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Remediation of Oil Production by Matrix Acidizing Method on an Oil Well

Kasi Njeudjang[a], Justine Yandjimain[b], Madeleine Nitcheu[c], and Théophile Ndougsa-Mbarga[b]

a Department of Quality Industrial Safety and Environment. National Advanced School of Mines and Petroleum Industries. University of Maroua. PO. Box: 46,Maroua, Cameroon
b Department of Physics, Advanced Teacher's Training College, University of Yaoundé I, PO. Box 47, Yaoundé, Cameroon
c Department of Basic Scientific Teaching, School of geology and mining engineering, University of Ngaoundere, P.O. Box 115 Meiganga, Cameroon

Abstract

The remediation oil production by matrix acidizing method on the well named "X" (for confidential reasons) is scrutinized in this paper. Initial production of 1150 bpd, production index of 2.8 STB/Psi/d and permeability of 150md, in 2018 two years down the lane this dropped to 450 bpd, production index 0.7 STB/Psi/d. The declined observed on the production index is trouble shouted and after elimination of (no completion damage/perforation damage), the skin is calculated by carrying out a well test (build-up test) whose extrapolation in excel over times gave us a skin of 40.The reservoir heterogeneity, containing >20% of feldspar, carbonates and paraffin's guided thematrix acidizing design and treatment proposition to remedy this problem. A positive displacement pump (HT400), boosted by a centrifugal pump were used to pump the acid treatment through high pressure treating line downhole. Halliburton insite for stimulation the (IFS) software monitored treating pressure and surface flow rate, keeping injection rate below fracturing pressure. PipeSim software is used to run the nodal analysis before and after treatment this helped to forecast optimal production rates and pressure after treatments. Matrix acidizing method applied on the well X increased the production to 850 bpd with production index of 2 STD/psi/d, skin - 1.5. The economic benefit to the company stood at (profit oil 21,699,500 USD.) over a two years period of production. Meanwhile uncertainties in demand and supply of crude oil at the international market cause constant fluctuation in oil prices, this should be strongly considered upon execution of this project. Overall applications of this acidizing treatment can be carried out on reservoirs with similar mineralogy. HCl/HF blend dissolves sandstone, mud stone and calcite minerals thus reservoir porosity and permeability can be enhanced in regions extending several meters around the injection well.

Keywords: Flow rate, matrix acidizing method, skin, productivity index, well, fluid dynamics.

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1- Introduction

The world energy demand increases by 1, 4% per year (IEA; 2008) with over 60% constituted of hydrocarbons [1-3]. Decline experienced in the oil and gas production coupled, (little/no oil field development in contemporary era, formation damages. According to the international energy agency, the world energy demand will continue to increase from 0,7 to 1,4% per year between 2008 to 2035 following different scenarios envisaged, however this will be dominated by fossil energy, notably hydrocarbons, though with a decline envisage [4-6]. With the continue increase in world demand for hydrocarbon coupled with an annual decline in exploration and drilling of new wells. Stakeholders have developed technologies/methods to sustain oil production in a more economic and profitable way, one of which is matrix acidizing [7-10]. An acidizing treatment is called a "matrix" treatment because the acid is injected at pressures below the parting pressure of the formation so that fractures are not created. Matrix acidizing can significantly enhance the productivity of a well when near-wellbore formation damage is present and, conversely, is of little benefit in an undamaged well [11-15]. The main goal of matrix acidizing is to restore and improve the formation's productivity by removing the near-wellbore damage and creating flow channels (wormholes) in carbonate formations [16]. Several factors must be considered in the process of choosing an adequate acid, for instance, temperature, pressure, crude composition, formation permeability, acid/crude compatibility, acid/additive compatibility, and compatibility between additives [17]. In matrix acidizing, the production of single and dominant wormholes is preferred. Previous experimental studies in the literature have shown the existence of an optimal acid injection rate at which maximum wormholing efficiency is produced [18-22]. Hence, the purpose of many laboratories' research focuses on finding this optimal injection rate, which could be defined as the injection rate that would produce the best wormhole with the lowest volume of acid.

Corresponding Author: Name: Kasi Njeudjang, Email: kasinj2006@yahoo.fr

Matrix acidizing method is applied in field named "Y" (for confidential reasons and its location not given) to enhance productivity and maximise recovery in its mature fields thus generating extra production capacity and restore original productivity in damage wells. The aim of this paper is therefore to remedy oil production by matrix acidizing method on the well X which belongs to the field Y and in an efficient manner. The objectives of this paper are as follows: Perform the nodal analysis to affirm the present state of this well (current permeability and production index); justify the choice of matrix acidizing by (13.5: 1.5% HCl:HF blend); perform the acid stimulation design (acid volumes and strengths); execute the acid stimulation job; perform well testing (build –up test) and run the nodal analysis to ascertain treated well ameliorated parameters (Permeability and Production index) and perform an Economic evaluation. To successfully achieve the set goals, this paper is divided into three sections: The first section deals with the introduction, the second section presents the data, tools and the obtained results. The paper ends by general conclusion.

2- Data, Methods and Result

The well X was worked over in 2018 and has never been stimulated, after completion the well-produced, with water production trend decreasing while oil production increasing. Before the production got stabilized, choke was opened, water production increased while we witnessed a drop in oil percentage. The well X is an oil producer well. Before the production got stabilized, choke was opened and then water production started increasing and oil decreasing. This suggests a possible water coning and water flow suggests presence of scales and suspected damage mechanism could be fines migration. Thus a drop in draw down at the level of the perforations which is choked due to drop in pressure and temperatures experienced at this node. Oil sample provided was an emulsion made of 40% water and 60% of oil. No incompatibility was observed when mixed to different fluids. However moderate sludge was observed with 10%HCl, with no rust added. Based on the lab testing, solvent preflush (Xylene + Diesel) and an emulsifier is added to the injectivity test fluid and in the non-acidic preflush, as they will be the first aqueous fluids to interact with the formation. Main treatment proposed for LRA-007 is 13.5:1.5% HCl: HF blend. This blend helps to remove damage from fines and clays as they might have accumulated near wellbore and reducing production on this formation. It contains acetic acid used to control aluminum scaling and iron precipitation, surfactant, clay and fines control additive. Table **1** presents the well X data.

The Excel software, IFS software, PipeSim software, matrix acidizing method and economic evaluation are used to attain the aims of this paper. This is made possible through the presentation of the injection path from surface lines to downhole, description and interpretation of the different graph’s obtained before and after acidification and at the end present the economic evaluation.

Table 1. Well X Data

Well data	
Well Name	X
Field	Y
Well type	Oil producer well
Treatment type	Matrix acidizing
Completion data	
Xmas tree	FMC 3 1/8” 5K
Tubing	3 1/2" L80 9.2# VAM
Tubing volume	60 bbl
Perforated interval data	
Height	10,000 ft MD/SV
Top	10,500ftTVD/SV
Total length	14.4m
Reservoir data	
Permeability(K) before treatment	150md
Permeability(K) after treatment	50 md
Porosity	29%
BHT	200 degF
Skin before treatment	40
Skin after Treatment	-1.5
Ks1	0.04K
Height (h)	48ft
Rw	0.5ft
Rs	2ft
Re	2000 ft
Oil formation volume factor	1.2
Gas oil ratio	500
Viscosity of Oil	1.2cp
Viscosity of Acid	1.7cp
BHTP	1171.6 psi
Frac gradient	0.33 psi/ft
Frac Pressure	3500 psi
Hydrostatic Pressure (with PAD Acid)	2078 psi
Friction pressure @ 4bpm	210psi
Maximum surface pressure	1632psi
80% Safety Factor	1305psi
Production data	
Oil flow rate	457 bpd
BSW	50.3%
Production index	0.7 STB/d/psi
TOS	NA
Matrix acidizing design data	
X_{HF}	0.08
β_{HF}	0.21
$X_{15\%\ HCL}$	0.35
β_{HCL}	0.12
Economic evaluation	
Capex	
Opex	
Net Profit Value	2 years
Royalty	10%
Oil price	70 USD per barrel

2.1. Description and interpretation of the different graph’s obtained before and after acidification

The well profile is illustrated in Fig. **1**. The well production condition over the years are concerned with the pressure transient over times was recorded and a nodal analysis performed to corroborate the drop in production rate, with PI 0.75 STB/Psi/d as shown in Fig. **2**.

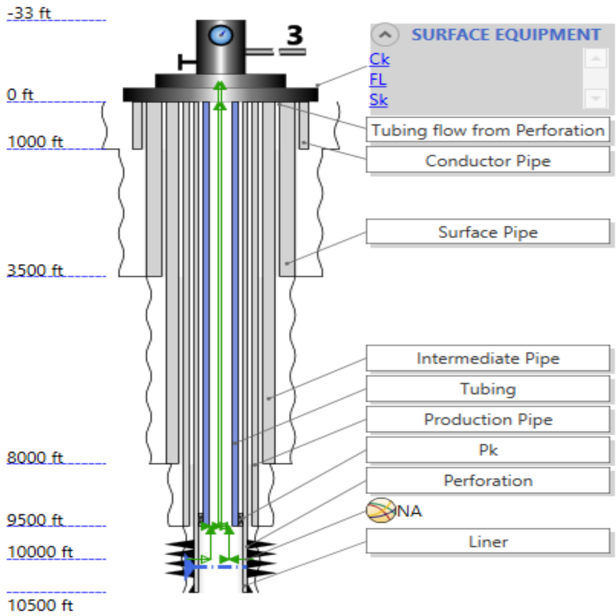


Fig. 1. Well Schematic

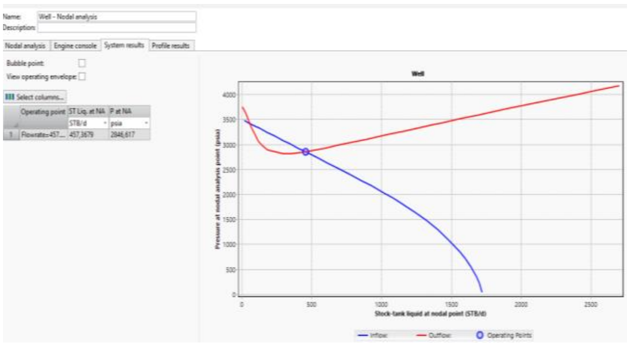
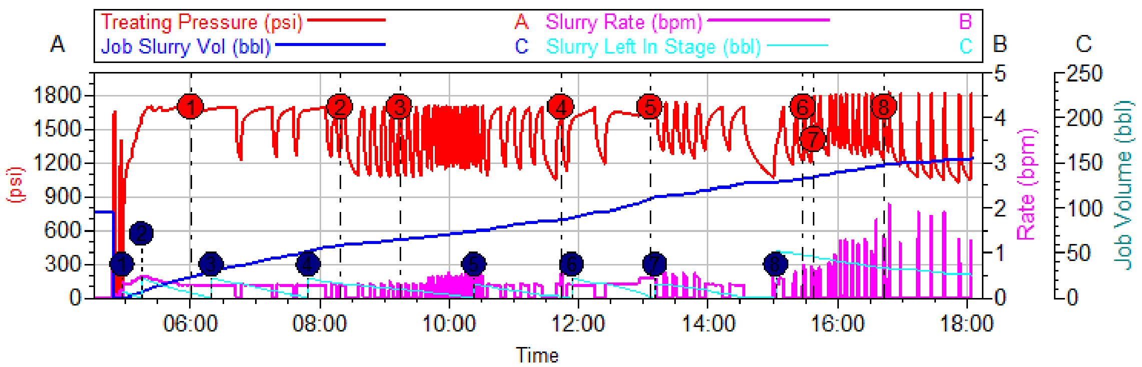


Fig. 2. Nodal Analysis before Treatment

In Fig. **2**, the rate is way below the economic objectives of this well set after completion which stood at 1150 bpd and bottom hole pressure 3500 psi. The inflow performance relationship (IPR) represents the oil flowing from reservoir drainage into the well bore area meanwhile vertical lift performance (VLP) represents the oil flowing to surface and the point of intersection stands for the optimal flowing condition of the well with reservoir damage.

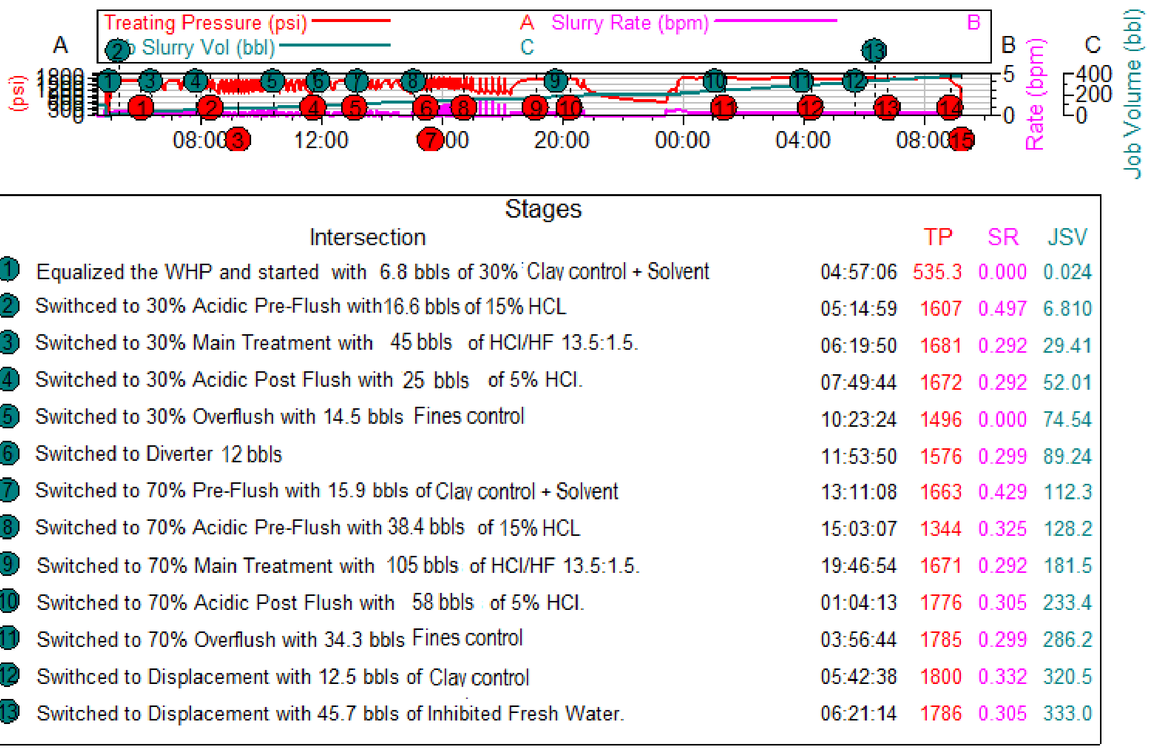
Based on the well log obtained during drilling well X is a high permeability well with more than 20 % Feldspar mineral, the heterogeneous nature of our reservoir allows us to envisage the presence of clay and carbonates in small quantities. The acid treatment is scheduled to be a 30:70 % coupled with a diverter to increase downhole treating surface area. A formation opening test is initially performed to ascertain opening pressures and maximum surface pressures, tubing cleaning is performed with 15% HCL acid. The main job treatments: 15% HCL –acidic preflush, Vol of HCL =2327 gal; main treatment 13.5:1.5% HCL/HF acid, Vol of HF = 6330gal; over flush 5% HCl, vol of 5% = 3554 gal; pumping rate = 4 bpm; and well surface pressure = 1632psi. Nevertheless, haven carried out laboratory analysis and simulation, once on the field. The formation is said to be tide, since we could only execute this job at an average 2.2 bpm and pumping intermittently as shown in Fig. **3**. However, all treatment volumes are successfully injected. The pumping schedule obtained from IFS (30:70 %) sequence of every fluid was respected. Though with longer treatment hours due to the formation tideness. Fluid volume are pumped accordingly and at the end of this treatment a tubing volume is considered to spot all treatment fluids into the formation as shown in Fig. **4**.



Stages

Intersection		TP	SR	JSV
Equalized the WHP and started with 6.8 bbls of Clay control	04:57:06	535.3	0.000	0.024
Swithced to 30% Acidic Pre-Flush with16.6 bbls of 15% HCL	05:14:59	1607	0.497	6.810
Switched to 30% Main Treatment with 45 bbls of HCl/HF 13.5:1.5.	06:19:50	1681	0.292	29.41
Switched to 30% Acidic Post Flush with 25 bbls of 5% HCl.	07:49:44	1672	0.292	52.01
Switched to 30% Overflush with 14.5 bbls Clay control	10:23:24	1496	0.000	74.54
Switched to Diverter 12 bbls	11:53:50	1576	0.299	89.24
Switched to 70% Pre-Flush with 15.9 bbls of Clay control + Solvent	13:11:08	1663	0.429	112.3
Switched to 70% Acidic Pre-Flush with 38.4 bbls of PAD 9:1 10% HCl.	15:03:07	1344	0.325	128.2

Fig. 3. Live Well Parameters



Stages

	Intersection		TP	SR	JSV
1	Equalized the WHP and started with 6.8 bbls of 30% Clay control + Solvent	04:57:06	535.3	0.000	0.024
2	Swithced to 30% Acidic Pre-Flush with16.6 bbls of 15% HCL	05:14:59	1607	0.497	6.810
3	Switched to 30% Main Treatment with 45 bbls of HCl/HF 13.5:1.5.	06:19:50	1681	0.292	29.41
4	Switched to 30% Acidic Post Flush with 25 bbls of 5% HCl.	07:49:44	1672	0.292	52.01
5	Switched to 30% Overflush with 14.5 bbls Fines control	10:23:24	1496	0.000	74.54
6	Switched to Diverter 12 bbls	11:53:50	1576	0.299	89.24
7	Switched to 70% Pre-Flush with 15.9 bbls of Clay control + Solvent	13:11:08	1663	0.429	112.3
8	Switched to 70% Acidic Pre-Flush with 38.4 bbls of 15% HCL	15:03:07	1344	0.325	128.2
9	Switched to 70% Main Treatment with 105 bbls of HCl/HF 13.5:1.5.	19:46:54	1671	0.292	181.5
10	Switched to 70% Acidic Post Flush with 58 bbls of 5% HCl.	01:04:13	1776	0.305	233.4
11	Switched to 70% Overflush with 34.3 bbls Fines control	03:56:44	1785	0.299	286.2
12	Swithced to Displacement with 12.5 bbls of Clay control	05:42:38	1800	0.332	320.5
13	Switched to Displacement with 45.7 bbls of Inhibited Fresh Water.	06:21:14	1786	0.305	333.0

Fig. 4. Pumping Stages

This is the pressure transient test performed after the treatment. The bottom hole pressure here is given by the reservoir pressure minus the draw down pressure given by Horner's formula (see Table **2** and Fig. **5**).

Table 2. Build–up Test Data Recorded after Treatment

Reservoir Pressure (pwf)(psi)	Bottom hole pressure (pi-pwf)(psi)	Horner's Time (dt+tp)/tp
3075	425	0.00597314
3125	375	0.01091003
3150	350	0.01474476
3175	325	0.01992734
3200	300	0.02693152
3225	275	0.03639758
3250	250	0.04919082
3275	225	0.06648071
3300	200	0.08984776
3325	175	0.12142801
3350	150	0.16410827
3400	100	0.29974617
3450	50	0.54749079
3500	0	1

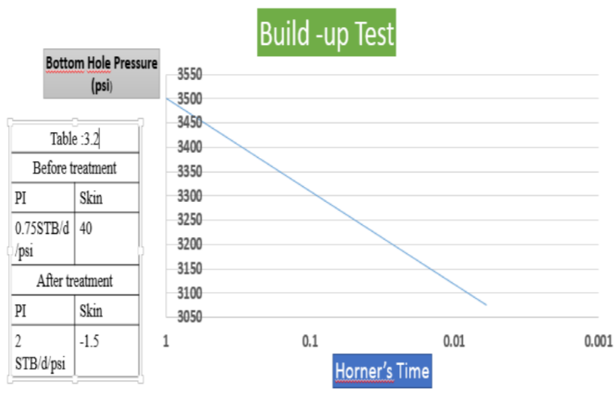


Fig. 5. Build – up Test Graph after Treatment

This analysis carried out after stimulation, optimal production rate of oil at our point of intersection stands at 850 bpd, bottom hole pressure 3076 psi as shown in Fig. **6**. This rate approaches us closer to the initial reservoir production condition just after drilling thus keeping us not to far from the well initial objectives.

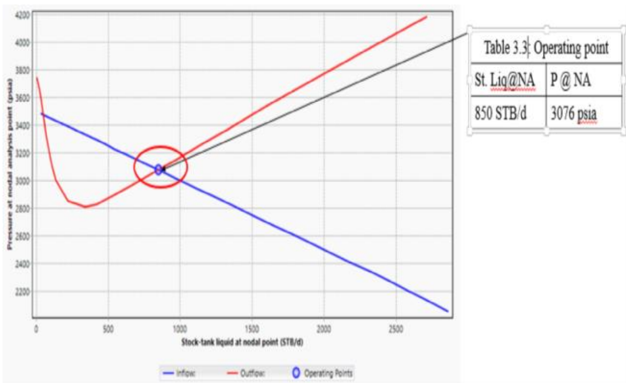


Fig. 6. Nodal Analysis after Treatment

2.2. Economical evaluation

The matrix acid method execution and production profile of the well X is obtained by simulation with the help of IFSand PipeSim software which constituted the first parts and the second consisted of carrying out an economic evaluation and to estimate gains to be generated by the company should this project be executed with this degree of success. To this effect consideration are made on the capital expenditures (Capex), operating expenditures (Opex) and the discount rate as shown in

Table **3**. The simulated results are 2 years for the return on investment.

Table 3. Equipment Well Data: Capex, Opex and Profit

Capex	Opex	Oil Market
Equipment rentals, Chemicals used 720,000 USD	Platform intergrity, Pump Hours, Accommodation 250,000USD	Selling Price for a barrel of crude oil : 70 USD
	Cost of producing a Barrel of oil :10$	Oil Daily Price
Taxes is 10%	Discount rate : 20%	

The revenue generated is based solely on oil produced from the well, the oil production rate per day for this well stands at 850 bpd, the company is said to pay taxes representing 10% of the revenue generated per year, with oil price at 70USD per barrel. Table **4** shows profit generated without taxes deducted.

Table 4. Oil Production Profit

Well Type	STB/d	STB/year	Per year ($)
Oil Production	850	310,250	21.717.500

Haven subtracted the expenses from our income generated; we deduced how much profit was generated by the company during this period. Let's note that matrix acid stimulation is successful and oil production following our nodal analysis is said to be stable for a period of 2 years. The net present value (NPV) which represents the company return on investment given by NPV = Gross oil – (Total cost+ discount rate). The results of its operation are highlighted in Table **5**.

Table 5. Company NPV for the Next Two Years

Total cost= (Capex + Opex + Taxes) USD	Profit Oil (USD)	NPV (USD)
5,313,500	43.435.000	29,434,500

Cost of Oil = 10USD * 850BPD * 365 * 2 = 6, 205,000 USD; profit oil (Gross oil) = 850BPD * 70 USD/B * 365 * 2 = 43,435,000 USD; taxes = 10% * profit oil = 4,343,500 USD; total cost = Capex + Opex + Taxes = 5,313,500 USD; discount rate = 20% * gross oil = 8,687.000 USD; NPV = Gross oil – (Total cost + discount rate) = 43,435,000 USD – (5, 313,500 USD + 8,687.000 USD) = 21,699,500 USD.

The return on investment is the ratio between net income and investment, it's equally another economic criteria used to determine the profitability of the project: ROI = NPV / Total cost (without taxes) = 29,434,500/ 970,000USD = 30.3. The economic results show a strong positive NPV and a good ROI though with oil price fixed at 70USD/barrel. The choice of production enhance is said to yield profit because it increases the percentage of oil recuperated with minimal cost on investment. Coupled with a possible increase in oil prices this methods remains the best alternative. The payback period (PBP) refers to the amount of time it takes to recover the cost of an investment, that's the length of time an investment reaches a break-even point. The data and procedure necessary to accomplish this calculation is given by: The total cost to carry out a matrix acid stimulation job; the cost of a barrel of oil per day (taxes inclusive = 10%) of total oil production; and oil price standing at 70 USD/STB. This is therefore given by: PBP = Total cost (USD) / Daily oil price (USD/d) as shown in Table **6**.

Table 6. Company Payback Period

Total cost= (Capex + Opex + Taxes) USD	Oil Prices (USD/STB)	Daily Oil Sales	PBP Days
5,313,500	70	59,500	90 days

Thus, after 90 days of production we start making profit from the investment, however let's not that, this matrix acidizing treatment is said to sustain the permeability of 50 md and a Skin of -1.5 for a period of two years, with this in mind we remain even more profitable should oil prices increase.

3- Conclusion

Sandstone-acidizing treatments were successfully performed in the field Y and encouraging results were obtained on well X. This study aimed to show case to matrix acidizing candidate selection; acid stimulation execution; and economic evaluation for a successful stimulation jobs. Considering the data obtained during mud logging, the different assumptions about the fluid and rock compositions, can be ascertain. The injection of 13.5:1.5% HCL/HF acid solution results in dissolution of calcite, clays and feldspar minerals. However, reservoir porosity and permeability can be enhanced in a region extending several meters around the injection well (Further studies can be carried out to ascertain this). Nevertheless, the high reactivity of the acid coupled with downhole temperatures of 200°F and a weak flow prevented the penetration of acid. This high reactivity also involves the risk of creating wormholes, able to increase the porosity but not always the permeability of the fractured reservoir, reasons why an over flush was performed. This technique is considered risky, due to the secondary and tertiary reactions between the spent acid and the rock. Precipitates form resulting from these reactions can be deposit in the pores and fractures of the rock and eventually negate the positive impact of the primary reaction. Surface pressure drops on the graph revealed that the treatment has touch the perforation. Consequently, being able to assess the extent of the secondary and tertiary reactions under reservoir conditions is therefore critical for the acid treatment success, during this job the acid reaction time was reduce to bear minimal (time to recommence the gas lift system of the well). Horner's equation was used on the plot of reservoir pressure over time, the slope of (m) was used to obtain the new skin and verify the permeability, and with these new set of reservoir properties a simulation performed in PipeSim software could gave the following: Production index = 2; production rate = 845bpd; skin = -1.5; and permeability = 50. The reservoir heterogeneity did not facilitate the smooth modelling of the treatment proposed, because we lack accurate data on the initial reservoir petrophysical properties, however the economic evaluation carried out showed the following: Discount rate = 20% * Gross oil = 8,687.000 USD; net present value = Gross oil – (Total cost + discount rate) = 21,699,500 USD; return on investment = 30.3; and payback period = 90 days.

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