Aphrons Technology – A Workover Solution

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Abstract

Mature reservoirs all-to-often are severely depleted. In that environment, the associated issues of effective, safe and economically viable well construction, completion and workover within that environment become more challenging on a daily basis. As these issues mount, fewer solutions are available, and those that are often bring increased costs and risks where safety is concerned. The aphrons technology offers a unique alternative option that can significantly improve the operational and economic aspects for continued development of these marginal assets.

Years of experience in diversified applications around the globe have proven the aphrons technology to be a viable solution within these difficult parameters. Field experience has shown that annular pressures exceeding depleted reservoir pressures by "several thousand" psi have not hindered the creation of the micro-environment seal and mitigating invasion. Because the seal is internal to the reservoir, conditions for differential sticking do not exist. No other fluids technology in the industry enables these types of operations. Nothing more than conventional fluid mixing equipment is required to employ the technology, thus making it highly compatible with standard wellsite operations.

Aphrons (micro-bubbles) are incorporated into drilling fluids to mitigate losses in depleted / high-permeability zones. These micro-bubbles differ significantly from aerated fluids and foams. They do not coalesce and upon entering a lower-pressure region within the depleted reservoir, while remaining discrete, will agglomerate creating a strong internal seal. Because affecting this seal requires a higher annular pressure than that of the reservoir it readily cleans up with reservoir flow back as production is initiated. Since the seal is minimally invasive it is easily perforated past thus allowing production to the wellbore from non-fluids damaged rock.

The authors will provide a brief overview of the design of aphron-based fluids, discuss how the features of the technology serve to provide operational leverage to workover operations of depleted assets and provide representative case histories.

Introduction

The conventionl industry approach to developing reserves is typically based upon technologies that are designed to function optimally in normal or over pressured environments. This is true not only for the mechanical tools being used but also with the fluid technologies within which these tools are to perform. This approach will suffice provided depletion is minimal and insufficient to compromise efficiencies of one or all of the technologies being employed. These mature environments are a result of the dynamics of change, have proven to be extremely challenging for traditional technologies and require new unconventional solutions to properly manage their continued reserves development.

One considered solution has been the use of underbalanced drilling (UBD) techniques. While the technology is appealing in theory it has proven tenuous at best to implement as a broad industry solution[1]. The associated costs with planning, equipment, and services are high. Well control issues cause safety concerns. The desire to reverse the underbalance reservoir to overbalance annulus pressured aspect to an overbalance reservoir to underbalance annulus pressured environment simply by injecting a gas is not always obtainable or easily sustainable throughout the well construction or workover project. With all of this in mind there is no guarantee that UBD will provide the desired solution.

Conventional industry fluid solutions require the creation of a seal between the two pressure regimes by depositing solid materials with the intent of forming a filtercake. This process was designed decades ago for fluid applications where borehole pressures did not greatly exceed formation pressures and the risks associated with temporary removal of the filtercake by mechanical or hydraulic erosion were not too severe. Just as fields have matured their mechanics have changed. Along with the severe draw down in formation pressures technologies for continued development of these reserves have not kept pace to a comparable degree. The industry seems to keep reworking the same old technologies with very limited step improvements being achieved.

The aphron technology offer a new lease on life for these mature assets. This fluid development serves as a pressure diverter allowing for the use of normally weighted fluids in severely depleted environments. In so doing, it minimizes damage commonly associated with conventional fluid approaches by controlling invasion of whole fluids, solids and filtrate. Due to the pressure diverting characteristics of the fluid, differential sticking is mitigated. This allows the fluid to serve as a "technologies bridge" enabling extended application of conventional downhole tools while significantly reducing the risks normally associated with their application in convention fluids under similar circumstances in comparable environments. The net result is this technology allows for improved economic management of these mature assets.

Description and Function of Aphron Fluids

Aphrons[2] (micro-bubbles) are incorporated into a specifically engineered base fluid[3] to aid in mitigating losses in depleted / highly permeable zones. These micro-bubbles differ significantly from aerated fluids and foams. Aphrons 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]. Affecting this seal requires a higher annular pressure than that of the reservoir. The seal readily cleans up with reservoir flow-back as production is initiated, particularly when employed in the "at balance" fashion as described by Brookey[1,3].

Synergies between the various features of the technology serve to minimize fluid invasion. The easily engineered high-LSRV properties of the base fluid are achieved with high-yield-stress-shear-thinning (HYSST) polymers. This promotes design capabilities that are well suited for optimizing diversion of annular pressures away from the depleted formations, thus minimizing whole fluid invasion. The surfactant package and the associated "meniscus-wrapping theory"[2,4] provide additional invasion control. The "energized-environment"[4,5] associated with aphrons employed to form the internal "micro-environment" solids-free seal and the resultant localized increase in LSRV also contribute to mitigating invasion. All of which can be observed with the Capillary Suction Test (CST) method for studying imbibation[1]

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 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 with array induction logs (beyond the investigative capabilities of the tool). The reactive radial interface from a borehole exhibiting an invasion profile of 90 in. and deeper is quite considerable. Depending upon the characteristics of the formation, the invading filtrate may not have much direct detrimental effect on the reservoir. However, the invading filtrate , may have a considerable effect on bordering reactive shales, thereby enhancing the propensity for the problems associated with shale breakout. Owing to excessive filter cake build-up in such environments, it is quite common to observe caliper logs exhibiting both severe breakout along these sand/shale interfaces and under-gauge sands. This is 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 down hole tools during well construction in high-annular and low reservoir-pressure applications[6].

Mexico Mature Field Workover Application

Rea et al[7] described the application of the aphron fluid for workover operations in three wells in the Poza Rica field of eastern Mexico. Three wells in the Tajin area were remediated and re-completed with mechanical pumps. Because of their tight features, these wells were fractured during their initial completion to optimize production. This fractured area causes frequent lost circulation to the depleted sands, constant gas influxes, and high potential for taking kicks.

The procedure for working over each of these wells consisted of displacing the aphron fluid at the top of cement plugs which covered the perforations across the depleted sands. After the displacement, the cement plug was drilled providing communication with a lower-pressure set of perforations. In one well, two cement plugs were drilled, providing even more communication with perforations across a low-pressure zone. In all cases the re-completion was accomplished with no losses and no operational problems despite the high pressure differential of the fluid and the fractured nature of the reservoir. Tables 1a, b, c show the schematics of the well re-completions.

The aphron technology proved to be an economically viable solution resulting in a 45% reduction in cumulative fluid costs and a 43% savings in costs associated with time reduction (Graphs 1, 2). Cumulatively, this translates into an average cost reduction of 44 % per workover. (Graph 3).

New Mexico Low Pressure H_2S Gas Carbonate Application

Kinchen et al[8] describes the application of the aphron system in a low-pressure carbonate reservoir in the Indian Basin field of New Mexico. This experience involves drilling through the Upper Pennsylvanian section in the Cisco dolomite. The Cisco dolomite is highly vugular, with fracture permeability. Figure 2 shows a formation imagery log with large openings with of more than three feet across. Figure 3 shows core samples of the Cisco. The large openings in combination with low formation pressures (1.1 to 2.8 lb/gal) present a difficult drilling challenge where lost circulation and resulting formation damage is severe.

Table 2 shows the various techniques employed to drill the 16 wells covered in this paper. The cleanup and time to production of the aphron drilled wells was much faster than those drilled with conventional fluid technologies. All of the aphron wells reached peak production in a few days while two actually reached peak in four days. This was in contrast to the other wells which typically took at least two months to reach their peak, while some produced on an incline for several months. This resulted in an enormous reduction in completion costs, and expedited return-in-investment (ROI).

Other significant factors were the successful cementing results. Even with two-stage cementing, the conventionally drilled wells experienced significant lost circulation during pumping and required extensive remediation. The aphron drilled wells had full returns throughout cementing with greatly improved coverage across the zone permitting selective perforation during completion. Owing to the control of lost circulation and support of the fluid column, intrusion of dangerous H_2S was prevented. A corrosion monitoring program showed very low corrosion rates even in the severe environment. The aphron system has certain scavenging and buffering characteristics that minimize corrosion even in the presence of acid gases.

Results and Conclusions

As illustrated in the case histories, the fluid can be used for drilling and workover low-pressure reservoirs. These operations may take place where normally pressured zones co-exist with low pressure zones in the same interval. In most cases, problems were reduced or eliminated, days on well were reduced, completions and time to production were minimized and in some instances, casing strings have been eliminated.

In many cases, the aphron fluids made coring possible. Hole conditions are excellent for obtaining good quality wireline logs. MWD and LWD perform very well in the system. Borehole stability was excellent, even in areas where highly reactive clays and shales were drilled. In most cases, losses were prevented or minimized even when borehole pressure differential exceeded formation pore pressure by several thousand psi.

Cementing results were excellent, demonstrating full returns during cementing, putting a reliable cement column across the depleted zones. Cement bonds results were very good with no instance of cementing failure even in the vugular, highly fractured reservoirs.

Completions were simplified with rapid cleanup. In some cases, peak production was accomplished in a few days in areas where wells historically were slow to clean up when drilled conventionally.

References:

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Fig.1 Internal Seal and Pressure Graph

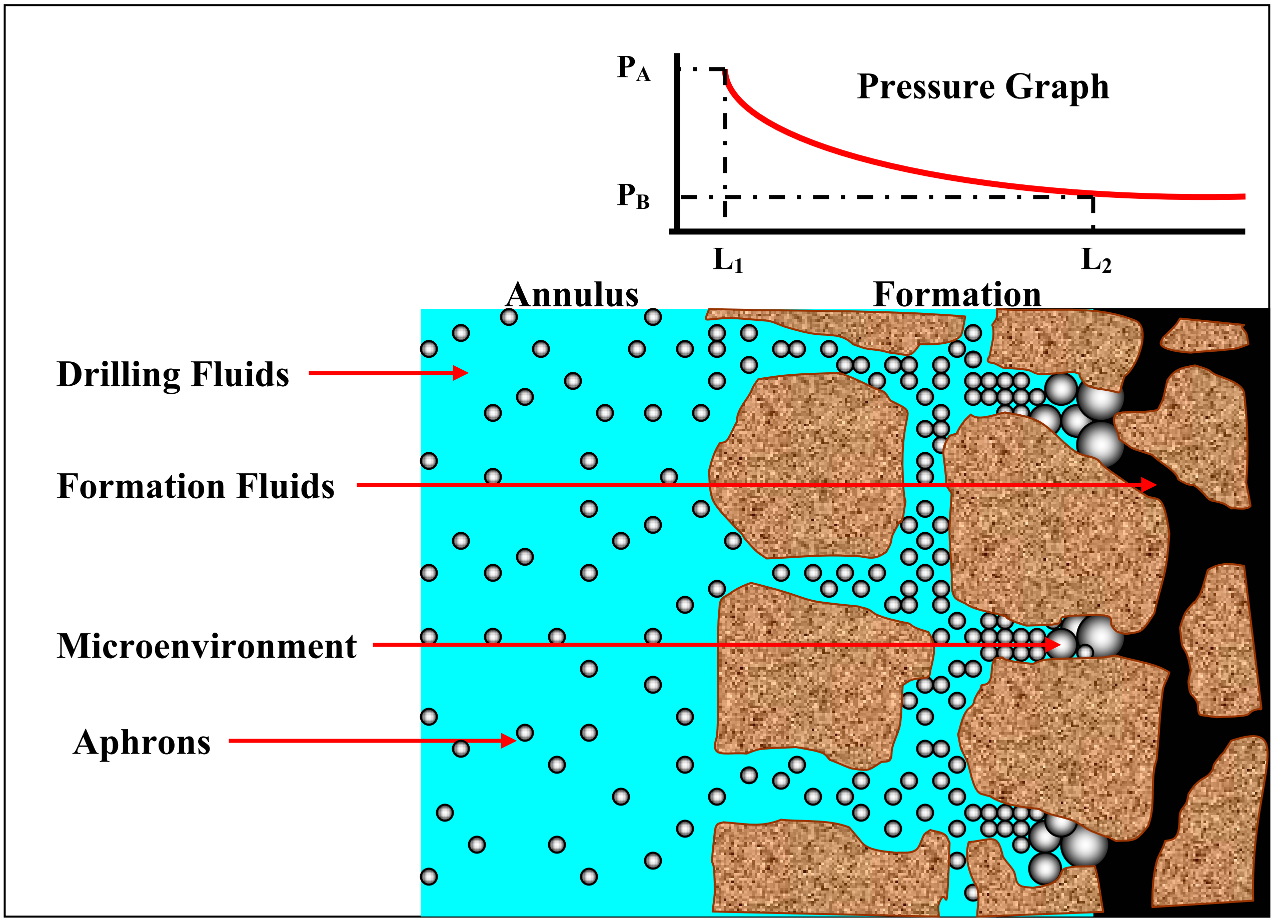


Fig. 2 Formation Imagery log

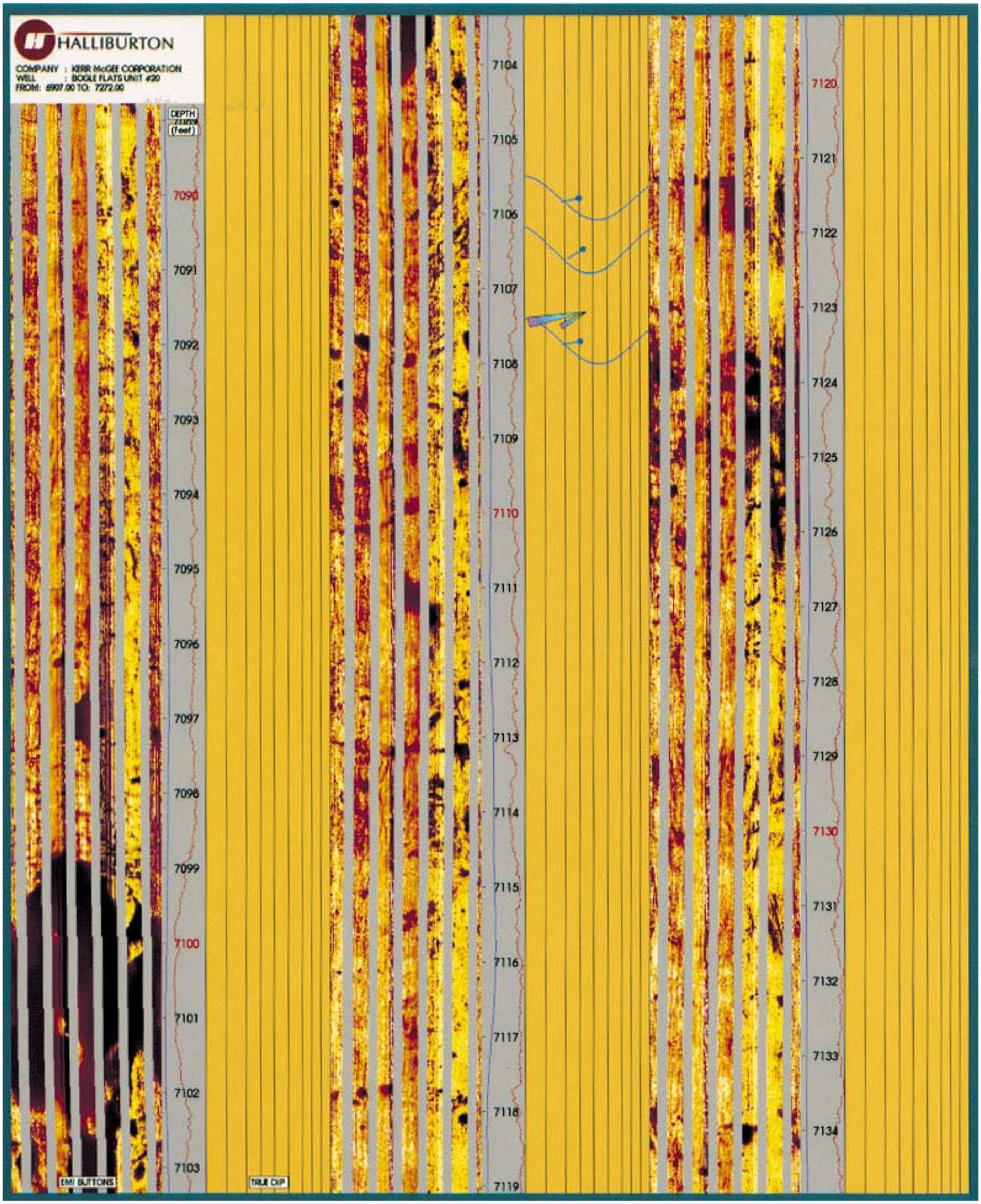


Fig. 3 Core Samples

Table 1a – Tajin re-completions

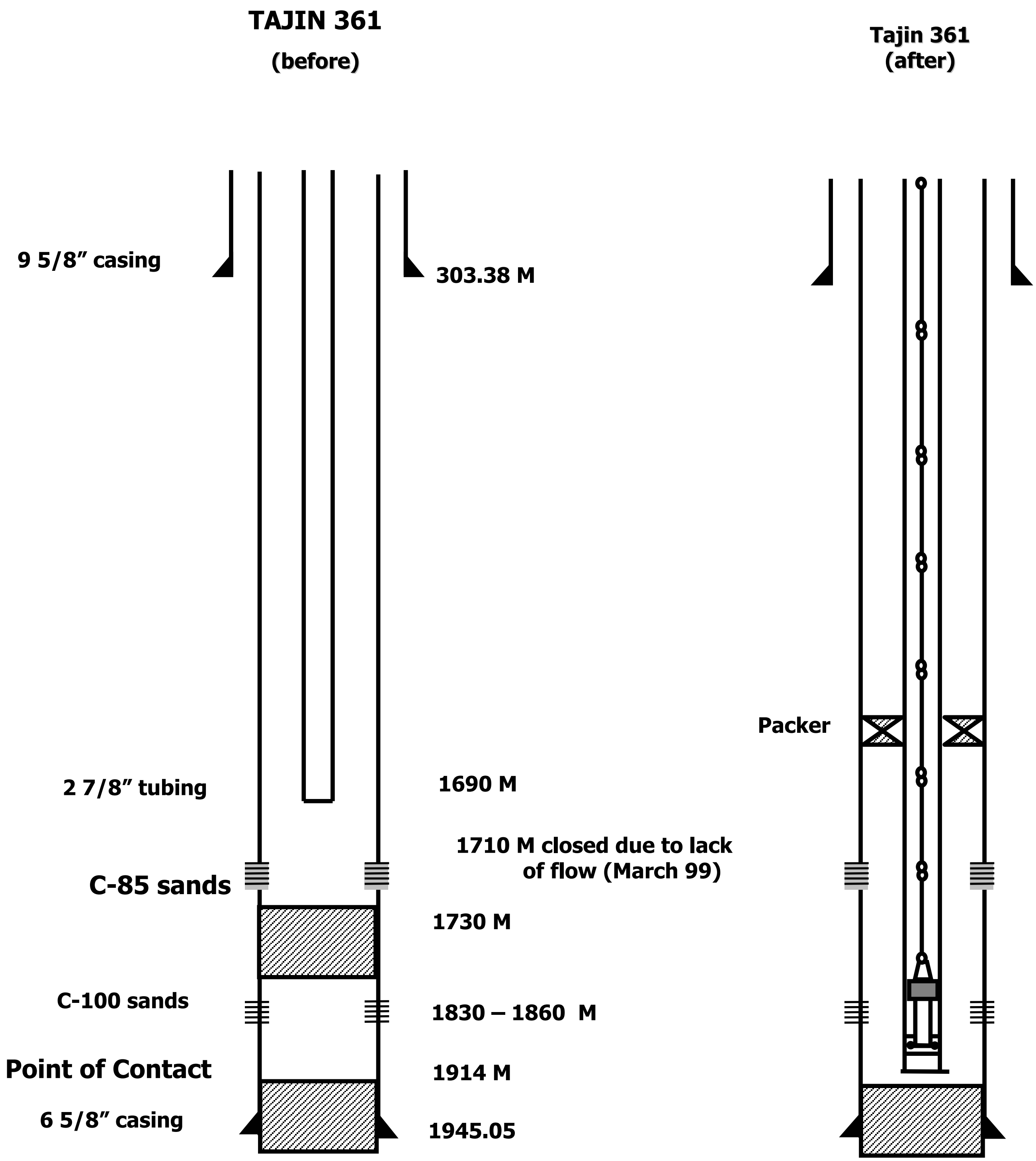


Table 1b – Tajin re-completions

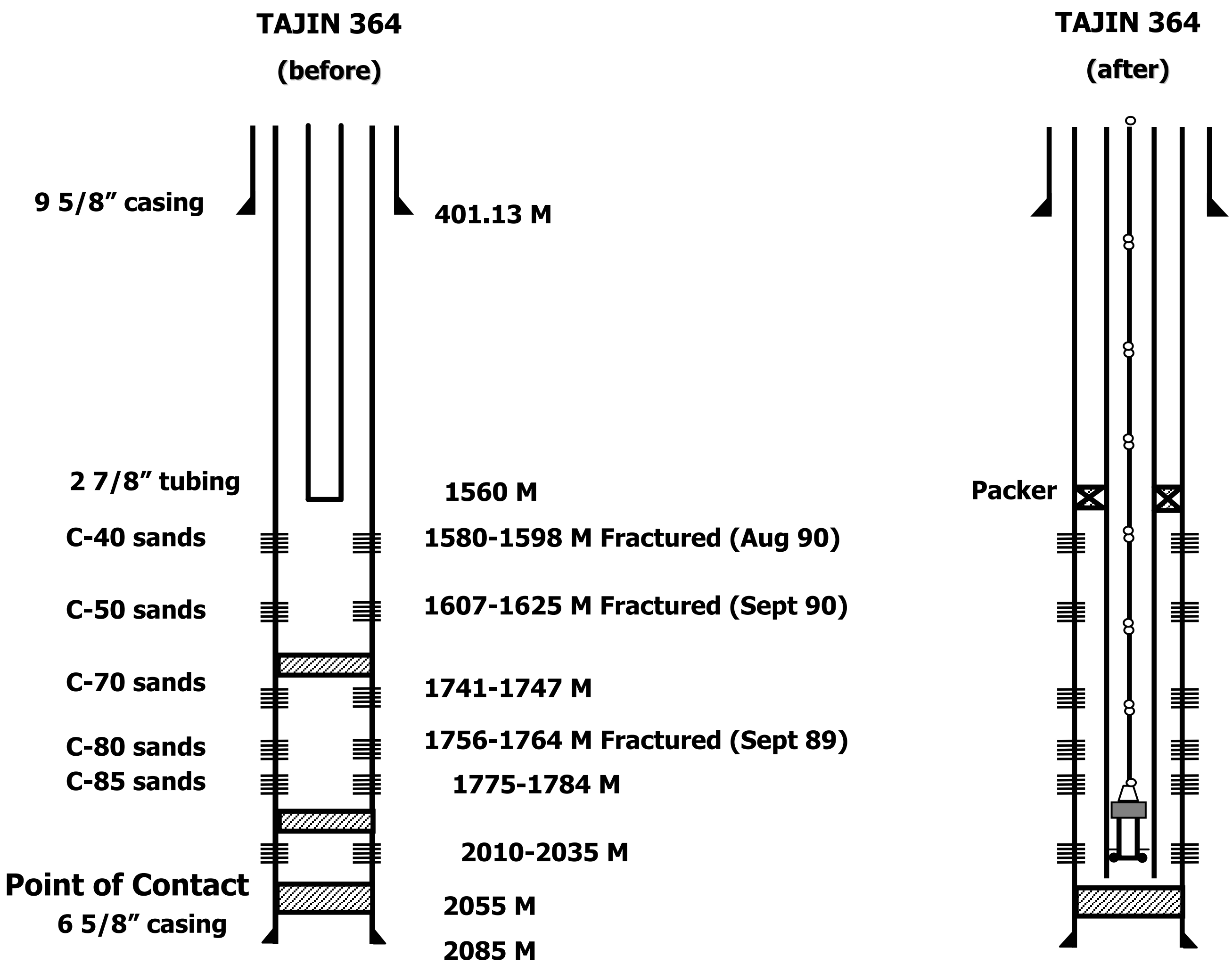


Table 1c – Tajin re-completions

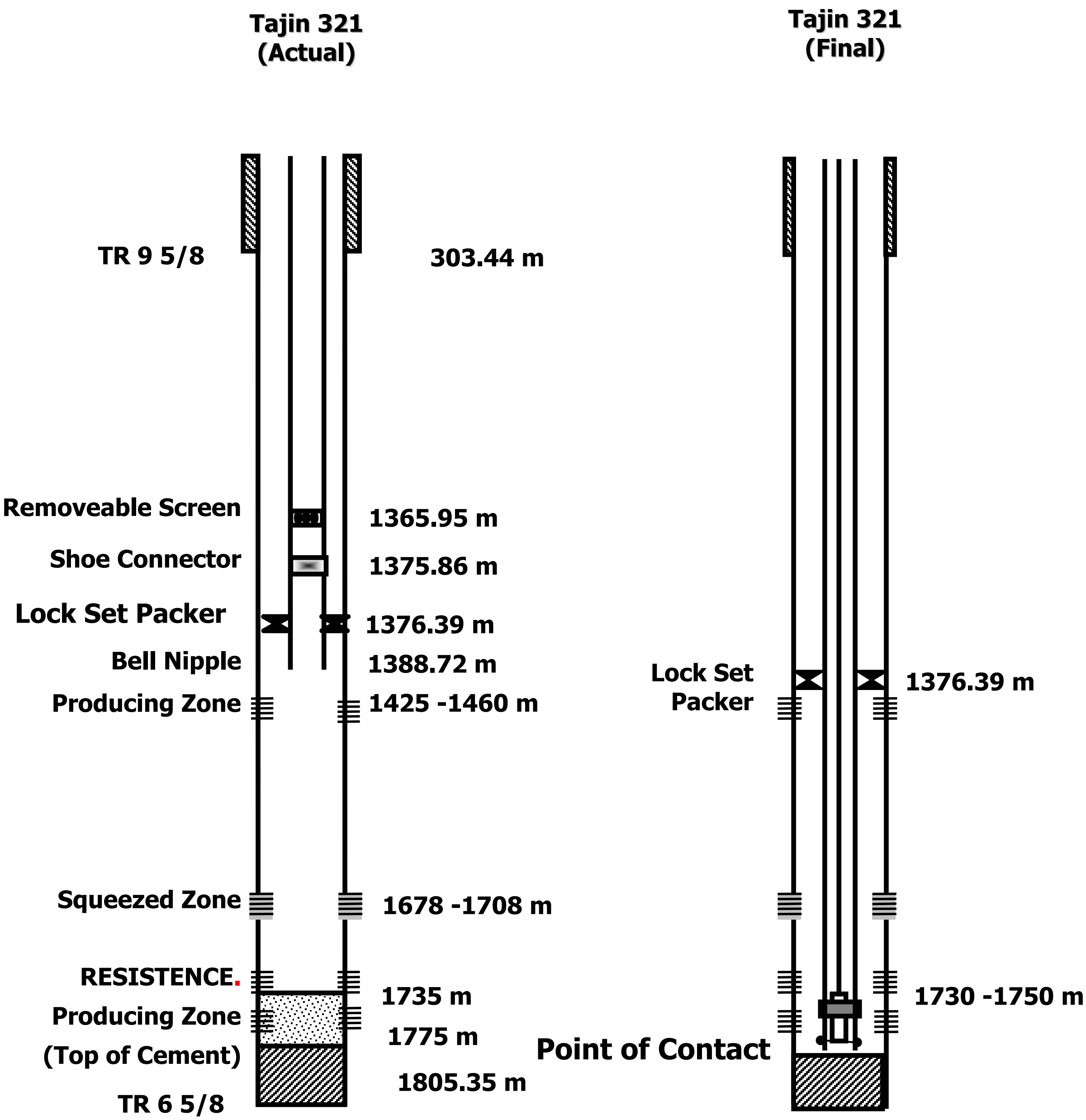


Table 2 – Indian Basin, New Mexico field experience

Water Based Mud with Lost Circulation Material

	Stimulation			Production Rate			Production
well	date	size, gals	type	gas, mmcfpd	oil , bopd	water, bwpd	method
Conoco St. #2	06/21/95	1680	15% neat	1430	0	0	flowing
	06/27/95	4300	15% foam	3418	8	9	flowing
	02/20/96	10000	15%foam	6775	14	5	flowing
Bogle Flats #11	07/17/95	7000	15%	4300	9	205	flowing
Bright Fed #2	07/30/95	20000	foam 15%	210	0	200	flowing
	03/08/96	20000	foam 15%	trace	0	200	swab
	05/04/98	33250	15%	170	0	234	sub
	07/14/00	90000	30Q foam	433	0	338	sub

Mist/Air Drill Open Hole Wells

	Stimulation			Production Rate			Production
well	date	size, gals	type	gas, mmcfpd	oil , bopd	water, bwpd	method
Bogle Flats #13	03/21/96	5000	15% foam	2677	3	8	flowing
	05/11/96	10000	15% foam	5034	13	2	flowing
Bogle Flats #14	04/26/96	9000	15% foam	1597	0	30	flowing
Bright Fed # 3	05/14/96	none	15% neat	0	0	0	swab
	06/20/96	10000	15% foam	648	0	260	pump
	10/20/99	20000	15% foam	305	0	211	sub
	11/24/99	107500	15% foam	0	0	0	collapsed hole

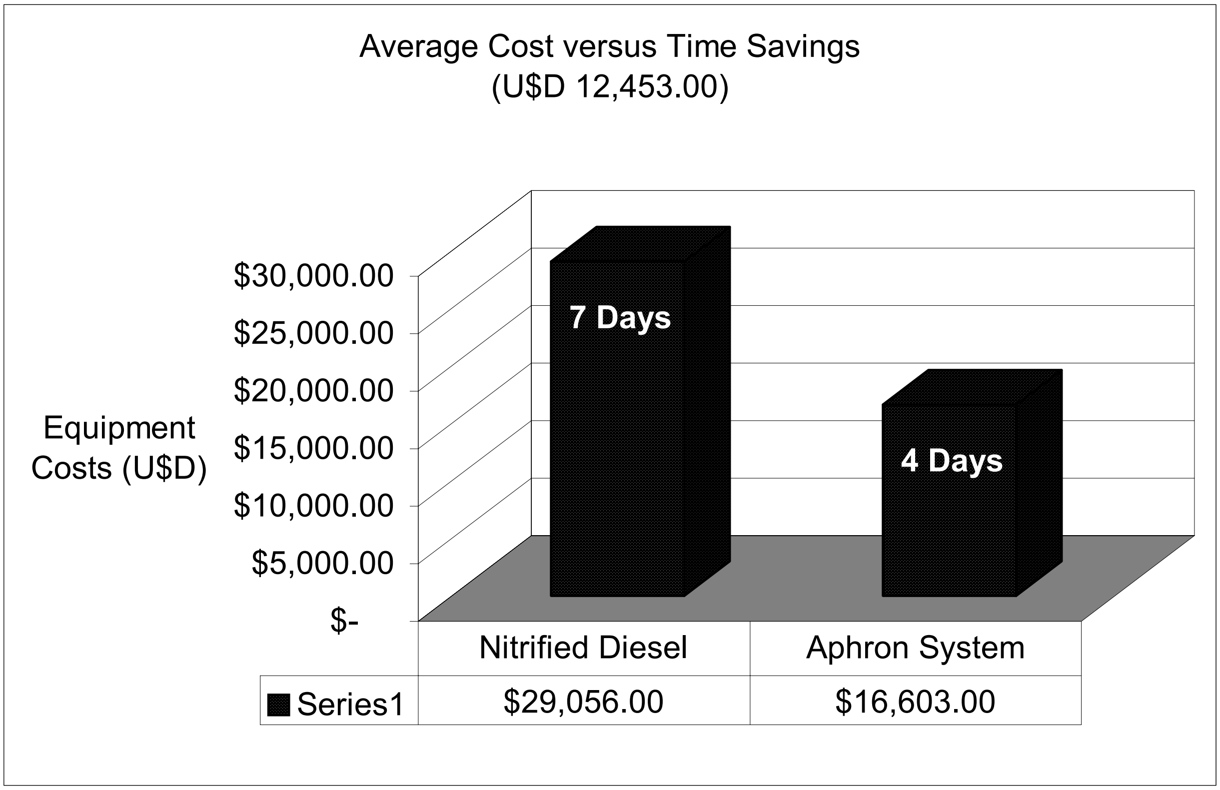
Dry Drill wells with LCM

	Stimulation			Production Rate			Production
well	date	size, gals	type	gas, mmcfpd	oil , bopd	water, bwpd	method
Bogle Flats #20	05/19/99	0	none	0	0	40	swab
	05/26/99	10000	15% foam	120	0	0	flowing
	06/04/99	20000	15% foam	1200	0	2169	sub
WIBU #1Y	03/28/00	62500	15% foam	2700	0	3207	sub

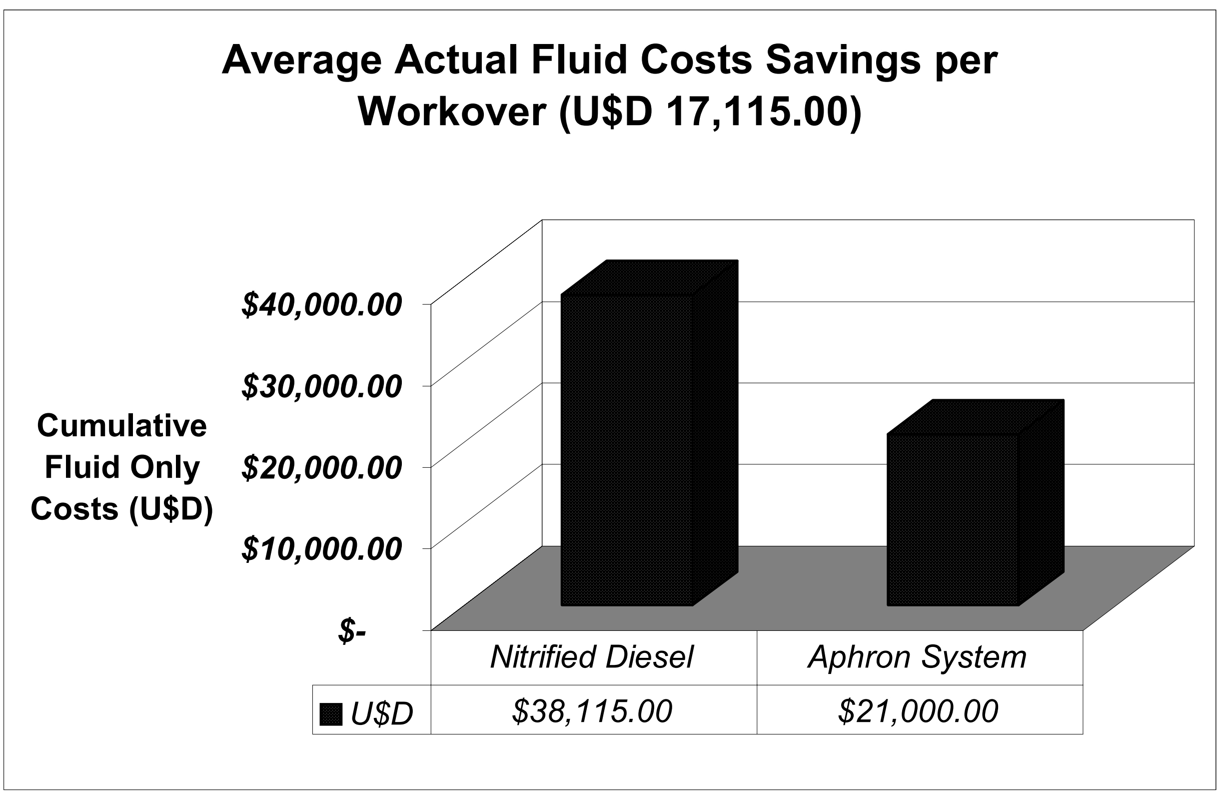
Aphron Drilling Fluid Wells

	Stimulation			Production Rate			Production
well	date	size, gals	type	gas, mmcfpd	oil , bopd	water, bwpd	method
Lowe State #4	07/11/99	35000	15% neat	702	0	831	sub
	08/25/99	30000	20% foam	1174	8	2386	sub
Lowe State # 5	07/29/00	40000	15% neat	4215	5	2417	sub
Conoco State #6	04/11/00	0	none	4014	0	1551	sub
Bogle Flats #21	06/04/00	40000	15% foam	250	0	553	sub
Conoco State #7	07/23/00	60000	15% foam	893	0	2315	sub
WIBU #5	09/14/00	10200	15% PPI	533	0	388	sub
Federal 28 #2	Waiting for facilities and pipeline construction.						

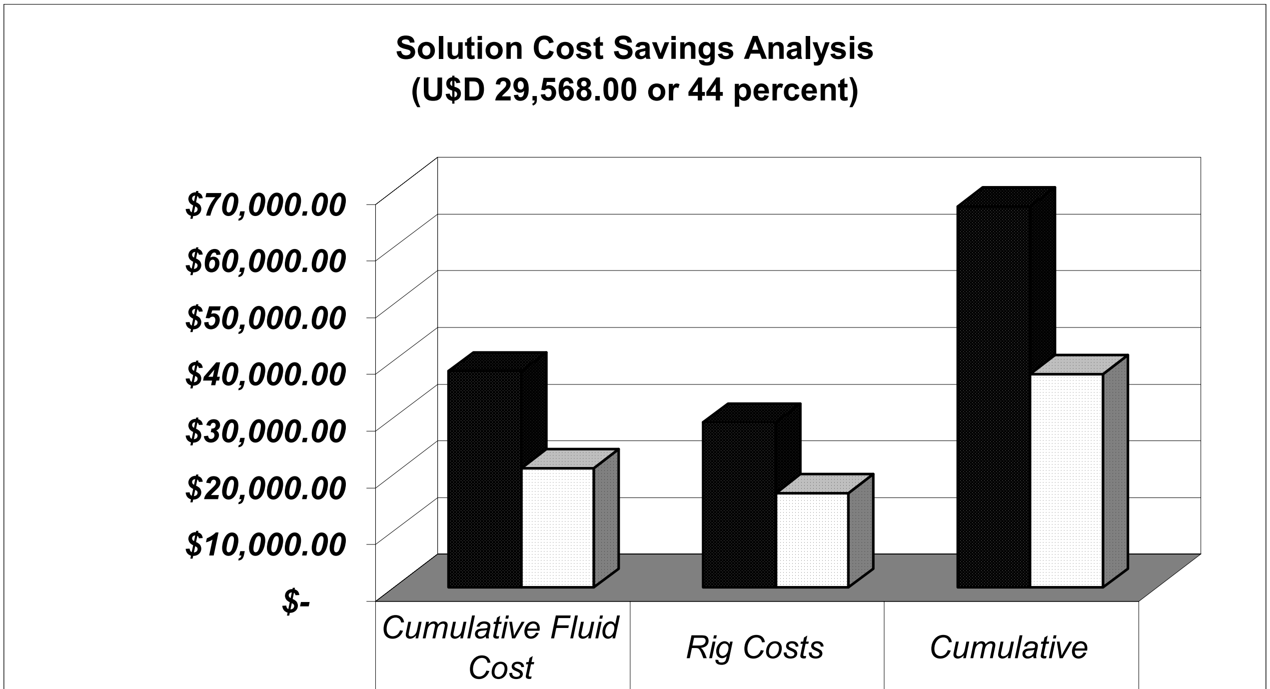
Graph 1 – Cost versus Time



Graph 2 – Comparative Fluids Costs



Graph 3 – Cost Analysis



	Cumulative Fluid Cost	Rig Costs	Cumulative
■ Low Density Fluid	$38,115.00	$29,056.00	$67,171.00
□ Aphron Fluid	$21,000.00	$16,603.00	$37,603.00