Gema Wiralodra

Publication details, including instructions for authors and subscription information:
https://gemawiralodra.unwir.ac.id

Gema WIRALODRA

Editor-in-Chief: Yudhi Mahmud

Publisher: Universitas Wiralodra

Productivity Calculation of Well Tlj-250 Post Hydraulic Fracturing Job at Pt . Bukit Apit Bumi Persada

Adrian Indarti[a*], Desi Kusrini[b], Isnani Agriandita[c], Rio Dwi Prakoso[d]

[a*]Institut Teknologi Petroleum Balongan, Indramayu, Indonesia, adrianindarti88@gmail.com
[b] Institut Teknologi Petroleum Balongan, Indramayu, Indonesia, desiakamigas18@gmail.com
[c] Institut Teknologi Petroleum Balongan, Indramayu, Indonesia, isnaniee@gmail.com
[d] Institut Teknologi Petroleum Balongan, Indramayu, Indonesia, rioprakoso97@gmail.com

To cite this article:
Indarti, A., Kusrini, D., Agriandita, I., Prakoso, R. D. (2024). Productivity Calculation of Well Tlj-250 Post Hydraulic Fracturing Job at Pt . Bukit Apit Bumi Persada. *Gema Wiralodra*, *15*(3), 987 – 997.
To link to this article:
https://gemawiralodra.unwir.ac.id/index.php/gemawiralodra/issue/view/27
Published by:
Universitas Wiralodra
Jln. Ir. H. Juanda Km 3 Indramayu, West Java, Indonesia

p – ISSN: **1693-7945**
e –ISSN: **2622 - 1969**

Orginal Article

Productivity Calculation of Well Tlj-250 Post Hydraulic Fracturing Job at Pt . Bukit Apit Bumi Persada

Adrian Indarti[a*], Desi Kusrini[b], Isnani Agriandita[c], Rio Dwi Prakoso[d]

[a*]Institut Teknologi Petroleum Balongan, Indramayu, Indonesia, adrianindarti88@gmail.com
[b] Institut Teknologi Petroleum Balongan, Indramayu, Indonesia, desiakamigas18@gmail.com
[c] Institut Teknologi Petroleum Balongan, Indramayu, Indonesia, isnaniee@gmail.com
[d] Institut Teknologi Petroleum Balongan, Indramayu, Indonesia, rioprakoso97@gmail.com

***Correspondence: adrianindarti88@gmail.com**

Abstract
PT Bukitapit Bumi Persada is a company engaged in oil well service including cementing, stimulation, fracturing, coiled tubing unit and nitrogen service. Hydraulic fracturing is a stimulation activity to repair wells due to damage to the formation by injecting fracturing fluid at high pressure to create channels and held with proppant so that the fractures formed do not close again. The TLJ-250 well in the Prabumulih field was stimulated using hydraulic fracturing on Sunday, April 24, 2022. The TLJ-250 well has sandstone lithology with low permeability of about 4 mD with a porosity value of 12% so that this well is not productive to produce hydrocarbons. The fracturing fluid used is water base fluid, which is a water-based fracturing fluid and the proppant used is carbolite 20/40. The process of hydraulic fracturing begins with a breakdown test, step rate test, mini frac, and main frac with the stages of injecting proppant starting with pre-pad, slug, pad, and flush. The reason for hydraulic fracturing in the TLJ-250 well is that the ex bore well is less economical when producing. After hydraulic fracturing, TLJ-250 well experienced an increase in permeability value of about 904.15 mD with an average permeability around 22.32 mD followed by an increase in productivity index (PI) with the Prats method around 3.75 and the Cinco-Ley method is around 3.57 times. The production rate at TLJ-250 well is 158 BFPD with oil production of 21 BOPD
Keywords: Permeability, Productivity Index, Proppant, Inflow Performance Relationship, Skin

1. Introduction

The TLJ-250 well is an ex bore well that was stimulated using hydraulic fracturing on Sunday, April 24, 2022. The TLJ-250 well has a sandstone lithology with a well depth of 2040 m (6692.91 ft), located in the Talang Akar formation of the South Sumatra basin and hydraulic fracturing is carried out at an interval depth of 1420 - 1425 m, has low permeability with a value of 4 mD (tight formation), Tight reservoir or tight formation is a low permeability value that has a value of 0 - 5 mD, and porosity is 12%. The reason for hydraulic fracturing is due to that low permeability (4mD) and porosity (12%) issues , whereas TLJ-250 is a new well. The application of hydraulic fracturing by creating cracks or fractures in the formation rock, hopes can increase its permeability and also porosity, so that can increase also the production fluid deliverability from the reservoir to wellbore. The research on this well is important to get gain production, gain profit, and add another experience of hydraulic fracturing application.

2. Method

2.1 Hydraulic Fracturing (HF) Process Procedure at Well TLJ-250

The execution of hydraulic fracturing in this well starts with quality control, tubing pickle, pressure test, step rate test (step up test & step down test), mini fracturing, main fracturing and flushing.

p – ISSN: **1693-7945**
e –ISSN: **2622 - 1969**

1. Quality Control

Quality control of the fracturing fluid is testing the feasibility of the fracturing fluid sample that has been made so that the sample is suitable for the well to be fractured and also check the well lithology.

2. Tubing Pickle

Tubing Pickle aims to clean the tubing string by pumping pickle treatment HCl and pumping displace bbl.

3. Breakdown Test

Breakdown test (BT) is an early stage test of hydraulic fracturing operations carried out by applying pressure for several minutes where the end of the tubing is installed with a plug to withstand pressure. The purpose of the tubing pressure test is to determine whether or not there is a leak in the tubing. The BT for this well applied 4000 psi for tubing pressure test, fluid volume pumped 57 bbls in 7 minutes ime duration.

4. Step Rate Test (Step Up Test & Step Down Test)

Step Rate Test (SRT) is a fluid rate test that is carried out in stages. The purpose of this test is to determine the injection rate when the rock begins to fracture. So that it is necessary to set an injection rate that increases little by little in stages, this serves to determine the pressure when the rock begins to break (breakdown pressure) and the pumping rate for fracture extension (pressure extension rate). The SRT in this well applied, 0.57 bpm min rate, 17.23 bpm max rate , 1.373 psi min pressure, 4.874 psi max pressure, total volume of pumped fluid is 77.93 bbl, and duration in 12 minutes.

5. Mini Fracturing

After the step rate test (step up test and step down test), the next execution is mini frac activity. The purpose of mini frac itself is to provide the best possible information within the formation. The mini frac at this well, applied 9.86 bpm min rate,14.58 bpm max rate, 2.914 psi min pressure, 3.739 psi max rate, total flush 32 bbl, total fluid pumped 212.19 bbl, duration 17 minute.

6. Main fracturing

After knowing all the data in the wellbore through the step rate test and mini frac, verification of the initial design with these data is carried out, which results in the required fluid volume, certainty of fluid parameters and the volume of proppant to be used. The main frac here, conducted by 8.44 bpm min rate, 17.59 bpm max rate, 2.640 psi min pressure, 4.698 psi max pressure, total clean pumped 740 bbl, total pumped proppant 100.58 klbs, and total time duration is 57 minutes.

7. Flushing

After the main frac is carried out, flushing or displace is carried out with slickwater in the form of 4% KCl with final presssure. Flushing aims to push the proppant that has been flowed into the well into the fracture formation. After that, stop pumping by waiting for the gluing fluid to melt and observing the pressure that occurs.

2.2 Additives

Additives are materials that are added to the fracturing fluid with a certain composition so that it can produce the expected performance. Additives that are often used in hydraulic fracturing operations include:

1. Crosslinker, serves to increase the viscosity of the fluid perekah, by binding molecules so that the chain becomes long.

p – ISSN: **1693-7945**
e –ISSN: **2622 - 1969**

2. Breaker, serves to reduce the viscosity of the fracturing fluid after completion of proppant placement, so that it can break the polymer chain and the production of oil flow again is easy to do.
3. Buffers, used to stabilize fluid pH levels.

2.3 Proppant

Propping agent (Proppant) is a material used as a gap filler as a result of fracturing delivered by the fracturing fluid into the fracture. The main function of this proppant is to fill the gaps after the fracturing process is carried out so that the gap is not closed back in its original form. Proppant must be able to withstand the closure stress pressure on the fracture so that the proppant must be of good quality and distributed appropriately.

2.3.1 Types of Proppant

There are several types of propping agents that are most commonly or frequently used, namely:
1. Natural Sand

Natural sand that is often used as propping material is Ottawa sand and Brady sand.
2. Resin Coated Sand

Resin Coating is applied to sand (usually norhthern white sand) to increase proppant strength, prevent proppant flow back during production, help distribute pressure, when crushed proppant grains cannot withstand the load received, the crushed grains will be attached to the formation and not carried away by fluid flow due to the resin layer. It has an SG of 2.55 and closure stresses up to 8000 psi, is stronger and has high conductivity than conventional sand.
3. Ceramic Proppant

Ceramic Proppant Is a type of proppant that functions to withstand high rock stress.

2.4 Fracture Geometry Model

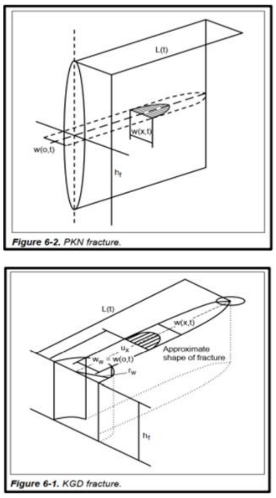
Fracture geometry models usually describe the relationship between the properties of the rock and fracturing fluid and the pressure distribution of the rock formation.

2.4.1 Two-dimensional (2D) Fracture Model

The two-dimensional model is a closed-form analytical approach assuming known constants and fracture height. For fracture lengths much greater than fracture height (xf>>hf), **Perkins and Kern** (1961) and **Nordgren** (1972) or PKN models are appropriate approximations. It is used to estimate the comparative productivity index (J/Jo) using the CSD method **(Cinco-Ley, Samaniego and Dominique)** and the Vogel equation. For fracture lengths greater than the fracture height (xf < hf), suitable models have been presented by **Khristianovic** (h) and **Zheltov** (1955) as well as **Geertsma and de Klerk** (1969) this is often known as the KGD model. The limiting case, where h = 2xf, is the radial or "penny shape" model. The fracture height, hf, used here is the dynamic value, i.e. the fracture height when the fracture length is equal to xf. The pictures are showed below.

p – ISSN: **1693-7945**
e –ISSN: **2622 - 1969**

Figure 1.
Fracture Geometry Model of PKN and KGD

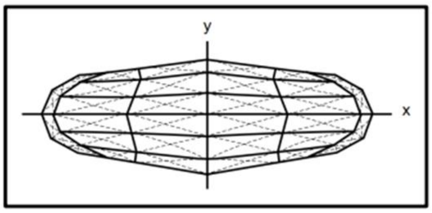


(Source Economides, 2000:200)

2.4.2 Three-dimensional (3D) Fracture Model

3D planar fracture expansion, 2D fluid flow. The model makes no assumptions about fracture orientation. Factors such as wellbore orientation or perforation pattern may cause fractures to initiate in a certain direction before changing to the final preferred orientation (perpendicular to the far-field minimum in-situ stress) as the following picture .

Figure 2.
3D Planar Fracture Geometry Model



(Source: Economides, 2000:211)

2.5 Evaluation of Hydraulic Fracturing Results

This evaluation is conducted to determine the level of success or the extent of success or failure of the implementation of hydraulic fracturing on well productivity. To determine the success of a hydraulic fracturing stimulation program, the easiest is to observe the production rate of the well. From these observations, we can find out whether the hydraulic fracturing stimulation program is successful or not, if there is an increase in production rate after hydraulic fracturing stimulation, then the program can be declared successful.

2.5.1 Based on Formation Permeability

To estimate the increase in production of a well is by looking at the price of the permeability distribution produced after fracturing. The assumption used is that the hydraulic fracturing stimulation causes the permeability price around the wellbore to be different from the permeability price in the zone far from the wellbore (discontinuous radial permeability).

p – ISSN: **1693-7945**
e –ISSN: **2622 - 1969**

2.5.2 Based on Productivity Index (PI)

Productivity index is an index that states the ability of a well to produce at a certain pressure condition. Theoretically, by performing hydraulic fracturing on a formation, the formation's ability to produce or supply fluid into the wellbore will increase, thus the productivity index price will increase as well.

2.5.3 Based on IPR Curve

In this case, the analysis of the increase in the well productivity index price is based on the performance of the formation fluid flow to the wellbore or the behavior of the productive formation, which is described in the form of an IPR curve. This flow behavior is expressed in terms of the relationship between well bottom flow pressure and oil or gas flow rate.

3. Results and Discussion

3.1 Well Profile

The Well TLJ-250 is an ex-bore well that was stimulated using hydraulic fracturing. The TLJ-250 well was subjected to hydraulic fracturing in the interval 1420 - 1425 m and the fracturing job was completed on Sunday, April 24, 2022. The methodology applied is by collecting data such as: well profile, post job report hydraulic fracturing, and production performance.

The assessment and calculation carried out in this final project research starts from the reason for hydraulic fracturing, data preparation, selection of fracturing fluid and proppant used, calculation of production increase, and comparison analysis of IPR (Inflow Performance Relationship) curves.

Several reasons for conducting hydraulic fracturing stimulation at the TLJ-250 well sandstone layer in the interval 1420-1425 m in the Prabumulih field.

Prabumulih field, namely:

1. It is a development well or a new well that is less economical when producing.
2. It has sufficient reservoir pressure (Pr) of 1800 psi.
3. The price of permeability (k) and porosity is relatively small, TLJ-250 well has a permeability of 4 mD and a porosity of 12 %.

3.2 Well Data

Well name : TLJ-250
Field : Prabumulih
Formation lithology : sandstone

Table 1.
Completion Data

Data	Value	Unit
Total Depth	2042	m MD
KOP	578	m
Casing 9 5/8" 43 ppf k55	1374	m MD
Casing 7" 26 ppf N80	1316 - 2040	m MD
Perforation Target	1420 - 1425	m MD

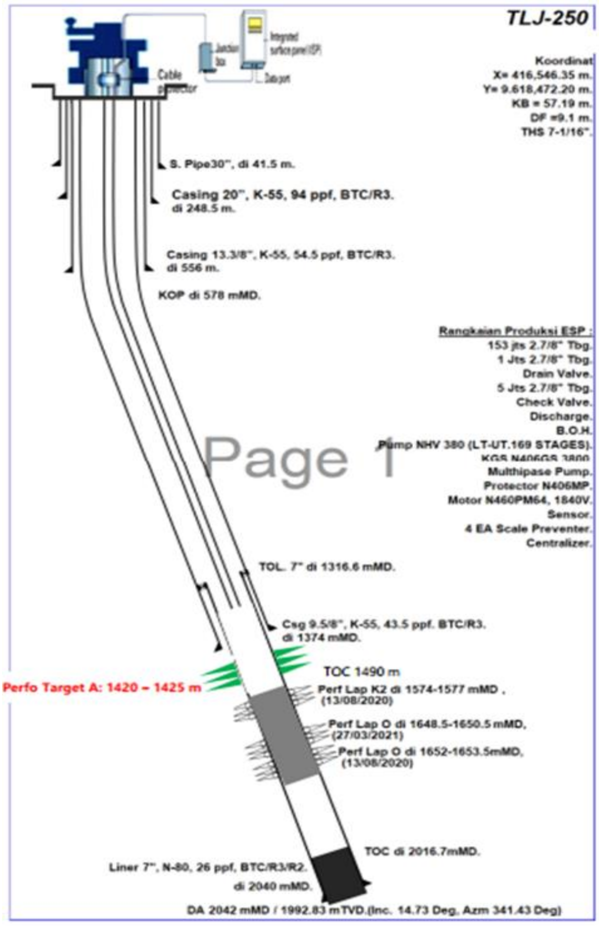
p – ISSN: **1693-7945**
e –ISSN: **2622 - 1969**

Table 2.
Reservoir Data

Data		Unit
Reservoir Pressure	1800	psi
Reservoir Temperature	204	ºF
Lithology	Sandstone	
Permeability	4	mD
Porosity	12	%
Thickness	5	m

(Source: Post Job Report Fracturing, PT. BBP, 2022)

Figure 3.
Well Profile Sumur TLJ-250



(Source: Post Job Report Fracturing, PT. BBP, 2022)

Figure 5 shows the sketch of the well, the data of well total depth in 2042mMD or 1992.83mTVD. perforation interval target in 1420 m – 1425 m, top of 7" liner (TOL) in 1316.6 mMD. Then the casing data, there are four types of casing installed in this well, first 30 inch conductor casing installed till 41.5 m, second 20 inch surface casing installed till 248.5m, third 13 3/8 inch intermediate casing installed till 556m, and the fourth 9 5/8 inch production casing installed till 1374 mMD.

p – ISSN: **1693-7945**
e –ISSN: **2622 - 1969**

3.3 Fracturing Fluid

The selection of fracturing fluid is usually based on reservoir data, where the fracturing fluid to be used in the implementation of hydraulic fracturing must be in accordance with the formation to be fractured. The fracturing fluid used in the hydraulic fracturing work at the TLJ-250 Well is BMT 35 System Medium Temp and KCL 2% KCL which is a water-based fluid. This layer is a formation consisting of sandstone and a little shale rock so that the fracturing fluid used is compatible with the reservoir rock, this fluid is also able to stabilize up to a temperature of 350 °F.

3.4 Proppant

Proppant selection is based on the size, quality and strength of the proppant and the shape of the proppant granules. The proppant or propping agent used in the implementation of hydraulic fracturing at the TLJ-250 well is the Carbo Ceramics type, namely 20/40 Carbo-Lite.

Table 3.

Proppant Data

Proppant Name	Spesific Gravity	Average Diamter (in)	Pack Porosity (%)	Permeability (mD)
Carbolite 20/40	2,71	0,0287	37	520

(Source: Post Job Report Fracturing, PT. BBP, 2022)

3.5 Analysis of Fracture Geometry

Evaluating the fracture geometry formed can be seen several parameters used to estimate the shape of the fracture that occurs. Before carrying out hydraulic fracturing work, a preliminary design is carried out so that the final results made can be achieved properly as expected or not.

Table 4.

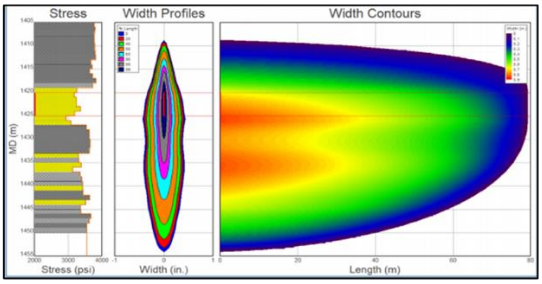
Fracturing Summary

Parameter	Satuan	Initial design	Final Design	Post Job Report
Half Length	m	76	79	65,58
Widht propped	inch	0,28	0,2	0,33
Frac Heigth	m	27	35	27,93
Conductivity	md.ft	11600	8300	14767
FCD		9,2	8,0	17,17

(Source: Post Job Report Fracturing, PT. BBP, 2022)

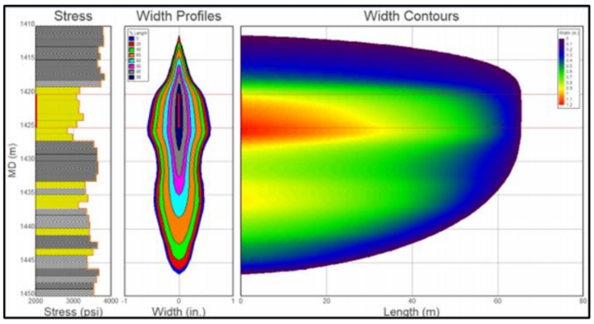
p – ISSN: **1693-7945**
e –ISSN: **2622 - 1969**

Figure 4.
Final Design Frac Geometry



(Source: Post Job Report Fracturing, PT. BBP, 2022)

Figure 5.
Post Job Frac Geometry



(Source: Post Job Report Fracturing, PT. BBP, 2022)

From figure 4 and 5 show the results of the fracturing that occurred in the TLJ-250 well, between the initial design and the final design showed that the final design results were not much different from the planned design results. The success of the fracture geometry formed is also seen from the amount of proppant (blue zone) that enters the fracture hole to match the target achieved.

3.6 Production Analysis

This analysis is carried out to determine the success or failure rate of the implementation of hydraulic fracturing that has been carried out on well productivity.

3.6.1 Permeability Analysis

The following is the calculation of the permeability price after fracturing (kf) and the average permeability distribution price (Kavg) as a result of hydraulic fracturing in the TLJ-250 Well using the **Howard and Fast** equations.

1. Calculating Fracture Permeability

$$K = \frac{(k \times h) + WK_f}{h}$$

$$K = \frac{(4 \text{ mD} \times 16{,}41 \text{ m}) + 14767 \text{ md.ft}}{16{,}41 \text{ m}}$$

$$K = 904{,}15 \text{ mD}$$

2. It is assumed that fracture formation causes the permeability around the well to differ from the permeability of the zone away from the wellbore. So that the average fracture permeability (Kavg)

$$K_{avg} = \frac{\log\left(\frac{re}{rw}\right)}{\left(\frac{1}{Kf}\right)\log\left(\frac{Xf}{rw}\right) + \left(\frac{1}{Ki}\right)\log\left(\frac{re}{Xf}\right)}$$

p – ISSN: **1693-7945**
e –ISSN: **2622 - 1969**

$$K_{avg} = \frac{\log(\frac{820{,}25\ ft}{0{,}40\ ft})}{(\frac{1}{904{,}15\ mD})\log(\frac{215\ ft}{0{,}40\ ft})+(\frac{1}{4\ mD})\log(\frac{820{,}25\ ft}{215\ ft})}$$

$$K_{avg} = 22{,}32\ mD$$

Based on the permeability calculation results, the average permeability price at Well TLJ-250 is 22.32 mD and greater than the initial effective permeability of 4 mD.

3.6.2 Analysis Produktivity Index (PI)

Productivity Index is a number that expresses the ability of a formation to produce. Theoretically, the productivity index price will increase after hydraulic fracturing is performed..

a. Methods Darcy (Before Hydraulic Fracturing)

PI = 0 bpd/psi (no production flow, since new well and very tight well)

b. Methods Darcy (After Hydraulic Fracturing)

$$PI = \frac{Q}{Pr - Pwf}$$

$$PI = \frac{158\ bopd}{1800\ psi - 1433\ psi}$$

PI = 0,4 bpd/psi

Before the hydraulic fracturing method, calculations were carried out using the Darcy method where the results were 0 bpd/psi, while calculations after hydraulic fracturing were 0.4 bpd/psi.

3.6.3 IPR Curve Analysis

The calculation steps for the TLJ-250 well of the Vogel method are as follows:

1. Calculate the total oil flow rate (Qo max) using the formula:

$$Qo\ max = \frac{Qo}{1 - 0{,}2(\frac{Pwf}{Pr}) - 0{,}8(\frac{Pwf}{Pr})^2}$$

$$Qo\ max = \frac{21\ bopd}{1 - 0{,}2(\frac{1433\ psi}{1800\ psi}) - 0{,}8(\frac{1433\ psi}{1800\ psi})^2}$$

Qo max = 62,92 BOPD

2. Calculating Qo for various Pwf assumptions, e.g. Pwf = 1433 Psi

$$Qo = Qo\ max\ (1 - 0{,}2\left(\frac{Pwf}{Pr}\right) - 0{,}8(\frac{Pwf}{Pr})^2)$$

$$Qo = 62{,}92\ bopd\ (1 - 0{,}2\left(\frac{1433\ psi}{1800\ psi}\right) - 0{,}8(\frac{1433\ psi}{1800\ psi})^2)$$

Qo = 21 BOPD

3. Calculating the water flow rate (Qw), e.g. Pwf = 1433 Psi

$$Qw = \left(\frac{WC}{100 - WC}\right) x\ Qo$$

$$Qw = \left(\frac{86{,}71\ \%}{100 - 86{,}71\ \%}\right) x\ 21\ bopd$$

Qw = 137 BWPD

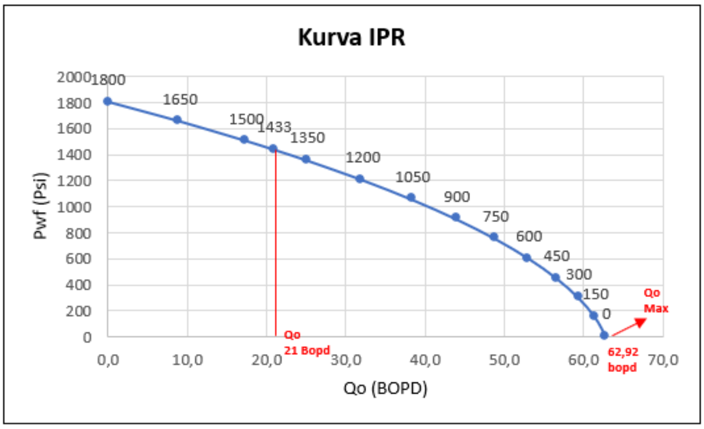
4. Calculating the total flow rate (Qt), e.g. Pwf = 1433 Psi

Qt = Qo + Qw
Qt = 21 bopd + 137 bwpd
Qt = 158 BFPD

Figure 6.

p – ISSN: **1693-7945**
e –ISSN: **2622 - 1969**

IPR Curve Well TLJ-250



(Source: Post Job Report Fracturing, PT. BBP, 2022)

From the calculation of the IPR curve in Figure 6 conducted at the TLJ-250 Well, it is known that the maximum oil flow rate (Qo max) in this well is 62.9 BOPD with an oil flow rate (Qo) of 21 BOPD. So that the implementation of hydraulic fracturing successfully increase the production.

4. Conclusion

From the results of the study that has been carried out, several conclusions can be drawn as follows:

1. This TLJ-250 well is an ex bore well consisting of a sandstone rock formation which is considered less economical when produced, it has a small permeability value of 4 mD (tight formation) and low porosity of 12% only, then has a fairly high reservoir pressure of 1800 psi,whereas this TLJ-250 well still has hydrocarbon reserves that are very potential for hydraulic fracturing stimulation.
2. The TLJ-250 well in the Prabumulih field has a permeability before hydraulic fracturing of 4 mD and after hydraulic fracturing has increased by 22.32 mD.
3. The TLJ-250 well in the Prabumulih field has productivity index (PI) before hydraulic fracturing is 0 bpd/psi, then after hydraulic fracturing, the PI shows higher in 0.4 bpd/psi. Its oil production rate after hydraulic fracturing increased by 21 Barrel Oil Per Day (BOPD),the result of Qo max value is 62.9 BOPD and the total flow rate (Qt) is 158 BFPD.

The hydraulic fracturing job at TLJ-250 well was successfully conducted , prooved by the increasing of production rate, this gain production will also contributes to gain the total production of the filed.

5. Acknowledgement

I would like to express our deepest gratitude to Allah SWT, and I wish to extend my sincere thanks to PT Bukitapit Bumi Persada, Mrs. Desi, Mrs. Isna, and Rio for their explanation, guidance, assistance, support, and patience to finish this paper

6. References

Aguilera, Roberto, 1980, “Naturally Fractured Reservoir”, Tulsa : PennWell Publishing Company.

p – ISSN: **1693-7945**
e –ISSN: **2622 - 1969**

Amalia. R. 2019. "Sensitivitas Konsentrasi Proppant Terhadap Peningkatan Indeks Produktivitas (PI) Pada Stimulasi Hydraulic Fracturing". Palembang: Jurnal Pertambangan.

Bimbi, C., Prabu, S.A., Herlina W. 2012. "evaluation of application hydraulic fracturing result at carbonate reservoir bcn-28 well app structure in pt pertamina ep asset 2 pendopo field". Palembang : Universitas Sriwijaya.

Boyun Guo, William C.Lyons, Ali Ghalambor, (2007). Louisiana: Petroleum Production Engineering.

Brown. K. E.1980. "The Technology of Artificial Lift Methods Volume 2a dan 2b". PennWell Publishing Company .Tulsa, Oklahoma.

Brown. K. E.1984. "The Technology of Artificial Lift Methods Volume 4". PennWell Publishing Company .Tulsa, Oklahoma.

Dedy, K., Jagadita. S., 2020. "An integrated analysis for post hydraulic fracturing production forecast in conventional oil sand reservoir". Yogyakarta : Journal of Earth Energy Engineering UIR.

Economides, Michael J., Kenneth G. Nolte. "Reservoir Stimulation", Houston, Texas: Energy Tribune Publishing Inc.

Jabbari, H., Benson, S.A. 2023. "Hydraulic Fracturing Design Optimization—Bakken Case Study", ARMA 13-177, US Rock Mechanics / Geomechanics Symposium, 23-26 June, San Francisco, USA.

Jasipto, A. 2020. "Redesign Hydraulic Fracturing Dalam Usaha Optimasi Produksi Pada Sumur X-100 Lapangan X Blok Rimau PT.XYZ". Lampung Selatan: Corresponding author.

Musnal, A., 2011. "Perhitungan Laju Alir Minyak Setiap Lapisan Pada Sumur Commingle". Pekanbaru: Jurnal Saintis.

Post Job Report Hydraulic Fracturing. 2022. PT. Bukit Apit Bumi Persada, Prabumulih.

Schechter, R.S. 1992. "Oil Well Stimulation". Texas. New Jersey: Prentience Hall.

Suwardi. 2009. "Evaluasi Hydraulic Fracturing Dalam Rangka Peningkatan Produktivitas Formasi". Jurnal Ilmu Kebumian Teknologi Mineral Vol.22. UPN Veteran Yogyakarta.

Thomas O. Allen and Alan P.Roberts.(2003). "Production Operation Vol 1 & 2". Tulsa, Oklahoma.

Tjondro, Bambang, Kamiso, Dave Rich, Suryaman. 1997. "Hydraulic Fracturing Intermediate".Jakarta.

Weiyong, L., Changchun, H. 2020 "Numerical simulation of the fracture propagation of linear collaborative directional hydraulic fracturing controlled by preslotted guide and fracturing boreholes" China: Engineering Fracture Mechanics.