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Aphrons Technology – A Solution

Boyd D. Schaneman, ChevronTexaco, Tom Jones, and Anthony B. Rea, M-I *L.L.C.*

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Abstract

As formation pressures are drawn down in mature reservoirs, the type and severity of critical operating issues are exacerbated and solution options become fewer. When taken in combination, operators are often faced with substantially increased costs and risk, particularly where HSE issues are concerned. The associated issues of effective, safe and economically viable well construction, completion and workover within low-pressure environments are becoming more challenging on a daily basis.

This paper discusses the application of the aphron fluids technology, which offers a unique alternative option that can significantly improve the operational and economic aspects for continued development of these marginal assets. The authors will detail the development of the unique microbubble technology and its successful application in mature and depleted fields.

Introduction

The problems associated with the pressure variances encountered in mature fields, coupled with the limitations of conventional fluid and equipment technologies to properly provide an equitable solution, have driven the need for a new approach to drilling and workover operations within depleted reservoirs in mature fields.

One of the latest approaches to this dilemma is the use of the aphrons drilling fluid technology. Hundreds of wells in diversified applications worldwide have proven the aphron technology to be a viable solution within these difficult operating parameters.

Field experience has shown that annular pressures exceeding depleted reservoir pressures by “several thousand” psi[1] have not hindered the creation of the micro-environment seal and mitigating invasion. This feature alone has allowed operators to eliminate casing strings, safely workover highly depleted wells and drill into normally pressure plays on wells with existing depleted production. All of this has been affected without compromising production. Because the seal is internal to the reservoir, (Fig. 1) conditions for differential sticking do not exist. In many parts of the world, this feature has successfully enabled high-angle and horizontal well construction of highly depleted reservoirs using conventional equipment. No other fluids technology in the industry enables these types of operations. Since standard well site fluid mixing equipment is all that is required to employ the technology, it is highly compatible with normal wellsite operations. As a drilling, completion or workover fluid, the aphron technology functions as the backbone of the operation. Serving as the bridging technology between the difficult operating parameters of mature fields and the limits of conventional equipment when employed to develop these depleted reservoirs, the aphron technology offers a solution for extending the economic attractiveness of these assets.

Theory of Technology

Aphrons[2,3] (micro-bubbles) are incorporated into a specifically engineered base fluid[3,4] to create a seal and aid in mitigating losses within depleted / highly permeable zones. These micro-bubbles differ significantly from aerated fluids and foams.[1,3] Aphrons aggregate, but do not coalesce. Upon entering the lower-pressure region within a depleted formation, aphrons remain discrete, yet will agglomerate to create a stable, but easily removed, internal seal called a “micro-environment”.[3,4] Because affecting this seal requires a higher annular pressure than that of the reservoir, aggregation occurs only within the formation when forming the seal. Furthermore, it deaggregates when the pressure differential is relieved during completion operations readily cleaning up with reservoir flow-back as production is initiated.

Synergies between the various features of the technology serve to minimize whole fluid invasion. Effectiveness of this process can be confirmed with a Triaxial Coreholder Sealing Tester (Fig. 2). The easily engineered high-LSRV property of the base fluid promotes design capabilities typical of reservoir drill-In fluids employing similar rheological design features. The addition of aphrons in various quantities and sizes (Fig. 3) provides superior sealing, thus optimizing diversion of annular pressures away from the depleted formations and minimizing fluid invasion (Fig. 4).

The aphron structure, its stability, the “Jamin Effect” and the associated “meniscus-wrapping theory”[1,2,3,6] work synergistically to provide optimized invasion control. These features enable one to visualize how sealing and pressure diversion away from the depleted reservoir is achieved. Depending upon the size of the opening to be sealed, a pore throat or a fracture, an individual aphron or an aggregated mass of aphrons can serve to bridge. The ability to seal larger openings is entirely dependent on the ability to deliver a sufficient concentration of aphrons into the potential thief zone.

Compared to a conventional external seal, the benefits obtained from the solids-free internal seal provide unique solutions to depleted reservoir wellsite operations. Unlike a conventional external seal that requires constant filtrate invasion[2] for maintenance, all further invasion stops once the "micro-environment" seal is established. This feature is very important when drilling or performing workover operations in depleted formations. When conventional fluid technologies are employed in such environments, it is not uncommon to observe very deep filtrate invasion resulting in shale breakout and under-gauge sands as observed from caliper logs in sand/shale sequence. The combination of these factors can result in an ideal environment for swabbing and the creation of bridges from caving.

Another benefit of the non-conventional internal seal is its effect on differential sticking. The seal exhibits a gradual pressure drop (Fig. 1) from the annulus to the seal interface with the reservoir fluids. This pressure absorption profile sufficiently alters the near-bore pressure drop environment, which effectively negates differential sticking. This translates into a considerable reduction in risk when employing costly downhole tools during well construction in high-annular and low reservoir-pressure applications.[8]

Indian Basin – Eddy County, New Mexico Field History

This field has been in development for more than 35 years, targeting the Cisco gas zone. The Cisco is a highly fractured Dolomite and limestone formation containing large vugs, most likely the result of karsting. As a result of the fields long producing life, bottomhole pressures are typically less than 600 psi (1.7 lb/gal EMW). The Cisco is also sour, with H_2S concentrations ranging from 6,000 to 8,000 ppm.

There are two schools of thought on how to drill through the Cisco. The first being, if you lose circulation, which is common in the field, to drill ahead and dry drill to TD. The downsides to this method are 1) with the low bottomhole pressures, it takes the wells a long time to push the water out before reaching their maximum gas production, 2) there is a real possibility of getting sour gas on the drill floor (safety issue), 3) the potential for differentially sticking increases (one episode on the New Mexico DF State #4 which cost 4½ hours of rig time) and 4) water must be trucked in, so there is an expense associated with dry drilling and trying to keep the hole clean.

The other school of thought is to drill with a system, like one employing the aphron technology, in an attempt to minimize fluid losses to the Cisco and to keep the sour gas off the floor.

Last year (2001), Texaco drilled a well to the Morrow horizon, which is below the Cisco. The New Mexico DF State #4, was dry drilled through the Cisco where the casing was set successfully. Earlier in 2002, an offset operator also drilled a Morrow well by drilling dry. The Federal 33 Com #3 (Fig. 5) was drilled with a water-based system employing aphrons (Tables 1, 2) and did not experience any significant fluid losses. The maximum static density observed while drilling through the Cisco was 8.9 lb/gal at 7,413 ft TVD. This equated to a minimum estimated overbalance of 2830 psi under static conditions. Neither the Mexico DF State #4 nor the Federal 33 Com #3 experienced any problems with sour gas on the floor. The keeping of a full hydrostatic column on the formation (as opposed to dry drilling) the penetration rates were slower (9.2 ft/hour compared with 13.9 ft/hour – 71½ hours to drill the 660 ft section compared to 47½ hours)

Conclusions

The sealing features of the aphron technology enabled a safer working environment for well construction of the Federal 33 Com #3 without experiencing any significant losses to the depleted H_2S bearing Cisco formations. This was achieved at significant overbalance (3,430 psi annular pressure versus 600 psi reservoir pressure) without observing any tendency for differential sticking.

As far as production results, these wells have not yet been completed in the Cisco as they are currently producing from the Morrow.

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Nomenclature

EMW = equivalent mud weight
ROP = drilling rate of penetration
LSRV = low shear rate viscosity
TD = total depth
TVD = true vertical depth

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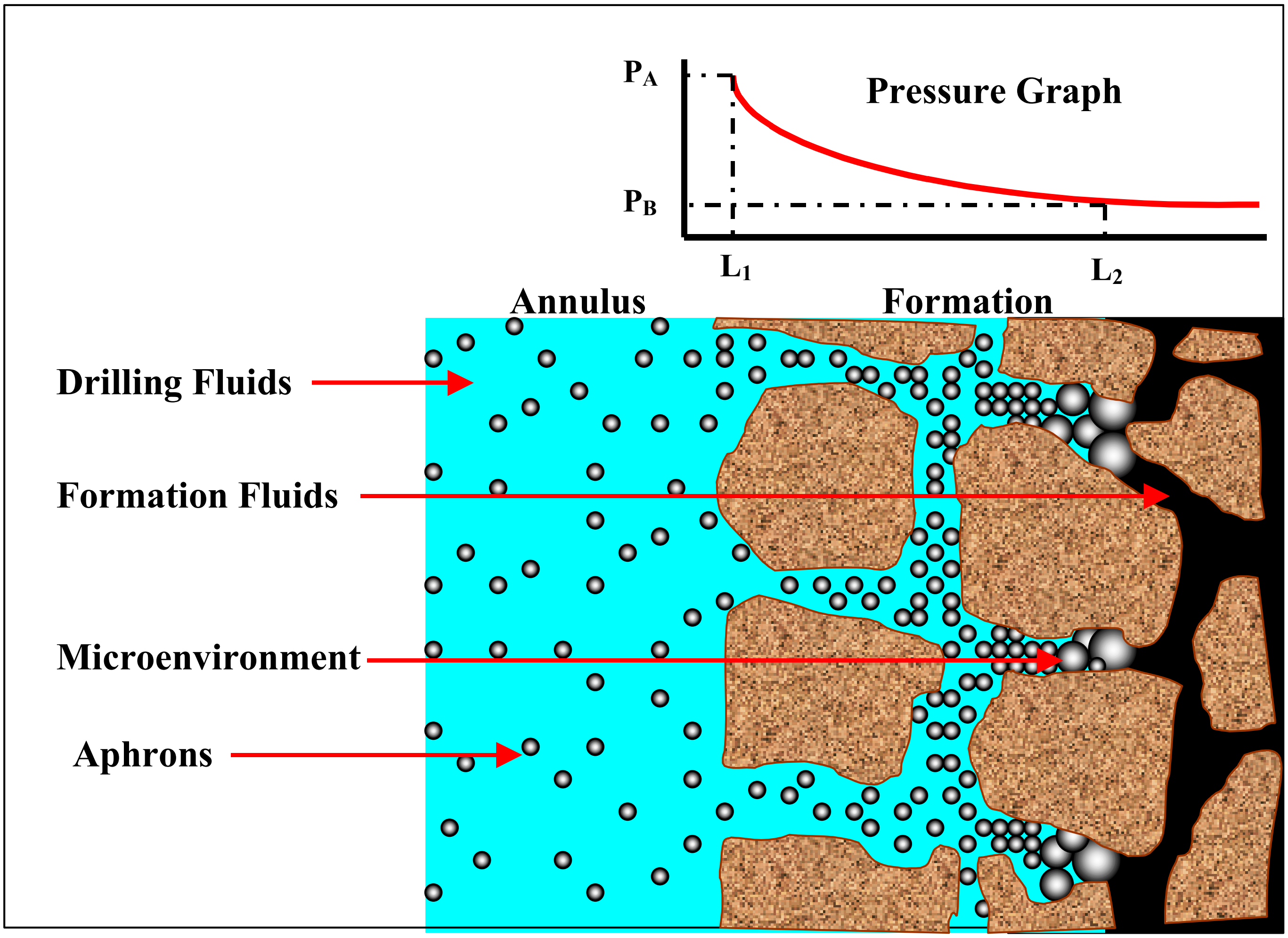


Fig. 1 Internal Seal and Pressure Graph.

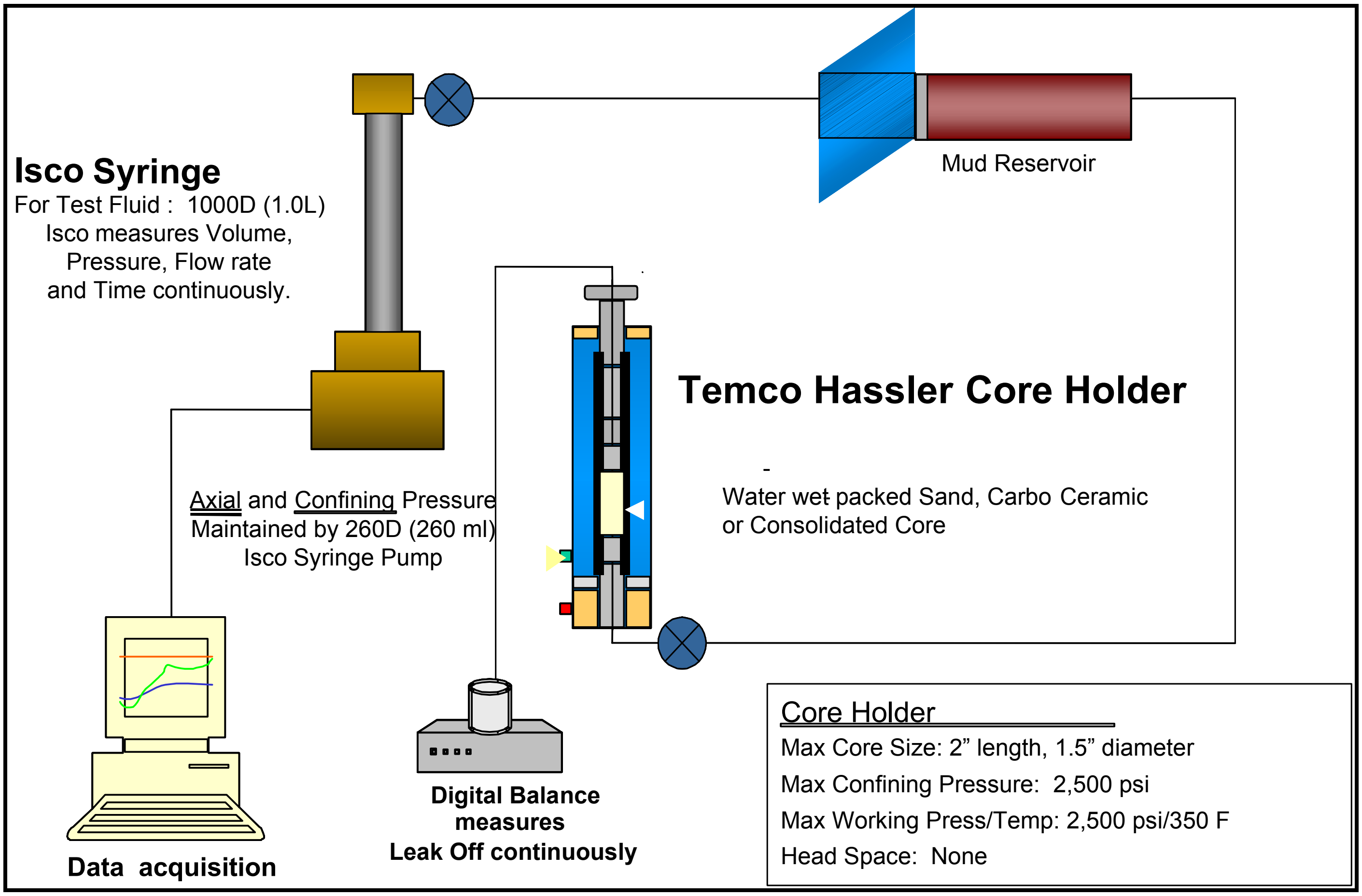


Fig. 2 Triaxial Coreholder for Sealing Tests.

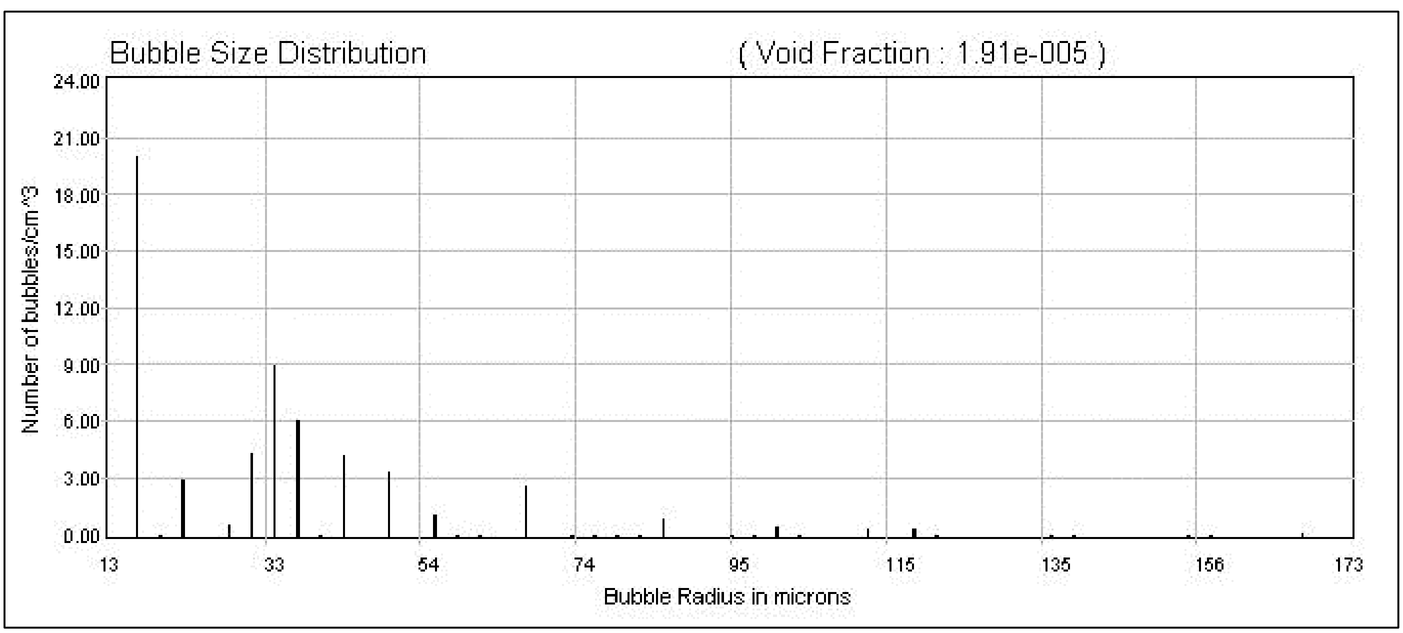
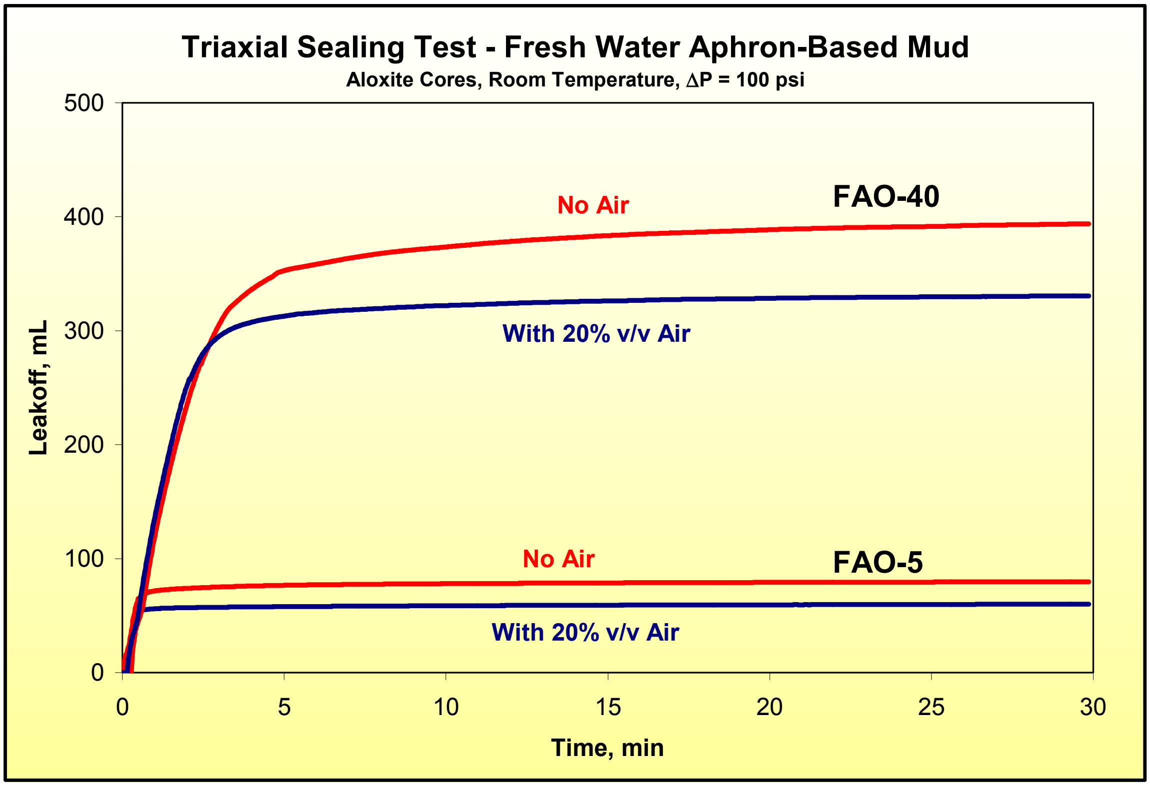
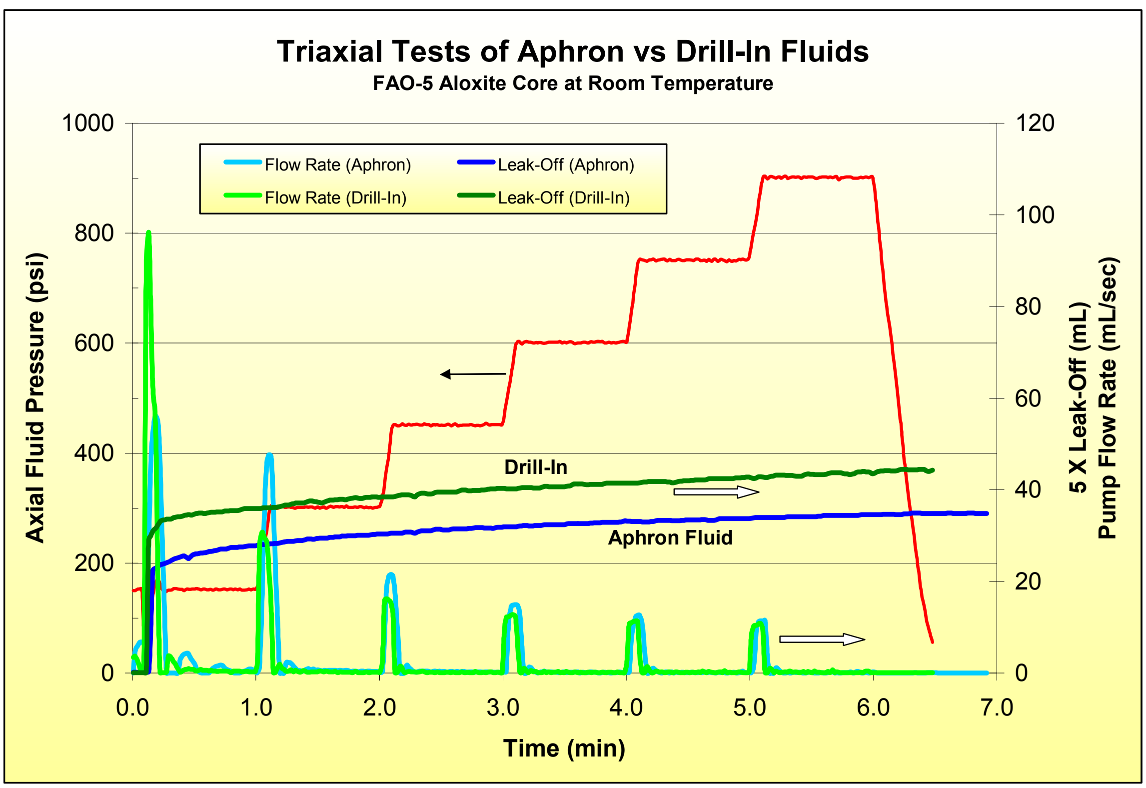


Fig. 3 Acoustic Bubble Spectrometer

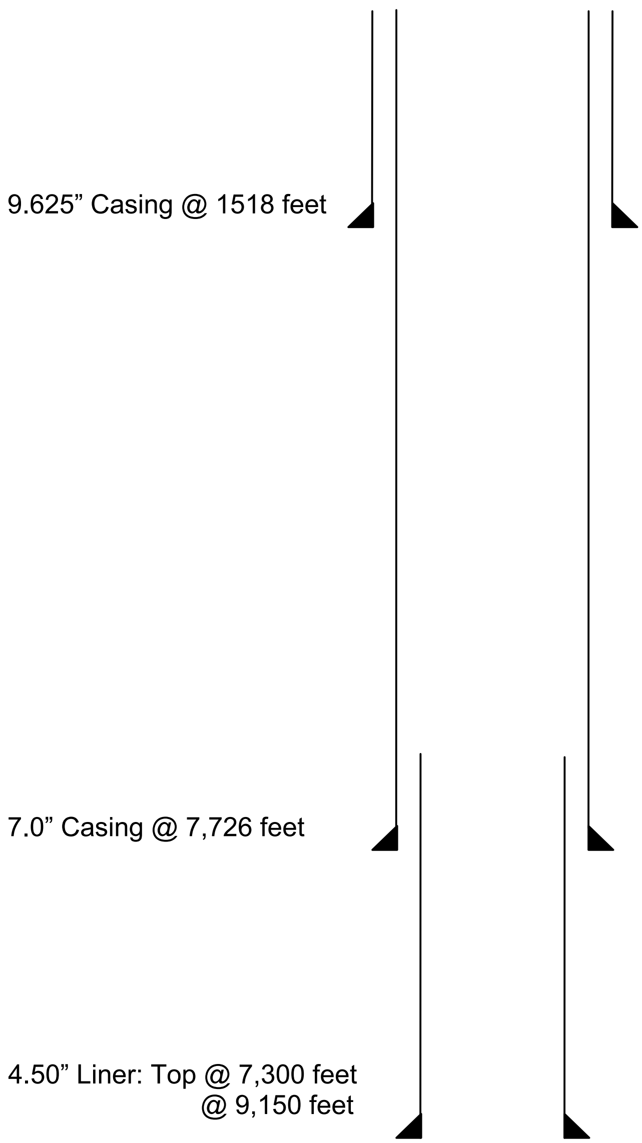


5-Darcy and 80-Darcy Aloxite core sealing with aphrons.



Aphrons-based versus typical Drill-In fluid sealing performance.

Fig. 4 Triaxial Sealing Tests.



Formation		Top (feet)
San Andres		425
Glorieta	(potential pay zone)	1,950
Yeso	(potential pay zone)	2,100
Bone Springs		3,425
Wolfcamp	(potential pay zone)	6,025
Cisco	(planned completion interval)	7,015
Canyon	(planned completion interval)	7,500
Morrow	(planned completion interval)	8,400
Morrow Clastics	(planned completion interval)	8,550
Barnett Shale		8,800
TD		9,000

Fig. 5 Well Design and Estimated Formation Tops.

Table 1 – Aphron Drilling Fluid Formulation		
Products	**lb/bbl**	**Desired Property**
Green-cide	0.5	
Soda Ash	1.5	< 100 mg/L
Soda Ash (additional addition after Total Hardness is achieved)	0.5 – 1.0	
Activator II	1.0	
Go-Devil II	3.5	
Go-Devil II (0.5 lb/bbl additions for desired Brookfield rheology)		50,000 cP
Activator I	5.0	
ActiGuard	0.25	
Blue Streak (until desired void fraction is achieved)	1.0 – 2.0	12 – 15 %

Table 2 – Aphron Drilling Fluid Properties		
Properties	**Initial**	**Final**
Density (lb/gal)	8.5	8.3
Funnel Viscosity (sec/1000 mL)	60	60
Plastic Viscosity	12	16
Yield Point (lb/100 ft^2)	44	27
6-rpm Dial Reading		21
3-rpm Dial Reading		19
10-sec gel (lb/100 ft^2)	11	13
10-min gel (lb/100 ft^2)	19	22
API Filtrate (mL)	4.0	3.6
Chlorides (ppm)	44,000	43,000
Calcium (ppm)	Trace	Trace
Brookfield LSRV 0.3 rpm (cP)	57,088	62,400
Aphrons (% void fraction)	12	11