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Jurnal : Jurnal Migasian

Penulis : Arinda Ristawati , Mulia Ginting, Jasmine Ghina Kaynes, Onnie Ridaliani Prapansya, Hari Karyadi Oetomo dan Michael Sultan Matheus Sahuleka

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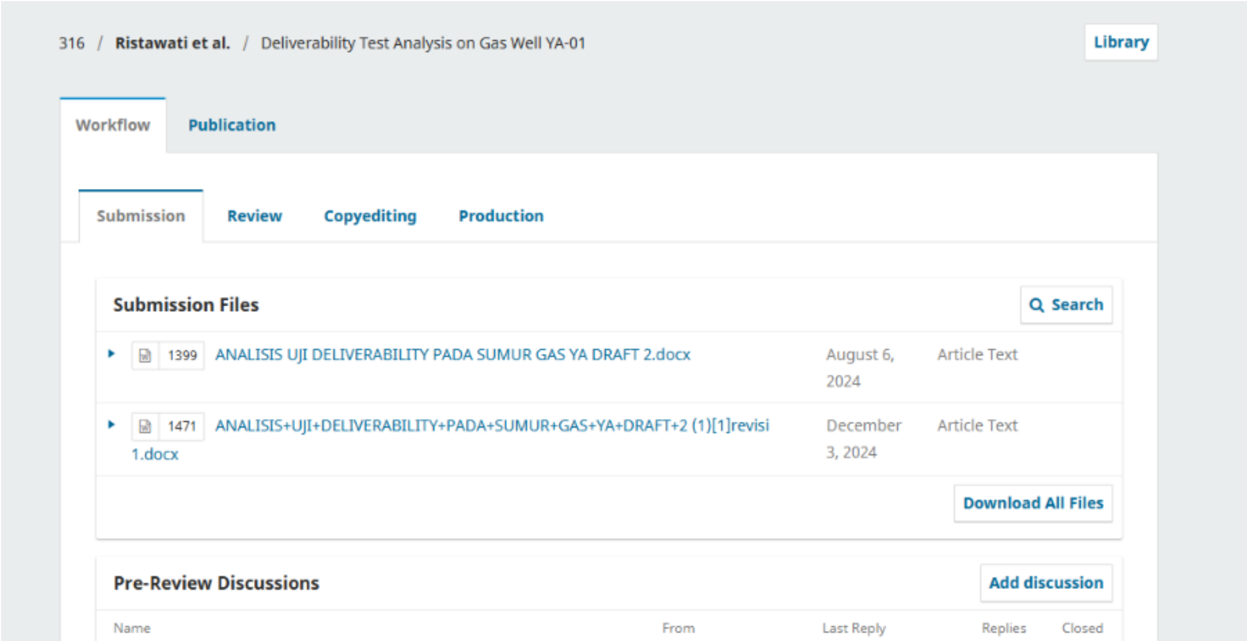

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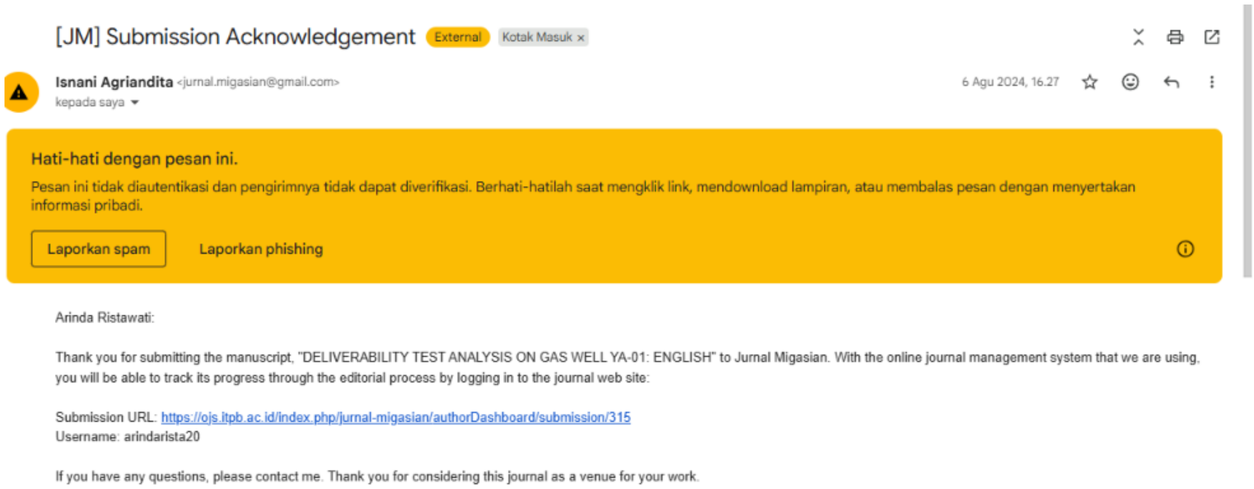

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ANALISIS UJI *DELIVERABILITY* PADA SUMUR GAS YA-01

DELIVERABILITY TEST ANALYSIS ON GAS WELL YA-01

Arinda Ristawati [1,a)*], Mulia Ginting[1], Jasmine Ghina Kaynes [1], Onnie Ridaliani Prapansya [1], Hari Karyadi Oetomo [1], dan Michael Sultan Matheus Sahuleka [1]

[1] *Petroleum Engineering, Universitas Trisakti, Jakarta, Indonesia, 1140*
Email : [a] arinda@trisakti.ac.id*

Diterima (Tanggal Bulan Tahun), Direvisi (Tanggal Bulan Tahun)

Abstract. *Deliverability tests are used to evaluate a well's production capability by estimating the Absolute Open Flow Potential (AOFP) and maximum flow rate. The three main methods applied are the Flow-after-flow Test, Isochronal Test, and Modified Isochronal Test. For the YA-01 gas well, the Flow-after-flow Test was used, which involves steps such as data compilation, plotting, calculation of the inverse slope (n), and determination of the AOFP and maximum flow rate (Qmax). Software analysis results indicated an inverse slope (n) of 1.19226, a C value of 0.000000418 MSCFD/psia², an AOFP of 12,930 MSCFD, and a Qgmax of 3,879 MSCFD. For verification, a manual analysis using the Rawlins-Schellhardt and Horner methods with a pseudo-pressure approach was conducted, yielding an AOFP value of 12,850 MSCFD. The combination of software and manual results provides a comprehensive and accurate understanding of the well conditions, supporting production optimization decisions and evaluating the effectiveness of the acidizing process.*

Keywords: *Deliverability Test, Absolute Open Flow Potential (AOFP), Flow-after-flow Test, Permeability and Skin Factor, Flow Efficiency.*

Abstrak. Metode deliverability test digunakan untuk mengevaluasi kemampuan produksi sumur dengan memperkirakan nilai Absolute Open Flow Potential (AOFP) dan laju alir maksimum. Tiga metode utama yang diterapkan adalah Flow-after-flow Test, Isochronal Test, dan Modified Isochronal Test. Pada sumur gas YA-01, Flow-after-flow Test digunakan, dengan langkah-langkah meliputi penyusunan data, plotting, perhitungan inverse slope (n), dan penentuan nilai AOFP dan laju alir maksimum (Qmax). Hasil analisis perangkat lunak menunjukkan nilai inverse slope (n) sebesar 1,19226, nilai C sebesar 0,000000418 MSCFD/psia², AOFP sebesar 12.930 MSCFD, dan Qgmax sebesar 3.879 MSCFD. Untuk verifikasi, analisis manual menggunakan metode Rawlins-Schellhardt dan Horner dengan pendekatan Pseudo-Pressure dilakukan, menghasilkan nilai AOFP sebesar 12.850 MSCFD. Kombinasi hasil dari perangkat lunak dan manual memberikan pemahaman yang komprehensif dan akurat mengenai kondisi sumur, mendukung keputusan optimisasi produksi dan evaluasi efektivitas proses acidizing.

Kata kunci: Deliverability Test, Absolute Open Flow Potential (AOFP), Flow-after-flow Test, Permeability and Skin Factor, Flow Efficiency.

Introduction

The deliverability test method is used to assess the production capability of a well by estimating the AOFP (Absolute Open Flow Potential) value and maximum flow rate [1]. There are three main methods in this test: Flow-after-flow Test, Isochronal Test, and Modified Isochronal Test. In the Flow-after-flow Test, different back pressures are applied by shutting the well down to stable pressure (Pr), then producing the well at a flow rate of qsc1 until stable pressure Pwf1 is reached [2]. This process is repeated four times without having to shut the well down each time a change in production rate is made. This method is effective if the reservoir has high permeability which allows stable conditions to be achieved quickly [3] [4]

Isochronal Test is used for wells with low permeability, where a long time is needed to reach a stable state. The test is carried out with the same flow time (t), by shutting the well down to stable pressure and recording the reservoir static pressure (Pr) [1]. The well is then produced at a flow rate of qsc1 for a certain time (Δt) without waiting for stable pressure, and shut back in until the pressure reaches Pr. This method is designed to provide an estimate of well deliverability with the same time each time the flow is performed [5] [6].

Modified Isochronal Test was developed to overcome the weakness of Isochronal Test which requires a long time. This test is carried out with the same flow time and well shut-in time [7]. In this method, the well is shut in until the pressure is stable and recorded as reservoir static pressure (Pr), then produced without waiting for the pressure to stabilize [6]. Thus, this method shortens the testing time and is more efficient than Isochronal Test, making it more practical to use in field conditions that require fast response time

Research Methods

In the YA-01 gas well, the method used for deliverability testing is the Flow-after-flow Test. The steps taken to obtain the AOFP (Absolute Open Flow Potential) value include several stages. First, compile data related to the pressure and flow rate of the well. After that, the results of the $Pr^2 - Pwf^2$ calculations are mapped against the flow rate (q) to obtain the slope using the y equation from the trendline on the graph [9]. The first step is to determine the value of n using equation 1.

$$n = \frac{\log q_{sc2} - \log q_{sc1}}{\log\left(P_r^2 - P_{wf}^2\right)_1 - \log\left(P_r^2 - P_{wf}^2\right)_2} \quad (1)$$

Once the value of n is obtained, the value of C can then be determined using equation 2.

$$n = \frac{\log q_{sc2} - \log q_{sc1}}{\log\left(P_r^2 - P_{wf}^2\right)_1 - \log\left(P_r^2 - P_{wf}^2\right)_2} \quad (2)$$

To find out the flow rate value, equation 3 is used.

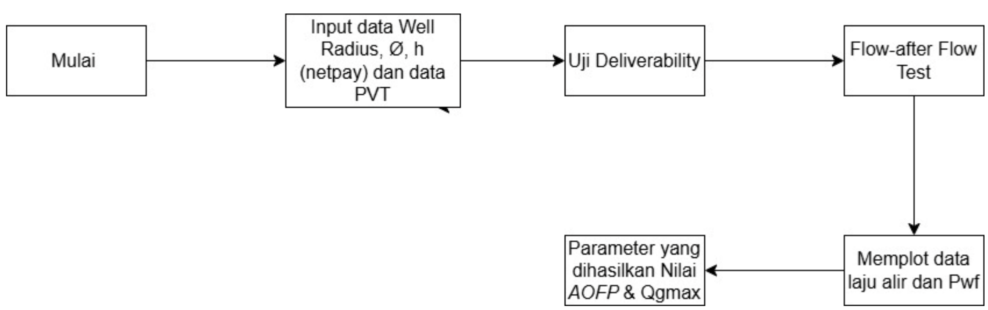
$$q_{sc} = C\left(P_r^2 - P_{wf}^2\right)^n \quad (3)$$

Next, the AOFP value can be determined using equation 4.

$$AOFP = C\left(P_r^2 - 14.7\right)^n \quad (4)$$

Finally, to determine the maximum flow rate value (Qmax), this value can be calculated as 30% of the AOFP result, using equation 5.

$$AOFP = C\left(P_r^2 - 14.7\right)^n \quad (5)$$



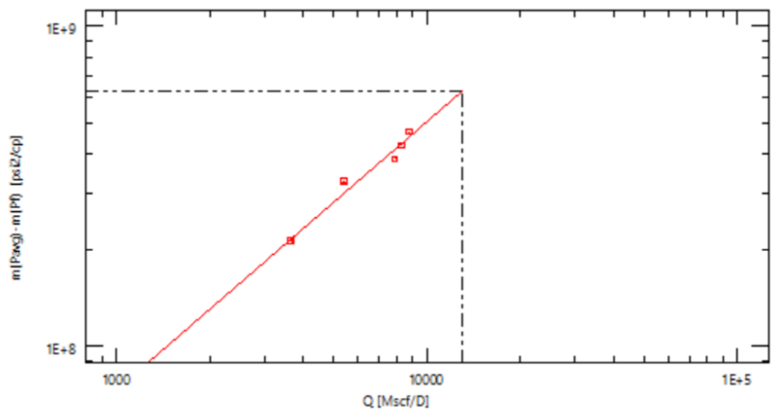
Picture 1. Work Flow on Well YA-01

Results and Discussion

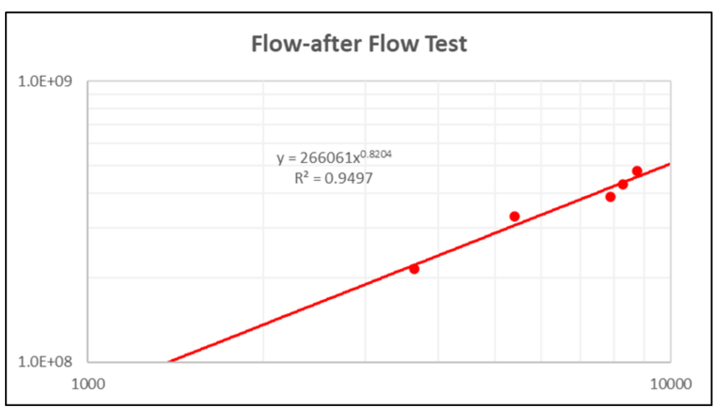
From the deliverability analysis using software after the acidizing process, important parameters for gas wells were obtained. The inverse slope (n) value obtained was 1.19226, while the C value was recorded at 0.000000418 MSCFD/psia². With this data, the Absolute Open Flow Potential (AOFP) value produced was 12,930 MSCFD. From this AOFP value, the maximum flow rate (Qgmax) that can be achieved by the well is 3,879 MSCFD.

Table 1. Flow-after Flow Test Data for Gas Well YA-01

P_{wf}	q_{sc}	$\overline{P}^2 - P_{wf}^2$	$\psi(\overline{P}) - \psi(P_{wf})$
Psia	MSCFD	$psia^2$	$psia^2/cp$
1810,41	7892,26	6.732.428,079	388.149.816,07
2445,36	3636,22	4.030.226,918	215.179.657,84
1645,11	8294,5	7.303.625,535	430.534.455,19
1453,32	8753,67	7.897.873,425	478.341.679,98
2028,93	5398,52	5.893.455,502	330.441.568,53
14,7	0	10.009.796,36	790.033.664,63



Picture 2. Flow-after Flow Test Analysis After Acidizing



Picture 3. Flow-after Flow Chart After Manual Acidizing

After obtaining the results from the software analysis, a manual analysis was carried out using the Rawlins-Schellhardt calculation method to verify the results obtained from the software.

This manual method aims to compare and ensure the accuracy of the deliverability test results previously performed. Figure 3 shows the Flow-after-flow Test graph generated from the manual analysis. This approach allows for cross-validation between the software and manual methods, providing more confidence in the accuracy of the parameters and deliverability test results from the YA-01 gas well after the acidizing process. Through this process, both the software and manual approaches can be viewed and analyzed simultaneously, providing a comprehensive picture of the performance and production potential of the well [10].

Conclusion

The results of the deliverability analysis after acidizing with the help of software showed an inverse slope (n) value of 1.19226, a C value of 0.000000418 MSCFD/psia², and an AOFP of 12,930 MSCFD with a Qgmax of 3,879 MSCFD while manual analysis using the Rawlins-Schellhardt method showed an inverse slope (n) value of 1.218901705, a C value of 0.000000223 MSCFD/psia², and an AOFP of 15,620 MSCFD with a Qgmax of 3,879 MSCFD Manual analysis using the Rawlins-Schellhardt method provided comparable results and ensured the accuracy of the parameters obtained from the software. This comparison between the software and manual results provides a comprehensive understanding of the well conditions.

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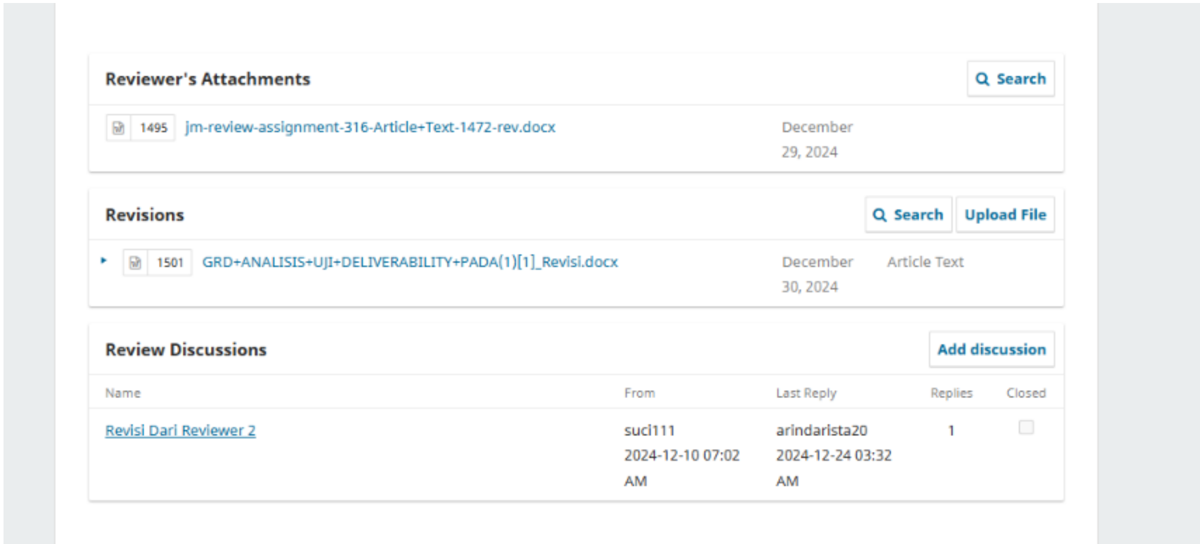
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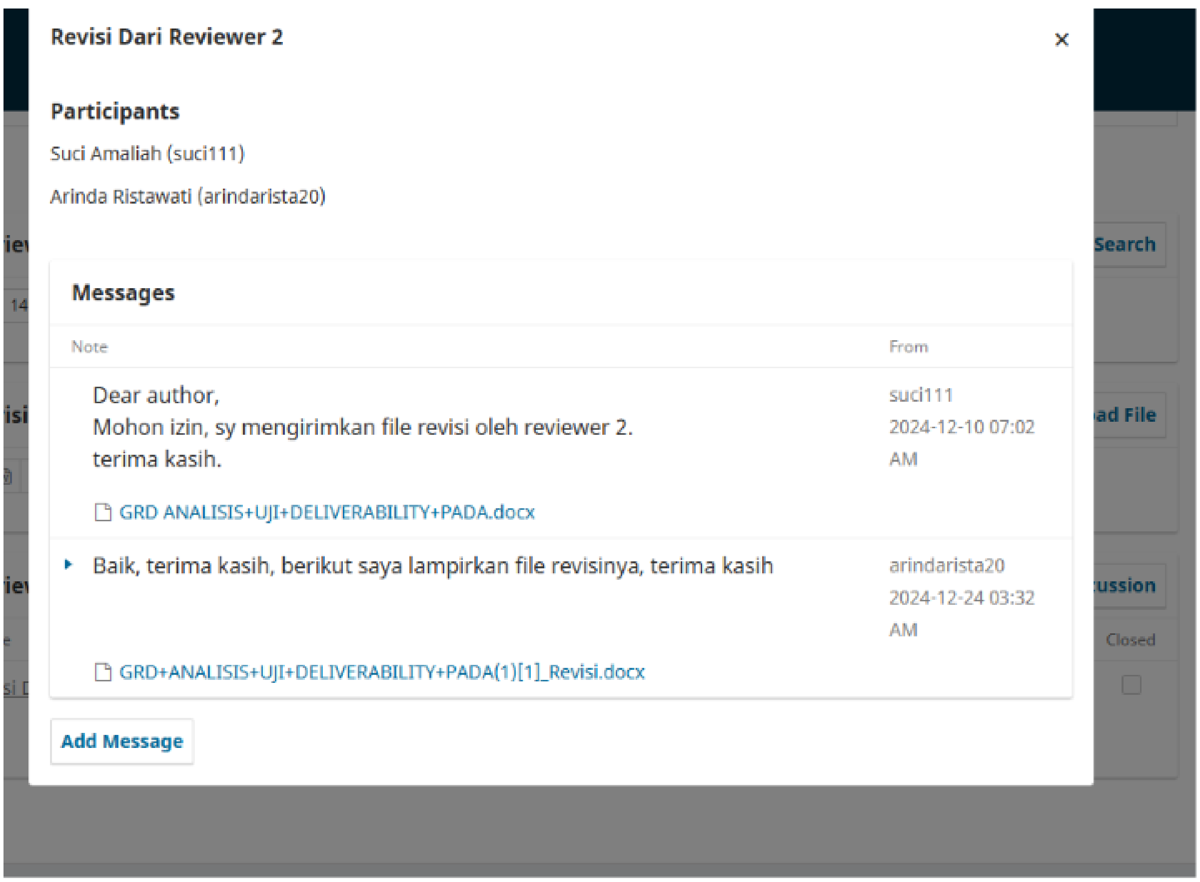
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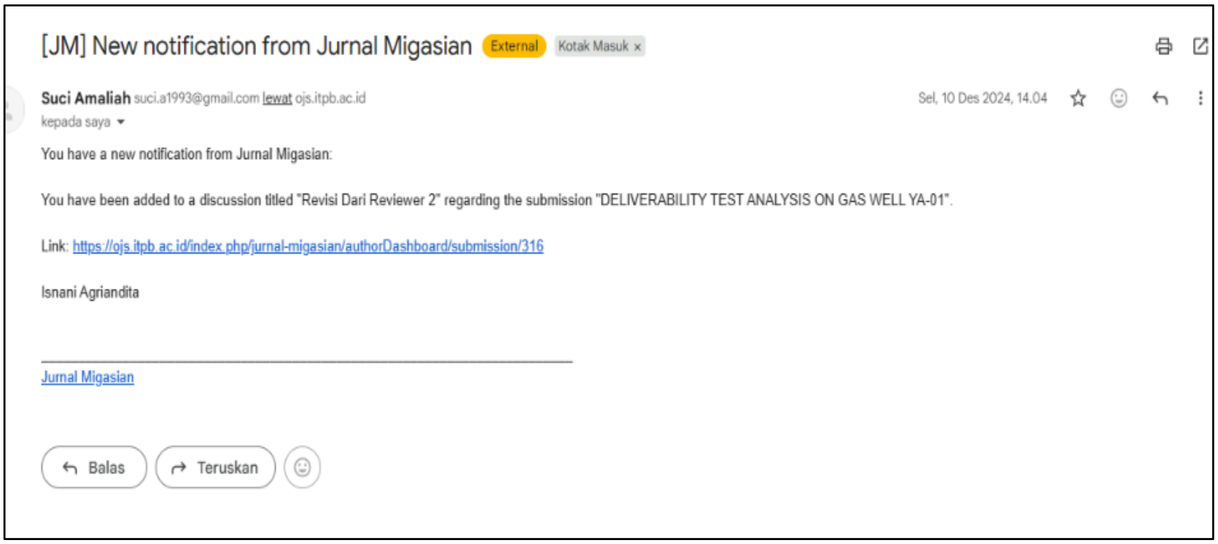

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Email : [a)] arinda@trisakti.ac.id*

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> **Commented [GRD1]:** Please elaborate more on the introduction. Please read and understand deeper about the gas deliverability tests available and the methods that may be used for gas deliverability.
> You need to know the gas type as well I believed, please elaborate more.
> Please put all equations needed in the introduction.
> Please research any papers that has been published regarding gas deliverability.

Research Methods

In the YA-01 gas well, the method used for deliverability testing is the Flow-after-flow Test. The steps taken to obtain the AOFP (Absolute Open Flow Potential) value include several stages. First, compile data related to the pressure and flow rate of the well. After that, the results of the $Pr^2 - Pwf^2$ calculations are mapped against the flow rate (q) to obtain the slope using the y equation from the trendline on the graph [9]. The first step is to determine the value of n using equation 1.

$$n = \frac{\log q_{sc2} - \log q_{sc1}}{\log(P_r^2 - P_{wf}^2)_1 - \log(P_r^2 - P_{wf}^2)_2} \quad (1)$$

Once the value of n is obtained, the value of C can then be determined using equation 2.

$$n = \frac{\log q_{sc2} - \log q_{sc1}}{\log(P_r^2 - P_{wf}^2)_1 - \log(P_r^2 - P_{wf}^2)_2} \quad (2)$$

To find out the flow rate value, equation 3 is used.

$$q_{sc} = C\left(P_r^2 - P_{wf}^2\right)^n \quad (3)$$

Next, the AOFP value can be determined using equation 4.

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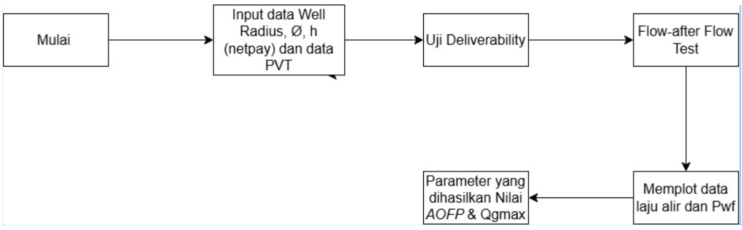
$$AOFP = C\left(P_r^2 - 14.7\right)^n \qquad (4)$$

Finally, to determine the maximum flow rate value (Qmax), this value can be calculated as 30% of the AOFP result, using equation 5.

$$AOFP = C\left(P_r^2 - 14.7\right)^n \qquad (5)$$



Picture 1. Work Flow on Well YA-01

Results and Discussion

From the deliverability analysis using software after the acidizing process, important parameters for gas wells were obtained. The inverse slope (n) value obtained was 1.19226, while the C value was recorded at 0.000000418 MSCFD/psia². With this data, the Absolute Open Flow Potential (AOFP) value produced was 12,930 MSCFD. From this AOFP value, the maximum flow rate (Qgmax) that can be achieved by the well is 3,879 MSCFD.

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P_{wf}	q_{sc}	$\overline{P}^2 - P_{wf}^2$	$\psi(\overline{P}) - \psi(P_{wf})$
Psia	MSCFD	$psia^2$	$psia^2/cp$
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1453,32	8753,67	7.897.873,425	478.341.679,98
2028,93	5398,52	5.893.455,502	330.441.568,53
14,7	0	10.009.796,36	790.033.664,63

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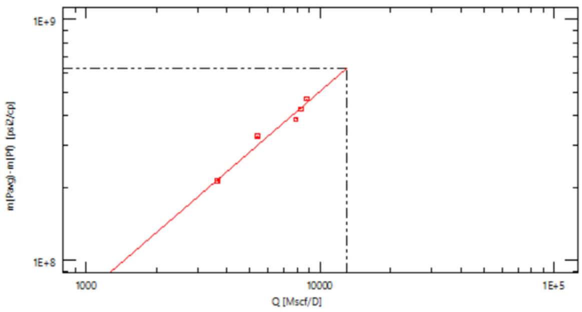
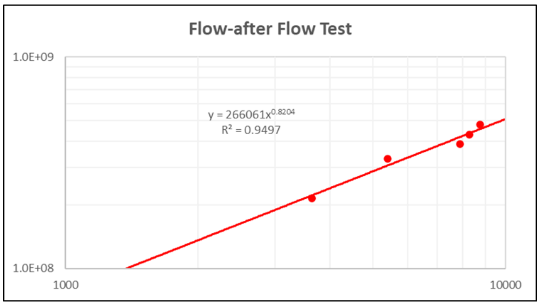


Picture 2. Flow-after Flow Test Analysis After Acidizing



Picture 3. Flow-after Flow Chart After Manual Acidizing

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Conclusion

The results of the deliverability analysis after acidizing with the help of software showed an inverse slope (n) value of 1.19226, a C value of 0.000000418 MSCFD/psia², and an AOFP of 12,930 MSCFD with a Qgmax of 3,879 MSCFD while manual analysis using the Rawlins-Schellhardt method showed an inverse slope (n) value of 1.218901705, a C

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Ensure to put percentage of differences between after / before acidizing and comparison between software and manual calculation.

Last but not least, :
Do not mix Bahasa and English
Improve the grammar
Create at least 7 pages.

value of 0.000000223 MSCFD/psia², and an AOFP of 15,620 MSCFD with a Qgmax of 3,879 MSCFD Manual analysis using the Rawlins-Schellhardt method provided comparable results and ensured the accuracy of the parameters obtained from the software. This comparison between the software and manual results provides a comprehensive understanding of the well conditions.

References

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[1] A. JIA *et al.*, "Technical measures of deliverability enhancement for mature gas fields: A case study of Carboniferous reservoirs in Wubaiti gas field, eastern Sichuan Basin, SW China," *Pet. Explor. Dev.*, vol. 44, no. 4, pp. 615–624, 2017, doi: 10.1016/S1876-3804(17)30070-8.

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3. Bukti menjawab reviewer 12 Desember 2024

ANALISIS UJI *DELIVERABILITY* PADA SUMUR GAS YA-01

DELIVERABILITY TEST ANALYSIS ON GAS WELL YA-01

Arinda Ristawati [1,a)*], Mulia Ginting[1], Jasmine Ghina Kaynes [1], Onnie Ridaliani Prapansya [1], Hari Karyadi Oetomo [1], dan Michael Sultan Matheus Sahuleka [1]

[1] *Petroleum Engineering, Universitas Trisakti, Jakarta, Indonesia, 1140*
Email : [a)] arinda@trisakti.ac.id*

Diterima (Tanggal Bulan Tahun), Direvisi (Tanggal Bulan Tahun)

Abstract. *Deliverability tests are used to evaluate a well's production capability by estimating the Absolute Open Flow Potential (AOFP) and maximum flow rate. The three main methods applied are the Flow-after-flow Test, Isochronal Test, and Modified Isochronal Test. For the YA-01 gas well, the Flow-after-flow Test was used, which involves steps such as data compilation, plotting, calculation of the inverse slope (n), and determination of the AOFP and maximum flow rate (Qmax). Software analysis results indicated an inverse slope (n) of 1.19226, a C value of 0.000000418 MSCFD/psia², an AOFP of 12,930 MSCFD, and a Qgmax of 3,879 MSCFD. For verification, a manual analysis using the Rawlins-Schellhardt and Horner methods with a pseudo-pressure approach was conducted, yielding an AOFP value of 12,850 MSCFD.*

Keywords: *Deliverability Test, Absolute Open Flow Potential (AOFP), Flow-after-flow Test, Permeability and Skin Factor, Flow Efficiency.*

Abstrak. Metode deliverability test digunakan untuk mengevaluasi kemampuan produksi sumur dengan memperkirakan nilai Absolute Open Flow Potential (AOFP) dan laju alir maksimum. Tiga metode utama yang diterapkan adalah Flow-after-flow Test, Isochronal Test, dan Modified Isochronal Test. Pada sumur gas YA-01, Flow-after-flow Test digunakan, dengan langkah-langkah meliputi penyusunan data, plotting, perhitungan inverse slope (n), dan penentuan nilai AOFP dan laju alir maksimum (Qmax). Hasil analisis perangkat lunak menunjukkan nilai inverse slope (n) sebesar 1,19226, nilai C sebesar 0,000000418 MSCFD/psia², AOFP sebesar 12.930 MSCFD, dan Qgmax sebesar 3.879 MSCFD. Untuk verifikasi, analisis manual menggunakan metode Rawlins-Schellhardt dan Horner dengan pendekatan Pseudo-Pressure dilakukan, menghasilkan nilai AOFP sebesar 12.850 MSCFD.

Kata kunci: Deliverability Test, Absolute Open Flow Potential (AOFP), Flow-after-flow Test, Permeability and Skin Factor, Flow Efficiency.

Introduction

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Please research any papers that has been published regarding gas deliverability.

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Gas deliverability testing is a fundamental procedure used to evaluate the production potential of a well, specifically by determining the Absolute Open Flow Potential (AOFP) and maximum flow rate. These parameters are crucial in reservoir engineering and production optimization as they provide insights into the well's ability to produce gas under various conditions. Gas deliverability testing is invaluable for characterizing well performance and understanding the interaction between reservoir properties and operational constraints. There are three main methods for conducting gas deliverability tests: the Flow-after-flow Test, Isochronal Test, and Modified Isochronal Test. Each method is designed to evaluate well performance under different operational scenarios and reservoir conditions. The selection of a method depends on factors such as reservoir characteristics, the time available for testing, and the desired level of result accuracy [1]

The Flow-after-flow Test involves applying different back pressures to the well by initially shutting it in to achieve stable reservoir pressure (Pr). The well is then opened to flow at a specific rate (qsc1) until a stable bottom-hole flowing pressure (Pwf1) is reached. This process is repeated several times, typically four, with variations in flow rate without shutting the well in again after the initial stabilization. This method assumes the reservoir has high permeability, allowing stable flow conditions to be quickly achieved. This test provides valuable data for constructing a deliverability curve, which is used to estimate AOFP and optimize production strategies [2]

The Isochronal Test is well-suited for reservoirs with low permeability or wells that require extended periods to reach stable conditions. In this test, the well is flowed at a constant rate for a short duration, followed by a shut-in period to allow pressure stabilization. This cycle is repeated multiple times, with flow rates and corresponding pressures recorded. The results are analyzed to determine the well's deliverability and AOFP [3]

The Modified Isochronal Test is a variation of the Isochronal Test, designed to address situations where stabilization during shut-in periods is difficult to achieve. In this method, the shut-in time is significantly reduced, and the focus is on the transient behavior of the well. This approach is particularly useful for time-sensitive operations or wells with challenging reservoir conditions. Understanding the type of gas being produced is critical in gas deliverability testing. Gas properties such as compressibility, viscosity, and composition significantly influence flow behavior and pressure responses. For example, the presence of impurities such as hydrogen sulfide (H2S) or carbon dioxide (CO2) can affect gas compressibility and necessitate adjustments in testing procedures and analyses. Accurate characterization of gas properties ensures reliable deliverability predictions and supports the design of efficient production systems [4][5]

The theoretical analysis of gas deliverability tests often involves applying fundamental flow equations. The backpressure equation, widely used in deliverability testing, is expressed as:

- where is the gas flow rate, is the deliverability coefficient, is the reservoir pressure, is the bottom-hole flowing pressure, and is the flow exponent. This equation provides the basis for constructing a deliverability curve and estimating AOFP. Another important equation is the pseudopressure function, which accounts for gas compressibility and the non-linear nature of gas flow

- where is the gas viscosity, is the gas compressibility factor, and is the pressure. This function is particularly useful for analyzing high-pressure gas wells and ensuring accurate deliverability calculations [6][7]

Numerous studies have explored advancements in gas deliverability testing methods and their applications. Recent research has focused on improving the accuracy of deliverability predictions by integrating real-time data acquisition, advanced computational models, and reservoir simulation techniques. For example, studies have demonstrated the use of machine learning algorithms to enhance the interpretation of deliverability test results and predict well performance under various operational scenarios.

In the YA-01 gas well, the method used for deliverability testing is the Flow-after-flow Test. The steps taken to obtain the AOFP (Absolute Open Flow Potential) value include several stages. First, compile data related to the pressure and flow rate of the well. After that, the results of the $Pr^2 – Pwf^2$ calculations are mapped against the flow rate (q) to obtain the slope using the y equation from the trendline on the graph [9]. The first step is to determine the value of n using equation 1.

The first step is to determine the value of n using equation 1.

$$n = \frac{\log q_{sc2} - \log q_{sc1}}{\log(P_r^2-P_{wf}^2)_1 - \log(P_r^2-P_{wf}^2)_2} \quad (1)$$

Once the value of n is obtained, the value of C can then be determined using equation 2.

$$n = \frac{\log q_{sc2} - \log q_{sc1}}{\log(P_r^2-P_{wf}^2)_1 - \log(P_r^2-P_{wf}^2)_2} \quad (2)$$

To find out the flow rate value, equation 3 is used.

$$q_{sc} = C(P_r^2-P_{wf}^2)^n \quad (3)$$

Next, the AOFP value can be determined using equation 4.

$$AOFP = C(P_r^2-14.7)^n \quad (4)$$

Finally, to determine the maximum flow rate value (Qmax), this value can be calculated as 30% of the AOFP result, using equation 5. The 30% assumption is widely adopted in petroleum engineering practices and is supported by empirical field observations as a conservative estimate for well deliverability under stabilized flow conditions [8]

$$AOFP = C(P_r^2-14.7)^n \quad (5)$$

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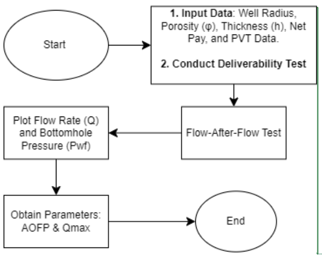
Research Methods

In the YA-01 gas well, the method used for deliverability testing is the Flow-after-flow Test. The steps taken to obtain the AOFP (Absolute Open Flow Potential) value include several stages. First, compile data related to the pressure and flow rate of the well. After that, the results of the $Pr^2 - Pwf^2$ calculations are mapped against the flow rate (q) to obtain the slope using the y equation from the trendline on the graph [9].

The research methodology begins with the collection of essential reservoir and well data, including well radius, porosity (φ), thickness (h), net pay, and PVT (Pressure-Volume-Temperature) data. These parameters serve as the foundation for evaluating the reservoir's characteristics and the well's production potential. Once the input data is prepared, a deliverability test is conducted to analyze the ability of the well to produce gas at varying pressure conditions, providing insights into the productivity and flow efficiency of the well.

Subsequently, a flow-after-flow test is performed to further investigate the relationship between the flow rate and bottomhole pressure. This step involves measuring the well's performance under different flow conditions to understand its behavior and capacity. The data obtained from the tests is then analyzed and visualized by plotting flow rate against bottomhole pressure, enabling the identification of trends and critical performance characteristics.

Finally, key performance indicators such as Absolute Open Flow Potential (AOFP) and maximum flow rate (Qmax) are calculated. These parameters are critical for understanding the well's potential under open-flow conditions and determining its maximum deliverability. The results of this methodology provide a comprehensive framework for optimizing gas well production and evaluating reservoir performance.



Picture 1. Flow Chart on Well YA-01

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Results and Discussion

From the deliverability analysis using software, important parameters for gas wells were obtained. The inverse slope (n) value obtained was 1.19226, while the C value was recorded at 0.000000418 MSCFD/psia². With this data, the Absolute Open Flow Potential (AOFP) value produced was 12,930 MSCFD. From this AOFP value, the maximum flow rate (Qgmax) that can be achieved by the well is 3,879 MSCFD.

Table 1. Flow-after Flow Test Data for Gas Well YA-01

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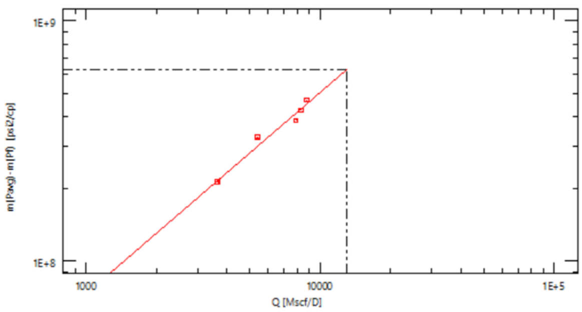
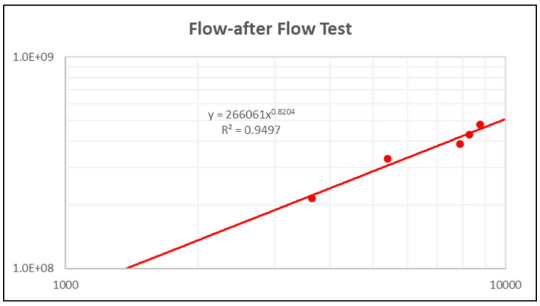
P_{wf}	q_{sc}	$\bar{P}^2 - P_{wf}^2$	$\psi(\bar{P}) - \psi(P_{wf})$
Psia	MSCFD	$psia^2$	$psia^2/cp$
1810,41	7892,26	6.732.428,079	388.149.816,07
2445,36	3636,22	4.030.226,918	215.179.657,84
1645,11	8294,5	7.303.625,535	430.534.455,19
1453,32	8753,67	7.897.873,425	478.341.679,98
2028,93	5398,52	5.893.455,502	330.441.568,53
14,7	0	10.009.796,36	790.033.664,63



Picture 2. Flow-after Flow Test Analysis



Picture 3. Flow-after Flow Chart

After obtaining the results from the software analysis, a manual analysis was carried out using the Rawlins-Schellhardt calculation method to verify the results obtained from the software. This manual method aims to compare and ensure the accuracy of the deliverability test results previously performed. Figure 3 shows the Flow-after-flow Test graph generated from the manual analysis.

Conclusion

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This study provides critical insights into the deliverability and performance of the analyzed gas well. Key parameters, including well radius, porosity (φ), reservoir thickness, net pay, and PVT properties, were incorporated to ensure the accuracy of the deliverability analysis. The flow-after-flow test revealed a clear relationship between flow rate (Q) and bottomhole pressure (Pwf), leading to the determination of Absolute Open Flow Potential (AOFP) and maximum flow rate (Qmax). These metrics offer a comprehensive understanding of the well's production potential.

References

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4. Keputusan Editor 30 Desember 2024

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Title : **ANALISIS UJI *DELIVERABILITY* PADA SUMUR GAS YA-01**
Author(s) : Arinda Ristawati, Mulia Ginting, Jasmine Ghina Kaynes, Onnie Ridaliani Prapansya, Hari Karyadi Oetomo, dan Michael Sultan Matheus Sahuleka

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ANALISIS UJI *DELIVERABILITY* PADA SUMUR GAS YA-01

DELIVERABILITY TEST ANALYSIS ON GAS WELL YA-01

Arinda Ristawati [1,a)*], Mulia Ginting[1], Jasmine Ghina Kaynes [1], Onnie Ridaliani Prapansya [1], Hari Karyadi Oetomo [1], dan Michael Sultan Matheus Sahuleka [1]

[1] *Petroleum Engineering, Universitas Trisakti, Jakarta, Indonesia, 1140*
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Accepted (30th December 2024), Revised (3th December 2024)

Abstract. *Deliverability tests are used to evaluate a well's production capability by estimating the Absolute Open Flow Potential (AOFP) and maximum flow rate. The three main methods applied are the Flow-after-flow Test, Isochronal Test, and Modified Isochronal Test. For the YA-01 gas well, the Flow-after-flow Test was used, which involves steps such as data compilation, plotting, calculation of the inverse slope (n), and determination of the AOFP and maximum flow rate (Qmax). Software analysis results indicated an inverse slope (n) of 1.19226, a C value of* $4{,}18 \times 10^{-7}$ *MSCFD/psia², an AOFP of 12,930 MSCFD, and a Qgmax of 3,879 MSCFD. For verification, a manual analysis using the Rawlins-Schellhardt and Horner methods with a pseudo-pressure approach was conducted, yielding an AOFP value of 12,850 MSCFD. The combination of software and manual results provides a comprehensive and accurate understanding of the well conditions, supporting production optimization decisions and evaluating the effectiveness of the acidizing process.*

Keywords: *Deliverability Test, Absolute Open Flow Potential (AOFP), Flow-after-flow Test, Permeability and Skin Factor, Flow Efficiency.*

Abstrak. Metode deliverability test digunakan untuk mengevaluasi kemampuan produksi sumur dengan memperkirakan nilai Absolute Open Flow Potential (AOFP) dan laju alir maksimum. Tiga metode utama yang diterapkan adalah Flow-after-flow Test, Isochronal Test, dan Modified Isochronal Test. Pada sumur gas YA-01, Flow-after-flow Test digunakan, dengan langkah-langkah meliputi penyusunan data, plotting, perhitungan inverse slope (n), dan penentuan nilai AOFP dan laju alir maksimum (Qmax). Hasil analisis perangkat lunak menunjukkan nilai inverse slope (n) sebesar 1,19226, nilai C sebesar $4{,}18 \times 10^{-7}$ MSCFD/psia², AOFP sebesar 12,930 MSCFD, dan Qgmax sebesar 3,879 MSCFD. Untuk verifikasi, analisis manual menggunakan metode Rawlins-Schellhardt dan Horner dengan pendekatan Pseudo-Pressure dilakukan, menghasilkan nilai AOFP sebesar 12,850 MSCFD. Kombinasi hasil dari perangkat lunak dan manual memberikan pemahaman yang komprehensif dan akurat mengenai kondisi sumur, mendukung keputusan optimisasi produksi dan evaluasi efektivitas proses acidizing.

Kata kunci: Deliverability Test, Absolute Open Flow Potential (AOFP), Flow-after-flow Test, Permeability and Skin Factor, Flow Efficiency.

INTRODUCTION

The deliverability test method is used to assess the production capability of a well by estimating the AOFP (Absolute Open Flow Potential) value and maximum flow rate [1]. There are three main methods in this test: Flow-after-flow Test, Isochronal Test, and Modified Isochronal Test. In the Flow-after-flow Test, different back pressures are applied by shutting the well down to stable pressure (Pr), then producing the well at a flow rate of until stable pressure is reached [2]. This process is repeated four times without having to shut the well down each time a change in production rate is made. This method is effective if the reservoir has high permeability which allows stable conditions to be achieved quickly [3] [4].

Isochronal Test is often used for wells with low permeability, where a long time is needed to reach a stable state. The test is carried out with the same flow time (t), by shutting the well down to stable pressure and recording the reservoir static pressure (Pr) [1]. The well is then produced at a flow rate of qsc1 for a certain time (Δt) without waiting for stable pressure, and shut back in until the pressure reaches Pr. This method is designed to provide an estimate of well deliverability with the same time each time the flow is performed [5] [6].

Modified Isochronal Test was developed to overcome the weakness of Isochronal Test which requires a long time. This test is carried out with the same flow time and well shut-in time [7]. In this method, the well is shut in until the pressure is stable and recorded as reservoir static pressure (Pr), then produced without waiting for the pressure to stabilize [6]. Thus, this method shortens the testing time and is more efficient than Isochronal Test, making it more practical to use in field conditions that require fast response time [8]

RESEARCH METHODS

In the YA-01 gas well, the method used for deliverability testing is the Flow-after-flow Test. The steps taken to obtain the AOFP (Absolute Open Flow Potential) value include several stages. First, compile data related to the pressure and flow rate of the well. After that, the results of the $Pr^2 – Pwf^2$ calculations are mapped against the flow rate (q) to obtain the slope using the y equation from the trendline on the graph [9]. The YA-01 gas well is located in a mature gas field with moderate permeability and significant production history. The field's geological structure consists of sandstone reservoirs with varying levels of porosity and permeability. Before the acidizing process, the well exhibited moderate skin effects, which hindered optimal gas flow. The primary objective of the acidizing process was to enhance permeability and reduce skin to achieve better deliverability. Reservoir pressures were measured to be stable, allowing for efficient application of the Flow-after-flow Test to evaluate well performance post-acidizing. The first step is to determine the value of n using equation 1.

$$n = \frac{\log q_{sc2} - \log q_{sc1}}{\log\left(P_r^2 - P_{wf}^2\right)_1 - \log\left(P_r^2 - P_{wf}^2\right)_2} \quad (1)$$

Once the value of n is obtained, the value of C can then be determined using equation 2.

$$n = \frac{\log q_{sc2} - \log q_{sc1}}{\log\left(P_r^2 - P_{wf}^2\right)_1 - \log\left(P_r^2 - P_{wf}^2\right)_2} \quad (2)$$

To find out the flow rate value, equation 3 is used.

$$q_{sc} = C\left(P_r^2 - P_{wf}^2\right)^n \quad (3)$$

Next, the AOFP value can be determined using equation 4.

$$AOFP = C(P_r^2 - 14.7)^n \quad (4)$$

Finally, to determine the maximum flow rate value (Qmax), this value can be calculated as 30% of the AOFP result, using equation 5.

$$AOFP = C(P_r^2 - 14.7)^n \quad (5)$$

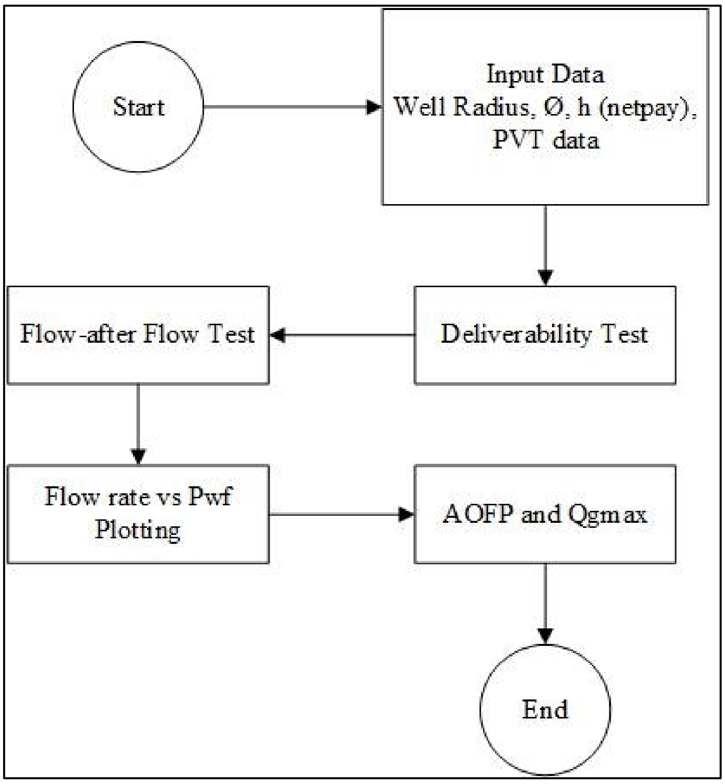

Figure 1. Work Flow on Well YA-01

RESULTS AND DISCUSSION

From the deliverability analysis using software after the acidizing process, important parameters for gas wells were obtained. The inverse slope (n) value obtained was 1.19226, while the C value was recorded at 4,18 × 10^{-7}MSCFD/psia^2. With this data, the Absolute Open Flow Potential (AOFP) value produced was 12,930 MSCFD. From this AOFP value, the maximum flow rate (Qgmax) that can be achieved by the well is 3,879 MSCFD. The acidizing process has proven effective in increasing gas flow capacity by improving reservoir permeability and reducing skin effects. Therefore, the well deliverability after acidizing has changed significantly compared to before the intervention. In the future, this data is valid to be used as a reference as long as there are no significant changes in reservoir conditions, such as drastic pressure drops or additional formation damage. However, periodic re-evaluation is still needed to ensure consistency of well performance and to consider potential changes in reservoir conditions that can affect deliverability parameters.

Table 1. Flow-after Flow Test Data for Gas Well YA-01

P_{wf}	q_{sc}	$\overline{P}^2 - P_{wf}^2$	$\psi(\overline{P}) - \psi(P_{wf})$
Psia	MSCFD	$psia^2$	$psia^2/cp$
1810,41	7892,26	6.732.428,079	388.149.816,07
2445,36	3636,22	4.030.226,918	215.179.657,84
1645,11	8294,5	7.303.625,535	430.534.455,19
1453,32	8753,67	7.897.873,425	478.341.679,98
2028,93	5398,52	5.893.455,502	330.441.568,53
14,7	0	10.009.796,36	790.033.664,63

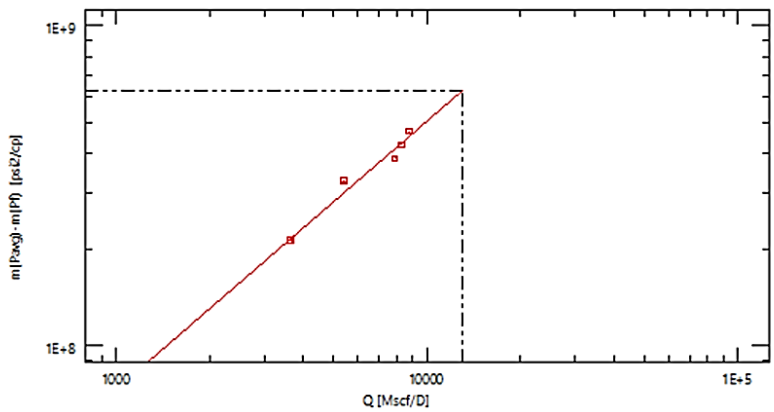

Figure 2. Flow-after Flow Test Analysis After Acidizing

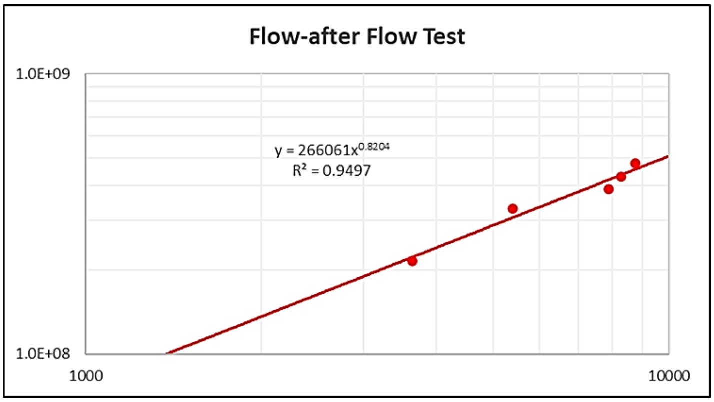

Figure 3. Flow-after Flow Chart After Manual Acidizing

After obtaining the results from the software analysis, a manual analysis was carried out using the Rawlins-Schellhardt calculation method to verify the results obtained from the software. This manual method aims to compare and ensure the accuracy of the deliverability test results previously performed. Figure 3 shows the Flow-after-flow Test graph generated from the manual analysis. This approach allows for cross-validation between the software and manual methods, providing more confidence in the accuracy of the parameters and deliverability test results from the YA-01 gas well after the acidizing process. Through this process, both the software and manual approaches can be viewed and analyzed simultaneously, providing a comprehensive picture of the performance and production potential of the well [10].

CONCLUSION

The results of the deliverability analysis after acidizing with the help of software showed an inverse slope (n) value of 1.19226, a C value of 4,18 × 10^{-7} MSCFD/psia², and an AOFP of 12,930 MSCFD with a Qgmax of 3,879 MSCFD while manual analysis using the Rawlins-Schellhardt method showed an inverse slope (n) value of 1.218901705, a C value of 2.23×10−7 MSCFD/psia², and an AOFP of 15,620 MSCFD with a Qgmax of 3,879 MSCFD Manual analysis using the Rawlins-Schellhardt method provided comparable results and ensured the accuracy of the parameters obtained from the software. This comparison between the software and manual results provides a comprehensive understanding of the well conditions.

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