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The Application of HTHP Water Based Drilling Fluid On a Blowout Operation



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Abstract

A high temperature water-base mud (WBM) has recently been used successfully on a blowout operation. This 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 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, satisfying the requirements. This fluid stability was necessary while procuring another drilling rig. Because of this extended down time, complications with weight suspension and the ability to break circulation were of major concern. 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.

The overall concerns of this project were weight suspension, gelation, lubricity, thermal stability, and contamination of the drilling fluid by carbon dioxide (CO₂), and hydrogen sulfide (H₂S). Additionally, resulting pump pressure and pressure losses had to be maintained in acceptable ranges for a successful operation. The HTHP Polymer fluid successfully met the requirements and on some occasions, surpassed expectations.

Introduction

High temperature polymer mud systems are traditionally used for applications above 350°F. However, extremely high pump pressures were required for killing the blowout. This called for a shear-thinning polymer fluid to minimize pump pressure at the anticipated flow rates. The high density fluid was also exposed to a multitude of contaminants. This unique situation, and combination of requirements, resulted in the selection of the HTHP Polymer system as the kill fluid. The fluid performance was excellent and costs were reasonable. These HTHP polymer products are frequently overlooked, or not considered, for applications on wells that are approaching the temperature limitations of conventional products. The unit cost of these high temperature stable

polymers is often cited as a limitation. The drilling fluid market today is unit cost driven by tender and bid requirements but unit product cost analysis can be misleading. When stable polymers are used long term mud stability is maintained and the product consumption decreases when compared to conventional polymers. During the planning phase consideration such as project objectives, the drilling environment, and total operating costs are an important part of the cost equation.

HTHP Polymer Drilling Fluid Formulation

The HTHP Polymer system that was used for this project has been employed in the oil and gas industry for the past 30 years. The system has also been used in geothermal operations for 25 years and is renowned for its performance on the ultra deep, KTB scientific project in Germany. The HTHP components are environmentally acceptable and have been employed in environmentally sensitive areas. This long term experience with the system has resulted in formulations that can accommodate most fluid requirements, even under the most hostile environments.¹⁻⁵

Wyoming bentonite is used as the primary viscosifier and filtration control agent. The bentonite is stabilized for elevated temperatures by low molecular weight copolymer deflocculant (SSMA)⁶ and/or a synthetic interpolymer deflocculant (AT). These deflocculants provide resistance to contamination even at temperatures in excess of 500°F. A low molecular weight 2-acrylamido-2-methyl-propane sulfonic acid/acrylamide copolymer (AMPS/AM)⁷ 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 alkylacrylamide (AMPS/AAM)⁸, can be used 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 600°F. A modified lignite polymer (CTX) is used as a high temperature lignite for HTHP filtration control, also providing a thinning effect on mud viscosity.

On this operation hydrogen sulfide (H₂S) and carbon dioxide (CO₂) gases were anticipated. To reduce the solubility of the H₂S and minimize the adverse effects of the acid gases the pH of the fluid was maintained at 10.0 to 10.5. To ensure a safe work environment and to minimize equipment exposure to H₂S, the systems were pre-treated with basic zinc carbonate as a hydrogen sulfide scavenger.⁹ Circulating temperatures on this project were below 325°F so complex polysaccharide (BPac) could be used to provide improved shear thinning characteristics.

Blowout Operation

On February 13th, 2001 Ronnie Musgrove, the Governor of Mississippi declared a state of emergency for Wayne County as a result of the blowout and subsequent fire at the Bean Resources, Inc. well Beard 29-7 No.1. A radius of 2 ½ miles was evacuated resulting in Bean Resources providing accommodations for 173 families and a no-fly zone was issued over this area. The well blew out while a production liner was being run after the well had reached a total depth of 18,500 feet with a 6 ¼" bit. Numerous government agencies coordinated state response to the well fire. The well control specialists, Boots and Coots, were selected to supervise the well control operations which included removal of the remaining parts of the Nabors Drilling Company drilling rig.

After securing the well, a snubbing unit was rigged up on the location. The plan was to dynamically kill the well after snubbing 3½ inch tubing down to the 7 5/8 inch casing shoe, located at 17,044 feet. Refer to Figure 1 for a diagram of the Dynamic Kill plan. The high pressure flow was from the Smackover Limestone formation with a pressure of 15,377 psi, which required an equivalent mud weight of 16.0 lb/gal. The well was to be killed using dynamic kill procedures. Therefore, to maximize flow rate and reduce circulating pressures, a shear thinning polymer kill fluid was needed. The HTHP Polymer drilling fluid system was recommended for this 300°F application because of the high pressures, possibility of contaminants, and required fluid stability.

The Baker Hughes INTEQ Drilling Fluids Laboratory in Houston performed pilot tests and provided an HTHP Polymer formulation for this operation. The first batch of mud was prepared at the liquid mud plant in Laurel, Mississippi. Lime additions were made as requested for hydrogen sulfide abatement. After the fluid was mixed, rheological properties were adjusted, and then the mud plant was shut down leaving the mud static overnight. This formulation resulted in a fluid that possessed inadequate suspension characteristics. The next

morning, settling had occurred in the mixing pit. Pilot testing was conducted and improvements were made to improve the suspension characteristics of the fluid.

An operations meeting was held with Spooner Petroleum Company, Boots and Coots, Halliburton and Well Flow Dynamics to discuss the difficulties that occurred with the first fluid formulation and to determine fluid requirements that would allow the project to successfully reach its objectives. It was agreed primary concerns were suspension of the weighting agents and the ability to ship and store the drilling fluid. The thermal stability and shear thinning characteristics, as well as the fluid's pumpability, were also of concern to the kill operation. Due to the complications associated with the lime treatments it was decided that basic zinc carbonate and caustic soda would be sufficient for H₂S treatment and that the lime could be omitted. Higher density drilling fluid formulation was also discussed. Hematite was recommended as the weight material for mud densities of 20 lb/gal or greater. It was agreed that rheological properties would be designed slightly higher than initially recommended, to improve the suspension characteristics. This change would help reduce the possibility of weighting material settling during transportation and storage.

Pilot tests of the high density fluids with barite and hematite were conducted. New formulations of the 16.6 lb/gal HTHP kill fluid without lime were evaluated and mixing of the second 500 bbl of kill mud commenced. After pilot testing was completed, estimated fluid properties ranges were provided to the operation. Refer to Table 1 for the drilling fluid property ranges. A total of 3000 bbls of 16.6 lb/gal and 400 bbls of 21 lb/gal HTHP Polymer drilling fluid were to be supplied to the location. Mixing, pilot testing and fluid testing continued until all muds were prepared, shipped and delivered to location. The fluid properties prior to shipment are found in Table 2. Pilot testing for thermal stability and suspension was conducted in the Laurel laboratory. An additional series of tests were conducted in the Houston laboratory to confirm the fluid design. The testing was conducted at intermediate temperatures (200°F – 225°F) and at the maximum temperature (300°F) to verify that acceptable rheological properties would be maintained throughout the well killing operation. This testing revealed the formulations to have the required thermal stability for the operation. Figure 2 contains the drilling fluid property ranges as determined by this pilot testing.

At the same time muds were being prepared at the plant, frac tanks were being placed on location and were manifolded to the mud pumps. This allowed the drilling fluids to be rolled (circulated) in the tanks and conditioned if necessary. These manifolds were also to

be used when pumping the mud during the well killing operations.

The 22 lb/gal hematite mud was isolated at the location in its own tank, with a dedicated mixing pump. A mixing pit and bulk bottle were installed but not required for the well killing operation. After all muds were received at location, fluid densities were verified to be the same as shipped.

The tubing was being snubbed into the hole while the mud was being delivered to location and the mud pumps were arranged. After all personnel, equipment and drilling fluid were in place, final pressure testing was conducted to 14,000 PSI. A combination safety and operations meeting was conducted. Well killing operations commenced immediately after the meeting. 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 lb/gal HTHP Polymer mud were used for the well killing operation. For the volume of mud pumped and tubing pressures, refer to the graphs from Well Flow Dynamics, in Figure 3 & 4. 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. Table 3 displays the flow rates and pressure data that were recorded when circulation was established.

The HTHP Polymer system was displaced with completion brine and the HTHP Polymer system placed in storage for future operations. There have been no complications during the storage of the HTHP Polymer system. The fluid has been stored for a period of approximately 6 months with only monthly agitation with the plant mud guns.

Conclusions

1. The HTHP Polymer fluid successfully met all requirements on the blowout.
2. The HTHP Polymer system provided excellent suspension of weight material during transportation and storage.
3. After killing, the blowout field static age test was successfully conducted at 300°F for 30 days.

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 dynamic kill operations.
5. The HTHP Polymer fluid provided stable rheological and filtration properties even when exposed to cement ($\text{Ca}(\text{OH})_2$), carbon dioxide (CO_2), and hydrogen sulfide (H_2S).
6. High density fluids are expensive. Therefore, the increased product 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 this operation successful.
7. The HTHP Polymer system has application at this temperature range due to its stability and resistance to contamination.
8. 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
Centistoke x 1.0	E-06	= m ² /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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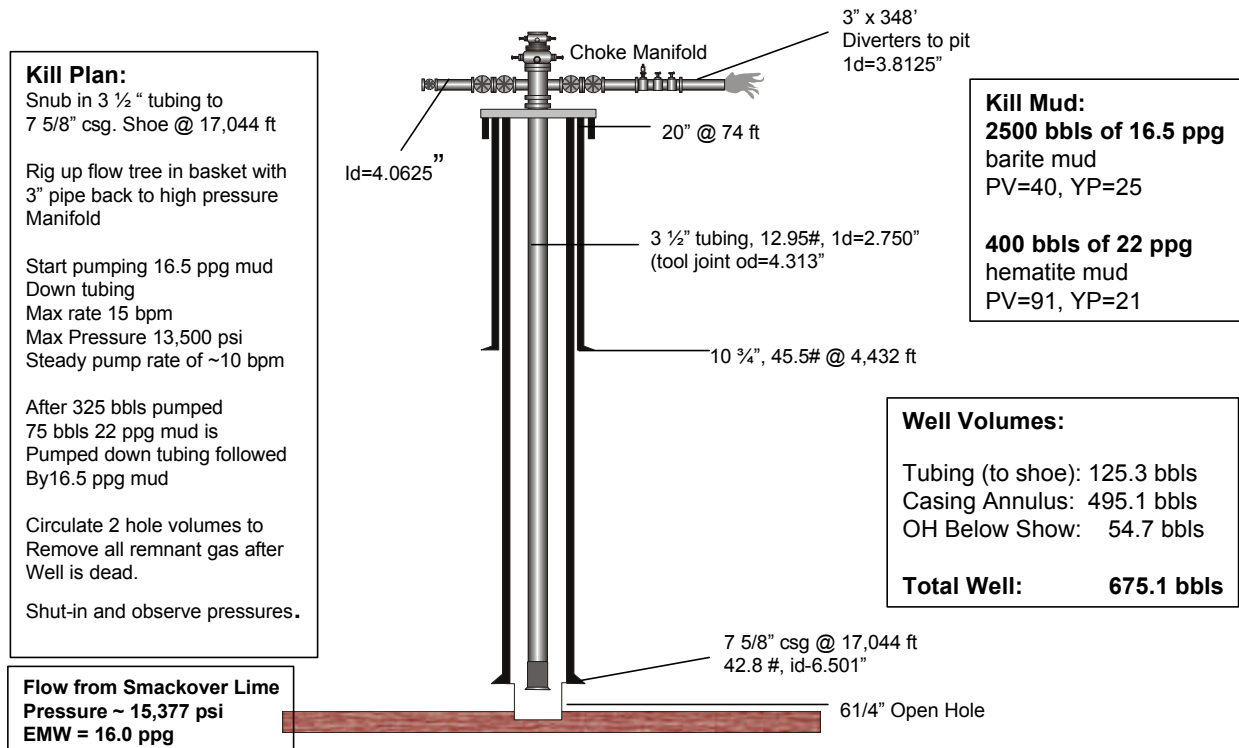
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Figure 1**The Dynamic Well Kill Plan**

Operator: Bean Resources/Boots&Coots
Well Name: Beard 29-7 No. 1
Location: Wayne County
State: Mississippi

**Table 1****Recommended Mud Properties Ranges of HTHP Polymer Muds**

Fluid Properties	Barite Mud	Barite Mud	Hematite Mud
Density, lb/gal	16.5	19.0	22.5
Plastic Viscosity, cp @ 120°F	40 - 55	80 - 100	130-150
Yield Point, lbs/100 sq ft	25 - 35	25 - 35	25-35
Gel Strengths, initial, lbs/100 sq ft	6 - 10	6 - 10	6 - 10
Gel Strengths, 10 min, lbs/100 sq ft	18 - 22	15 - 21	15 - 22

Table 2

Fluid Report on HTHP muds prior to shipment to location.

**FLUIDS TECHNOLOGY - LAUREL MISSISSIPPI
TECHNICAL SERVICE LABORATORY REPORT**



INTEQ
DRILLING FLUIDS

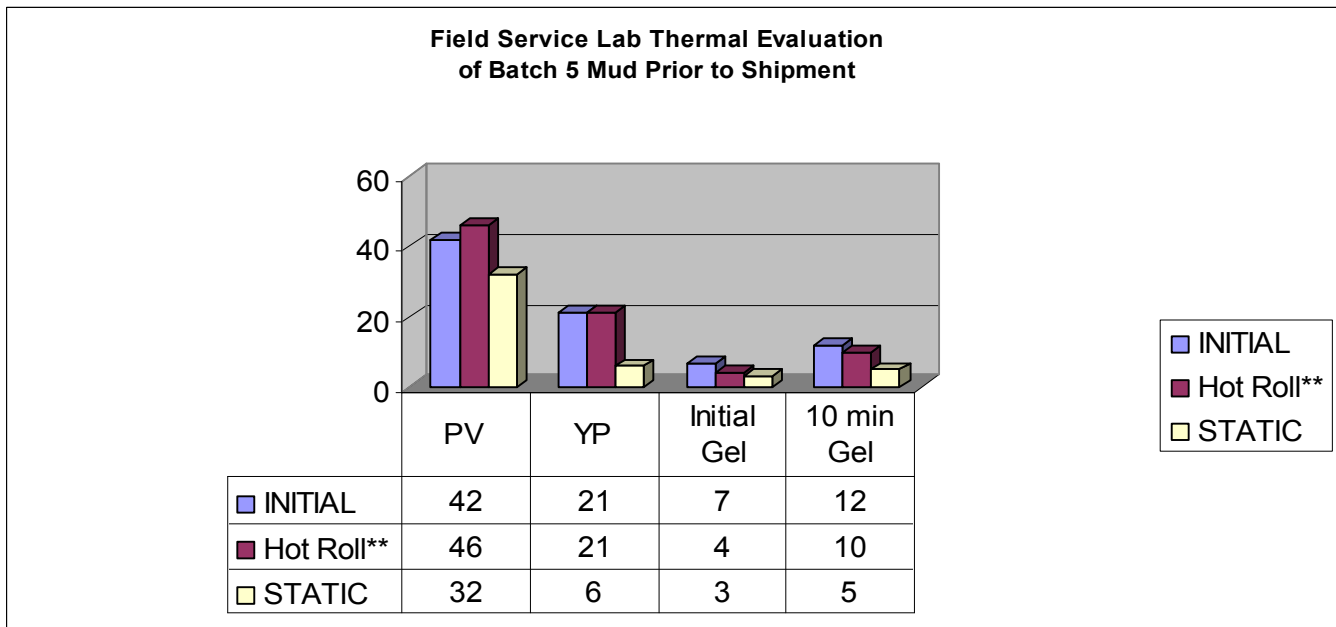
Operator: Bean Resources/Boots&Coots **FSR No.** 01-0228
Well Name: Beard 29-7 No. 1 **Batch No.** 1 through 7
Location: Wayne County **Date Submitted:** 02/25/2001
State: Mississippi **Date Completed:** 03/04/2001
Mud Type: PYRO-DRILL

Volume	bbbls
1 - 6	500
7	400

Mud Properties	Batch No. 1	Batch No. 2	Batch No. 3	Batch No. 4	Batch No. 5	Batch No. 6	Batch No. 7
Density, lbm/gal	16.6	16.7	16.7	16.6	16.6	16.7	22.0
Rheology @:	120°F	120°F	120°F	120°F	120°F	120°F	120°F
Plastic Viscosity, cP	61	43	42	45	42	45	91
Yield Point, lbf/100 ft ²	37	27	29	27	21	27	21
Initial Gel Strength, lbf/100 ft ²	8	5	5	7	7	7	5
10 min. Gel Strength, lbf/100 ft ²	10	8	8	12	12	12	14
API Filtrate, cc/30 min.	8.0	4.0	4.0	4.6	4.4	4.4	6.0
pH of filtrate, by meter	12.5	11.4	11.4	11.4	11.4	11.4	11.3
PM	11.0	1.1	1.1	1.0	1.2	1.2	1.0
pf	1.3	1.0	1.0	0.9	1.1	1.1	0.9
mf	2.0	3.0	3.1	3.0	3.4	3.4	3.0
Chlorides, mg/L	2100	2100	1800	1800	800	800	1000
Total Hardness, mg/L	280	80	80	tr	tr	tr	tr
Water, % by Vol.	69	69.5	69.5	69.5	69.5	69.5	58.5
Oil, % by Vol.	0	0	0	0	0	0	0
Solids, % by Vol.	31	30.5	30.5	30.5	30.5	30.5	41.5
600 rpm Reading	159	113	113	117	105	117	203
300 rpm Reading	98	70	71	72	63	72	112
200 rpm Reading	73	52	52	53	47	57	81
100 rpm Reading	48	33	32	36	31	37	47
6 rpm Reading	9	7	7	10	5	13	6
3 rpm Reading	6	4	4	9	4	11	4

Batch 1 - PYRO-DRILL/Lime
 Batch 1 - 7: PYRO-DRILL, Fresh Water. Batch 7 weighted with Densimix.

Figure 2
Graph of test values from Laurel Fluids Laboratory report conducted while the mud was being built.



Mud was static for 16 hrs @ 300°F, no settling was observed.

** The hot roll was to simulate circulating temperatures; 1 hr @ 150°F, 2 hrs @ 250°F, 1 hr @ 225°F, 1hr @ 150°F.

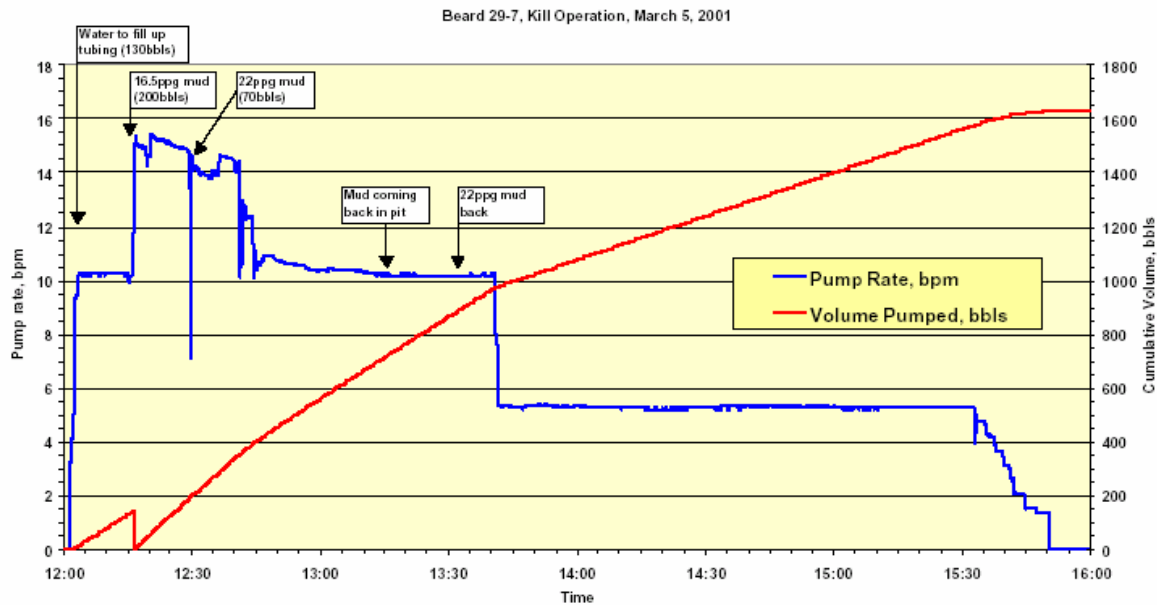
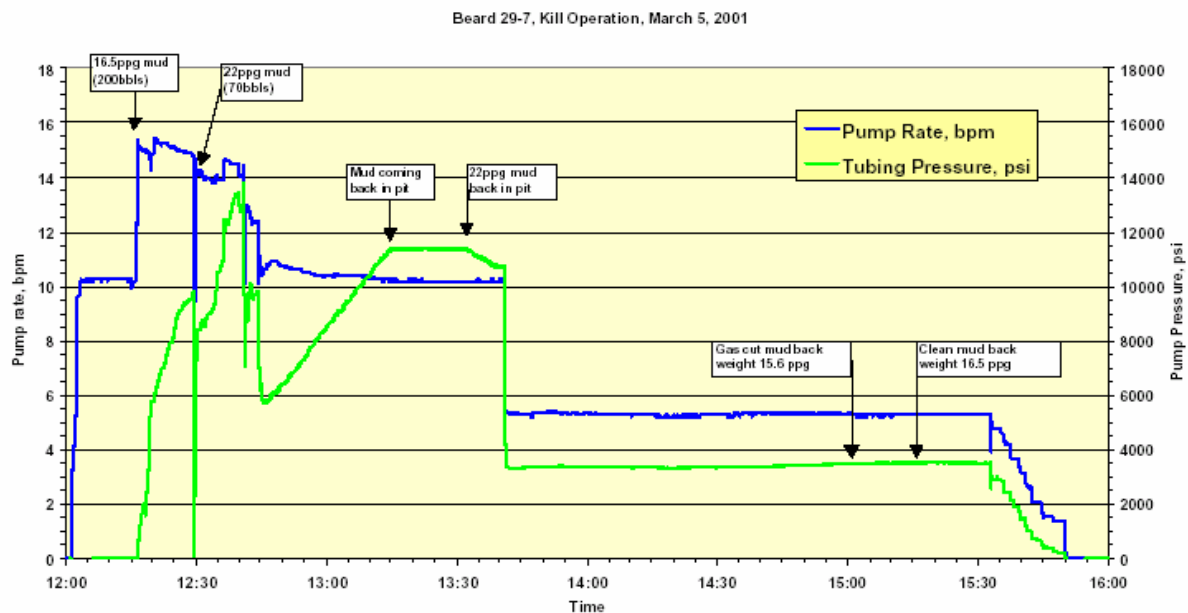
Figure 3 - Pump Rate and Fluid Volume Data during Dynamic Kill*Pump rate and cumulative volumes. Kill operation March 5, 2001.***Figure 4 - Pump Rate and Pressure Data during Dynamic Kill Operation***Pump rate and tubing pressure. Kill operation March 5, 2001.*

Table 3

Flow Rates, Circulating Times and Pump Pressures as reported by Halliburton when breaking circulation on Bean Resources well Beard 29-7 after well was static for 30 days. The Nabors Drilling rig reported similar pressures and flow rates (i.e. 4-5-01: 1324 psi @ 123.6 gpm)

Date: 4-4-01

Time, min.	Rate, gpm	Volume, bbls	Pressure, psi
1223	10.5	0.1	1400
1238	21		1400
1245	42		1300
1249	84		1400
1514	84	306	1150
1600	105	415	1180
1636	94.5	500	1100
1705	117.6	565	1350