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Research Paper

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Evaluation of Differential Pressure Sticking and Stuck Pipe in Oil and Gas Drilling Technology and Its Production Operations

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Abstract- The research work is to evaluate and study differential pressure sticking and stuck pipe in oil and gas drilling technology and its productions operations, using practical field operations of Nigerian petroleum Development Company as a case study. A clear attempt have been made in this research work to investigate and mitigate differential pressure sticking and stuck pipe problem experienced by the industry in the portion of their Well 9 and 10 offshore deviated well of total depth of 14,500ft and 13,500ft as compared with a deviated producing offshore well 6 of a total depth of 15,400ft and a producing onshore vertically well XI of a total depth 10,500 ft. Since the problem is monotonous, a viable pipe releasing agent (PRA) fluid and Surge method was suggested in this study in addressing this problem at the point of occurrence with an appropriate VERSA system composition fluid with other necessary reagents. A flow chart model was used in this study to simulate how this fluid can be spotted around the stuck zone, in freeing the stuck pipe from the wellbore, after soaking for 20-40 hour alongside with proper jarring mechanism the free point depth was determine with stretch method. Chart was used to evaluate well 9 & 10 with stuck pipe and their economic losses in relating with well 6 and producing well XI, depth graphs of well 9 & 10 were plotted to analyze the in-depth point of differential pressure sticking and stuck pipe zone at about 13,604ft & 11,677ft. Temperature increased with depth graph and its behavior with pressure were also plotted and analyzed.

Keywords— Differential Pressure Sticking, Oil Well, Stuck Pipe, oil and gas Drilling, Spotting Fluid, Production, Temperature, pressure, OKONO & ABURA (Oil well field name).

I. INTRODUCTION

The Petroleum industry is one of the biggest industries in the world and it has a significant impact on the world economy. Its business spreads over continents and it controls the most important asset of nonrenewable energy. One of the major aspects of the oil and gas industry is drilling. Drilling started as the straightforward procedure of digging a gap into a repository. The oil and gas industry resembles any industry on the planet, which involves many issues in its operations. However, drilling down gap issues are ranked among the most significant issues as they bring about immense uses. Although all down opening drilling issues are challenging, unpredictable, and involve spending loads of time and cash, stuck pipe is viewed as one of the most troublesome drilling issues. Stuck pipe can be depicted with the end goal that during drilling a well, the up or/and down pipe development or/and pipe rotation is out of nowhere confined or solidified. In this manner, drilling operations are suspended as no all the more drilling is achieved. Pipe sticking could happen because of many causes. It very well may be because of ill-advised drilling liquid properties, well geometry, the nature of the bored formation, and/or inappropriate drilling parameters. In drilling industry, stuck pipe has been classified into several sorts according to various basis and categories. Generally, the most well-known two kinds of stuck pipe in the literature are differential and mechanical. Often during drilling operations the drill string gets stuck. Sticking can happen while drilling, making an association, logging, testing, or during any kind of operation which may involves leaving the hardware in the gap.

In the case of differential sticking, it has an immediate relation to differential pressure between the hydrostatic segment created by the drilling liquid in the well and formation pressure. Differential sticking happens when high overbalanced drilling liquid applies a large amount of differential pressure across a thick mud cake. A stuck pipe situation can take place anywhere on the planet where drilling operations are led and it has a long history. Several authors have thought of certain statistics that show the seriousness of substantial misfortunes because of stuck pipe. In 1991 [26]. Directed some research and found that BP (British Petroleum) had spent more than $30 million every year for stuck pipe issues. Between 1985 and 1988, an average of $170,000 was spent per well because of stuck pipe. In addition, they stated that stuck pipe charges in the whole oil industry were estimated to surpass $250 million yearly. Then again, a study within Sedco Forex in 1992 showed that stuck pipe accounts for 36% of total drilling issues [55].

A. PURPOSE OF THE STUDY

The aim of this study is to evaluate differential pressure sticking and stuck pipe in oil and gas drilling technology and its production operations by utilizing the general handy field of oil and gas drilling and production operations of Nigerian petroleum Development Company as a case study. in summary, the research is of importance because problems are what drilling operations and personnel are about! We recognize that if we could eliminate the drilling problems peculiar to a given area, we could reduce the oil and gas well cost, by Understanding fundamental causes of such problem and determining the most expeditious and economical solution to this problem, this prompt us in looking for a lasting solution to stuck pipe caused by differential pressure sticking within the oil and gas wellbore in OKONO field area, using the most recent spotting fluid method and surge or u-tubing method in freeing of this stuck pipe with an appropriate VERSA system fluid compositions and formulations.

B. OBJECTIVE OF THE STUDY

The objective of this study is to investigate and mitigate the effect of differential pressure sticking and stuck pipe problem within the wellbore in OKONO 9 and 10 deviated well in oil and gas drilling operations. Differential pressure sticking and stuck pipe is one of most basic issue looked during drilling of oil and gas well. With gigantic effect on drilling proficiency, well expenses and rough creation in oil industry. Setting out on the impact and alleviation of differential pressure sticking and stuck pipe is a complex one, which incorporates intensive research work and questionnaire within the company oil and gas fields and the department in concern. Here we try to assess and alleviate the reasons for event of such issues to disregard risks and outrageous drilling expenses and recommending down to business well-site approach in freeing this stuck pipe and keeping it from further occurrence and minimizing its activities by utilizing spotting fluid and U-TUBE method applied by flowchart simulation model. More than a significant extended period of time oil industry is defying inconveniences related with the stuck pipe. These events are assessed to cost the industry many countless dollars every year, events related to differentially pipe sticking can be at risk for as much as half of unquestionably the well cost. Differential pipe sticking problems by and large result in the huge amount of personal time, well expense and time overruns as a non-productive time regarding loss of rig days either due to halting of drilling operations or an endeavor to free the stuck pipe. This huge misfortune is constantly accounted for in the well budget cost as a possibility factor for the dangers related with the stuck pipe problems in the well arranging and drilling execution approach, the ongoing increment in drilling movement, lack of experienced personnel and equipment, and drilling in higher-dangers zones have expanded the danger of stuck pipe occasions in all drilling operations. Differential pipe sticking is a serious problem particularly in drilling cutting edge wells like profoundly directional or deviated wells, level wells, and multilaterals, vertical well and so forth. It can runs in seriousness from minor burden to significant difficulties, which can have fundamentally negative results, such as loss of the drill string or complete loss of the well. To formulate water base mud and oil base mud as pipe releasing spotting fluid with average application procedure for freeing stuck pipe and likewise to evaluate NPDC well 10, 9 and 6 deviated well with vertical well profundity information and looked at production loss information of barrel of crude produced every day for economical purpose. The results included temperature impact with profundity, contact time, spotting fluid types formulation for pipe freeing and application procedures, normal field application impact of differential sticking to well production cost and economic loss, looking at the potential of differential pipe sticking to drilling practice, field information data, probability of sticking pipe by deciding sticking time, plausibility of stuck pipe by differential pressure sticking in a deviated well over vertical well.

The paper is organizes as follows, Section I of the paper contains general introduction of the study which entails aim and purpose of the research work, Section II contain the literature review of the research work, Section III contain the methodology and Materials use for pipe releasing agent fluid formulation and applications at the stuck zone, section IV of the study contain necessary discussion of results, Drilling and production well field Data under study, temperature and differential pressure sticking graphs, well data tables, histogram, vertical and directional schematic wellbore Architecture and construction summary, Section V of the study contain the conclusion and recommendation of future approach for Nigerian petroleum development company in addressing oil and gas drilling operations problem as regards to differential pressure sticking of stuck pipe during drilling practices.

II. REVIEW OF LITERATURE

More than quite a while oil industry is confronting inconveniences related with the stuck pipes. Differential pipe sticking is one of the stuck pipe mechanisms with a significant effect on drilling efficiency and well expenses [5],[85],[89]. These events are basic wherever on the planet and are evaluated to cost the business a huge amount of dollars every year. Well instability keeps on being a refreshed difficulty for oil and gas industry notwithstanding of various advances in drilling procedures[2],[3],[8],[11],[19],[23],[26],[84],[92]. This issue has been an exceptional center point since drilling of wells have been growing up to get more access to crude oil. According to economic perspective, the loss of one billion dollar for each year due to the wellbore hazards [90]. On missing time comparing to 40% of all drilling related non-gainful time, builds the significance of wellbore strength issue for the drilling business [73]. A few investigations additionally accentuations that the differential pipe sticking seriously influences well expense and activity time as a non-profitable time [1],[6],[24],[89].

In spite of the fact that the expense of stuck pipe in profound oil and gas wells is evaluated to be the quarter of all out spending plan [87]. This occurrence is constantly represented in the well spending cost as a possibility factor for the dangers related with the stuck pipe problem in the well structure and drilling execution approach [1],[6],[24],[74],[89]. The ongoing increment in drilling practice, deficiency of experienced work force and personnel, and drilling in higher-dangers zones, have expanded the danger of stuck pipe occasions in all drilling activities [92]. The idea of differential pressure sticking of drill pipe was first revealed by [47]. As indicated by laboratory tests, they expressed that pipe sticking outcomes when the drill pipe gets moving against a penetrable bed and a part of the zone of the pipe is disengaged by mud cake [49]. Investigated pipe sticking typically dependent on drilling parameters [24]. Created an information base remembering 22 drilling parameters for 73 non-pipe stuck wells and 54 pipe sticking wells in Mexico's inlet. As of late, some examination is being directed so as to decide the qualities of stuck pipe, for example, the profundity of pipe sticking [8]. Attempted to decide the profundity of pipe sticking by methods for consistent Free-Pipe logs. These investigations were the base of essential near examination that could recognize the pipe sticking mechanisms notwithstanding its likelihood forecast [50]. Improved the expectation stuck pipes' models by applying measurable procedures in 100 wells of Mexico's inlet. These models were utilized for counteraction of pipe sticking and activity sparing [78]. As of late introduced an utilization of Artificial Neural Network (ANN) techniques for understanding the reasons for differential stuck pipe [58]. Actualized ANN to anticipate the pipe sticking in Iranian seaward oil fields [63]. Did an examination to anticipate and stay away from pipe sticking dependent on versatile fluffy rationale [10]. Examined use of ANN and Support Vector Machines (SVM) in stuck pipe expectation [53]. utilized SVM with Gaussian portion capacity to anticipate differential pipe sticking [36]. Did an exhaustive report to look at the execution of various Neural Networks and Neuro Fuzzy Systems in expectation of pipe stuck. In 2010 [73]. Led an examination to explore stuck pipe likelihood by ANN in one of Iranian oil fields. The consequences of their examination indicated over 90% exactness for stuck pipe expectation in the researched oilfield. In their investigation, a complete number of 275 cases were gathered from the day by day drilling reports (DDRs) in one of the Iranian oil fields. The information contained 115 stuck and 160 non-stuck cases. Non-stuck information were gathered from days that the wells were totally protected and had not gotten stuck in a similar general zones of activity [5].Improved the current consistency models in pipe sticking.

III. METHODOLOGY AND MATERIALS.

A. *PIPE RELEASING AGENT FLUID MIXING PROCEDURE*

A VERSA system was firmly emulsified, with a stable temperature, transform emulsion, oil-base liquids. The accompanying system and combination was embraced with oil to water proportion of about 70:30 % was utilized and included after which 4 lb/bbl VG-69T Organophilic Mud which was also utilized to viscosify the liquid to help weight material and give gel qualities, 10lb/lbb of HRPE or VERSAMOD was likewise included, customary VERSA composition 6lb/bbl VERSAMULT was added to respond with 8lb/bbl lime to shape a calcium cleanser to go about as an emulsifier. The framework was kept basic, 3lb/bbl VERSACOATT was additionally added to the plan, estimated and permitted to blend for 20 minute, and Calcium chloride brine water was utilized as the internal phase of the transform emulsion. Measured saline solution will influence the properties and detail Concentration of calcium chloride of 38% by weight was utilized and 6lb/bbl VERSA TROL which was permitted to blend for 30 minute was also included generally to have an adequately low liquid loss with basic formulations.

Table 1.The following is the Materials that was selected in order of composition and formulation for oil base mud (diesel and crude oil) composition for spotting fluid formulation as prevalent fluids for freeing stuck pipe for typical well site Approach Applications

FUNCTION	PRODUCT
CONTINUOUS PHASE	BASE OIL
DISPERSED PHASE	WATER
SALT (FOR BRINE)	$CaCl_2$
PRIMARYEMULSIONANT	VERSA MUL
SECONDARY EMULSIONANT	VERSACOAT*
FLUID LOSS AGENT	VERSA TROL
ALKALINITY PROVIDER	LIME
ORGANOPHILIC CLAY	VG-69
WEIGHTING AGENT	BARITE

Table 2 CONVENTIONAL VERSA SYSTEM FORMULATIONS OF 25% BY WT CACL2 BRINE: 96% SALT PURITY)

VERSA SYSTEM	UNITS	Quantity
VERSAMULT	lb/bbl)	6.**00**
VERSACOATT	lb/bbl)	3.**00**
Lime	**lb/bbl)**	8.**00**
VG-69T	lb/b**bl)**	4.**00**
VERSATROLT	lb/bbl	6.**00**
Oil	Ib/bb	70.**0**
Mud Weight	bbl/gal)	8.5**0**
Water	**bbl**	30.**0**
CaCl2	**lb/gal**	32.**0**

B. *SPOTTING FLUID OR PIPE REEASING AGENT (PRA) PROCEDURE AND APPLICATION IN FREEING STUCK PIPE*

The oil base muds, water base mud, are all PRA, this liquid spotted all over the stuck zone, which enter the filter cake and evacuate it. The idea of spotting fluid(s) is like the oil-base alters (water-in-oil) emulsion mud. Both depend on the osmotic weight idea. Oil-base mud and additionally spotting liquid is exceptionally smooth mud in which the level of hindrance is constrained by changing the chloride substance of the water stage. Chlorides marginally higher than the chlorides in the water in the shale will restrain the shale. Chlorides a lot higher will expel the water from the Shale, which toughens the mass of the gap. Checks openings are generally penetrated with alter emulsion oil mud in light of the fact that the shale is profoundly hindered. On account of spotting liquid, the chloride substance of the water stage (inner stage) was blended higher than the saltiness of the mud framework. This distinction in saltiness will bring about osmotic weight that will restrain and toughen the mud filter cake.

Table 3 Standard Formulation: The table below shows the formulation for mixing 50 bbl of the complete weighted Spotting fluid of the above oil base mud and typical application Procedure

Mud weight(ppg)	Oil-base mud (bbl)	Pipe free drums	Water-base Mud (bbl)	Barite (MT)
8.0	30	3	18	0.5
10.0	29	3	13	32
12.0	27	3	11	5.7
14.0	25	3	10	8.0
16.0	25	3	6	10.5
18.0	22	3	5	12.9

i. A PRA Pill which is 1.5 bigger than the annulus volume and adjacent to the uppermost Permeable segment in which the pipe was stuck.
ii. The pill should be invariably 1-2 ppg (0.1-0.2 SG) heavier than the mud.
iii. Prepare a 50 - 100 bbl low YP spacer (base oil, brine, seawater) for pumping in front of the pill. Check the spacer is good with both the mud and the PRA Pill.
iv. After which, Spot the spacer and the pill at the maximum stream rate in a conceivable manner. This is important in order to get the PRA behind the pipe where it was stuck exactly.
v. Leave the pill in order to drench until the pipe is free or the choice is made at a satisfied point. But at this point is advisable not to try circulate out and pull out if the pipe doesn't give off an impression of being liberating; this isn't successful.
vi. Again, tried work the pipe while the pill is drenching: slack off 20,000lbs, work RH torque into the string (±0.75 turn/1000ft), discharge torque. This will work the stuck point down the gap a couple of inches or a couple of feet each time until the pipe 'suddenly' pulls Free.

Note that Differentially stuck pipe turns out to be more stuck with time. It is important to blend and spot the spotting fluid as quickly as possible. It is informed to blend an overabundance regarding
Spotting fluid, so sufficient volume is left inside the drill string to permit 1-2 bbl for every hour of crisp fluid to be pumped over the stuck zone.

C. The following was used to formulate water base mud as spotting fluid sea water, barite, lignosulfonate caustic soda ,PAC, CMC and $CaC0_3$ as pravelent fluids as pipe releasing agent

D. Surge or U-tubing method of freeing stuck pipe (Differential stickin)

To a reasonable position. This lighter fluid is a combination of diesel oil, crude oil, water, nitrogen, HCL, gas or any fluid that is accessible with a suitable weight. This can be a quick and viable liberating method, for the most part not used in conceivably precisely unstable formations as it will in general stun the formation. Anyway U-tubing can be used ordinarily a while later with no threat of any harm to the formation.

E. U-tubing procedure in well site application

(There can't be a strong buoy valve in the string for this procedure.)

i. In this procedure of pipe freeing method a full-opening Kelly rooster valve is introduce into drill string at a working state, on the apparatus Switch, required volume of light fluid is circulated into the annulus by means of the stifle line With a concrete pump (for accuracy). CLOSE THE CHOKE
ii. An RH torque is work into the string (±0.75 turns/1000ft) and slack off. Vent the drill pipe over the Kelly through the standpipe to permit air to be sucked in.
iii. Therefore suck off the back pressure on the gag in stages and Monitoring the return of the light fluid accurately by means of outing or strip tank (while working pipe).
iv. Work the pipe vigorously at each seep off stage and, when it is moving keeps it moving.
v. The annular preventer is open and circulate back to mud. (On the off chance that there is any threat of gas, make sure to Circulate through the stifle before opening the annular.)
vi. The Floor underneath the top drive, circulate the head, or Kelly drive.
vii. Perform all the necessary calculations according to the worksheet. The necessary Calculations are for U-tubing to formation pressure. In the event that an alternative hydrostatic pressure is required (i.e. which is above or beneath formation pressure) make sure to calculate the equivalent formation pressure and use it in the worksheet as necessary as possible.
viii. Therefore Close the annular preventer with minimum shutting press requires.

Table 4 U-Tube calculations Variables

pp	Formation pressure at zone of interest (SG)(or) maximum formation pressure
PP_2	Formation pressure at 2^{nd} zone of interest
TVD	True vertical depth of zone of interest
TVD_2	True vertical depth of 2^{nd} zone of interest
MDX	Actual length of light fluid column(m)
MDA	Actual length of air column in pipe after U-tubing(m)
MW	Mud density in hole (SG)
WW	Density of light fluid to be pumped (SG)
CH	Height of choke line (m)
CC	Capacity of choke line (bbl/m)
Ann	Capacity of drill pipe /casing annulus (bb/m)
DP	Capacity of drill pipe (bb/m)

F. MATHEMATICAL EQUATIONS OF U-TUBING METHOD OF FREEING STUCK PIPE.

The equations that can be adopted in the field using u-tubing or surge method in the quest of stuck pipe freeing are as follows;

i. True Vertical depth of light fluid in gag/annulus after U-tubing = X m
X = (MW - PP) x TVD ÷ (MW - WW)
True Vertical depth of mud in annulus after U-tubing = Y m
Y = TVD - X

ii. Volume of light fluid in annulus/stifle after U-tubing = V bbls
V = (CH x CC) + [(MDX - CH) x Ann]

iii. True vertical depth of air in drill pipe after U-tubing = Am
Am = (MW - PP) ÷ (MW x TVD)

iv. The Volume of air in drill pipe after U-tubing = VA bbls
VA = MDA x DP

v. Complete volume of light fluid to be pumped = Vo bbls
Vo = V + VA

vi. Max drawdown on some other formation in the well = DR psi
DR = ((Pm - PP2) x 1.421 x TVD2)
Pm = x WW + [(TVD2 - X) MW] ÷ TVD2
(In the event that TVD2 < X, at that point Pm = WW)

vii. Starting pressure on gag in the wake of pumping but before seep off = P CH
P CH = X1. (MW - WW) x 1.421
In the event that PP > MW, at that point PCH given by:
[(X1. (MW - WW)) + (TVD). (PP - MW))] X 1.421
X1 = True vertical tallness of light fluid subsequent to pumping.

viii. Measuring stretch method

When pipe becomes stuck, the first step is to determine at what depth the sticking has occurred. Stretch in pipe can be measured and calculation made to estimate the depth to the top of the stuck pipe. If the length of stretch in the pipe with a given pull is measured, the amount of the free pipe can be calculated. A point was mark at the rotary table level with the hook load completely slacked off. Tension on the pipe was pulled at least equal to the normal hook load (air weight) of the pipe prior to getting stuck. The tensions applied as a pulling force, F1, and measure the stretch, S1, in the pipe in inches, due to the pulling force F1 was recorded. Next, additional tension was pulled which has been predetermined within the range of safe tensional limits on the pipe. The new pulling force was recorded as F2, and the stretch, S2, was measured in inches, which resulted due to the pulling force F2. The stuck pipe depth can be determined by using the following equation:

Stuck Pipe Depth, D = Stuck Pipe Depth,

$$D = \frac{7351000 * W * DS}{F2 - F1}$$

Where W =weight of drill pipe
$(S_1 - S_2)$ =The stretch of the pipe from
The reference point (in.)
F2 –F1 = Additional pull require (lbs)
Drill string is stuck if BF + FBHA > MO
Where MO, maximum over pull:
F, background friction:
FBHA: force exerted on BHA

G. COLLECTION AND ASSESSMENT OF WELL 9 & 10 DATA IN WHICH DIFFERENTIAL STICKING OCCURRED WHEN IT WAS DRILLED THROUGH DAILY WELL REPORT.

Through questionnaire and field trip experience, the well were drilled base on the following data with appreciable occurrences of differential pipe sticking Within High pressure High temperature (HPHT) formation zone WELL 9 & 10 were drilled to appraise the deeper reservoir OKONO deep levels (sands H & I) in the eastern flank of OKONO field with sand-I as the primary target and sand-H the secondary target. Both are deviated well i. e directional drilled well

Table 5 WELL TRAJECTORIES UNDER STUDY DEPTH DATA COLLECTED OF WELL 9 & 10 CONSTRUCTION SUMMARY

Well time estimate	Planned Depth(ft)	Planned Duration
Well time Activity		
Rig move and position	0	6.0
Drilling 81/2" pilot hole	750	1.0
Drilling 36'' hole section	750	1.0
Run and Cmt 30'' conductor pipe	700	2.0
Drill 26'' hole open hole section	1610	2.0
Run & Cmt 20" casing	1610	1.5
Run well + BOP+ Marin rises/Test	1610	2.0
Drill 12 1/4'' pilot hole	0	0.0
Wire line logging/formation Evaluation	0	0.0
Drill 171/2" hole	6500	8.0
Wiper trip condition hole/Mud & POOH for Csg Run	6500	2.0
Run and Cmt 13 3/8'' casing	6500	3.0
N/U And Test BOP	6500	2.0
Drill 12 ½'' to TD @12,500ft -ss	12300	10.0
Wiper trip condition hole/Mud & POOH for Csg Run	12300	2.5
Run & Cmt 9 5/8'' casing	12300	6.0
Drilled 8 1/2'' hole to 14,347ft	13400	2.0

Wiper trip condition hole/Mud & POOH for Csg Run	13400	2.0
Run & Cmt 7'' liner	13400	2.0

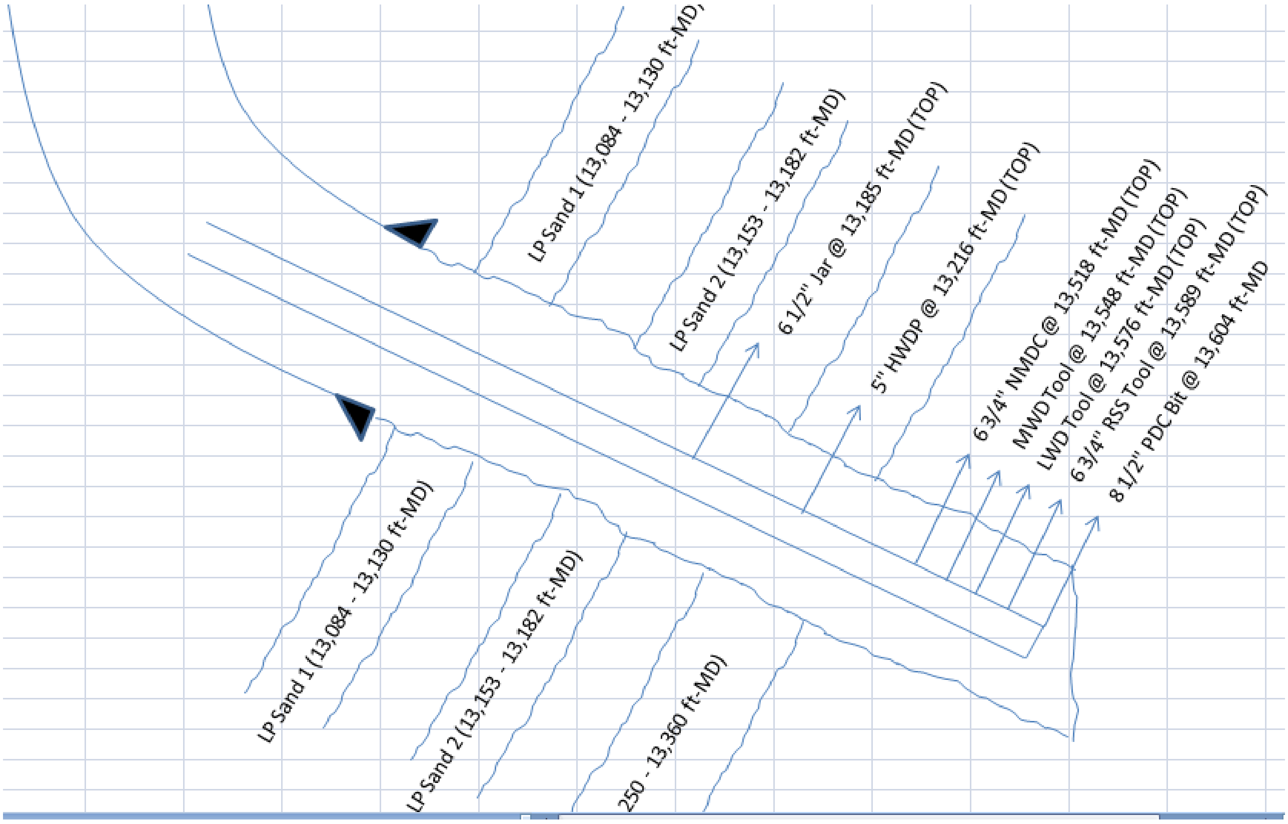


Fig 1 directional well trajectory of Okono we

H. SOME PIPE RELEASING AGENT (PRA) MATERIALS AND LABORTORY APPARATUS

Plate 1 Sample bay

Plate 2 Electro thermal heating mantle

Plate 3 Metler electrical balance

plate 4 separating funnel

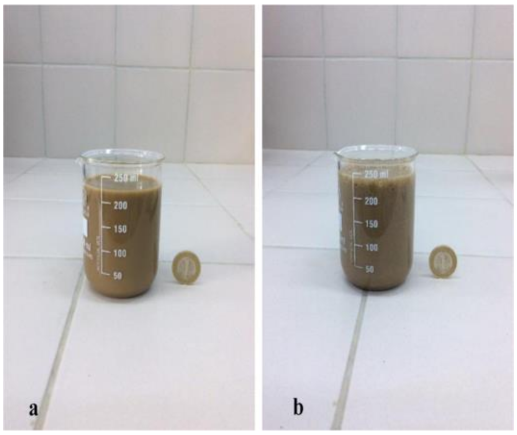


Plate 5 sample of lignosulfonate, unweight fluid

Well 6 & Abura XI well successfully drilled without stuck pipe occurrence (producing wells) data.
The analysis of the data for this well were made by comparing them with the impediment of non-producing well because of differential pressure sticking From drilling report obtained, **(OKONO 6)** is a developmental and deviated well with the following drilled depth; **2000ft, 4000ft, 6000ft, 8000ft, 10000ft, 12000ft, 14000ft and 16000ft .**

WELL XI; is an onshore well, which is producing successfully and is a deviated well. From the well report method and questionnaire we found out that the well was drilled base on the data in table

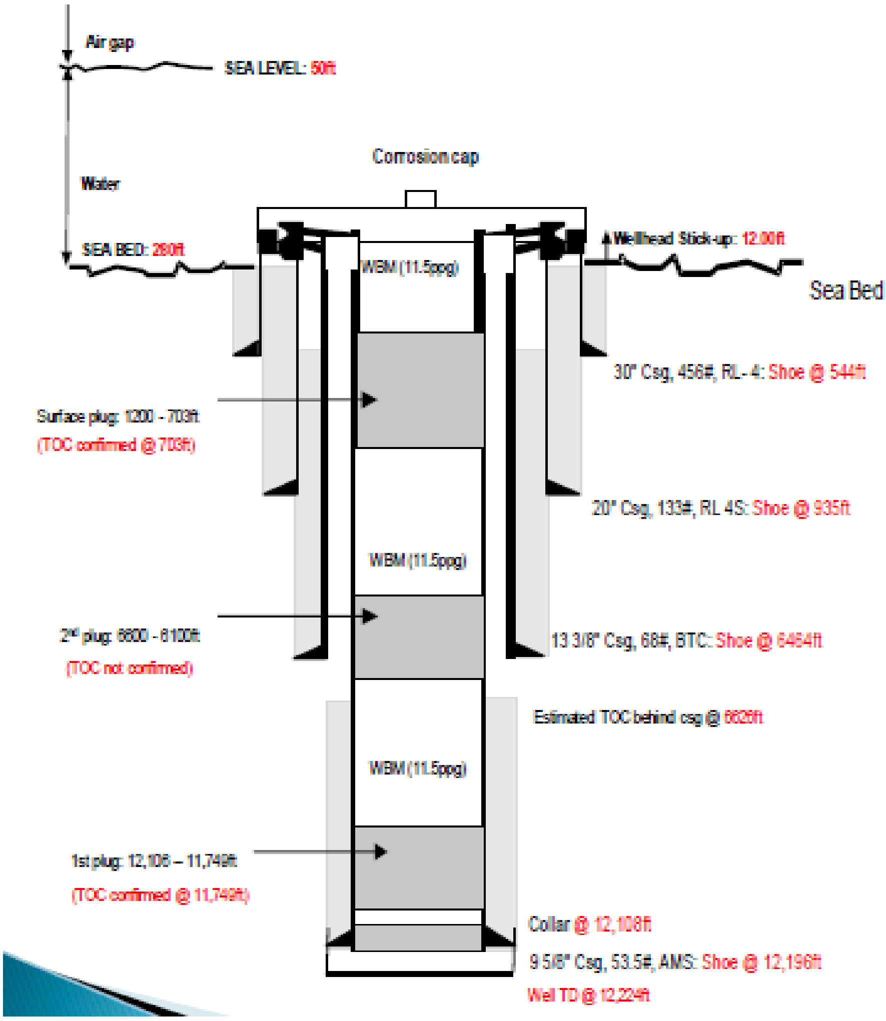


FIG 2 Practical Okono well 6 schematic depth (Deviated well) due to differential sticking

IV. RESULT AND DISCUSSION OF SPOTTING FLUID APPLICATIONS IN THE OIL WELL FIELD UNDER STUDY

i. The adequacy of how spotting fluid and U-tubing method that was received to free stuck pipe caused by differential staying can be applied through the use of simple flow chart simulation model over the underlying mechanical method and hydraulic method that was used in Well 9 and 10 without success.
ii. The impact of stuck pipe occurrence on Well 9 and 10 as contrast and a producing admirably production limit information for efficient purpose.
iii. Analysis of the Well 9 ,10, and Well XI by graphical well profundity information and number of cumulative days spent in penetrating such well , due to possibility of stuck pipe in both veered off well and vertical well.

A. *FREEING STUCK PIPE BY SPOTTING FLUID OR PIPE RELEASING AGENT (PRA) AND U-TUBING OR SURGE METHOD USING SIMPLE FLOW CHART SIMULATION MODEL*.

In Fig 4, the flowchart below, any PRA pill should be spotted within the time of 4h of sticking for better results. After the hours of 16 hours there is a minimal possibility of the pill working, so the method should be discourage after this time in terms of usage. Unlike U-tubing, there are no hydrostatic limitations on using pipe discharge agents (PRAs). For environmental consistence in any case, a great PRA line up with the nature of the environment should be adopted or used.

- WITH SPOTTING FLUID; the final product is that the filter cake shrinked, resulting in a littler contact region between the filter cake and the stuck pipe. Literature shows that the osmotic pressure between salt-saturated calcium chloride brine inverse crisp water shale at 25°C can reach up to 24,400 PSI. In the meantime, the osmotic pressure between salt-saturated sodium chloride brine inverse new water shale at 25°C can arrive at 5,800 PSI. This makes the calcium chloride brine transcendently used in oil-base muds and spotting fluids. The freeing fluid is constantly lighter than the mud in the opening, so there will be extensive movement up the gap after it is spotted. It is important that another slug be spotted about like clockwork. At any rate eight hours should be took into consideration the procedure to produce results. Torqueing the pipe during this time is fitting and limited quantities of weight can be left on the stuck pipe on the off chance that it is off base.

- WITH U-TUBING; as the fluid is spotted around the stuck pipe, the fluid flowed back, thereby bringing down the fluid level in the annulus; therefore the hydrostatic pressure on the formation is reduced. In the event that this is sufficient to at any rate equal the formation pressure, the string will come free. This method of freeing the pipe is protected since the pressure can be reduced in a few stages. The mud weight itself isn't reduced, and if a kick occurs, the fluid which was flowed out of the annulus can control it.

The weight of an oil-based mud oscillates between *(7.5 lb/gal) to (22 lb/gal)*. The bottom hole density is more consistently affected by temperature and pressure conditions than water-based muds. The temperature increasing will decrease the mud density because of thermal expansion phenomena, while the high pressure will increase the density compressing the oily phase
.

B. *THE FLUID AND RHELOGICAL PROPERTIES*

The Viscosity is affected either by temperature and pressure. As the temperature builds, the viscosity diminishes. Then again, the pressure expanding causes a viscosity expanding. Marsh viscosity of the liquid is firmly impacted by temperature conditions. This sort of estimation, be that as it may, has a demonstrative capacity the rheological properties of mud are controlled through a rotating viscometer. The plastic viscosity, yield point and gel quality are estimated (as indicated by the pseudo plastic rheological model) with a rheometer. A most precise examination of the mud rheology is finished by the "Power Law" model. Drilling cuttings and weighting materials in suspension are observed through the examination of the gel quality for static settling or through perusing at 3 or 6 rpm for dynamic settling.

Rheological tests on oil-based mud must is done at the base opening temperature as the plastic viscosity of these muds is truly reasonable to temperature varieties. By and large, the higher the temperature, the lower the plastic viscosity. The yield is very impacted by the temperatures in which tests are made. In any case, the reliance of the yield point on temperature is considerably progressively worried above 175°C. The yield point is expanded with organoliphic mud, fluidizing or weakening with oil. The gel quality acts like the yield point. It increments including organoliphic dirts water or rheological modifiers and then again, it will diminish with the utilization of wetting specialists, fluidizers and weakening with the base oil

C. *THE GRAPH OF PROBABILITY OF PIPE FREEING AGAINST SOAKING TIME (HOURS)*

Graph and table below shows the likelihood of the pipe coming free against absorbing time hours. This was used to calculate the time a pill was left to splash before circulating out and chilling out. From examine, it is prudent to douse for a minimum of 20 hours and a maximum of 40 hours. Before attempting to liberate stuck pipe from the formation

TABLE 6- THE GRAPH OF PROBABILITY OF PIPE FREEING AGAINST SOAKING TIME (HOURS)

Probability of pipe freeing (%)	0, 10, 20,30,40,50, 60, 70 80, 90.
Soaking Time (HOURS)	0, 10, 20, 30, 40, 50.

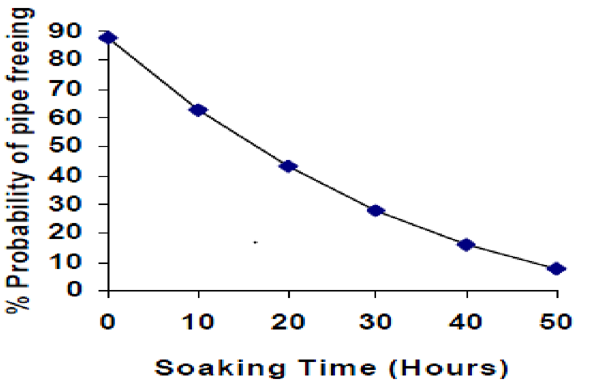
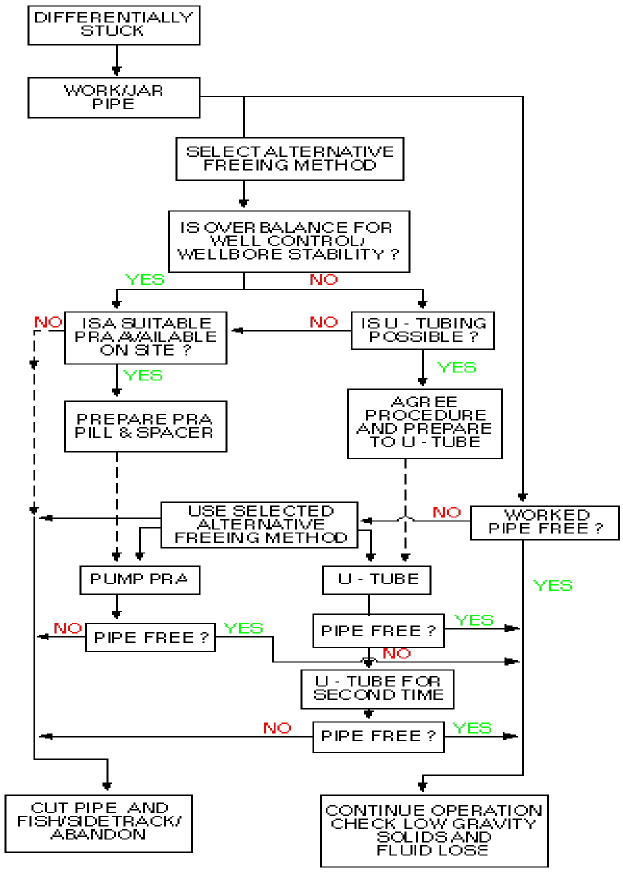


Fig 3. The graph of probability of pipe freeing against soaking time



LEGEND; PRA = pipe release agent.

Fig 4 freeing flowchart by PRA and U- tubing application

D. THE INITIAL MECHANICAL JARRING AND HYDRAULIC METHOD THAT WAS USED IN WELL 10 & 9 WELL IN FREEING STUCK PIPE WITHOUT SUCCESS (NO SUCCESS).

Number of reasons in which the jars fail to free the stuck pipe.

i. Incorrect weight applied to fire container - at least one presumptions in computation error.
ii. *Pump open force exceeds compression force at jar (no down jar action).*
iii. *Stuck above the jar.*
iv. *Jar mechanism failed.*
v. *Jar not cocked.*
vi. *Drag too high to allow sufficient force to be applied at the jar to fire it (usually mechanical jars).*
vii. *Well path is such that compression cannot be applied to the jar. (No down jar action).*
viii. *Jar is firing but impact cannot be felt at the surface.*
ix. *Right hand torque is seems trapped in torque at a set able mechanical jars.*
x. *Not waiting long enough for the jar to fire*

E. MATHEMATICAL MODEL THAT WAS ADOPTED WITHOUT SUCCESSFUL OUTCOME

Tripping in; over pull/ container upwards
Tripping out; slack- off/ container downwards
Circulation if potential was set up.

The Pipe Was Worked In a Descending Order; Worked torque into the string down to the suck point which is normally 0.75 Turns/100ft know the impact of the torque on the containers, slack off and let the containers fire down

The Pipe Was Worked upwards; the force was expanded gradually or maximally applied from the beginning at first container with 40-50,000LBS
Over the force required to trip the jar. The force increase gradually was over an hour no success.

Overpull calculations
Beginning Overpull
1/2 x BHA weight underneath jars (in air)
Calculation of Maximum Overpull
Estimate frail purpose of string. (Typically drill pipe at surface, however check if running a blended
String eg. 6.5/8"/5" drillpipe.)
Most extreme overpull at powerless point (Tm)
Tm = 0.85 x Tensile quality at feeble point
Calculate weight of drill string in air above feeble point (Wsw).
(Wsw = 0 if feeble point at surface).
Most extreme overpull on weight indicator (Wim):
Wim = Wb + Tm + Wsw
Calculation of Overpull at stuck point (To):
To = Wi - Wb – Ws
where:
Wb = square weight
Wi = weight indicator perusing
Ws = weight of drill string in air above stuck point
Note:
Wi should never surpass Wim
Jarring calculations
Burden Required to Trip Jar Upwards
Ls = Wi - Wj + Lj+ Dh – Pf
Burden Required to Trip Jar Downwards
Ls = Wi - Wj - Lj - Dh – Pf
Where:
Ls = surface burden to operate jar (lbs)
Wi = weight indicator perusing (lbs)
Lj = wanted jar load (lbs)
Dh = opening drag (lbs) Wj = weight of BHA in air beneath jar (lbs)
Pf = siphon open force (lbs)

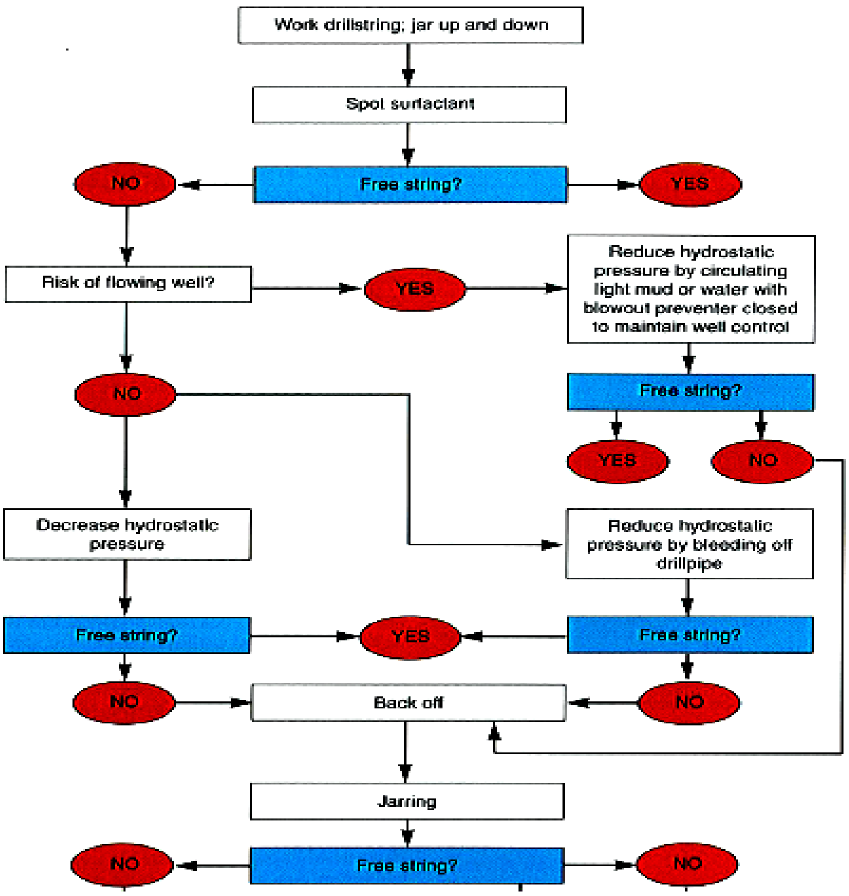


Fig. 5 Flow chart of free stuck pipe by hydraulic and mechanical method (NO SUCCESS)

F. THE EFFECT OF STUCK PIPE OCCURENCES ON OKONO 9 AND 10 WELL AS COMPARE WITH A PRODUCING WELL PRODUCTION CAPACITY DATA FOR ECONOMICAL PURPOSE.

Differential sticking has been one of the major challenges in most of the NPDC WELLS with negative effect on drilling efficiency, well cost and production capacity. From data collection, it was found that losing an oil well because of differential pressure sticking and stuck pipe can lead to huge economic loss of about $60,000,0000 per well. As a result of this impediment WELL 9 and 10 are not producing, therefore shutdown for the quest of drilling another well, which in turn lowering NPDC production capacity of barrel of crude oil generated per day in the WELL area. So the answer to increase their hydrocarbon reservoir base around WELL area is to drilled more well successfully as possible with a lasting solution to differential pressure sticking and stuck pipe as regards to the method suggested in this research work so as to eliminate and prevent future occurrence of such problem, because the preventive and predicting stuck pipe are more economical to solving the problem when stuck in the hole.

TABLE 7- PRODUCTION DATA TABLE

WELL NAME	OKONO 6	OKONO 9	OKONO 10	ABURA XI
PRODUCTION CAPACITY (bopd)	9237	0	0	5000

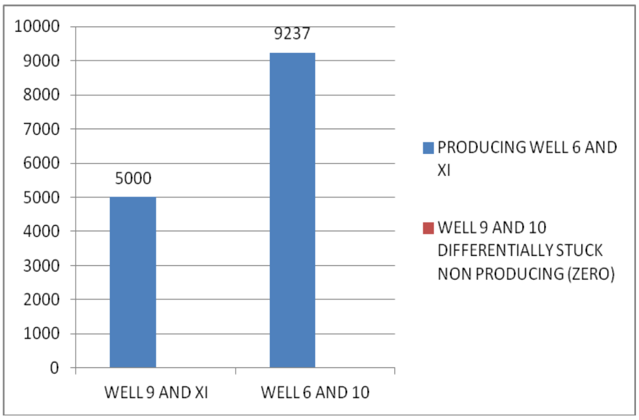


Fig 6 histogram of producing well compared with non producing well

For NPDC to really fulfiled their mission statement of increasing their hydrcarbon reservoir base, more well needed to be drill successfully without impediment of differential pressure sticking and stuck pipe incident as the major problem in the WELL field area, the above chart simply explain the production capacity of WELL 6 with 9237bopd barrel of crude produce per day and that of WELL XI FIELD with production capacity of 5000bopd as compare with WELL 9 &10 with zero production because of the incident of stuck pipe caused by differential pressure sticking, instead of abandoning this well and questing to drilled new once with unforseen circumstances that may generate,the problem of the stuck once can be tackled severly by right method of using spotting fluid and U- TUBE method as regards to the one analysed in this research work along side with proper jarring method to free this pipe thereby increasing the number of wells and also result in huge economical saving.

The second figure describe huge amount loss to differential stuck problem per well, as this problem continueously escalating in the WELL FIELD AREA production capacity keep decreasing and thereby result to huge economical losses.

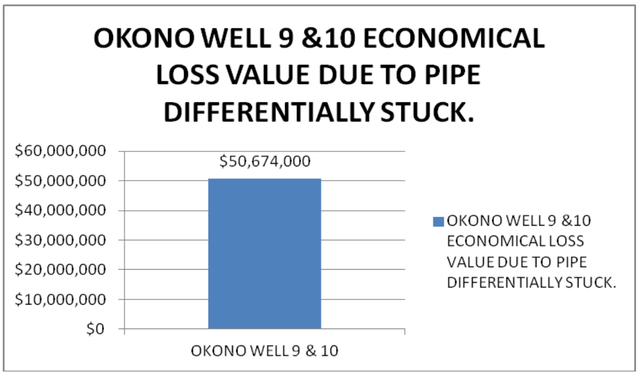


Fig 7 Bar chart of economical loss due to pipe differentially stuck

The figure above describe huge amount loss to differential stuck problem per well, as this problem continuesly escalating in the OKONO FIELD AREA production capacity keep decreasing and thereby result to huge economical losses.

G. *THE DATA OF AMOUNT LOSS ECONONMICALLY IN OKONO 10 OR J DUE TO STUCK PIPE CAUSED BYDIFFERENTIAL PRESSURE*.

TABLE 8 - WELL COST ESTIMATE LOSS PER WELL

S/N	DESCRITION OF COST ITEM	AMOUNT ($x1000)	PERCENTAGE OF WELL COST (%)
1.0	**INTANGIBLE COSTS**		
1	Rig Operating Days (67days)	20,837.00	41.12
2	Rockbit	300.00	0.59
3	EIA	68.00	0.13
4	Mud Chemical / Engineering	1,200.00	2.37
5	MWD/LWD	2,400.00	4.74
6	Directional Drilling	420.00	0.83
7	Mud Logging	250.00	0.49
8	Cementing / Additives / Accessories	1,500.00	2.96
9	Casing Running	450.00	0.89
10	Solids Control	1,100.00	2.17
11	Jars/Tools Rental	450.00	0.89
12	ROV	1,600.00	3.16
13	Wireline Logging	2,300.00	4.54
14	Rig Positioning	100.00	0.20
15	Seabed Survey	111.00	0.22
16	Supply Vessel 1	1,200.00	2.37
17	Supply Vessel 2	1,200.00	2.37
18	Security Vessels	1,920.00	3.79
19	Borehole Survey	85.00	0.17
20	Helicopter Services	2,400.00	4.74
21	Drilling Consultant	240.00	0.47
22	Homage	34.48	0.07
23	ICT	240.00	0.47
24	Logistics Handling	2,300.00	4.54
25	Fuel, Lube, Water	182.00	0.36
26	Welding Services	80.00	0.16
	SUB-TOTAL	**42,967.48**	**84.79**
27	**TANGIBLE COSTS**		
28	Well Head and Accessories	950.00	1.87
29	Casings	1,820.00	3.59
30	Liner hanger & Accessories	330.00	0.65
	SUB-TOTAL	**3,100.00**	**6.12**
31	**TOTAL**	**46,067.48**	
32	**ADD 10% CONTINGENCY**	**4,606.75**	**9.09**
	GRAND TOTAL	**50,674.23**	**100.00**

TABLE 9- TEMPERATURE PROFILE OF THE WELL FORMATION TABLE

DEPTH(TVD)ft	***TEMP.DEG.^{0}F***
0	0
2000	110
4000	140
6000	170
8000	190
10000	230
12000	260
14000	300
16000	330

H. TEMPERATURE GRAPH INCREASE WITH DEPTH

The graph below show how temperature increased with depth when the well was drilled and as you drilled below the formation the higher the temperature and the higher the risk of stuck pipe in the high temperature high pressure zone.

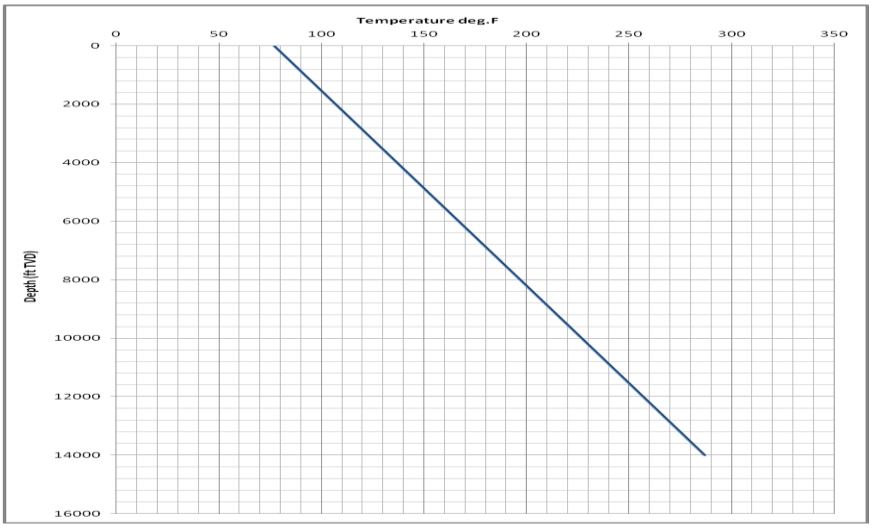


Fig. 10 temperature graph increase with depth graph of depth of Okono10 well

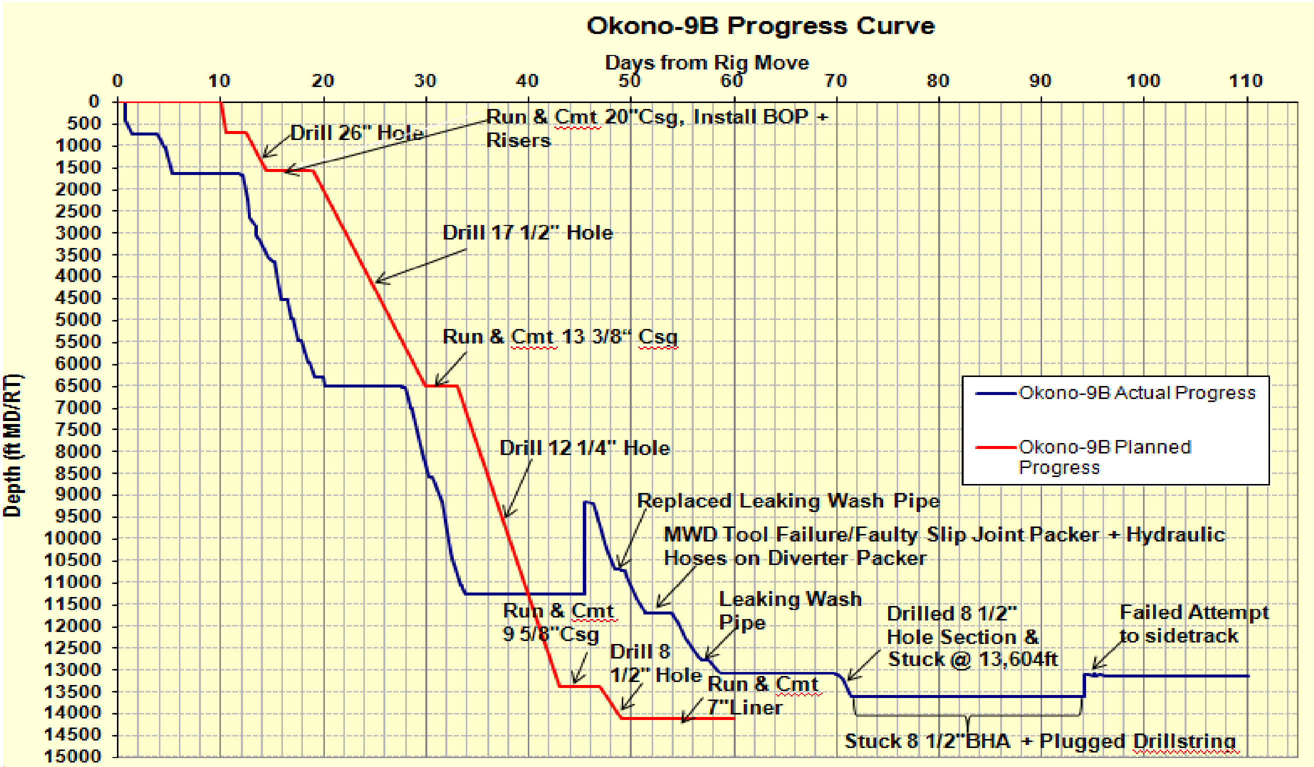


Fig 11 Okono 9 graph showing differential pressure sticking and stuck pipe with depth

The graph above show the depth at which differential pressure sticking occurred and stuck pipe when the well was drilled and trying jarring method of freeing this pipe prove abortive and is summarize below.

1ST STUCK PIPE

i. First stuck pipe occurred @ 11280ft MD on June 15, 2013.
ii. Severed drill collar @ 10960ft MD on June 20, 2013.
iii. Set 500ft of cement plug with TOC @ 10460ft on June 24, 2013.
iv. Sidetracked well @ 9154ft MD on June 27, 2013.

2ND STUCK PIPE

v. Second stuck pipe occurred @ 13604ft on 23/7/2013.
vi. Lost rotation & observed 200psi pressure increase.
vii. Worked string and regained circulation but no rotation.
viii. Unable to Jar free stuck drill string (Jar cocking & firing well).
ix. Discovered restriction in drill string @ 10710ft while RIH FPI tool on 26/7/2013.
x. Dislodged restriction from 10710ft - 13520ft & recovered "G" sand on August 7, 2013.
xi. Drillstring severed @ 13170ft on August 8, 2013.
xii. Set 500ft of cmt plug above fish with TOC @ 12520ft on 10/8/2013.
xiii. Attempted to sidetrack in 8½" open hole @ 13091ft & unsuccessful.

And it can be seen that the well above is a deviated well with a total depth of 13500f

TABLE 10- TEMPERATURES AGAINST PRESSURE GRAPH OKONO 10

DEPTH(ft TVD)	***PRESSURE(ppge)***
0.00	0.00
2000	8
4000	9
6000	10
8000	11
10000	12
12000	13
14000	14
15000	15
16000	16
17000	17
18000	18
19000	

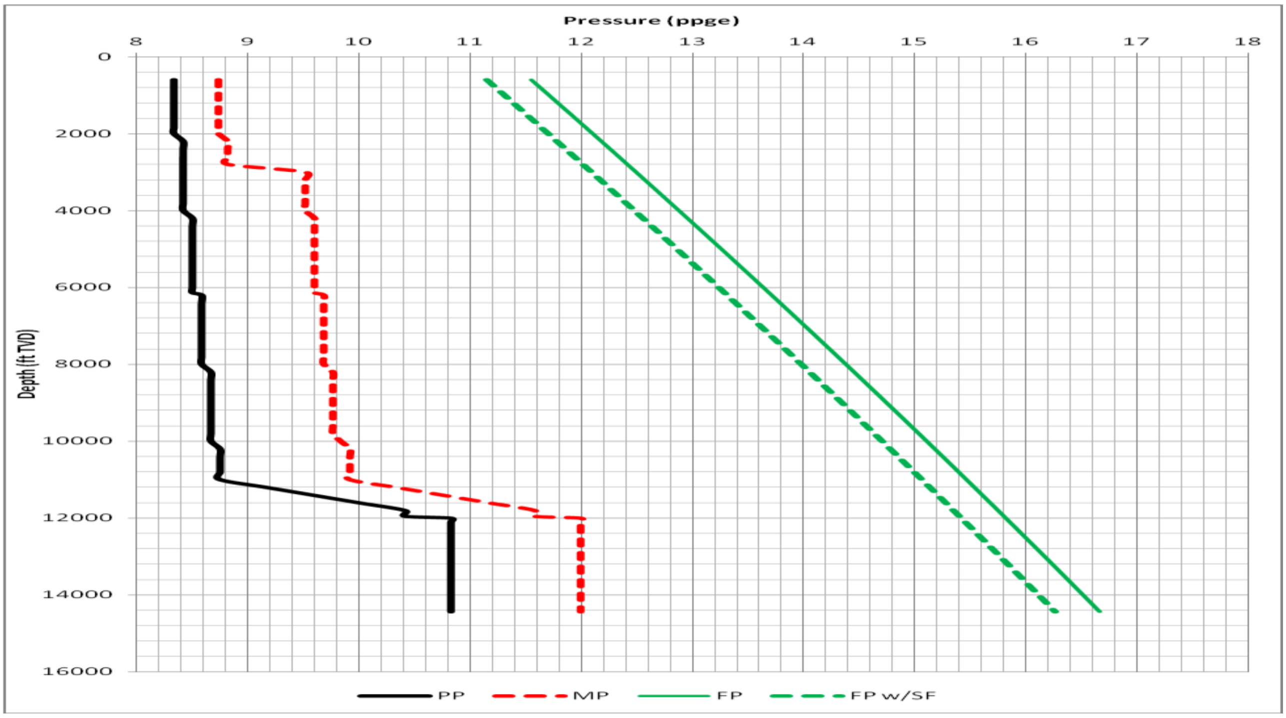


Fig. 12 Temperatures against Pressure Graph Okono 10

Table 11- ABURA XI WELL DATA

O/B(psi)	MW(ppg)	P/P(ppg)	FP(ppg)	Depth(ft)	Depth(ft)(TVD)
16.22	8.6	8.34	9.5	1200	1200
112.32	8.7	8.34	15	6000	6000
209.49	8.8	8.34	15	8920	8758
185.95	9.0	8.6	15	9118	8940
217.24	9.0	8.6	16	11280	10444
296.74	9.1	8.6	16	13450	11413
320.58	9.1	8.6	16	15500	12301

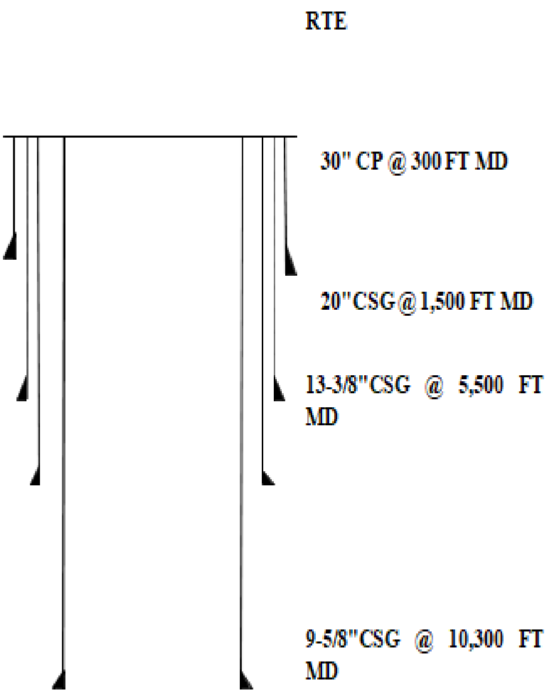


Fig 14 abura well-**xi vertically producing well**

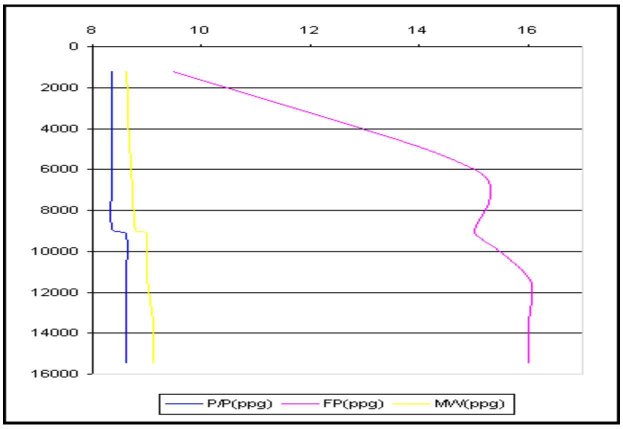


Fig. 15 graph of depth (ft) against mud weight (ppg) of Abura xi well

The above graph shows ABURA vertical well, producing successfully with production capacity of about 5000bopd at about 10,500ft and from practical point view and well data analysis, it can be deduced that the chance of getting stuck in a deviated well are far higher than the vertical well, since more well are needed to be drilled and technology has drastically improved more hydrocarbon are targeted directionally in the reservoir than vertical drilled well, p/p represent pore pressure, FP represent fracture point at which formation can fracture and mud weight (MW) in ppg.

V. CONCLUSION AND RECOMMENDATION

A. CONCLUSION

As for the application of spotting fluid or PRA and U-TUBE Method with typical oil and gas well data obtained in this study, we can emphatically say that spotting fluid and U- tube alongside with proper jarring mechanism are considered as appropriate method in freeing stuck pipe caused by differential pressure sticking and they are extremely capable of eliminating this common problem in NPDC oil and gas drilling operation and production operations and at the same time proved helpful in decreasing economical loss of well suspension or abandonment in the quest to drill new once due to this problem. As technology begins to improve, more deviated well and sensitive formations are drill, stuck pipe problem needs to be put into consideration to avoid this unforeseen problem during drilling operation, because research and field data analysis used in this project work reveals that the chances of getting stuck in a deviated wells are more higher than that of vertically drill wells as a result of this understanding the reasons for pipe sticking and executing great drilling practices, for example, great mud and filter cake properties, pipe and drill string development, wiper trips, taper type and spiral bottom hole assembly, formation and hydrostatic pressure, controlling entrance rate and limiting contact area, the sticking problem can be diminished or total eliminated, resulting in enormous savings and increase production capacity of crude oil for the company. This work also revealed that when freeing stuck pipe by U-tube method is very safe since the pressure can be reduced in several steps. The mud weight itself is not reduced, and if a kick occurs, the fluid which was flowed out of the annulus can control it and that of spotting fluid or PRA is that the filter cake will shrink, resulting in a smaller contact area between the filter cake and the stuck pipe, , the freeing fluid is perpetually lighter than the mud in the hole, so there will be impressive migration up the gap after it is spotted.

In this research work, it can be succinctly reveals that flowchart model has been used to enumerate the way and manner spotting fluid and U- TUBE method can be practically adopted in the field when differential pressure sticking and stuck pipe occurs and also shows it efficiency and effectiveness over the use of hydraulic and mechanical method that was initially used by NPDC in freeing this pipe. Graphs were also used to evaluate and analyzed the stuck zone of this pipe and manner of well deviation in regards to stuck pipe, also chart that explained producing well and none producing were drawn and analyzed.

B. RECOMMENDATION

We can therefore recommended based on the research work that spotting fluid and U- tube method are highly effective in freeing stuck pipe in stubborn and sensitive formation zone such as high temperature high pressure (HTHP) . NPDC to dim it fit to always adopt this method when stuck pipe occur due to differential pressure sticking in their drilling and production operation in order to increase their hydrocarbon reservoir base and to maximize profit and reduce the cost of loosen well due to stuck pipe problem.

C. PREVENTIVE MEASURE RECOMMENDED AGAINST FUTURE OCCURRENCE OF STUCK PIPE

- **i.** Need for regular and improved communication between NPDC & Management of all Service Providers.
- **ii.** All well-site reps must communicate all abnormal situations to their supervisor(s) at base as often as observable.
- **iii.** Regular & effective communication on the rig (inform team members what hole is saying; handover hole condition report at shift change ;brief your relief; share knowledge).
- **iv.** Unavailability of pipe freeing chemicals on the rig at both times, and delay in spotting the pipe freeing chemicals when got stuck should be eliminated because this may lead to inability to free the strings on both occasions.
- **v.** Mud engineering contractor should ensure mobilization of adequate quantity of pipe freeing agents + additives at the beginning of operations and must also ensure prompt replenishment when used.
- **vi.** Wrong pore pressure prediction should be avoided so as to avoid stuck pipe.
- **vii.** All contractors must improve on periodic maintenance to forestall frequent failure of equipment.
- **viii.** All equipment must be checked for potential drop objects before any operation on the rig floor.
- **ix.** Keep track of differential pressure in sands if possible.
- **x.** Don’t stop too long for a survey. If necessary continue drilling after the precursor comes up.
- **xi.** Keep the mud weight under control.
- **xii.** Use a short BHA. Make frequent wiper trips

REFERENCES

[1] Aadnoy BS, Larsen K, Berg PC (1999). “Analysis of Stuck Pipe in Deviated Boreholes”, paper SPE 56628 presented at the 1999 SPE Annual Technical Conference and Exhibition, Texas, Oct. 3-6.

[2] Aadnoy, B.S., 2003. Introduction to special issue on borehole stability. J. Petrol. Sci.

[3] Aadnoy, B.S., Belayneh, M., 2004. Elasto-plastic fracturing model for wellbore sta- bility using non-penetrating fluids. J. Pet. Sci. Eng. 45 (3-4), 179–192..

[4] Abu Dhabi Company for Onshore Oil Operations (ADCO) Drilling manual volume-1

[5] Adams N (1977a). Member SPE-AIME, Prentice and Records Enterprises, Inc.“A Field Case Study of Differential-Pressure Pipe Sticking.” SPE 6716.

[6] Adams, N., 1977b. A field case study of differential pressure pipe sticking. SPE 6716, SPE Annual Technical Conference and Exhibition, Denver, Oct. 12.

[7] Agarwal, S.and Agarwal, N., Auto Release Drill Collars, Paper SPE 112348 presented at the Indian Oil and Gas Technical Conference and Exhibition, Mumbai, India, 4-6 March 2008.

[8] Al-Ajmi, A.M., Zimmerman, R.W., 2006. Stability analysis of vertical boreholes using the Mogi-Coulomb failure criterion. Int. J. Rock. Mech. Min. 43 (8), 1200–1211. http://dx.doi.org/10.1016/j.ijrmms.2006.04.001.

[9] Al-Ajmi, A.M., Zimmerman, R.W., 2006. Stability analysis of vertical boreholes using the Mogi-Coulomb failure criterion. Int. J. Rock. Mech. Min. 43 (8), 1200–1211.

[10] Al-Baiyat A, Heinze L (2012). “Implementing Artificial Neural Networks and Support Vector Machines in Stuck Pipe Prediction.” SPE Kuwait International Petroleum Conference and Exhibition, Kuwait City, Kuwait.

[11] Al-Bazali, T., Zhang, J., Chenevert, M.E., Sharma, M.M., 2008. Factors controlling the compressive strength and acoustic properties of shales when interacting with water-based fluids. Int. J. Rock. Mech. Min. 45 (5), 729–738..

[12] Annis MR, Monaghan PH (1962). “Differential Pressure Sticking – Laboratory Studies of Friction between Steel and Mud Filter Cake.” SPE 151. JPT 15(5):537-543.

[13] ARAMCO WELL CONTROL MANUAL October 2002 Drilling & Work over pp. 30

[14] Associate Professor Jorge H.B. Sampaio Jr., PhD April 3, 2007 Curtin University of Technology Department of Petroleum Engineering Drilling Engineering Fundamentals pp 1-27.

[15] Bagheri SS (2000). “A Novel Fuzzy Approach to Modeling and Control and its Hardware Implementation Based on Brain Functionality and Specifications.” The University of Electro Communications.

[16] Bagheri SS, Honda N (1997). “A New Method for Establishment and Saving Fuzzy Membership Functions.” 13th Fuzzy Symposium, Toyama, Japan pp. 91-94.

[17] Bagheri SS, Honda N (1999). “Recursive Fuzzy Modeling Based on Fuzzy Interpolation,”J. Adv. Comput. Intell. 3(2):114–125.

[18] Bagheri SS, Honda S, Yuasa G (1999). "Fuzzy interpretation of human intelligence." Int. J. Uncertainty Fuzziness Knowl.-Based Syst. 7(4):407-414.

[19] Bailey, L., Denis, J. H. & Maitland, G. C. 1991 Drilling Fluids and wellbore stability- current performance and future challenges. In Proc. R. Soc. Chem. 150th Annual Congr. Chemicals in the Oil Industry Symposium (ed. P. H. Ogden), RSC special publication,

[20] Baker Hughes INTEQ 80270H Rev. B December 1995 Drilling Engineering Workbook .A Distributed Learning Course pp.3-82

[21] Baker Hughes INTEQ Training Guide 80912 Rev. B May(1996) Oil Field Familiarization PP. (2-17)

[22] BC oil &Gas commission manual August |(2012) WELL DRILLING GUIDELINE Version 1.5 PP. 10

[23] Bell, J.S., 2003. Practical methods for estimating in situ stresses for borehole sta- bility applications in sedimentary basins. J. Petrol. Sci. Eng. 38 (3-4), 111–119. http://dx.doi.org/10.1016/S0920-4105(03)00025-1.

[24] Biegler, M.W., Kuhn, G.R., 1994. Advances in Prediction of Stuck Pipe Using Multi- variate Statistical Analysis. SPE 27529. In: SPE/IADC Drilling Conference, 15–18

February, Dallas, Texas. http://dx.doi.org/10.2118/27529-MS.

[25] Bourgoyne, Adam; Keith Millheim, Martin Chenevert, F.S. Young Jr. (1986). *Applied Drilling Engineering*. Richardson, TX: Society of Petroleum Engineers. p. 274 p.. ISBN 1-55563-001-4.

[26] Bradley, W.B., Jarman, D., Plott, R.S., Wood, R.D., Schofield, T.R., Auflick, R.A., Cock- ing, D., 1991. A task force approach to reducing stuck pipe costs, SPE 21999. In: IADC/SPE Drilling Conference, Amsterdam, 11–14 March.

[27] Bureau of Land Management, "OnshoreOil and Gas Order No. 1:Approval of Operations on Onshore FederalandIndianOilandGas Leases,"United States Department of Interior,Bureau of Land Management, Washington, D.C., 1983.

[28] Bushnell-Watson YM, Panesar SS (1991). "Differential Sticking Laboratory Tests Can Improve Mud Design." Paper SPE 22549-MS presented at the SPE Annual Technical Conference and Exhibition, 6-9 October, Dallas, Texas.

[29] Bushnell-Watson YM, Panesar SS (1991). "Differential Sticking Laboratory Tests Can Improve Mud Design." Paper SPE 22549-MS presented at the SPE Annual Technical Conference and Exhibition, 6-9 October, Dallas, Texas.

[30] Cheatham, Jr., J.B. 1984. Wellbore stability. *JPT*, June.

[31] Courteille JM Zurdo C (1985). "A New Approach to Differential Sticking." Paper SPE 14244 presented at the SPE Annual Technical Conference and Exhibition, 22-26 September, Las Vegas, Nevada.

[32] Courteille JM Zurdo C (1985). "A New Approach to Differential Sticking." Paper SPE 14244 presented at the SPE Annual Technical Conference and Exhibition, 22-26 September, Las Vegas, Nevada.

[33] Differential-sticking mechanisms and a simple well site test for monitoring and optimizing drilling mud properties. SPE Drill. Completion 15(2):97-104.(2000)

[34] Drillpipe Situations, SPE 14181, SPE Drilling Engineering, September 1987.

[35] Elahi Naraghi M, Ezzatyar P, Jamshidi S (2013). "Adaptive Neuro Fuzzy Inference System and Artificial Neural Networks: Reliable approaches for pipe stuck prediction." Aust. J. Basic Appl. Sci. 7(8):604-618, 2013, ISSN 1991-8178.

[36] Elahi Naraghi M, Ezzatyar P, Jamshidi S (2013). "Adaptive Neuro Fuzzy Inference System and Artificial Neural Networks: Reliable approaches for pipe stuck prediction." Aust. J. Basic Appl. Sci. 7(8):604-618, 2013, ISSN 1991-8178.

[37] 38 (3-4), 79–82. http://dx.doi.org/10.1016/S0920-4105(03)00022-6.

[38] Eng. 38 (3-4), 79–82. http://dx.doi.org/10.1016/S0920-4105(03)00022-6.

[39] ETA Offshore Seminars, Inc.The Technology of Offshore 'Drilling, Completion and Production manual By Shri S. Shankar , DGM(Wells) well logging techniques and formation

[40] Farshad, F., Garber, J. D. and Lorde, J. N., "Predicting temperature profiles in producing oil wells using artificial neural networks", Paper SPE 53738, Presented at the Sixth Latin American and Caribbean Petroleum Engineering Conference held in Caracas, Venezuela, 21-23 April, (1999).

[41] Firoozi, M., Prediction of Bit Wear Using Artificial Neural Network, Ms Thesis, PUT, 2011. Fitzpatrick, M., "Common Misconceptions about the RCRA Subtitle C Exemption from Crude Oil and Natural Gas Exploration, Development and Production," Proceedings from the First International Symposium on Oil and Gas ExplorationWaste Management Practices, pp. 169–179, 1990.

[42] Fitzpatrick, M., "Common Misconceptions about the RCRA Subtitle C Exemption from Crude Oil and Natural Gas Exploration, Development and Production," Proceedings from the First International Symposium on Oil and Gas ExplorationWaste Management Practices, pp. 169–179, 1990

[43] Glenn K.Gabrielsen (2009) well planning and control pp 1, 41,120,180 and 198

[44] Goda, H. M., Maier, H.R., and Behrenbruch, P., "The development of an optimal artificial neural network model for estimating initial, irreducible water saturation-Australian reservoirs", Paper SPE 93307, Presented at the Asia Pacific Oil & Gas Conference and Exhibition held in Jakarta, Indonesia, 5-7 April (2005).

[45] Gonzalez, O., Bernat, H. and Moore, P., The Extraction of Mud-Stuck Tubulars Using Vibratory Resonant Techniques, Paper SPE 109530 presented at the SPE Annual Technical Conference and Exhibition, Anaheim, California, U.S.A., 11-14 November 2007.

[46] Halliday, W. and Clapper, D., Toxicity and Performance Testing of Non-Oil Spotting Fluid for Differentially Stuck Pipe, Paper SPE/IADC 18684 presented at the SPE/IADC Drilling Conference, New Orleans, Louisiana, U.S.A., 28 February-3 March 1989.

[47] Helmick WR, Longley AJ (1957). "Pressure Differential Sticking of Drill Pipe and How It Can Be Avoided or Relieved.', Oil Gas J. 55:132.

[48] Hempkins WB, Kingsborough R.H, Lohec WE, Nini CJ (1987). "Multivariate Statistical Analysis of Stuck drill Pipe Situations." SPE DRILLING ENGINEERING.

[49] Hempkins WB, Kingsborough RH, Lohec WE, Nini CJ (1987). "Multivariate Statistical Analysis of Stuck drill Pipe Situations." SPE DRILLING ENGINEERING.

[50] Howard JA (1994). Enertech Engineering & Research Co., and Glover.S.S., Enertech Europe ''Tracking Stuck Pipe Probability While Drilling.'' Paper SPE 27528 presented for Presentation at the 1994 IADC/SPE Drilling conference held in Dallas, Texas.

[51] Isambourg P, Ottesen S, Benaissa S, Marti J (1999). "Down-Hole Simulation Cell for Measurement of Lubricity and Differential Pressure." Paper SPE 52816-MS presented at the SPE/IADC Drilling Conference, 9-11 March, Amsterdam, Netherlands.

[52] J.A. "Jim" Short (1990) a source book on oil and gas well drilling from exploration to completion pp .117 &241

[53] Jahanbakhshi R, Keshavarzi R (2012). Intelligent Prediction of Differential Pipe Sticking by Support Vector Machine Compared with Conventional Artificial Neural Networks: An Example of Iranian Offshore Oil Fields. SPE Drill. Completion J. 27(4):586-595.

[54] Jahanbakhshi R, Keshavarzi R (2012). Intelligent Prediction of Differential Pipe Sticking by Support Vector Machine Compared with Conventional Artificial Neural Networks: An Example of Iranian Offshore Oil Fields. SPE Drill. Completion J. 27(4):586-595.

[55] Jardine, S.I., McCann, D.P., Barber, S.S., 1992. An Advanced System for the Early Detection of Sticking Pipe, SPE 23915, SPE Drilling Conference. New Orleans, pp. 18–2

[56] Kemp, Gore. 1986. *Oilwell Fishing Operations: Tools and Techniques*.

[57] Kessler, C., Dorffer, D., Crawford, D., Dehart, R. and Weiser, J., Case Histories of a New Wireline Logging Tool for Determination of Free Point in Support of Drilling and Pipe Recovery Operations. SPE/IADC 119907, presentation at the SPE/IADC Drilling Conference and Exhibition held in Amsterdam, The Netherlands, 17–19 March 2009.

[58] Miri R, Sampaio J, Afshar M, Lourenco A (2007). 'Development Of Artificial Neural Networks To Predict Differential Pipe Sticking in Iranian Offshore Oil Fields. Paper SPE 108500 presented at the 2007 international Oil conference and Exhibition in Mexico held in Veracruz, Mexico.

[59] Mita T (2000). "Introduction to Nonlinear Control – Skill Control of Underactuated Robots." (Japanese), Syokodo Pub. Co.

[60] Mohaghegh, S. D., Virtual Intelligence Applications in Petroleum Engineering: Part 1–Artificial Neural Networks, paper SPE 58046, JPT, 64, (September 2000).

[61] Mohammed A., Okeke C.J. and Abolle-Okoyeagu I., 2012. Current Trends and Future Development in Casing Drilling, *International Journal of Science and Technology,* Vol. 2 (8): 567-582.
[62] Mohanna, A., Voghell, M., Alali, A., Bakir, R. and Al-Mousa, A., A Step Change in Fishing Efficiency: Recovering Stuck Pipe Using the Fishing Agitation Tool, SPE 160880, presentation at the SPE Saudi Arabia Section Technical Symposium and Exhibition held in Al-Khobar, Saudi Arabia, 8–11 April 2012.
[63] Murillo A, Neuman J, Samuel R (2009). "Pipe Sticking Prediction and Avoidance Using Adaptive Fuzzy Logic and Neural Network Modeling." Paper SPE 120128 presented at Production and Operations Symposium held in Oklahoma City, Oklahoma, USA.
[64] Nigeria Petroleum Development Company (NPDC) *Drilling Department Training resource* manual 2010 volume 1.section 1-30
[65] Nishino L, Tagawa A, Shmi H, Odaka T, Ogura H (1999). “Hierarchical Fuzzy Intelligent Controller for Gymnastic Bar Action.” J. Adv. Comput. Intell. 3(2):106-113.
[66] Practical Eyes Saw Experience Knowledge both Onshore and Offshore drilling operations
[67] PULJET KONSULT (2010) WELL CONTROLS EQUIPMENT Drilling & Well Services Training manual.pp 1-10.
[68] Reid P, Meeten G, Way P, Clark P, Chambers B, Gilmour A, Sanders M
[69] Sagha H, Bagheri SS, Khasteh H, Kiaei AA (2008). “Reinforcement Learning Based on Active Learning Method.” IEEE Second Int. Symp. Intell. Inf. Technol. Appl. 5:598–602.
[70] Sakurai Y, Honda N, Nisbino J (2003). "Acquisition of Knowledge for Gymnastic Bar Action by Active Learning Method." J. Adv. Comput. Intell. Intell. Inform. (JACIII) 7:1.
[71] Schlumbearger training manual (2010) Introduction to Drilling technology pp32
[72] **Schmidt et al. 2004**. Schmidt, G.A., D.T. Shindell, R.L. Miller, M.E. Mann, and D. Rind, 2004: General circulation modelling of Holocene climate ...
[73] Shadizadeh, S. R., Karimi, F. and Zoveidavianpoor, M., Drilling Stuck Pipe Prediction in Iranian Oil Fields: An Artificial Neural Network Approach, Iranian Journal of Chemical Engineering Vol. 7, No. 4 (Autumn), IAChE, 2010.
[74] Sharif QJ (1997). “A Case Study of Stuck Drill pipe Problems and Development of Statistical Models to Predict the Probability of Getting Stuck and If Stuck, the Probability of Getting Free.” University of Engineering & Tech, Lahore, Pakistan.
[75] Shell Intensive Training Programme manual (SPDC) Well Engineering Cost pp.31-54.
[76] Shell petroleum Development company (SPDC) standard drilling procedures manual REV 4-2007 chap.12 well evaluation and control
[77] Shell Special Intensive Training Programme manual drilling problem pp.4&10
[78] Siruvuri C, Halliburton Digital and Consulting Solutions, Nagarakanti S, Samuel R (2006). “Stuck Pipe Prediction and Avoidance: A Convolutional Neural Network Approach.” Paper SPE 98378 presented at the 2006 IADC/SPE Drilling Conference, Miami, Florida.
[79] Symposium held in Oklahoma City, Oklahoma, USA.
[80] T/27P BARRAMUNDI-l August, (1999) OPERATIONS MANUAL pp5910-01/0172.
[81] TAMU – Pemex drilling manual 2013 Offshore Drilling technology.
[82] Torne, J., Rourke, M., Derouen, B. and Kessler, C., Middle East Case-Study Review of a New Free-Pipe Log for Stuck-Pipe Determination and Pipe-Recovery Techniques, SPE 147859, SPE Asia Pacific Oil and Gas Conference and Exhibition held in Jakarta, Indonesia, 20–22 September 2011.
[83] USEPA, “RCRA Information on Hazardous Wastes for Publicly Owned Treatment Works” Office of Water Enforcement Permits, Washington, D.C., 1985.
[84] Wang, Y., Dusseault, M.B., 2003. A coupled conductive-convective thermo-por- oelastic solution and implications for wellbore stability. J. Pet. Sci. Eng. 38 (3-4), 187–198.
[85] WARREN, T., TESSARI, R. and HOUTCHENS, B., 2004. *Directional casing while drilling. Proceedings of World Oil Casing Technical Conference.* 30-31March 2004. Houston, Texas: World Oil.
[86] Weakley RR (1990). Chevron Services Inc. “Use of Stuck Pipe Statistics to Reduce the Occurrence of Stuck Pipe.” SPE 20410.
[87] WILLIAM C. LYONS 2010 working guide to drilling equipment and operations pp 32.
[88] William C., Lyons, P.E., Plisga, Gary J., 2005. Standard Handbook of Petroleum and Natural Gas Engineering, 2nd Ed. Gulf Professional Publishing, pp. 4–378.
[89] Wisnie, A.P., Zheiwei, Z., 1994. Quantifying stuck pipe risk in gulf of mexico oil and gas drilling. SPE 28298. In: SPE Annual Technical Conference and Exhibition, 25-28 September, New Orleans, Louisiana,
[90] Yarim G, Uchytil R, May R, Trejo A, Church P (2007). “Stuck Pipe Prevention – A Proactive Solution to an Old Problem.” Paper SPE 109914 presented at the SPE Annual Technical Conference and Exhibition, 11-14 November, Anaheim, California.
[91] Zeynali, M.E., 2012. Mechanical and physico-chemical aspects of wellbore stability during drilling operations. J. Pet. Sci. Eng. 82-83, 120–124.
[92] Zoback, M.D., Barton, C.A., Brudy, M., Castillo, D.A., Finkbeiner, T., Grollimund, B.R., Moos, D.B., Peska, P., Ward, C.D., Wiprut, D.J., 2003. Determination of stress orientation and magnitude in deep wells. Int. J. Rock. Mech. Min. 40 (7-8), 1049–1076.

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