Hydraulic Fracturing Planning to Increase Well Productivity in RAG Well of Cessna Field

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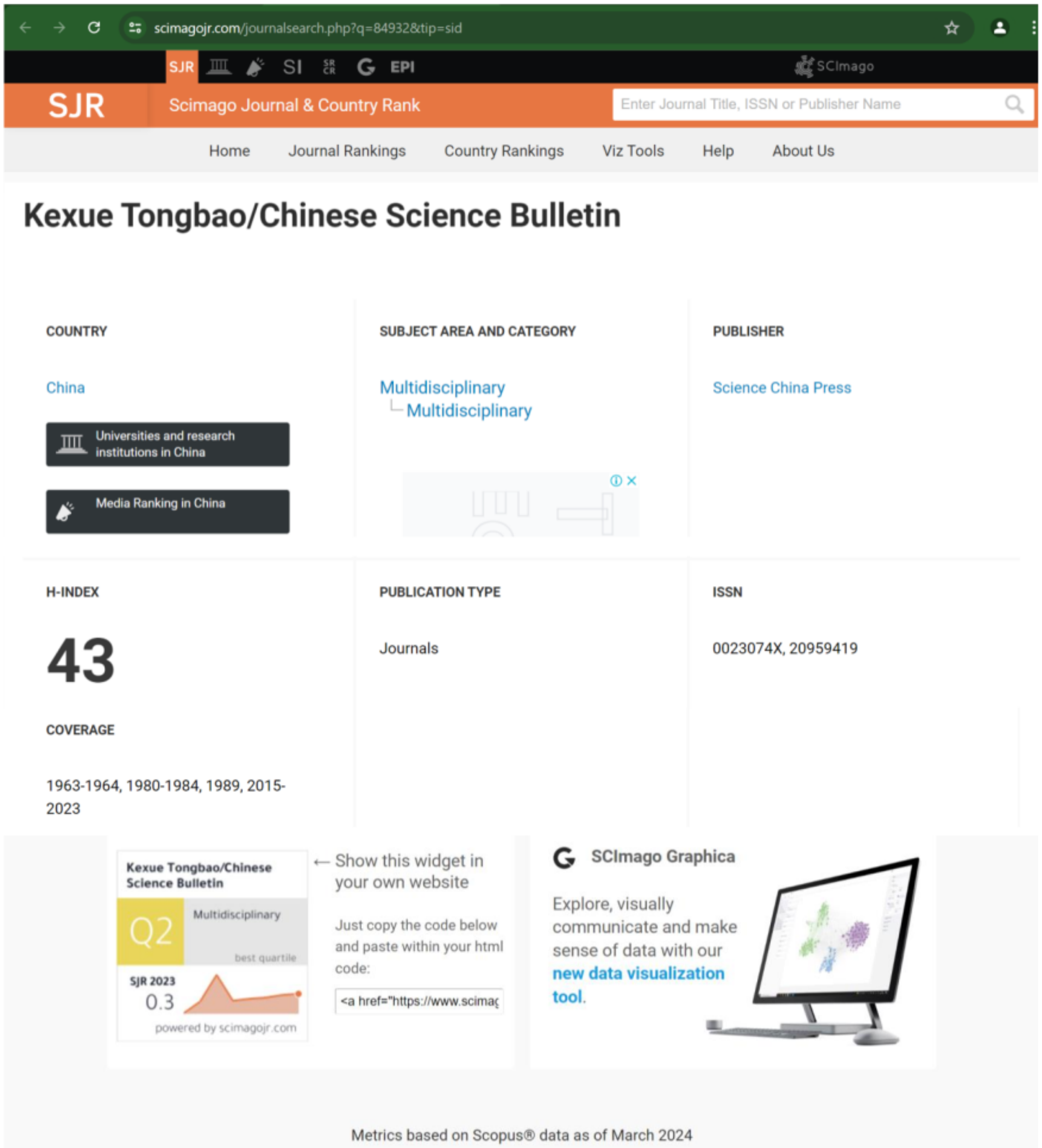

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Hydraulic Fracturing Planning to Increase Well Productivity in RAG Well of Cessna Field

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Hydraulic fracturing, Proppant, Productivity, Stimulation, Inflow performance relationship.

ABSTRACT

The RAG well is an oil well that has been workover by moving layer workover at a depth of 3788.1 - 3820.1 ft MD in TAF tight sandstone formation with a directional well configuration located in the Cessna field of the Northern West Java basin. This well has a shaly sandstone reservoir with silt rock intrusions with a permeability value of 10 mD and a porosity of 15%. This low permeability of the formation may affect the daily barrel fluid per day produced from the well, this is the main reason why it is necessary to plan stimulation in the form of hydraulic fracturing in RAG well with the hope of increasing well productivity in RAG well. The method used in planning the implementation of hydraulic fracturing in RAG well includes planning hydraulic fracturing on RAG well, followed by executing hydraulic fracturing based on the simulation design, as well as analyzing the success of hydraulic fracturing in accordance with the planning that has been carried out. Based on the results of the analysis of hydraulic fracturing success parameters, it was found that there was an increases in production parameter post hydraulic fracturing job in the RAG well, including an increases in the average permeability of the formation from 10 mD to 162.89 mD, fold of increase (FOI) to 6.33, productivity index, oil flow rate based on Wiggins IPR analysis from 6.39 Bopd to 40.44 Bopd with the maximum fluid flow rate also increasing from 86.97 Bfpd to 550.67 Bfpd.

1. INTRODUCTION

Decreasing well productivity is a common problem that occur in oil and gas wells that has been produced, either it is a new production well or even well that has been produced for a long time. This problem usually caused by the low permeability of the reservoir in the prospect productive formation even though it still has potentials oil reserves because it will affect the daily production rate of the fluid produced later [1- 3].

To increase the productivity of well in formations, there are several methods that can be used, such as stimulation method such as acidizing and fracturing [1- 3]. In this research, will be focusing the topic on the hydraulic fracturing method. Hydraulic fracturing is a method used to increase formation productivity through fracturing the formation, where the fractures formed will be filled with proppant strong enough to hold the formation that has been fractured. This is different from acidizing, where acidizing focuses more on injecting acid on near wellbore problems and is generally carried out in carbonate formations, while fracturing focuses more on the reservoir fracturing characteristics of the formation especially in tight sand formation [1], [4]. In this case TAF (Talangakar sandstone formation) of RAG well at 3788.1 ft - 3821.0 ft (MD) is the target formation for hydraulic fracturing planning.

The main reason of choosing hydraulic fracturing as the stimulation method in stimulating RAG well is due to the low reservoir value of the targeted reservoir which has a value of 10 mD with a lithology of shaly sandstone based on logging data. The targeted formation has a shale formation above and underneath. Based on previous production data this well only produced the amount of daily oil per day rate of 6.9 Bopd and liquid per day rate of 86.97 Bofd. meanwhile this formation still had an amount of 6063 Stb of potential. Prior planning the hydraulic fracturing, several data needed are the reservoir data of the well, well completion data, well test data, geomechanics data and petrophysics data off the well. from the data gathered the hydraulic planning will be conducted by inputting the calculation results in hydraulic fracturing supporting simulator.

Based on the simulation result. the result will be calculated and evaluated focusing on parameters such as the increase of productivity index, inflow performance relationship, increase in permeability, and fold of increase after performing hydraulic fracturing jobs in RAG well according to the planned that has been conducted.

2. METHODOLOGY

The methodology on this research is intended to solve the main problems that are occurring at Cessna field, especially on RAG well; which comprised of data compilation and preparation, succeeded by data analysis and evaluation. The steps that are taken in this research are as follows:

a. Gathering several data needed including the reservoir data of the well, well completion data, well test data, geomechanics data and petrophysics data off the well,

b. Conducted hydraulic fracturing simulation in order to simulate the designated hydraulic fracturing design by inputting the data gathered,

c. Determining the fracturing model, proppant determination, and the suitable fracturing fluid that will be used for hydraulic fracturing planning on RAG well.

d. Give recommendation for hydraulic fracturing strategy to be implemented in RAG well.

Based on fracturing model design, the fracturing method will used the principle of PKN (Perkins, Kern, Nordgren) due to it presumption to generate longer fracture length (Xf) rather than fracture height (hf) after conducting the fracturing process [5], [6], the fracture height is assume has the same value as the reservoir thickness of the targeted formation at 44.9 ft with fracture length of 248.95 ft and this method is suitable for formation with low reservoir permeability such as the TAF (Talangakar formation) designated fracturing interval of RAG well that has permeability of 10 mD at depth of 3788.1 - 3821.0 ft (MD) with tight sandstone formation. The proppant and fracturing fluid that determination is also considered by the formation characteristic and fracturing fluid guide for oil well by M. J. Economides, and K.G. Nolte, 2000 [7] which will be adjusted with the database of simulation. After the design has been executed, the simulator will show the fracturing design geometries (length, width, and height), fracture conductivity value and estimated closure time of the designated hydraulic fracturing plan.

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After conducting the simulation, the result will be calculated to evaluate the increasing of productivity index and production rate after conducting hydraulic fracturing based on Cinco-ley, Samaniego and Dominguez method [8] and also evaluate increasing inflow performance prior and after conducting hydraulic fracturing in RAG well based on the designated plan.

3. RESULTS AND DISCUSSION

3.1 Field Data

The data needed in order to planning hydraulic fracturing in RAG well include reservoir data, well completion data, and perforation data, as shows in Table 1 through Table 3, respectively.

Table 1. Reservoir data

Parameter	Value	Units
Well Type	Oil	
Reservoir Thickness	44.9	ft
Reservoir Pressure	1700	Psi
Flowing Well Pressure	1150.64	Psi
Bottom Hole Temperature	210	˚F
Porosity	15	%
Permeability	10	mD
SG Gas	0.67	
Gas Component (N_2)	0	%
Gas Component (CO_2)	0	%
Water Salinity	20000	Ppm
Water Compressibility	1.00E-06	1/Psi
Fracture gradient	0.797	Psi/Ft

Table 2. Well completion data

Parameter	Value	Units
Casing OD	7	Inch
Casing ID	6.366	Inch
Tubing OD	3.5	Inch
Hole Size	8.5	Inch
Wellbore radius (rw)	0.125	ft
Drainage radius (re)	328.08	ft
Packer Setting Depth	3239.24	ft
Top Perforation	3788.1	ft
Mid Perforation	3804.5	ft
Bottom Perforation	3820.9	ft
Perforation Diameter	0.4	Inch
Well Depth	4831.79	ft

Table 3. Perforation data

Parameter	Value	Units
Top Perforation (MD)	3788.1	Ft
Mid Perforation (MD)	3804.5	Ft
Bottom Perforation (MD)	3820.9	Ft
Perforation Diameter	0.4	Inch

Perforation Number	165

3.2 Analysis and Result

3.2.1 Fracture geometry

In order to calculate the length of the fracture, it can be calculated using the following equation:

$$X_f = \frac{(W+2Sp)qo}{4\pi hf\, C_L^2} \left[\exp(\beta^2)\, \mathrm{erfc}(\beta) + \frac{2\beta}{\sqrt{\pi}} - 1 \right] \tag{1}$$

Afterwards, to calculate the fracture width, it can be calculated using the following equation:

- PKN (Perkins, Kern, Nordgren)

$$W_{(o)} = 9.15\, \frac{1}{2\, n^F+2} \text{ x } 3.98\, \frac{n^F}{2\, x\, n^F+2} \text{ x } \left[\frac{1+2{,}14\, x\, n^F}{n^F}\right] \frac{n^F}{2n'+2} \text{ x } K' \frac{1}{2\, n^F\ +2} \left[\frac{qi^{n}\, .\, hf^{(1-n')}\, .\, xf}{E}\right]^{1/(2n'-2)} \tag{2}$$

- KGD (Kristianovich, Geertsma, De Klerk)

$$W_{(0)} = 11.1\, \frac{1}{2n^F+2} \text{ x } 3{,}24\, \frac{n^F}{2n^F+2} \left[\frac{1+2n^F}{n'}\right] \frac{n^F}{2n^F+2} \text{ x } K' \frac{1}{2\, n^F\ +2} \left[\frac{qi^{n^F}\ .\ Xf^2}{hf^{n^F} E'}\right]^{1/(2n^F+2)} \tag{3}$$

Assuming the shape factor with the following equation:

$$W = \left(\frac{\pi}{5}\right) w(0) \tag{4}$$

Calculating the fracture conductivity using the following equation:

$$Wkf = Kf \text{ x } W \tag{5}$$

The fracture geometry model will be carried out using the 2D PKN Method. the fraction geometry calculation was carried out with the following data in Table 4.

Table 4. Fraction Geometry Calculation Data

Parameter	Value	Units
Young Modulus (E)	3.82E+06	Psi
Poisson Ratio (v)	0.22	Ft
n'	1	Ft
k'	0.0000209	Pa $det^{1/2}$
Injection Rate (qi)	19	Bpm
hf	44.9	Ft
Xf	248.95	Ft
Total leak-off coefficient (Cl)	0.0038	$m/s^{1/2}$
Total treatment time (ti)	72.3	Min
Spurt loss (Sp)	0	$Gal/100ft^2$

Initial length of fracture iteration (Xf(iteration+1)) = 75.88 m = 248.95 ft. this value is used because it is the result of simulation, where the maximum fracture width will be calculated using the equation:

$$W_{(o)} = 9.15\, \frac{1}{(2\, n'+2)} \text{ x } 3.98\, \frac{n'}{(2\, x\, n'+2)} \text{ x } \left[\frac{1+2{,}14\, x\, n'}{n'}\right] \frac{n'}{(2n'+2)} \text{ x } K' \frac{1}{(2\, n'\ +2)} \left[\frac{qi^{n}\, .\, hf^{(1-n')}\, .\, xf}{E}\right]^{1/(2n'-2)} \tag{6}$$

$$W_{(o)} = 9.15\, \frac{1}{(2\,(1)+2)} \text{ x } 3.98\, \frac{1}{(2\, x\,(1)+2)} \text{ x } \left[\frac{1+2{,}14\, x\, 1}{1}\right] \frac{1}{(2\,(1)+2)} \text{ x } 0.0000209 \frac{1}{(2\,(1)\ +2)}$$

$$\left[\frac{0{,}050318333^1\, .\, 13{,}68552^{(1-1)}\, .\, 75{,}88}{4014291{,}72}\right]^{1/(2\,(1)-2)}$$

$W_{(o)} = 0.01248$ m

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$W_{(o)} = 0.0409$ ft

The average fracture width (W_{avg}) is calculated by using the following equation:

$$W_{avg} = \left(\frac{\pi}{5}\right) \text{ x } w(0) \quad (7)$$

$$W_{avg} = \left(\frac{3{,}14}{5}\right) \text{ x } 0.01248$$

$$W_{avg} = 0.00784 \text{ m}$$

$$W_{avg} = 0.02572 \text{ ft}$$

Calculate the fracture conductivity using the following equation:

$$Wkf = K\ \textit{proppant} \text{ x } W_{(0)} \quad (8)$$

$$Wkf = 622098 \text{ x } 0.0257$$

$$Wkf = 16004.10 \text{ md ft}$$

3.2.2 Fracturing fluid design

Determination of fracturing fluid in planning hydraulic fracturing stimulation needs to be adjusted to the characteristics of the reservoir to be fractured. So that the implementation of hydraulic fracturing can run well according to plan without causing problems when carrying out the work [7], [9]. Determining the fracturing fluid can be viewed based on the characteristics of the formation to be fractured, the amount of clay content, the reservoir content, and the pressure in the reservoir. Based on existing log and petrophysical data, it can be seen that the RAG well is a well with an oil reservoir where the lithology in the zone to be fractured is shaly sandstone with a slight intrusion of siltstone which has a permeability of 10 mD with a reservoir pressure of 1700 psi and a bore hole temperature of 220 ℉.

Based on the guidance for selecting fracturing fluids for oil wells according to [7], [10], that the fracturing fluid that is suitable for application in planning hydraulic fracturing in RAG well is a fracturing fluid with the Low pH Crosslinker + 25% CO^2 type. Based on the results of trials carried out on the simulation, trials have been carried out on several fracturing fluids, and in this plan the fracturing fluid to be injected is of the YF430LpH-(CO_2 70Q)-F104 type, which is a type of water-based fluid with a low pH crosslinker. The reason of choosing this type of fluid is because the crosslinker has the ability to linked molecules so that the viscosity of the fluid will increase so that it is able to maintain the condition of the fluid at a high temperature for a long time and because this fluid is low pH so it is able to provide fluid stability at high bore hole temperatures up to 300 ℉. This also allows the injected fluid with the addition of CO^2 to tend to lower the pH. Furthermore, for example, the pH of the fluid is below around pH 7, the fluid will reduce the tendency for scale deposits to form. Hence, it is suitable for application in RAG well with a borehole temperature of 220 ℉. The fracturing fluid composition is shown in Table 5, while the fracturing fluid additives is shown in Table 6.

Table 5. Fracturing fluid design composition

Parameter	Value	Units
Fracturing fluid	YF430LpH-(CO_2 70Q)-F104	
Fluid Type	Water Based	
Frac Fluid Density	62.4	lb/Ft^3
SG Fracturing fluid	1.02	Pa $det^{1/2}$
n’	1	

K'	0.0000209	$Lbs.s^n/ft^2$

Table 6. Fracturing fluid additives composition

Type	Name
Biocide	M275-Microbiocides
Clay Stabilizer	M117-Potassium Chloride
Surfactant	F108-Surfactant
Gelling Agent	J876-HPG *Polymer slurry*
Iron Control	L401-Stabililzing Agent
Crosslinker	J532-Crosslinker
Surfactant	F104-Foaming Agent
Breaker	J218-Breaker

The explanation of the additives function used on the fracturing fluid design are as follows:

1. Biocides
   The use of M275-Microbiocides functions is to eliminate bacterial content that can damage the polymer bonds in the fracturing fluid that might reduce its viscosity. The use of biocides is mixed with water that has not been mixed with polymer, because the enzymes produced by bacteria (even if the bacteria are dead) can break down the bonds in the polymer.
2. Clay Stabilizer
   The use of M117-Potassium Chloride as a clay stabilizer is used to prevent the spread of clay, especially in sandstone formations such as kaolinite, illite, chlorite and smectite which can be a problem in production. Clay is also commonly found in shale rock formations. Because in the "RAG" Well the formation to be fractured is in a formation with shaly sandstone lithology, the use of a clay stabilizer is very necessary to prevent the spread of clay by providing cationic properties to prevent ion transfer and prevent the development of clay.
3. Surfactant
   In this fracturing fluid composition, there are two types of surfactants used, namely F108 which is used as a surface-active control agent to facilitate the breakdown of water from the surface of the formation, prevent emulsion formation and facilitate fracturing. And is able to change the contact angle of the leak-off fluid into the pores which is able to change the wettability of the fluid to the formation. then the usage of F104 as a foaming agent to make foam.
4. Gelling Agents
   The use of J876- HPG Polymer Slurry as a High-Pressure Guar gelling agent functions to increase the viscosity of water so that it can form a gel, in this case the viscosity of YF430LpH-(CO2 70Q)-F104 which is a water based fracturing fluid under RAG well pressure conditions of 1700 Psi.
5. Iron Control
   The use of L401-Stabilizing agent is used to control pH because the fracturing fluid used is a low pH type fluid and is used to prevent the deposition of Fe^{3+} ions in the fracture zone. Where the "RAG" well that is to be fractured is a sandstone formation with minerals such as kaolinite, illite, chlorite, and smectite, where these minerals can form iron oxide, so the use of L401-Stabilizing agent is needed to prevent oxidation of Fe^{3+} ions.
6. Crosslinker
   The use of J532-crosslinker aims to increase the viscosity of the fracturing fluid used by binding the molecules. The high fluid viscosity is able to maintain the fluid at high temperatures for a long time, where in this case, the RAG well has a fairly high temperature of 220 °F. The crosslinker is needed to strengthen the fracturing fluid molecules so that they unbreak when fracturing fluid is

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injected into the formation.

7. Breaker
   The use of J218-Breaker as a breaker is used to reduce the viscosity of the fracturing fluid used after the job is carried out. The breaker will help the fracturing fluid to become more liquid from previously being in a gel phase so that it is easy to clean/flush after fracturing in the RAG well.

3.2.3 Proppant determination

In general, the factors that influence proppant selection are the strength of the proppant to be able to withstand the closure pressure of the formation, the size of the proppant to be able to enter the fracture in the perforation hole formed, and the increase in conductivity when using type of proppant [11]. If the proppant experiences stress that exceeds its strength limit, the proppant will experience crushing and this will cause a decrease in fracture conductivity and affect the effectiveness of the hydraulic fracturing. In order to calculate proppant strength, the following equation is used:

$$P_{closure} = (Gf \times D) \tag{9}$$

$$P_{closure} = (0.797 \times 3804.46)$$

$$P_{closure} = 3029.6 \text{ Psi}$$

The determination of proppant in this planning is based on the results of sensitivity tests on the ability of various types of proppants to withstand the minimum horizontal stress which is assumed to be the closure pressure value of 3029.6 psi, as shown in Figure 1, that the most suitable proppant is the 16/20 proppant XRT Ceramax.

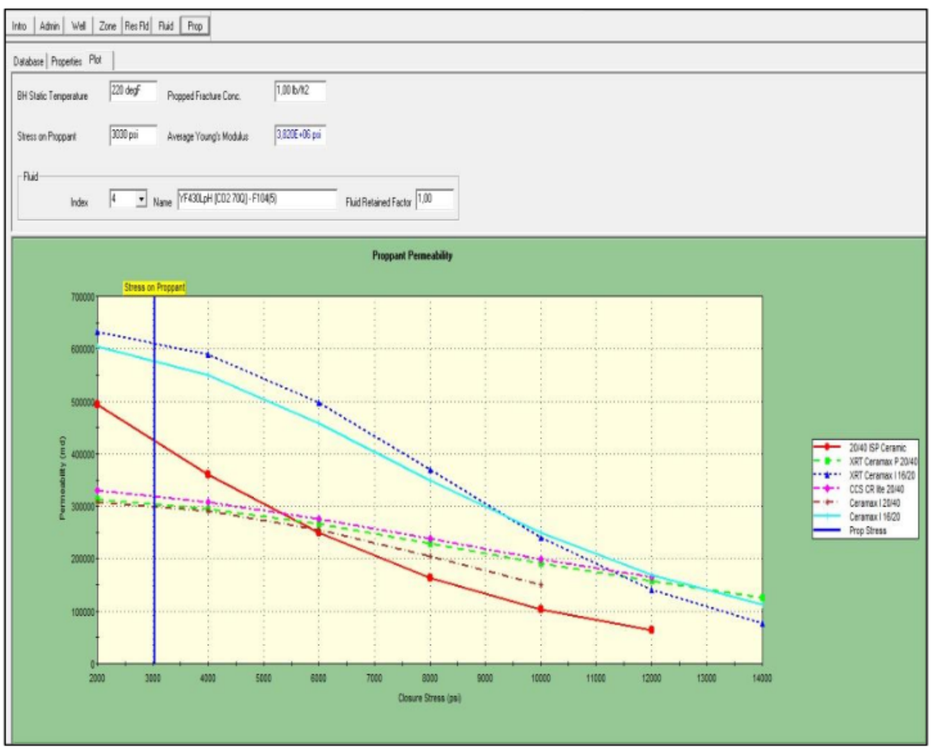

Figure 1. Sensitivity result comparison between proppant permeability vs closure stress

for several proppant

3.2.4 Injection pressure and pump horse power

As the final stage in the entire fracturing design process, a final pump pressure plan is required to achieved the desired level of conductivity in the hydraulic fracture corresponding to the selected hydraulic fracture plan. the reason why it is necessary to design pump pressure is due to the dominant factor influencing the fracture shape is the peak value of the disturbance and stress increase along the pump pressure [2], [3], [12]. Pumping horse power and injection pressure needs to be adjusted in order to create the designated fracture in the targeted formation by injecting fracturing fluid in a state of injection pressure way higher than formation fracture pressure ($P_{inj} > P_{rf}$). The following is the data needed in order to determine the injection pressure at the surface as shown at Table 7.

Table 7. Surface injection pressure calculation data

Parameter	Value	Units
Injection Rate (Qi)	19	Bpm
ID DP	2.441	Inch
n'	1	Ft
k'	0.0000209	Pa det$^{1/2}$
Fracturing Fluid Density	62.4	Lb/gall
SG Fracturing Fluid	1.02	
Tubing Length	3631.63	Ft
Perforation Diameter	0.4	Inch
Perforation Number	165	
Fracture gradient	0.797	Psi/ft
Mid Perforation (TVD)	1159.60	FT
P_{net}	1831.24	Psi
Closure Pressure	3029.62	Psi

Injection pressure calculated used the following equation:

$$WHTP = BHTP + Ppf + Pf - Ph \quad (10)$$

$$WHTP = 912.6052 + 0.1046 + 4534.02 - 502.29234$$

$$WHTP = 4944.4389 \text{ psi}$$

and for calculating of the pump horse power as follows:

$$HHP = \frac{Qi\ Pwtr}{40.8} \quad (11)$$

$$HHP = \frac{19\ x\ 4944.4389}{40.8}$$

$$HHP = 2302.5573 \text{ HP}$$

3.2.5 Pumping schedule

The pump rates used in hydraulic fracturing according to the planning carried out can be seen in Table 8. The pump rate was obtained at 19 bpm based on test results on several pump rate values. The pump rate is chosen based on the pump's ability to inject the fracturing fluid and proppant used so that it can fractured the formation.

Table 8. Pumping schedule

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No. Stage	Injection Rate (Bbl/min)	Fluid Volume (Gallon)	Proppant Concentration (PPA)	Proppant Mass (lbs)	Slurry Volume (Bbl)	Injection Time (Minutes)
1 (Pad)	19	2270	0	0	54	2.8
2	19	2530	1	2530	63	3.3
3	19	2250	2	4500	58.4	3.1
4	19	1790	3	5370	48.4	2.5
5	19	2433	4	9732	68.4	3.6
6	19	2544	5	12720	74.2	3.9
7	19	2777	6	16662	84	4.4
8	19	2788	7	19516	87.3	4.6
9	19	2579	8	20632	83.5	4.4
10	19	2877	9	25893	96.3	5.1
11	19	3000	10	30000	103.6	5.5
12	19	3155	11	34705	112.3	5.9
Flush	19	18454	0	0	439.3	23.1
		Total Injection Time				**72.3**

The total time required to pump YF430LpH-(CO_2 70Q)-F104 fracturing fluid and XRT Ceramax 16/20 mesh proppant according to the pumping schedule is 72.3 minutes. The fracture geometry model that has been formed after executing the design using the simulation based on the 2D contour plot is shows in Figure 2 and the conductivity contour is shows in Figure 3.

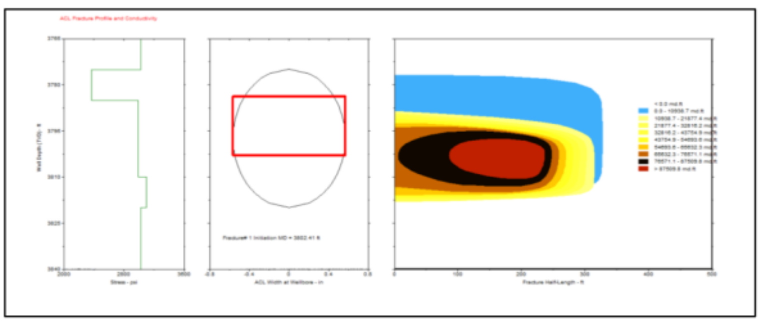

Figure 2. Fracture geometry model of RAG well based on 2D contour plot

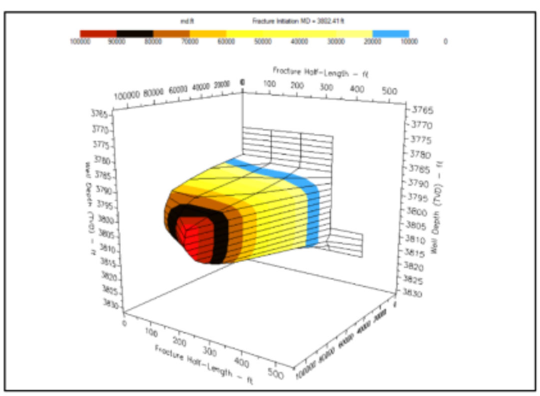

Figure 3. Fracture geometry model of RAG well based on conductivity contour

3.3 Analysis of RAG well hydraulic fracturing planning after fracking

3.3.1 Formation permeability before and after fracking

The results of implementing hydraulic fracturing stimulation will influence the increase in rock permeability values which will later influence the fluid flow rate in the formation where hydraulic fracturing stimulation [2], [3]. Calculation of fracture permeability and average permeability values was carried out using the Howard and Fast equation. The data required to calculate the increase in permeability after fracturing is shows in Table 9.

Table 9. Permeability calculation data

Parameter	Value	Units
Wellbore radius (rw)	0.125	Ft
Drainage radius (re)	328.08	Ft
hf	44.9	Ft
Xf	248.95	Ft
Formation Permeability (k_{for})	10	mD
Fracture Width (w_0)	0.0257	Ft
Proppant Permeability (k_{Prop})	622098	Md

The following step is explained to calculate fracture permeability and average permeability after conducting hydraulic fracturing:

Calculating the fracture conductivity using the following equation:

$$\text{Wkf} = \text{K } proppant \text{ x } W_{(0)} \tag{12}$$

$$\text{Wkf} = 622098 \text{ x } 0.0257$$

$$\text{Wkf} = 16004.10 \text{ md ft}$$

Calculating the Fracture Permeability by using the following equation:

$$K_{frac} = \frac{(\text{k x hf})+\text{Wkf}}{\text{hf}} \tag{13}$$

$$K_{frac} = \frac{(10 \text{ x } 44.9)+16004.10}{44.9}$$

$$K_{frac} = 366.43 \text{ mD}$$

Calculating the average formation permeability after fracking by using the following equation:

$$\text{Kavg} = \frac{\log(\frac{re}{rw})}{[\frac{1}{kfrac} x \left(\log\frac{xf}{rw}\right)+\{\frac{1}{kfor} x \left(\log\frac{re}{xf}\right)]} \tag{14}$$

$$\text{Kavg} = \frac{\log(\frac{328.08}{0.125})}{[\frac{1}{366.43} x \left(\log\frac{248.95}{0.125}\right)+\{\frac{1}{10} x \left(\log\frac{328.08}{248.95}\right)]}$$

$$\text{Kavg} = 162.89 \text{ mD}$$

Based on the results of the calculations that have been carried out, it can be concluded that there was an increase in the average permeability of the formation in the RAG well after hydraulic fracturing stimulation in accordance with the planning. Before hydraulic fracturing stimulation was carried out, the permeability value in the formation was 10 mD. Meanwhile, after hydraulic fracturing stimulation was carried out in accordance with the plans that had been carried out, the permeability value increased to 162.89 mD.

3.3.2 Increase in productivity index

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The method used to calculate the productivity index is by using Cinco-Ley, Samaniego, and Dominguez methods. This method is used in fracture conductivity and also for quick evaluation to calculated the estimated increase of productivity (K2P) in hydraulic fracturing. This method is used to calculate productivity index (PI) by considering skin factor and pressure changes in the targeted reservoir [8], [13], [14]. This method also assumes that the well has a cylindrical drainage area, cased hole well completion configuration, homogenous reservoir, limited by impermeable layer above and below the productive layer, has a constant productive layer thickness, permeability and porosity, the produced fluid has constant compressibility and viscosity values, fully penetrating and finite conductivity fracture, gravity effects are ignored and the fluid flow regime is laminar type [8], [14]. This assumption has the same characteristic with RAG well. The following steps was to determine the PI based on Cinco-Ley, Samaniego and Dominguez method.

Calculating the value of Dimensionless Fracture Conductivity by using the following calculation:

$$Fcd = \frac{wKf}{K \times (Xf)} \tag{15}$$

$$Fcd = \frac{16004.10}{10 \times (248.95)}$$

$$Fcd = 6.4$$

Find the rw'/Xf value by plotting the Fcd value into a rw'/Xf vs Fcd graph, as shown in Figure 4.

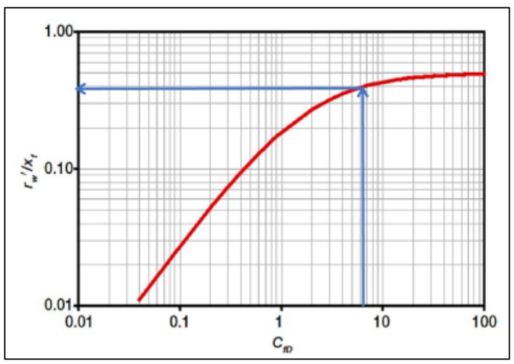

Figure 4. Graph of rw'/Xf vs Fcd

Based on the results of the Cinco-ley Samaniego and Dominguez plot on the rw'/Xf vs Fcd graph, the rw'/Xf value is 0.38.

Calculating the rw' value by using the following equation:

$$rw' = Xf \times 0.4 \tag{16}$$

$$rw' = 248.95 \times 0.4$$

$$rw' = 94.6 \text{ ft}$$

Calculating the skin factor by using the following equation:

$$S = -\ln\left(\frac{rw'}{rw}\right) \tag{17}$$

$$S = -\ln\left(\frac{94.6}{0.125}\right)$$

$$S = -6.62$$

Calculating the comparison of productivity index before and after hydraulic fracturing using the following equation:

$$FOI = \frac{J}{Jo} = \frac{ln\left(\frac{re}{rw}\right)}{ln\left(\frac{re}{rw'}\right)} \quad (18)$$

$$FOI = \frac{J}{Jo} = \frac{ln\left(\frac{328.08}{0.125}\right)}{ln\left(\frac{328.08}{94.604}\right)}$$

$$FOI = \frac{J}{Jo} = 6.33$$

3.3.3 Inflow performance relationship

In this research, the inflow performance relationship (IPR) comparison calculation before and after implementing hydraulic fracturing uses the Wiggins IPR method. Based on [15], the results of the analysis of the Wiggins method state that the two-phase method from Vogel is a three-phase method, so that a three-phase method is obtained which is simpler than the previously existing three-phase method.

In the Wiggins method it is assumed that each phase is treated separately, so that the results between oil rate (qo) and water rate (qw) can be calculated separately. When comparing the Wiggins IPR equalization method with the Hagerdorn-Brown and Pudjo Sukarno methods, this method will get production rate results that are equivalent and almost the same, this indicates that the Wiggins three-phase IPR equalization results are correct. The maximum difference from this ratio is 3.98% for oil and 7.08% for water. The reason for using the Wiggins IPR method is considering that the fluid flowing in the well is a three-phase fluid with a positive skin value of +0.53 and the assumption in this method is that the water-cut percentage exceeds 40% where the water-cut in the RAG well is high, reaching 93% based on last well test results. Determination of IPR comparison results before and after fracturing carried out according to the plan for the RAG well which is shown in Table 10 and Table 11, respectively.

Table 10. Inflow performance relationship data before fracturing

Pwf (Psi)	Qo (BOPD)	Qw (BWPD)	Qtot (BFPD)
0	14.92	209.63	224.55
100	14.44	200.55	214.98
200	13.91	191.06	204.96
300	13.33	179.54	192.77
400	12.70	170.86	183.56
500	12.02	160.16	172.18
600	11.29	149.05	160.33
700	10.51	137.53	148.04
800	9.68	125.60	135.28
900	8.80	113.27	122.08
1000	7.88	100.53	108.41
1100	6.90	87.39	94.29
1150.64	6.39	80.58	86.97
1200	5.87	73.84	79.72
1300	4.80	59.89	64.68
1400	3.67	45.52	49.19
1500	2.50	30.76	33.25
1600	1.27	15.58	16.85
1700	0	0	0

In order to predict the increase in inflow performance after hydraulic fracturing, used the following equation:

Calculating Qomax after fracturing, this is also applied for Qw and Qtot.

$$\text{Qomax After} = \frac{J}{Jo} \text{ x Qomax Before} \quad (19)$$

Qomax After = 6.33 x 14.92

Qomax After = 94.44 Bopd

Table 11. Inflow performance relationship data after fracturing

Pwf (Psi)	Qo (BOPD)	Qw (BWPD)	Qtot (BFPD)
0	94.44	1327.10	1421.54
100	91.90	1269,60	1361.00
200	88.04	1209.54	1297.58
300	84.36	1146.91	1231.27
400	80.38	1081.70	1162.08
500	76.08	1013.92	1090.00
600	71.46	943.57	1015.03
700	66.54	870.65	937.18
800	61.29	795.16	856.45
900	55.74	717.09	772.83
1000	49.87	636.46	686.32
1100	43.69	553.25	596.93
1150.64	40.44	510.13	550.57
1200	37.19	467.47	504.66
1300	30.38	379.12	409.5
1400	23.25	288.20	311.45
1500	15.82	194.70	210.52
1600	8.07	98.64	106.7
1700	0	0	0

Based on the IPR tabulation on Table 10 and Table 11, then the following inflow performance relationship comparison before and after conducting hydraulic fracturing according to the designated plan on RAG well could be constructed, as shows at Figure 5 and Figure 6, respectively.

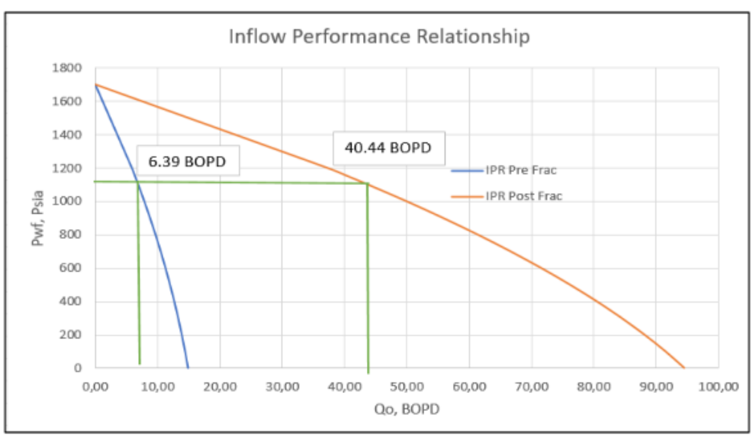

Figure 5. Inflow performance relationship comparison pre and after hydraulic fracturing for oil rate

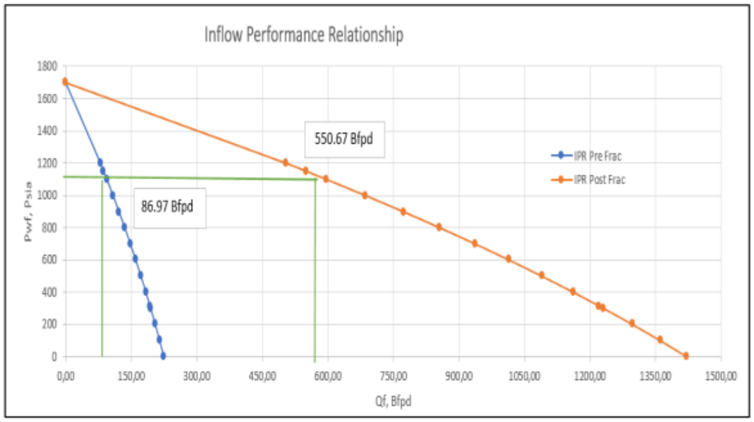

Figure 6. Inflow performance relationship comparison pre and after hydraulic fracturing for liquid rate

Based on the IPR graphic curve in Figure 5, it is found that the increase in oil rate after conducting the hydraulic fracturing in RAG well using the Wiggins IPR Method at Pwf = 1150.64 psi is in-creased from 6.39 Bopd to 40.44 Bopd. whereas in Figure 6 show an increase in fluid rate after frac-turing from 86.97 Bfpd to 550.67 Bfpd. Therefore, it can be concluded that the hydraulic fracturing planning in RAG well can increase well productivity as indicated by an estimated increase in the IPR curves.

4. CONCLUSIONS

From the result and discussion above, it concludes that:

1. Based on the simulation design results, it was found that the fracture geometry using PKN geometry models, and were obtained parameters in the form of fracture length (Xf) of 248.95 ft, fracture height (hf) of 44.9 ft, fracture width (W(0)) of 0.4680 inch and fracture conductivity (Fcd) of 75094 md ft.
2. The hydraulic fracturing plan for the RAG well usage fracturing fluid YF430LpH-(CO_2 70Q)-F104 low pH crosslinker + 25% CO^2 with additional additives that have been adjusted and using XRT Ceramax 16/20 mesh proppant.
3. In operation of hydraulic fracturing in the RAG well, has been determined that the surface injection pressure used of 4944.4389 psi, with a pumping horse power of 2302.5573 HP at an injection rate of 19 bpm and a treatment time of 72.3 minutes.
4. Based on the analysis of parameters, it was found that there was an increases in parameters in the RAG well including an increases in the average permeability of the formation from 10 mD to 162.89 mD, fold of increase to 6.33, productivity index, and rate of oil production based on Wiggins IPR analysis from 6.39 Bopd to 40.44 Bopd with fluid flow rate also increasing from 86.97 Bfpd to 550.67 Bfpd.

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