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The Application of High Temperature Polymer Drilling Fluid on Smackover Operations in Mississippi

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Abstract

A high temperature polymer drilling fluid (HTPDF) that was used for a blowout operation has been used successfully to drill subsequent wells, in Mississippi. The blowout operation required a shear thinning, polymer fluid to kill the high temperature high pressure (HTHP) well blowout. During the operation fluid densities of 16.5 and 22.0 lb/gal were circulated to kill the well, with lower pump pressures than hydraulics models had predicted. The fluid was stable at a temperature of approximately 300°F for 30 days, while a drilling rig was procured. Even after this extended period of time, circulation was established without difficulty. After operations were resumed, the hole was side tracked and drilled to total depth without incident. Due to the favorable results obtained, another well with similar requirements was drilled using the HTPDF system. This well was drilled successfully, again with stable fluid properties and with minimal treatment. After the continued successes, the fluid was considered and used on additional drilling operations. The HTHP Polymer fluid was selected because of past performance, fluid availability, and environmental concerns.

The overall concerns of these projects were weight suspension, gelation, lubricity, and contamination of the drilling fluid by anhydrite ($CaSO_4$), carbon dioxide (CO_2), and hydrogen sulfide (H_2S). Additionally, resulting pump pressure and pressure losses had to be maintained in acceptable ranges for a successful campaign. The high temperature polymer fluid successfully met the requirements and on some occasions, surpassed expectations.

Introduction

High temperature polymer drilling fluids have been used world wide to drill wells with extreme temperature, often together with elevated pressure conditions. Polymers designed to withstand high temperature can provide viscosity and good filter cake quality without the temperature gellation and loss of filtration control that can often occur with water-based muds. Because high performance polymers are used in this fluid design, it has a comparatively high cost per barrel, when compared to conventional water-based muds. This higher cost per barrel has resulted in the overlooking of the advantages with this drilling fluid design. The inherent fluid stability results in decreased daily maintenance costs, less potential for problems resulting from swab and surge pressures. It also allows equivalent circulating density (ECD) to be more predictable and manageable. This was especially evident during a blow-out kill operation in Mississippi in 2001. The high degree of stability the HTPDF exhibited during the kill operation made it evident that this design would make a cost effective drilling and/or work-over fluid.

Blowout Operation

The blowout and subsequent fire at the Beard 29-7 No. 1 occurred while a production liner was being run after the well had reached a total depth of 18,500 feet with a 6 ¼" bit.[1]

After securing the well, a snubbing unit was rigged up on the location. The well was killed with the bottom of the tubing assembly at the 7 5/8 inch casing shoe at 17,044 feet, approximately 1,450 feet off of the bottom of the hole. Approximately 1,700 bbls of 16.6 lb/gal and 75 bbls of 22.0 lb/gal HTHP Polymer mud were used for the well killing operation. The initial plan to run to bottom after killing the well and to circulate the hole was changed due to problems. After running a couple of joints of tubing, an obstruction was tagged and operations were suspended until a suitable rig could be obtained.

This resulted in thirty days elapsing between killing the well and the next attempt to break circulation. There were concerns about the settling of weight material and/or mud gellation because of the extended down time. However, circulation was broken without difficulty and no settling of weight material was observed.

Extremely high temperatures were not encountered on this operation. However, the high density water-based mud system used for the blow out kill accomplishment demonstrated outstanding fluid stability at 325°F. Based on the observations during the blow out kill procedures, this fluid design was chosen for use on future drilling and work-over operations.

HTHP Polymer Drilling Fluid Formulation

The polymer system components used for these operations are environmentally acceptable and have been employed in environmentally sensitive areas. This long term experience with the system has resulted in formulations that have accommodated most fluid requirements, even under the most hostile environments. [2-6]

Because the maximum temperature to be encountered was below 325°F, a complex polysaccharide (BPac) could be used in conjunction with Wyoming bentonite for viscosity and filtration control. This combination provided improved shear thinning characteristics. The bentonite was stabilized for elevated temperatures by low molecular weight copolymer deflocculant (SSMA)[7] and a synthetic inter-polymer deflocculant (AT). These deflocculants stabilize the system because they provide resistance to contamination, even at temperatures in excess of 500ºF. A low molecular weight 2-acrylamido-2-methyl-propane sulfonic acid/acrylamide copolymer (AMPS/AM)[8] was also utilized. This co-polymer is suitable for high density formulations and provides HTHP filtration control. This low molecular weight polymer also provides shale stability and lubricity. A second high temperature copolymer, AMPS/sodium alkyl-acrylamide (AMPS/AAM)[9] was used because it provides stability at any hardness level or elevated pH. This AMPS/AAM copolymer is used for HTHP filtration control and for viscosity in fresh water systems. Both of these AMPS copolymers have thermal stability in excess of 600ºF. A modified lignite polymer (CTX) was used for HTHP filtration control. This polymer also imparts a thinning effect on fluid viscosity.

Because all of these operations anticipated hydrogen sulfide (H_2S) and carbon dioxide (CO_2) gases, the pH of the fluid was maintained at 10.0 to 11.5 to buffer and reduce the adverse effects of these acid gases. The systems were pre-treated with basic zinc carbonate as a hydrogen sulfide scavenger. [10] This pretreatment helped to ensure a safe work environment and to minimize equipment exposure to H_2S. This pH range also controlled the hardness at a reasonable level, when anhydrite was drilled. This resulted in a very stable system when influxes of carbon dioxide were encountered.

The drilling fluid was also used to drill the production zone. Therefore, applicable drill-in fluid technology was employed. The original system was formulated with 20 lb/bbl sized calcium carbonate to improve pore throat bridging and filter cake quality. Lab test indicated that this design would minimize fluid invasion into the producing formation.[11] The HTHP Polymer system formulated with the BPac and sized calcium carbonate provided an appropriate drilling fluid for the desired cost. As a result, this improved bridging and cake quality, at high mud densities, reduced the risk of differential sticking.[11-13]

Drilling Operation

Planned Fluid Operation

After observing the performance benefits with the kill fluid used on the blowout operation, a similar polymer fluid designed for thermal stability was considered for HTHP drilling applications. The first Bean Resources, Incorporated well after the blowout operation to use the HTHP polymer fluid was, Joshua Timber Company 35-9 No.1, drilled in Section 36-T8N-R8W, of Wayne County, Mississippi. The HTHP polymer fluid met expectations. Therefore, it was employed on the next HTHP, Bean Resources, Incorporated well; G.N. Jones 32-10 No.1, Section 32-T8N-R7W, of Wayne County, Mississippi. These projects had similar requirements as the Bean Resources well, Beard 29-7 No.1. The production intervals were in limestone, so a fresh water, polymer fluid was applicable.

In addition to high temperature, contamination from anhydrite, salt, carbonates and hydrogen sulfide was anticipated. Lost circulation and differential sticking was also a concern due to high circulating and differential pressures. Therefore, a thermally stable contamination resistant fluid was required for these projects.

Because this drilling fluid was to be used to drill the potential production interval, supplementary recommendations were made to minimize formation damage. The minimization of formation damage with the use of sized calcium carbonate for bridging was proposed. Testing indicated that the minimization of the depth of fluid invasion into the reservoir would be beneficial to increase production. The HTHP return permeability testing and field success in other areas of the world was referenced as an example of the importance of proper bridging. Return permeability was improved from 25% to 95% with the use of appropriately sized calcium carbonate.

A maximum mud density of 16.0 to 18.5 lb/gal was anticipated. For mud weights in excess of 16.5 lb/gal the use of hematite would be considered. Employing an HTHP Polymer system in conjunction with a blend of hematite and barite as the weighting agents would provide a more acid-soluble fluid than a conventional, lignosulfonate drilling fluid. The use of a chelating agent was recommended when acidizing to avoid undesirable iron compounds from forming. Also, by using hematite, the rheological properties would be reduced compared to the higher density fluid weighted only with barite. Because mud density did not reach the 18.0+ lb/gal range, no hematite was used in the drilling applications.

The use of AMPS/AM and CTX was recommended in the formulation for improved filtration control and improved cake quality. Since the HTHP filtration was not of primary concern on the Beard well, these products were not used on that project and would be an addition to the earlier formulations.

The drilling fluid system used to drill to the top of the production interval would have drilled considerable footage in the previous interval and have a density of less than 11.0 lb/gal. Therefore, a new HTHP Polymer fluid was blended to avoid costly reconditioning while building the high density, high temperature reservoir drilling fluid. Acid-soluble lost circulation material was recommended to avoid formation damage, in the event lost circulation occurred.

Application of Fluid Plan

The Bean Resources, Incorporated well, Joshua Timber Company 35-9 No.1, Section 36-T8N-R8W, was drilled using a gel water spud mud for the surface hole. Water with gel sweeps were used to drill the majority of the intermediate hole. The lower portion of the intermediate hole was drilled with a lignosulfonate water-based drilling fluid from 12,000 feet to 18,230 feet, as programmed. At this depth, prior to the high pressure transition zone, a 7 5/8 inch liner was run and cemented. The mud system used was inexpensive and mud weights required to this point were minimal. At this point the system had been used to drill a considerable amount of hole. Based on experience, it was more economical to displace to a fresh HTHP Polymer system rather than to convert the existing system to a high density system. The HTHP Polymer system was mixed at the mixing plant in Laurel, Mississippi to reduce rig time. The HTHP Polymer fluid was shipped to location and stored in frac tanks until the operation was ready to proceed with the displacement and drilling. The transportation and storage of the 2,000 bbls of the HTHP Polymer fluid was successfully conducted without difficulty.

After drilling out the casing shoe and performing a formation integrity test, the lignosulfonate drilling fluid was displaced with the HTHP Polymer fluid. No problems were encountered with the displacement. The HPHT filtration rate was reduced from 24 to less then 15 cc./ 30 min. @ 300ºF, shortly after drilling continued.

When the Lower Haynesville formation anhydrite was drilled the total hardness increased from 100 mg/L to 400 mg/L. The hardness was left in the system in anticipation of the upcoming Smackover and the associated H_2S and CO_2 contamination expected in this formation. The pH of the fluid was maintained at 10.0 to 11.5 to help control the H_2S and minimize the adverse effects of the acid gases. The zinc carbonate H_2S scavenger was built into the system at 2 lb/bbl and maintained throughout the operation. Lime was used to maintain pH and treat the carbonate contamination.

The HTHP Polymer system showed no adverse affects from contamination, lime additions or the high temperatures. The yield point and gel strengths remained stable. The API and HTHP filtration control was not affected by the contamination and remained stable throughout the operation.

The HTHP Polymer system was formulated initially with 6 to 8 lb/bbl bentonite. Daily monitoring of the cation exchange capacity of the mud with the Methylene Blue Test (MBT) in conjunction with filtration rates and cake quality were used to determine when additional bentonite treatments were required. BPac and AMPS/AAM were used for filtration control and to provide a reduced bentonite content fluid. This modification of the fluid composition enhanced the fluids shear thinning characteristics. At the HT Polymer deflocculant, concentration was maintained at 1.5 lb/bbl to ensure fluid thermal stability. The defloculant also was used to minimize the effects of the various contaminants encountered.

The only problem encountered during this operation was differential sticking after the drill string remained motionless for an extended period of time. This situation was addressed by spotting diesel oil that was treated with a pipe freeing agent and lowering the mud weight to reduce the hydrostatic pressure. The spot and the reduction of mud weight in conjunction with jarring on the drill string resulted in the pipe coming free.

A concentration or 20 lb/bbl sized calcium carbonate was initially added to the HTHP Polymer fluid for improved cake quality and improved bridging. However, this concentration was not maintained which may have contributed to the differential sticking tendencies.

Joshua Timber Company 35-9 No.1, was drilled to a total depth of 19,500 feet MD with a maximum fluid density of 16.5 lb/gal.

Refer to figure 1 for a graphical overview of the well. The graphs illustrate the high pressure transition zone and the necessary increase in mud density. Note the improvement in fluid properties at 18,230 feet.

Figure 2 is the graphical overview of the HTHP interval, from 18,230 to 19,500 feet. The stable rheological and filtration properties are displayed in the interval graphs.

Upon completion of the drilling operation the HTHP polymer mud was returned to the Liquid Mud Plant (LMP) in Laurel, Mississippi.

The next Bean Resources, Incorporated well; G.N. Jones 32-10 No.1, was drilled in Section 32-T8N-R7W. A similar drilling fluid program was followed for this hole as for Joshua Timber Company 35-9 No.1. The intermediate hole was drilled to 16,650 feet and the 7 5/8 inch liner run prior to drilling the high pressure transition zone. The inexpensive, low density, solids laden mud system used to drill the intermediate hole was discarded and the mud system was displaced with the HTHP polymer fluid that was used on the previous well.

The HTHP Polymer system was stored for 6 months without treatment and only agitated twice during storage. The mud maintained its density and only required a minor treatment to return it to the required specifications.

The HTHP Polymer fluid was shipped to location and stored in frac tanks until the operation was ready to proceed with the displacement and drilling. The transportation and storage of the 2,000 bbls of the HTHP Polymer fluid was successfully conducted without difficulty.

As demonstrated on the previous well, the HTHP Polymer system showed no adverse affects from contamination or temperature. The yield point and gel strengths remained stable. The API and HTHP filtration control was not affected by the contamination and remained stable throughout the operation.

On this well additional sized calcium carbonate was used to maintain a concentration of 20 lb/bbl. There were some indications of differential sticking but string never became stuck. This was a considerable improvement to Joshua Timber Company 35-9 No.1.

G.N. Jones 32-10 No.1 was drilled to a total depth of 17,350 feet MD with a maximum fluid density of 16.5 lb/gal. There were no problems or unusual costs associated with disposal of mud or cuttings during this drilling project.

Figure 3 is a graphical overview of the well. These graphs display a similar high pressure transition zone, increased mud density and improved mud properties at 16,500 feet.

Figure 4 is the graphical overview of the HTHP interval, from 16,500 to 17,350 feet. These graphs display stable rheological and filtration properties, even when exposed to contamination.

The HTHP Polymer system exceeded the objectives requested by Spooner Petroleum Company. On the drilling location it was noted that after trips, the fluid circulation could be broken with minimum pressure. This eliminated having to "stage" into the hole, requiring expensive rig time. The depth and hole size in this situation generally limits hydraulics. The results from this project indicated improved hydraulics and it was observed that there was less friction pressure loss than on previous drilling operations. This allowed higher flow rates at lower pressures and better bit and annular hydraulics. The drilling fluid rheological properties allowed for higher flow rates at lower pressures, enhancing the mud motor performance.

There were no problems or unusual costs associated with disposal of mud or cuttings during this drilling project.

Conclusions

1. The HTHP Polymer fluid successfully met all requirements on the blowout and drilling operations.
2. The HTHP Polymer system provided excellent suspension of weight material during transportation and storage.
3. There were difficulties with conventional muds after trips but not with the HTHP Polymer system, Circulation was established without difficulty. There was no settling or gellation observed and the mud properties remained stable.
4. The high density, HT Polymer system provided low, stable pump pressures and good lubricity allowing for successful drilling operations.
5. The HTHP Polymer fluid provided stable rheological and filtration properties even when exposed to cement ($Ca(OH)_2$), anhydrite ($CaSO_4$), carbon dioxide (CO_2), and hydrogen sulfide (H_2S).
6. High density fluids are expensive. The cost for HTHP Polymers was justifiable for the appreciable increase in fluid stability obtained. This improved fluid stability reduced maintenance costs and assisted in making these operations successful.
7. The HTHP Polymer system has application at this temperature range due to its stability and resistance to contamination.
8. The HTHP Polymer drilling fluid was stored for extended time and required minimum treatment to meet specification.
9. The HTHP Polymer system was environmentally acceptable and no difficulty was incurred with disposal of mud or cuttings.

Nomenclature

SI Metric Conversion Units

(°F-32)/1.8		= °C
lb/bbl x 2.853009	E+00	= Kg/m^3
lb/100 ft^2 x 0.4788026	E+00	= Pa
lb/gal x 1.198264	E+02	= Kg/m^3
PSI x 6.894759	E-03	= Mpa
Centipoise x 1.0	E-03	= Pa.s
ft x 3.048	E-01	= m
lb/ft^2/yr x 4.9	E+00	= Kg/m^2/yr

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Figure 1 Well Overview - Joshua Timber Co. 35-9 #1

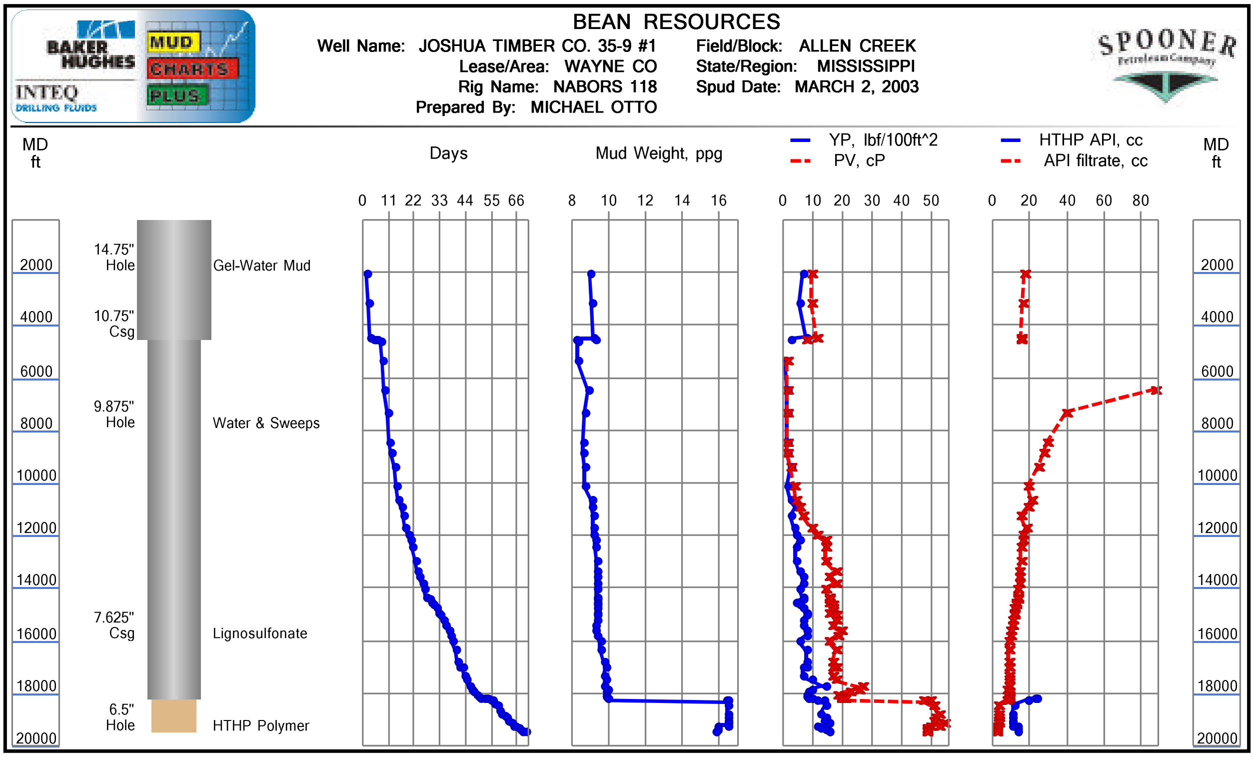

Figure 2 HTHP Interval Overview - Joshua Timber Co. 35-9 #1

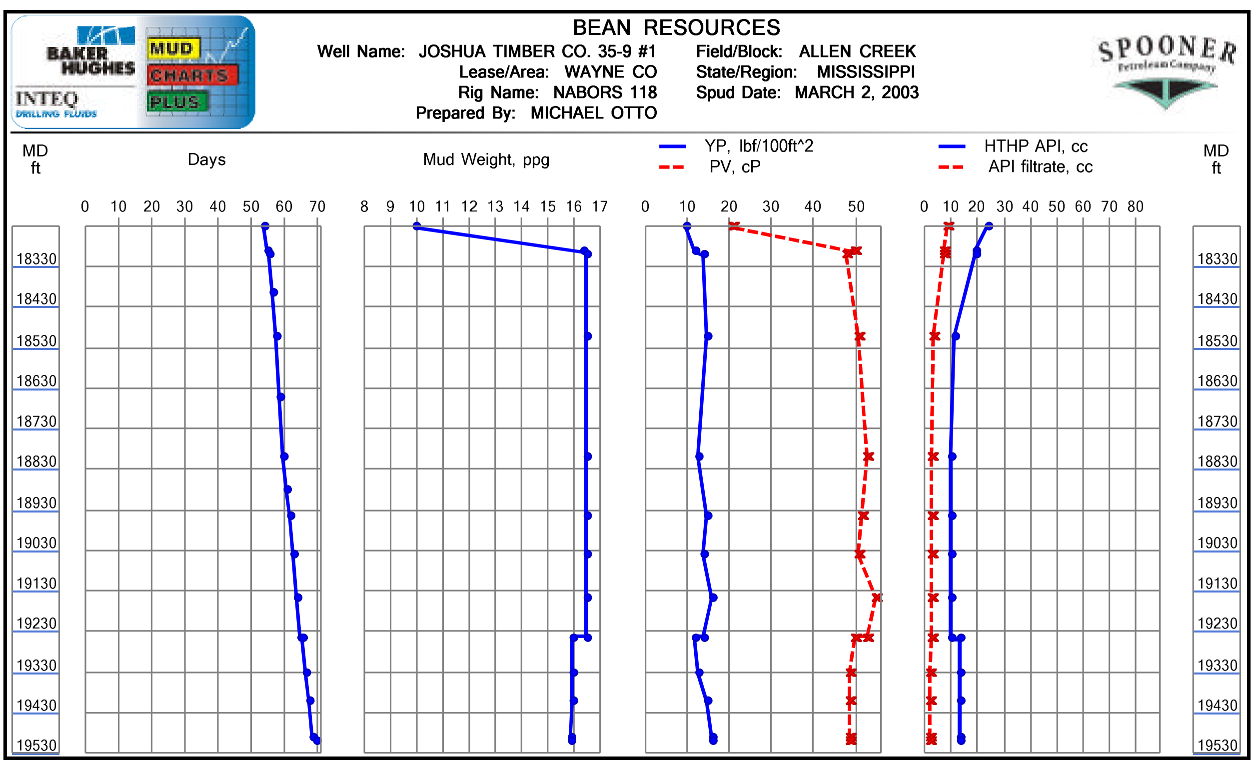

Figure 3 Well Overview - G. N. Jones 32-10 #1

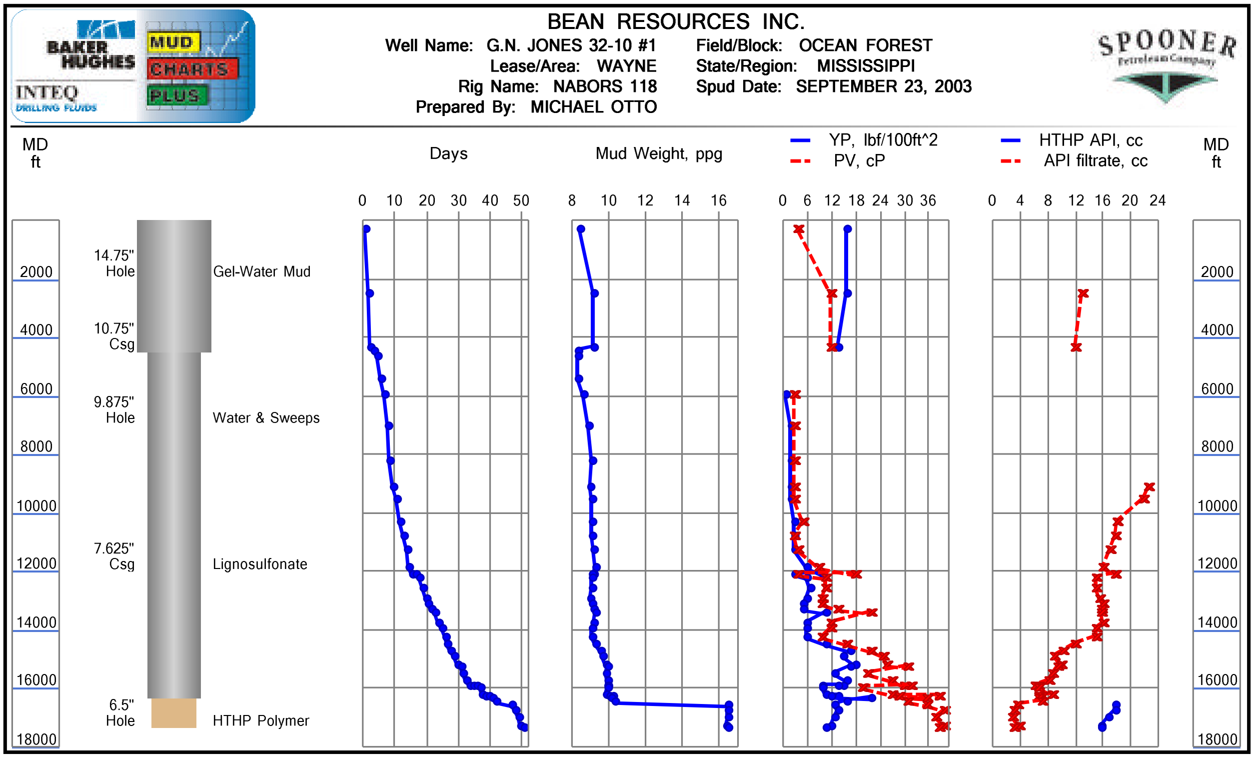

Figure 4 HTHP Interval Overview - G. N. Jones 32-10 #1