loss at elevated circulation rates. This improvement broadens the opportunity window for the industry by expanding the utility of pressure-limited equipment. Standard tools such as coiled tubing and rig pumps can now deliver higher volumes of high-carrying-capacity fluid at similar or lower circulating pressures.

THE APHRON TYPE:

Aphron drilling fluids have been successfully used in 300+ applications worldwide to drill depleted reservoirs in mature oil and gas fields, high-permeability formations and micro fractured rock. These fluids serve as a successful and cost-effective alternative for avoidance of whole fluid loss and differential sticking. There are two chief attributes of these fluids that permit a decrease of fluid invasion and damage to the formation. First, the properties of the base fluid are such that upon entering a loss zone, the flow rate decreases dramatically. This occurs because the bulk fluid is very highly shear-thinning and possesses a very high LSRV (Low-Shear-Rate Viscosity). Second, very tough and flexible microbubbles are incorporated into the bulk fluid with conventional mud mixing equipment. These highly stabilized bubbles, or "aphrons," are essential to sealing the problem area by forming an internal bridge that acts as a loss circulation material. Currently, there are two water-based aphron drilling fluids, APHRON ICS^{TM} and APHRON EMS-2100, and one oil/synthetic-based aphron drilling fluid, POLYPHRON ICS^{TM}.

THE APHRON STRUCTURE

THE APHRON STRUCTURE Water-based aphrons, as found in APHRON ICS^{TM} and EMS-2100 systems, consist of two essential elements: a spherical core of air and a protective outer shell. Water-based aphrons have a trilayer surfactant shell, Fig. 1, enabling it to be much more robust to temperature and pressure than a standard air bubble, which is stabilized by only a monolayer of surfactant. Around the air core, an inner surfactant film is enveloped by a viscous water layer, and an outer bilayer of surfactants provides rigidity and low permeability to the structure while imparting some hydrophilic character to. Under quiescent conditions, the structure is compatible with the aqueous bulk fluid, but when enough shear or compression is applied to the aphron, e.g. when bridging a pore network, the outermost shell layer is stripped, rendering the aphron hydrophobic. Oil-based aphrons (in POLYPHRON ICS^{TM} systems) are similar in structure, as shown in Fig. 2, but do not contain the outermost surfactant layer: around the air core, an inner surfactant film is overlayed by a viscous water layer and a single outer layer of surfactant.

Aphrons act as a unique bridging material, forming a micro-environment in a pore network or fracture that appears to behave in some ways like foam, and in other ways like a solid, but flexible bridging material. As is the case with any bridging material, concentration and size of the aphrons are critical to the mud's ability to seal thief zones. Aphrons are created and entrained in the bulk fluid with standard mud mixing equipment, which reduces the safety concerns and costs associated with high-pressure hoses and compressors commonly utilized in air or foam drilling. Although each application is customized for the individual operator's needs, the mud system is generally designed to contain 12-15% by volume air. Aphrons are thought to be sized or polished at the drill bit to achieve a size of 15-100 µm diameters, which is typical of many bridging materials.

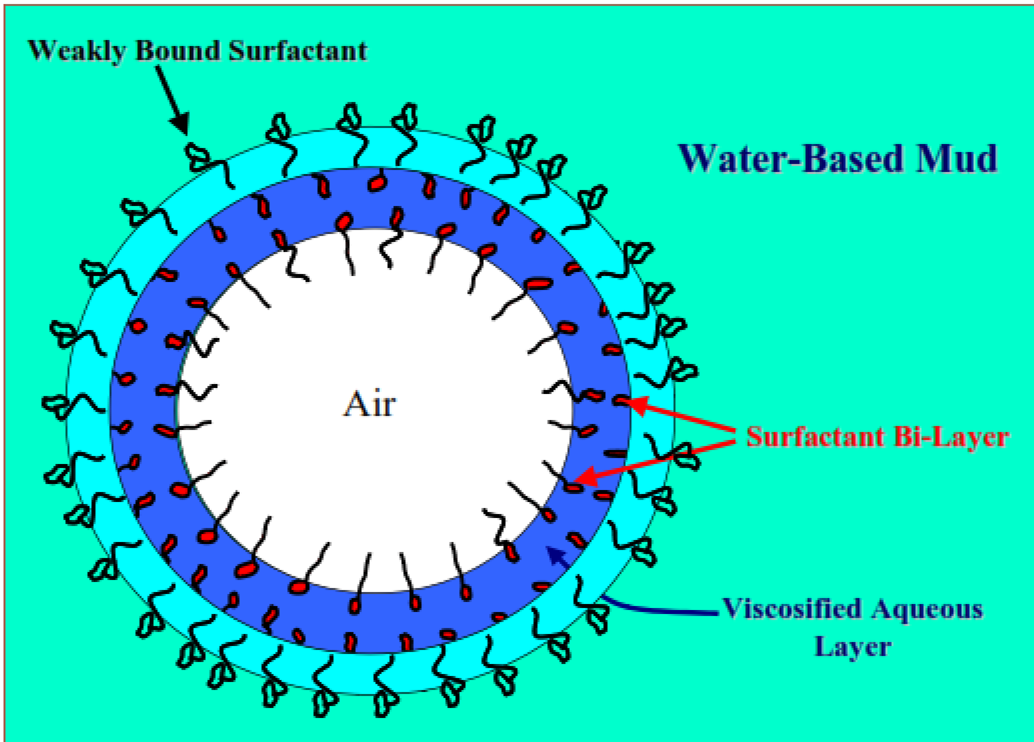


Figure1. Schematic of Water-Based Aphron

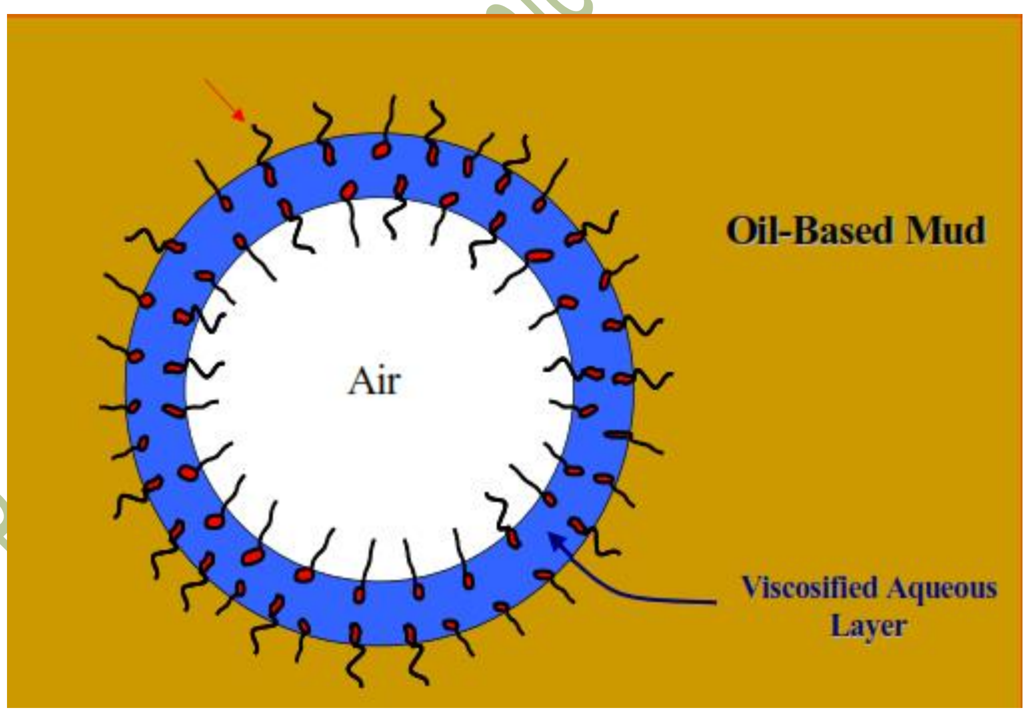


Figure2. Schematic of Oil-Based Aphron

HOW APHRON DRILLING FLUIDS WORK

Aphron drilling fluids reduce fluid invasion both rheologically and mechanically. The base fluid has a very high LSRV, as stated earlier, yet its viscosity at high shear rates is unusually low. Thus, equivalent circulating density (ECD) is quite low and the potential for fracture initiation and propagation is also low. In addition, the base fluid has relatively low thixotropy, as evidenced by the similarity between the 10-min and 10-sec gel strengths. Thus, when fluid suddenly enters a low-shear-rate region, viscosity builds very rapidly. In contrast, typical clay-based fluids are very thixotropic, as evidenced by highly progressive gels, and minutes(if not hours) are required for viscosity of a clay-based fluid entering a loss zone to build to the high level required to stem fluid invasion. Mechanical stabilization of the wellbore is also of paramount importance for aphron drilling fluids.

Aphrons can form bridges within the loss zone that act as an internal seal to complement the rheological properties of the base fluid. For aphrons to be effective, they must be stable. Aphron stability is accomplishedthrough control of the size, collision rate and mechanical properties of the microbubbles. The bubble size can be controlled by the amount of shear energy put into the system, along with the surfactant type and concentration. The collision rate is inversely proportional to the bulk fluid viscosity, so that an increase in bulk viscosity decreases the rate of coalescence among aphrons. Not only does the high viscosity of the base fluid itself slow fluid invasion in the loss zone, it also reduces the rate of coalescence and aggregation of the bubbles until they reach the pore throat or fracture tip, at which point they are forced together into a large bubble complex of deformed bubbles. Thus, an internal seal is formed, as shown schematically in Fig. 3.

This seal may have properties not unlike that of a non-adhering foam, i.e. the bubbles do not wet the pore/fracture walls; consequently, the bubbles are easily flushed back out via formation fluids during production.

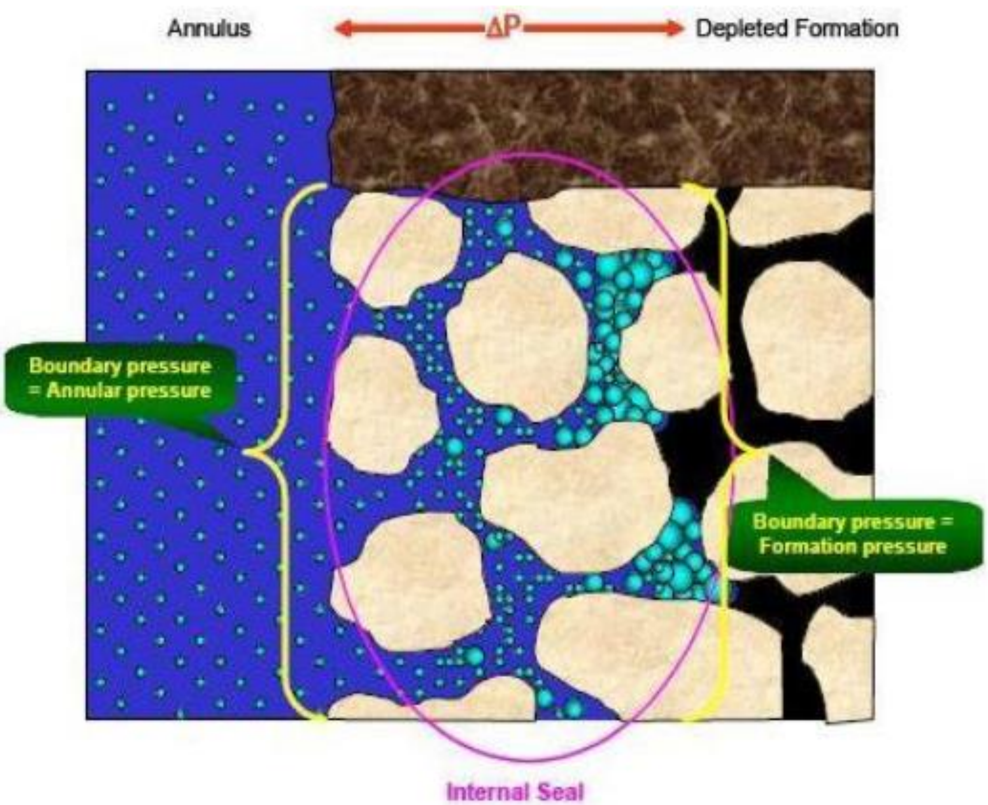


Figure3. Formation Invasion by Aphron Drilling Fluid

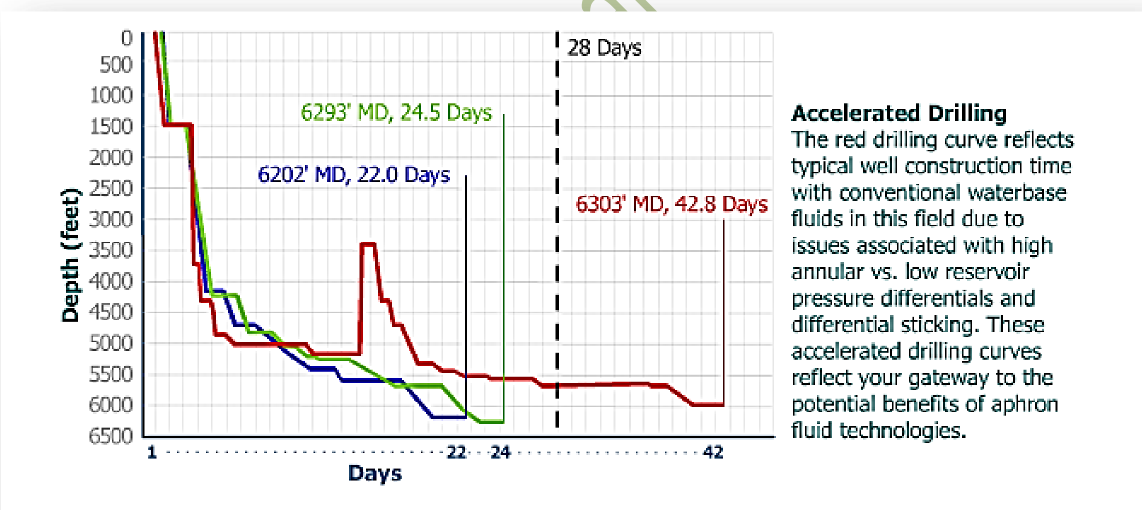
APHRON helped to Improve Operations (Field Data)

Aphron Fluid Systems improves well construction performance as demonstrated in the following field data.

A series of horizontal wells were drilled in an environment where very high annular-to-reservoir pressure differentials existed across high porosity and high permeability sands. Differential sticking and related issues historically translate into significant loss of time as well as cost over-runs. The Aphron Fluid System alleviates many of these issues.

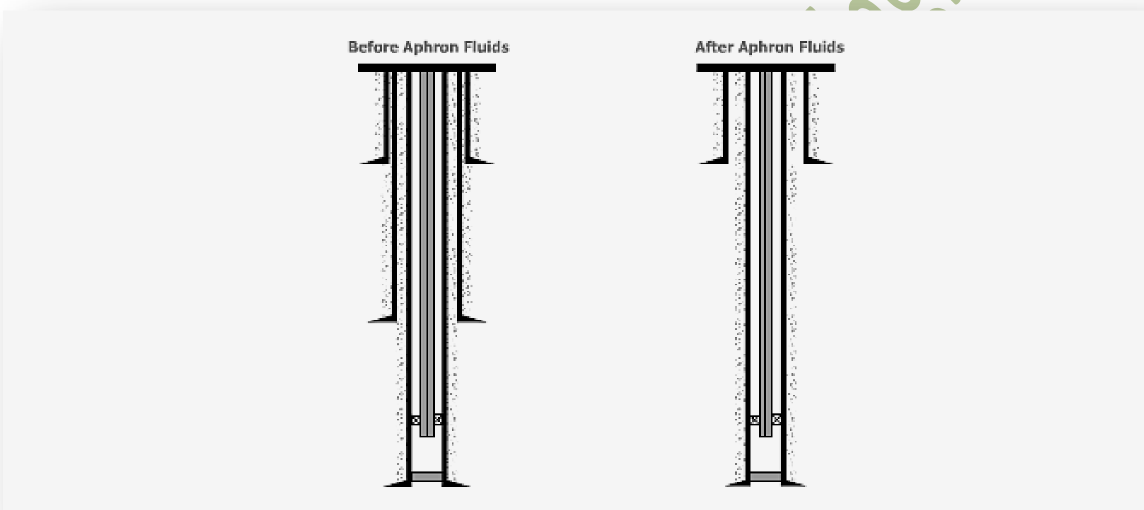
The Aphron Fluid System serves as a technological bridge between the formations and the drilling equipment, thereby negating the differential sticking issues and allowing for the use of a full density fluid ensuring stability of exposed pressured shale's, as well as enables the use of LWD technology, and optimized overall well construction performance.

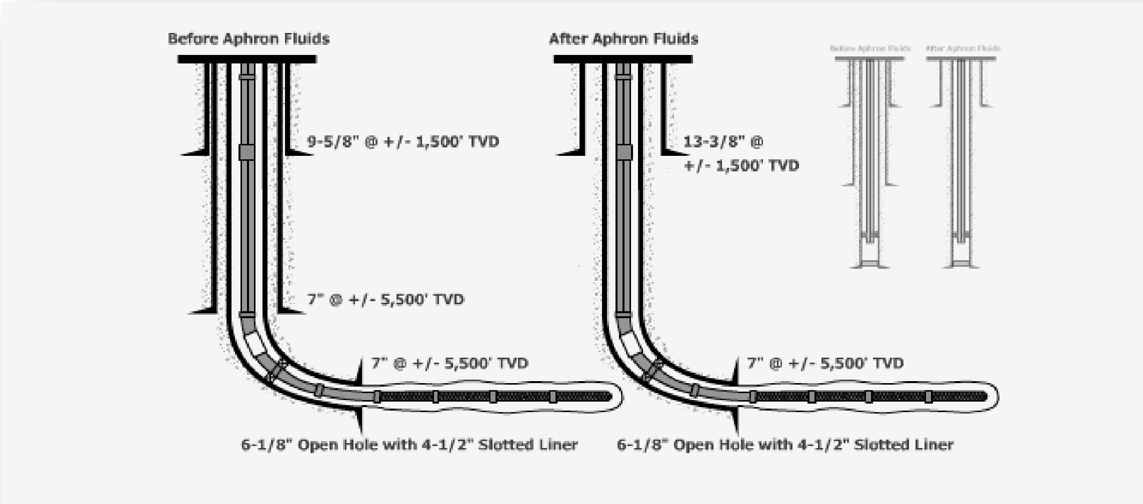
The net result was a 45 percent reduction in well construction time (22 – 25 days versus the historical 43 days) and all wells achieving their design criteria



APHRON helped to Improve Well Design (Field Data)

The Aphron Fluid System optimizes well design efficiencies as demonstrated in the following field data. Aphron Fluid System has enabled the redesign of wells in mature field's thereby driving improved field economics into the picture. When reservoir depletion has you thinking your only solution is intermediate pipe to potentially achieve your well design objective, think again. Time and time again the Aphron Fluid System has mitigated the issues associated within these challenging mature environments, enabling the use of full density fluids, optimizing the working environment and eliminating the need for an intermediate string of pipe. The net result has shown reduced well construction costs by $1,500,000.00 - $2,000,000.00 per well.





APHRON helped to Improve Well Production (Field Data):

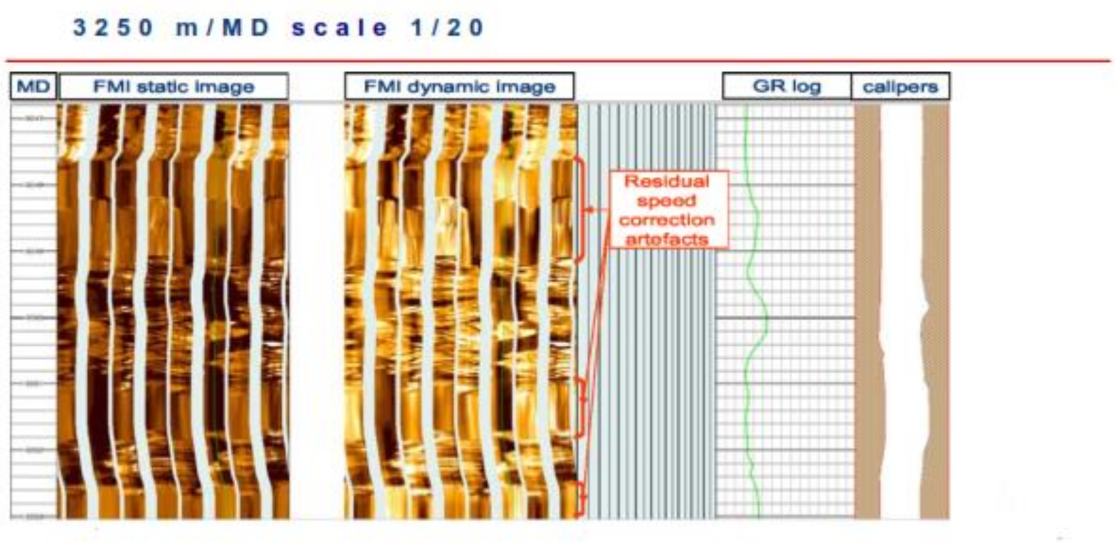
The Aphron Fluid System product line has been used on hundreds of wells to date in various global settings, with consistent success in controlled invasion and leakoff, improved wellsite operations, accelerated fluid recoveries, improved production profiles, and improved well design efficiencies. The technology has been deployed in various phases of drilling and production with marked positive results.

The Aphron Fluid System is custom designed to optimize your operations, reservoir potential, and production. This means improved ROI for you

Comparison of KHA wells			
MUD TYPE	WELL	Production (BOPD)	Mud losses (bbl)
Polymer	KHA 101	1003	1780
Polymer	KHA 201	1497	11400
Polymer	KHA 106	1449	4300
Polymer	KHA 402	822	1550
Polymer	KHA 401	0	No loss
Aphron system	KHA 403	3632	1500 polymer 1200 Aphron
Aphron system	KHA 404	5620	1500 polymer 0 polymer

Results of Field Operations

1. **A solid -free aphron drilling fluid was used to drill successfully into the oil-bearing, fractured granite basement of the KHA 403 well for TOTAL in central Yemen. KHA 403 is the third of several planned development wells into the fractured basement. This well, which reached TD on Jan 17, 2005, tested at 6, 088 BOPD with negligible clean up. The production interval was successfully drilled through fractured basement rock at an initial inclination of 36" and increasing to 55" at total depth. The well was conventionally logged on wire-line without problems prior to running open hole completion. The logistical benefits of using a fluid system that does not require supplying a large replacement volume under high dynamic loss rates are simple to appreciate. More significant, however, are the reduction in time and the elimination of equipment, and personnel involved in conventional clean-up procedures to facilitate full production. The final and most rewarding aspect of this application of aphron drilling fluid technology was a substantial improvement in productivity. Table shows the reduced mud losses and enhanced production experienced with the APHRON ICS mud on the KHA 403 well, compared to previous wells drilled with a polymer mud. The total volume of aphron drilling fluid built to drill the reservoir interval was 696m^3, and losses incurred totaled 265 m^3 into formation fractures. A subsequent well, KHA 404, was drilled in the same area with the APHRON ICS mud, and it experienced no losses of the APHRON ICS mud and even greater production.**



This event image shows the highly intensive fracturing of a fault that was drilled. The calipers through this section follow the axis of the event. Although the rubble in this section makes logging tenuous, it is clear that this is a potentially high-volume oil-producing segment. It is believed that had the section been drilled with a conventional water-based mud, massive losses would have occurred, necessitating the use of conventional sealing materials or even cement, either of which would have resulted in deep damage to the formation.

2. **In Luanda, Angola, Pacassa Field the formation Mississippian Age Fractured Vugular Dolomite with pressure Less than 599 kg/m. The operator needed to drill a fractured, vugular formation eliminating differential sticking and Fluid losses. Operator Also needed to control the frequent occurrences of H_2S and CO_2 gas and kicks at the top of the Albian A formation.**
   The Hi-tech engineering group recommended the use of our Aphron ICS™ Fluid System. Switching from invert to Aphron ICS™ Fluid System, wells were successfully drilled to TD with minimal losses and no stuck pipe. The Aphron ICS™ System also allowed for 99.9% core integrity, a full open-hole logging series and eliminated cementing issues. Combined, these successes allowed for expanded development of the Pacassa Field.
   The results was Losses reduced from 3000 BBL to 251 BBL, ROP increased from 10.5 to 26.4 feet per hour and the Rig Days reduced from 50 days to 29 days .

3. **The first Aphron-Based System Field Trial in Lake Maracaibo was performed in the reservoir section of the VLA 1321 well. This well was characterized by a formation pressure gradient of 0.15 psi/ft to 0.30 psi/ft. The offset well data that were analyzed during the planning stage of this field trial. The aphron-based system was displaced to drill the reservoir section after the 13⅜-in. casing was set at 5,477 ft. and the interval was drilled to 6,855 ft. The total section length was 1,378 ft. and throughout this interval 390 ft were cored with 91% recovery. At the section total depth (TD), three logging runs were made and the 9⅝-in. casing was run without any problems. During all these operations (drilling, logging, running casing and cementing), no mud losses were experienced. The repeat formation tester data (RFT) are presented in Fig. 8. The formation gradients were ranging from 0.15 psi/ft to 0.33 psi/ft while the mud gradient varied from 0.39 psi/ft to 0.41 psi/ft.**

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