Journal of Energy Research and Reviews

Volume 16, Issue 6, Page 34-46, 2024; Article no.JENRR.118666
ISSN: 2581-8368

Characterization of Flow Behaviour in a Crude Oil Production Well

Laura Sfiriac [a], Doru Stoianovici [b], Maria Stoicescu [b] and Timur Chis [b*]

[a] Ph.D. Department, Oil-Gas University, Ploiesti, Romania.
[b] Oil and Gas Engineering Faculty, Oil-Gas University, Ploiesti, Romania.

Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/jenrr/2024/v16i6356

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://www.sdiarticle5.com/review-history/118666

Original Research Article

Received: 15/04/2024
Accepted: 22/06/2024
Published: 28/06/2024

ABSTRACT

The estimation of pressure drop in vertical wells is not just important, it's a critical aspect.
Reservoir production capacity depends on Reservoir Pressure, Thickness and Permeability of the Production Zone, Type and Spacing of Reservoir Boundaries, Well Radius, Reservoir Fluid Properties, Near Well Conditions, and Relative Permeabilities of the Reservoir.
Reservoir production capacity can be mathematically modeled based on flow regimes such as transient flow, steady-state flow, and pseudo-steady flow. These models can describe how a reservoir produces hydrocarbons as a function of variations in pressure and other parameters.
The well's flow rate as a function of bottom pressure characterizes the flow through the reservoir, and this defines the well's behavior curve (IPR—"Inflow Performance Relationships").
To moddeling to oil well production I analysis the mechanical skin factor calculated using the Karakas and Tariq (1991) to the diameter of the perforations of 10 mm and the length of a performance of 152.4 mm and the diameter of the perforations of 40 mm and the length of a

---

*Corresponding author: E-mail: timur.chis@gmail.com;

Cite as: *Sfiriac, Laura, Doru Stoianovici, Maria Stoicescu, and Timur Chis. 2024. "Characterization of Flow Behaviour in a Crude Oil Production Well". Journal of Energy Research and Reviews 16 (6):34-46. https://doi.org/10.9734/jenrr/2024/v16i6356.*

perforation of 1270 mm for the Duns & Ros, Orkiszewski, Hagedorn & Brown, and Beggs & Brill correlation.

This paper addresses the procedures for establishing IPR curves for various reservoir types and well configurations.

Keywords: Oil field; productivity; flow moddeling; inflow performance relationships.

1. INTRODUCTION

The total pressure drop from the bottom of the well to the surface has three components [1]:

- Hydrostatic pressure drop;
- Pressure drop through friction;
- Pressure drop due to acceleration.

In a properly filled oil well, the hydrostatic component should account for approximately 80% of the total pressure drop through the tubing, with the component due to acceleration being negligible. In the case of a gas well, especially at low pressures, the pressure drop due to friction becomes dominant in the calculation of the total pressure drop, and the acceleration of the fluids must be taken into account [2].

Efforts to estimate the pressure drop in an oil well date back to the early 1950s, when Poettmann and Carpenter published their predictive scheme. Since then, there have been many attempts to estimate the complex flow behavior in a borehole, starting from modifying the Poettmann-Carpenter correlation to complex mathematical models of hydrodynamic flow.

Although numerous correlations and models have been proposed for determining the pressure drop in vertical wells, their effectiveness is still under discussion [3].

Currently, no single correlation or model can accurately estimate pressure drop because there is a wide range of well operating conditions worldwide.

The flow correlations/models can be classified as follows:

1.1 Homogeneous Flow Model (Homogeneous Flow Model), [4]

The first method of establishing some correlations treated the problem of multiphasic flow, like the flow of a homogeneous mixture of gas and liquid.

This model assumes that the multifazic mixture behaves more like a homogeneous single-phase fluid, with values of the properties that represent an average (of weight, volumetric, etc.) of the constituent phases.

Thus, the model implies that there is no speed difference between phases.

This approach completely ignored the fact that the gaseous phase, due to its low density, exceeds the liquid phase, resulting in a "slip" between phases. The slip increases the density of the mixture's flow to the homogeneous flow of the two phases at equal speeds.

This category is the pioneering activity of Poettmann and Carpenter, as well as the subsequent changes made by Baxendell and Thomas, Tek, Fancher and Brown, and Hagedorn and Brown [5].

Each modification of the Poettmann-Carpenter correlation improved its applicability, but these studies also concluded that the assumptions on which the original work was based were very limited. Moreover, in this model, the effects of the gas-liquid ratio, the total flow rate, the fluid's viscosity, and the diameter of the tubing are not properly treated [6].

Also, in some wells, the Poettmann and Carpenter method gave deviations, especially in wells with low production, low bottom pressure, and high viscosity crude oil. This is mostly due to the fact that they considered a factor of energy loss through constant friction along the entire length of the extraction pipes [7].

Govier and Aziz developed other correlations from laboratory experiments on air-water systems, which could have found more applicability in industry [8].

Due to the faulty physical model adopted, these correlations have a very low calculation accuracy.

Another motivation for this aspect is the complexity of multiphase flow in vertical wells.

While crude oil and water have nearly equal velocities, gases have a much higher velocity. The velocity difference affects the pressure drop [8].

1.2 Separate Flow Pattern or Slip (Separate Flow or Slip Model)

This model considers the slip effect that appears because the two phases (gas and liquid) have different speeds due to the floatability. In particular, this is the case of flowing at low speeds. It involves the artificial division of the phases with uneven speeds (slip).

Thus, the sliding speed or the fraction of each in-situ phase and the frictional interactions between the phases with the well and between the phases themselves must be known.

To calculate the friction, it is necessary to estimate the speeds of the two phases. The fact that the two fluids have different speeds also influences their surface occupied. The fluid that moves faster (gas) will occupy a smaller space because it moves faster. This has a significant influence on the general density of the mixture.

In 1965, Hagedorn and Brown developed a correlation that requires estimating an effective free gas fraction. Despite its empirical origin, this correlation is widely applied in the industry [8].

Numerous correlations have been developed using the slip model for horizontal multiphase flow. Also, the pioneering work of Lockhart and Martinelli is based on this model [8].

1.3 Flow Pattern Approach

In this approach, an attempt is made to define a flow correlation for each flow regime, together with the delimitation of the flow regimes. Although, in principle, this technique is intended to be the most rigorous of all, the difficulty of identifying each flow regime leads to different maps of the flow regimes and, hence, to different correlations. A map of the flow regimes is made based on the superficial velocities of the gas and liquid and depending on the diameter of the tubing.

Estimating the flow regime occurring at a given moment in the borehole is extremely important. All flow regime predictions are based on data from low-pressure, negligible interphase mass transfer, and single-phase liquid systems. These flow regimes are shown in Fig. 1.

In real conditions, a transition between flow regimes can occur, and different regimes can occur in the case of horizontal and inclined wells.

In the pioneering activity of Ros, respectively Duns & Ros, the use of a map of flow regimes with dimensionless gas and liquid velocities was realized. Other flow regime maps published in the early 1960s are those of Griffith and Wallis and Gover et al., which other authors later used to develop correlations for pressure drop.

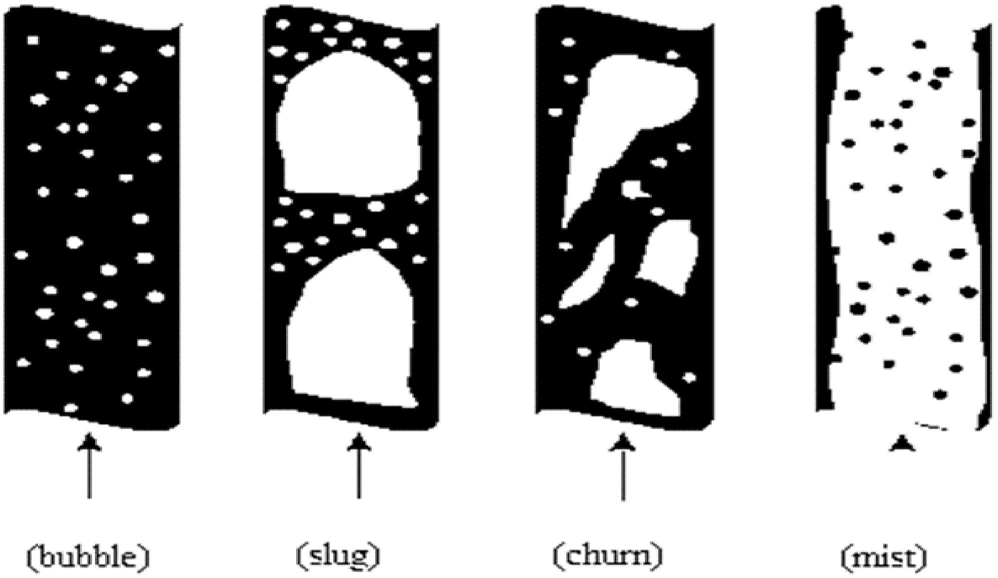

Fig. 1. Types of flow regimes in a vertical well

Orkisewski [1967] proposed a model in which the transition from bubble flow to plug flow follows the Griffith and Wallis criterion, while the transition from plug flow to foam and from foam to annular flow follows the criterion of Duns and Ros.

The Orkiszewski method has proven to be the most accurate correlation used in the oil industry.

In the 70s, four other correlations appeared in the specialized literature:

- The mechanistic model of Aziz et al. based on the Gover-Aziz flow regime map;
- The Beggs and Brill correlation, based on extensive laboratory data and the own map of flow regimes developed for horizontal flow;
- Chierici et al. who modified the prediction regarding the free fraction during bullet flow;
- Gould et al. modified the free fraction prediction during bubble flow.

The last two correlations were published in 1974 and derived from the Orkiszewski model with minor modifications.

Among all these correlations, the mechanistic model of Aziz et al. proved to be one of the best methods. The mechanistic model assumes that a complex system can be understood by examining its parts and their interaction.

In 1986, Hasan and Kabir developed a multiphase flow model in which the free gas fraction or mixture density estimation for each flow regime and the transition from one flow regime to another are rigorously modeled [8].

In 1994, M.A. Aggour presented a comprehensive evaluation of Beggs and Brill, Hagedorn and Brown, and Hasan and Kabir correlations, analyzing over 400 field data sets to determine and recommend the best correlation for various deposit conditions. He suggested that the Hasan and Kabir correlation is better for total liquid flow rates above 20,000 barrels/day (3,200 m^3/day) [8].

2. MATERIALS AND METHODS

In the case of a well, an analysis study is carried out on the influence of some properties of the reservoir rocks and reservoir fluids on the flow performance using the behavior curves of the well. The operating conditions, technical characteristics and properties of the fluids involved in the process are known based on the correlations. With the help of numerical simulators, the behavior curves of the layer were drawn.

The data of the probe chosen by us are given in Table 1.

For all cases analyzed, the mechanical skin factor was calculated using the Karakas and Tariq (1991) [8] method.

Input Data:

- Fluid type: crude oil
- Well type: production
- Node position: Probe head
- Correlations used:

  - For the wellbore: Hagedorn & Brown for crude oil (1963)
  - For the mixing line: Beggs & Brill (1973)
  - For bubble flow: Griffith & Wallis (1961)
  - For heat/temperature transfer calculation: Alvez et al. (1992) unified model
  - For the productivity index: Jones et al. (1976)

*kc - permeability of the compacted zone around the perforation (crushed zone permeability).

kz - average permeability of the deposit.

Table 1. Oil field properties

Fluid Properties	Units	Value
Oil density	g/cm^3	0,82
Specific gravity of the gas		0,65
Impurities	%	10
The density of water	g/cm^3	1,070
Crude gas ration	m^3_N/m^3	172
Separator temperature	°C	10
Separator pressure	bar	8

Characteristics Of The Deposit		
Press#ure	bar	185
Temperature	°C	60
Average permeability	mD	2,2
The thickness of the productive layer	m	32
Perforated interval	m	14
The skin factor		5
Probe radius of influence	m	280
Construction And Production Data Of Wells		
Probe radius	mm	70
The outside diameter of the column	mm (in)	139,7(5 ½)
The inside diameter of the column	mm (in)	127,31(5)
Column depth	m	2300
Tubing depth	m	2100
The outside diameter of the tubing	mm (in)	73,03($2^{7/8}$)
The inner diameter of the tubing	mm	59
Head perforations	m	2180
Flow	m^3/zi	22,9
Data Relating To Complete Method		
Perforated interval	m	14
Perforation density	gl/m (spf)	19,7(6)
The diameter of the perforations	mm (in)	10 (0.4)
The length of a perforation	mm	152,4
kc/kz ratio*		0,7
Permeability of the damaged zone around the borehole	mD	1
Radius of the damaged area around the borehole	mm	900
Angle of phase shift of the perforations		60º
Skin factor due to perforations		-0.604
Characteristics Of The Mixing Line		
The length	m	800
Internal diameter of mixture line	mm (in)	52.5 (2)
Nozzle inner diameter	mm	3.5
Specific heat of the gas	kJ/kgK	2.26

3. RESULTS AND DISCUSSION

3.1 The Influence of the Diameter and Length of the Perforations (Duns and Ros Correlation)

In the first case, based on the data presented, where the correlation of Duns and Ros was used for the borehole with the diameter of the perforations of 10 mm and the length of a performance of 152.4 mm, the behavior curve of the layer was created. This is represented in the following Fig. 2.

In the second case, based on the data presented, where the correlation of Duns and Ros was used - for the borehole with the diameter of the perforations of 40 mm and the length of a perforation of 1270 mm, the behavior curve of the layer was made. This is represented in the following Fig. 3.

In the following Fig. 4, the behavior curves for the two cases presented above have been superimposed.

Regarding the influence of the change of perforation length and perforation diameter on the flow performance for the two cases, the following can be observed:

- the flow rate of the well increases with the increase in the length of the perforations as well as with the diameter of the perforation;
- the pressure in the eruption head increases with the increase in the length of the perforations as well as with the diameter of the perforation;
- the total skin factor decreases with the increase in the length of the perforations as well as with the diameter of the perforation;
- small pressure variation depending on the change in the length of the perforations as well as the diameter of the perforations.

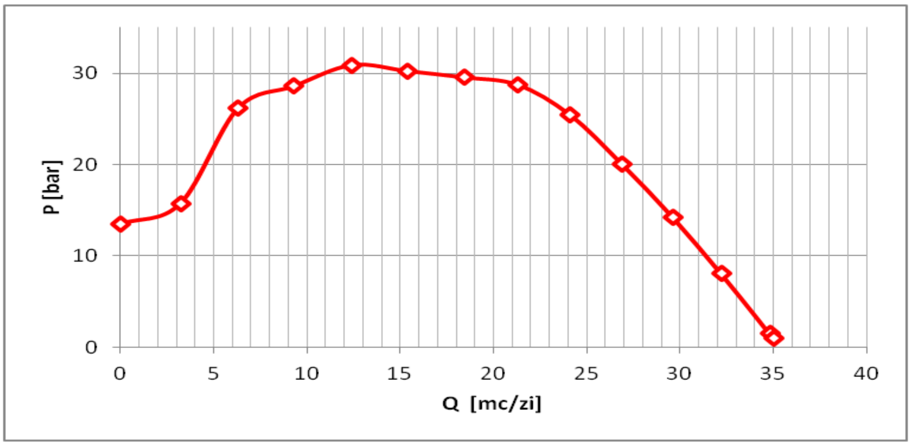

Fig. 2. Variation of the flow rate depending on the pressure- Duns and Ros correlation (diameter of the perforations of 10 mm and the length of a performance of 152.4 mm)

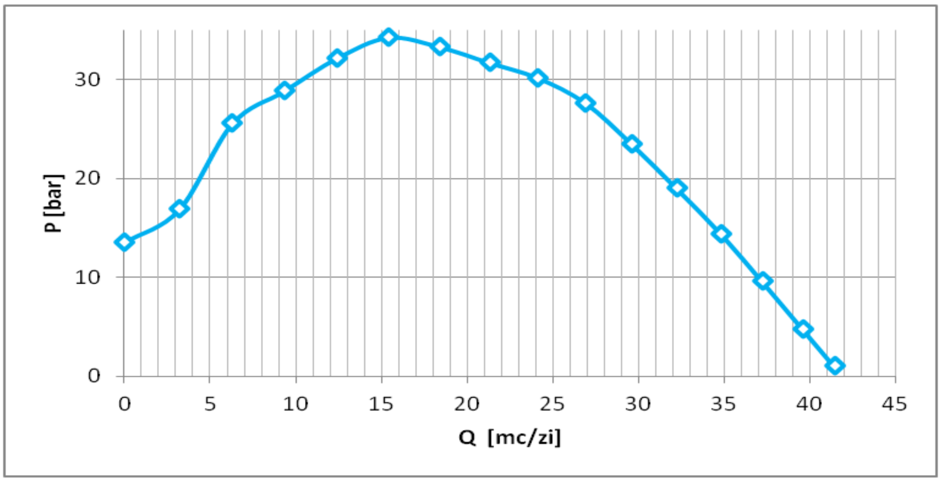

Fig. 3. The variation of the flow depending on the pressure - Duns and Ros correlation (diameter of the perforations of 40 mm and the length of a perforation of 1270 mm)

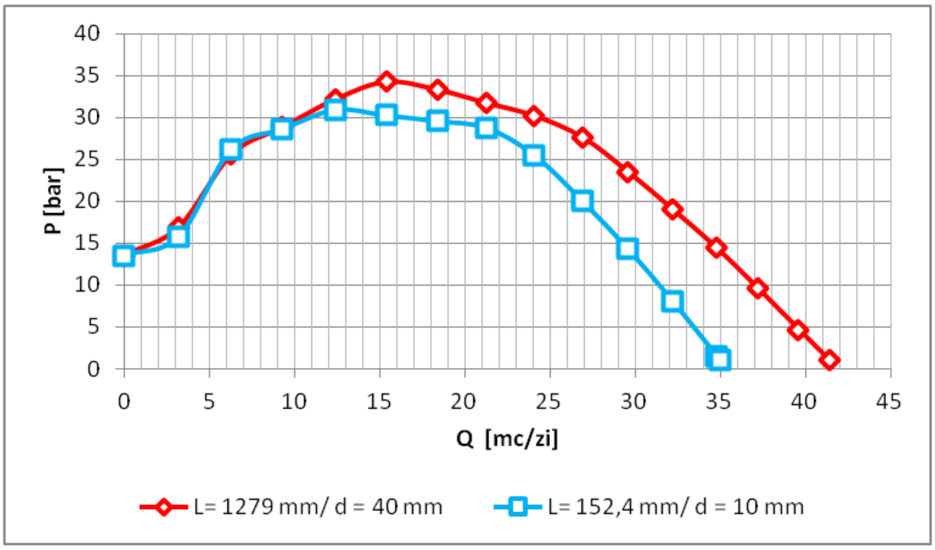

Fig. 4. The variation of the flow depending on the pressure - Duns and Ros correlation

3.2 The Influence of the Diameter and Length of the Perforations (Orkiszewski correlation)

In the first case, based on the data presented, where the Orkiszewski correlation was used - for the borehole with the diameter of the perforations is 10 mm and the length of a perforation is 152.4 mm, the behavior curve of the layer was created. This is represented in the following Fig. 5.

In the second case, based on the data presented, where the Orkiszewski correlation was used - for the borehole with the diameter of the perforations is 40 mm and the length of a perforation is 1270 mm, the behavior curve of the layer was made. This is represented in the following Fig. 6.

In the following Fig. 7, the behavior curves for the two cases presented above have been superimposed:

Regarding the influence of the change in the length of the perforation as well as the diameter of the perforation on the flow performance for these 2 cases, the following can be observed:

- The flow rate of the well increases with the increase in the length of the perforations as well as with the diameter of the perforation;
- The pressure in the eruption head increases with the increase in the length of the perforations as well as with the diameter of the perforation;
- Small pressure variation depending on the change in the length of the perforations as well as the diameter of the perforations.

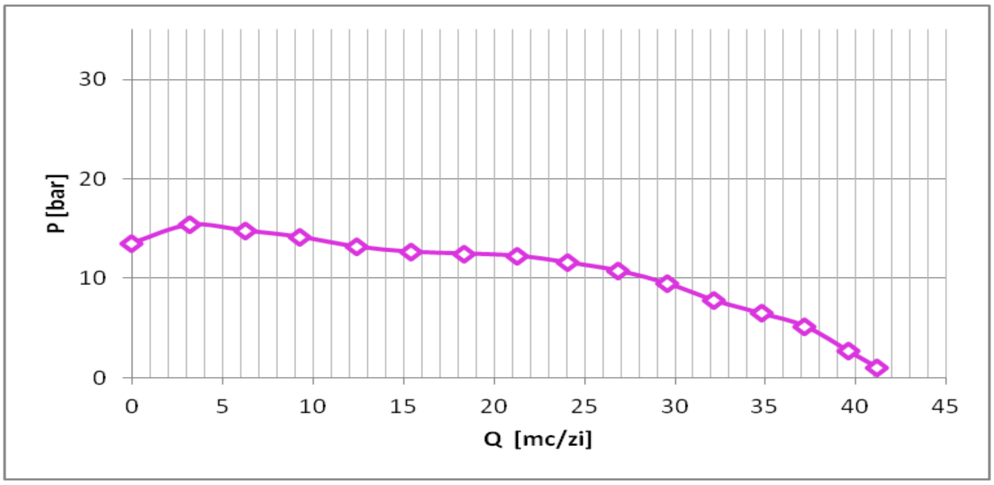

Fig. 5. The variation of the flow depending on the pressure- Orkiszewski correlation (diameter of the perforations is 10 mm and the length of a perforation is 152.4 mm)

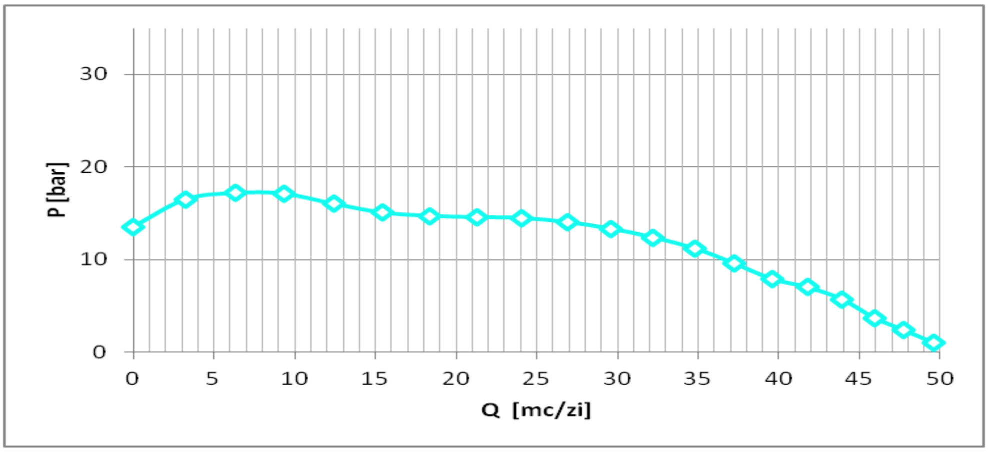

Fig. 6. The variation of the flow depending on the pressure- Orkiszewski correlation (diameter of the perforations is 40 mm and the length of a perforation is 1270 mm)

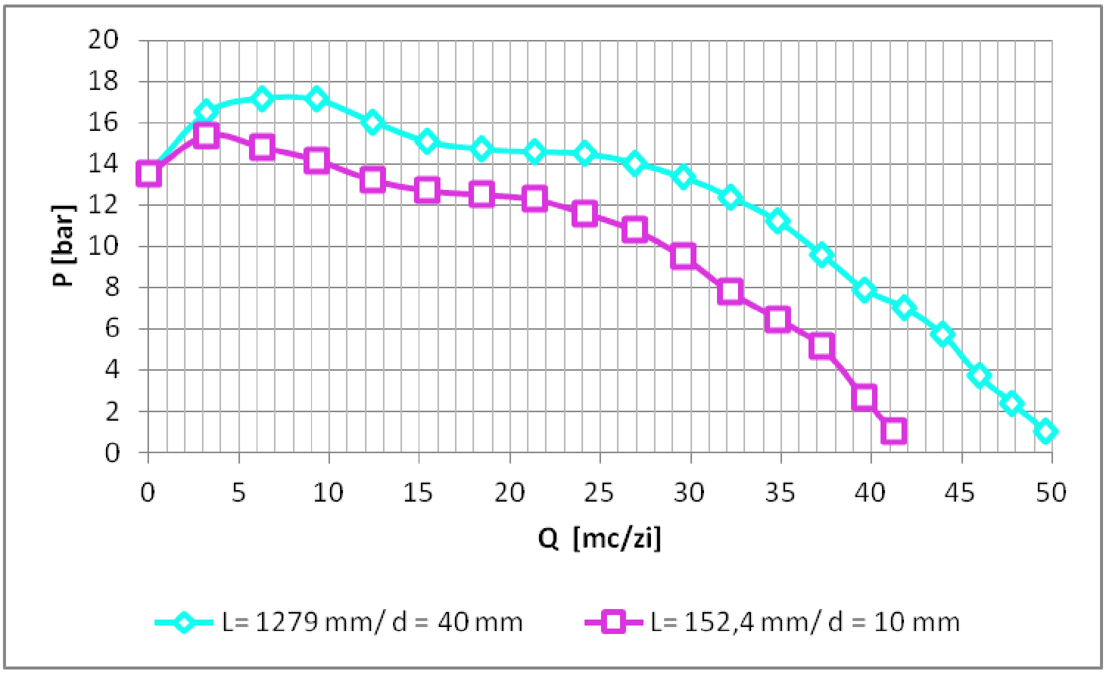

Fig. 7. The variation of the flow depending on the pressure - Orkiszewski correlation

3.3 The Influence of the Diameter and Length of the Perforations (Hagedorn & Brown correlation)

In the first case, based on the data presented, where the Hagedorn & Brown correlation for crude oil (1963) was used - for the borehole with the diameter of the perforations is 10 mm and the length of a perforation is 152.4 mm, the behavior curve of the layer was created.

This is represented in the following figure:

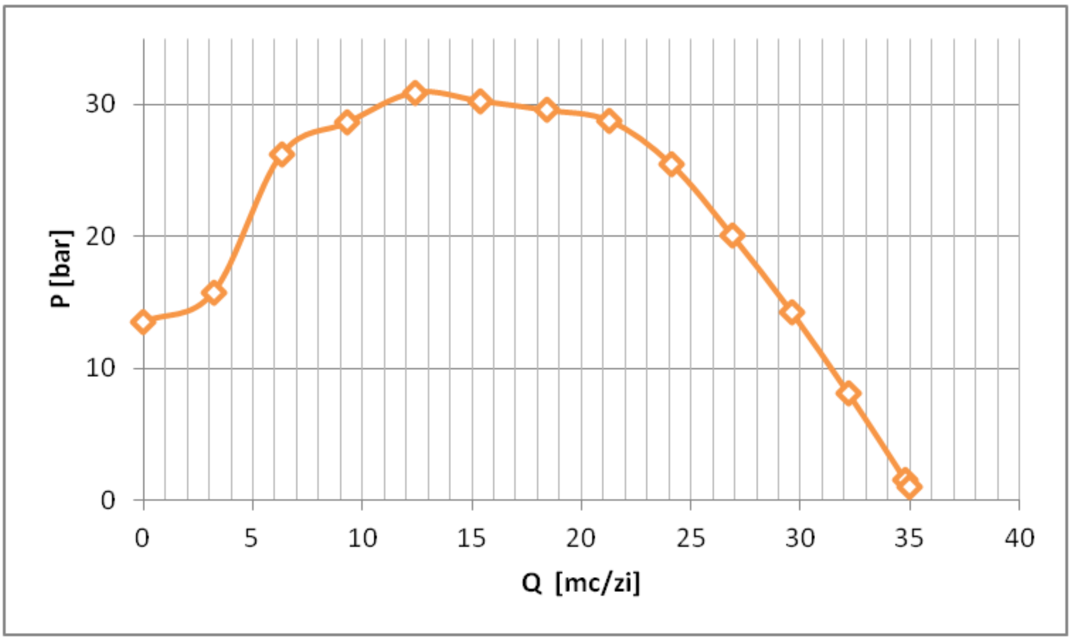

Fig. 8. The variation of the flow depending on the pressure- Hagedorn & Brown correlation (diameter of the perforations is 10 mm and the length of a perforation is 152.4 mm)

In the second case, based on the data presented, where the Hagedorn & Brown correlation for crude oil (1963) was used - for the borehole with the diameter of the perforations is 40 mm and the length of a perforation is 1270 mm, the behavior curve of the layer was created.

This is represented in the following figure:

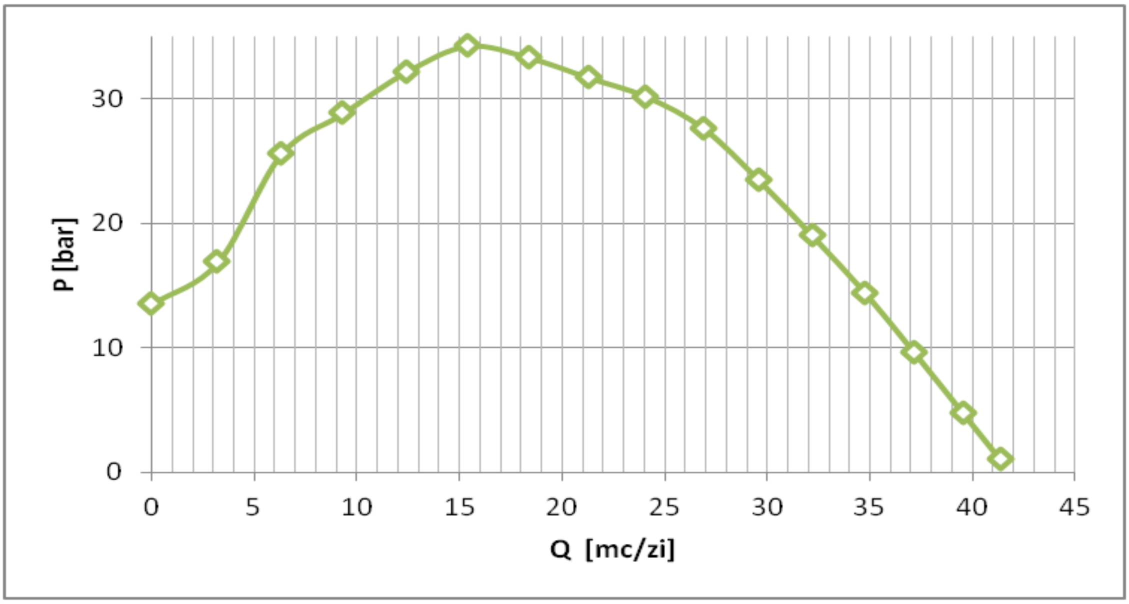

Fig. 9. The variation of the flow depending on the pressure- Hagedorn & Brown correlation (the diameter of the perforations is 40 mm and the length of a perforation is 1270 mm)

In the following figure, the behavior curves for the proofs presented above have been superimposed:

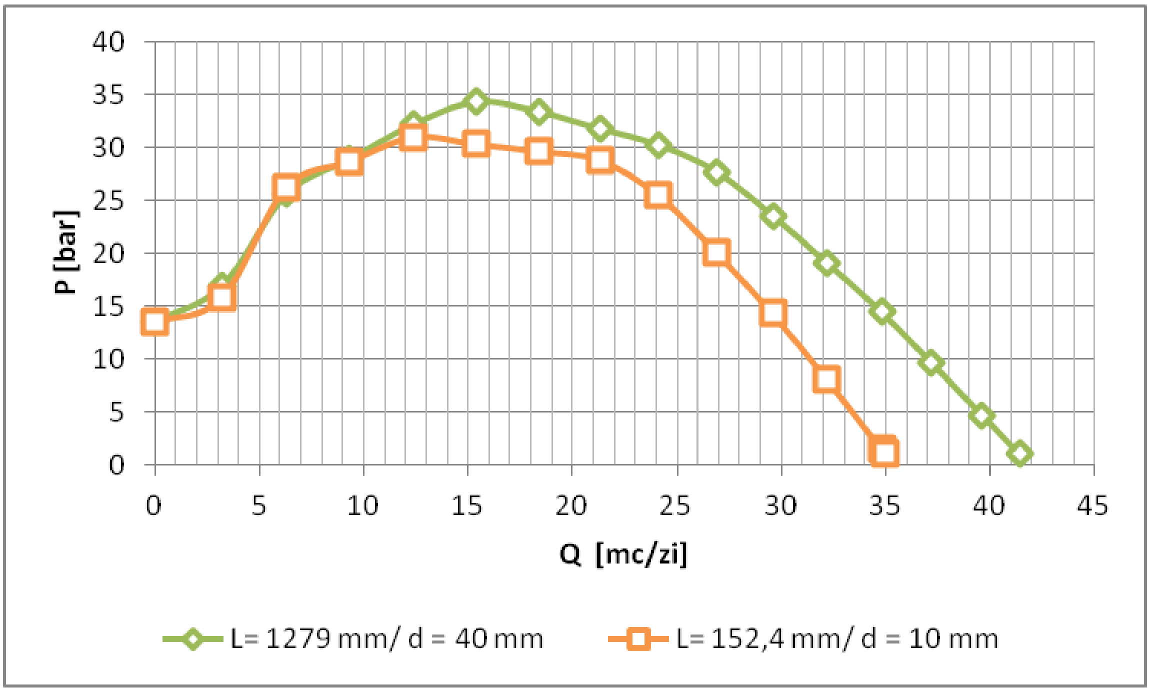

Fig. 10. The variation of the flow depending on the pressure - Hagedorn & Brown correlation

Regarding the influence of the change in the length of the perforation as well as the diameter of the perforation on the flow performance for these 2 cases, the following can be observed:

- The flow rate of the well increases with the increase in the length of the perforations as well as with the diameter of the perforation;
- The pressure in the eruption head increases with the increase in the length of the perforations as well as with the diameter of the perforation;
- The total skin factor decreases with the increase in the length of the perforations as well as with the diameter of the perforation;
- Small pressure variation depending on the change in the length of the perforations as well as the diameter of the perforations.
- The total skin factor decreases with the increase in the length of the perforation.

3.4 The Influence of the Diameter and Length of the Perforations (Beggs and Brill correlation)

In the first case, based on the data presented, where the Beggs and Brill correlation was used - for the borehole with the diameter of the perforations is 10 mm and the length of the perforations is 152.4 mm, the behavior curve of the layer was created.

This is represented in the following Fig. 11.

In the second case, based on the data presented, where the Beggs and Brill correlation was used - for the borehole with the diameter of the perforations is 40 mm and the length of a perforation is 1270 mm, the behavior curve of the layer was created. This is represented in the following Fig. 12.

In the following Fig. 13, the behavior curves for the two cases presented above have been superimposed:

Regarding the influence of the change in the length of the perforation as well as the diameter of the perforation on the flow performance for these 2 cases, the following can be observed:

- The flow rate of the well increases with the increase in the length of the perforations as well as with the diameter of the perforation;
- The pressure in the eruption head increases with the increase in the length of the perforations as well as with the diameter of the perforation;
- The total skin factor decreases with the increase in the length of the perforations as well as with the diameter of the perforation;
- Small pressure variation depending on the change in the length of the perforations as well as the diameter of the perforations.
- The total skin factor decreases with the increase in the length of the perforation.

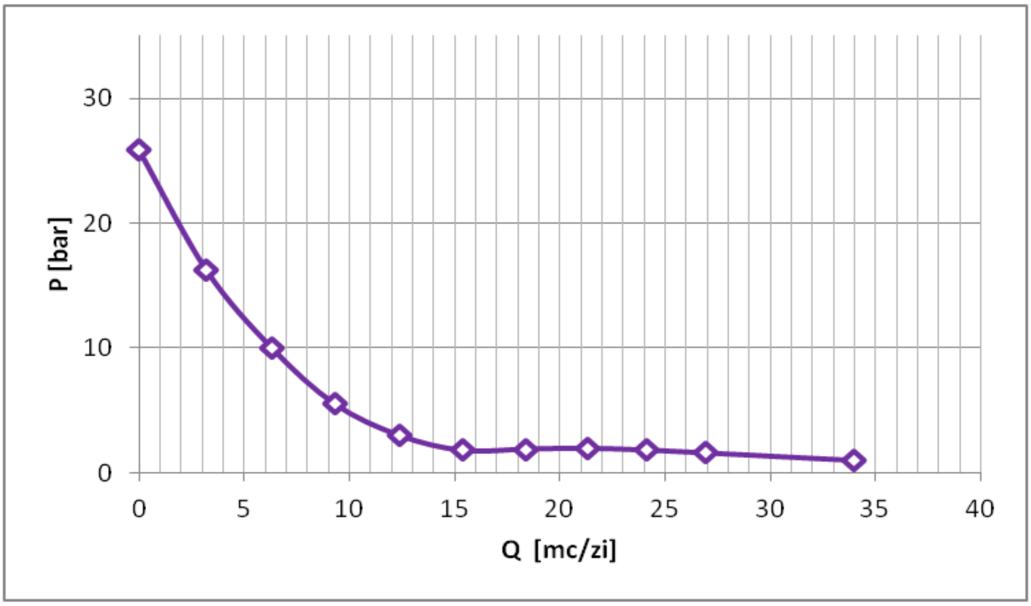

Fig. 11. The variation of the flow depending on the pressure- Beggs and Brill correlation (perforations is 10 mm and the length of the perforations is 152.4 mm)

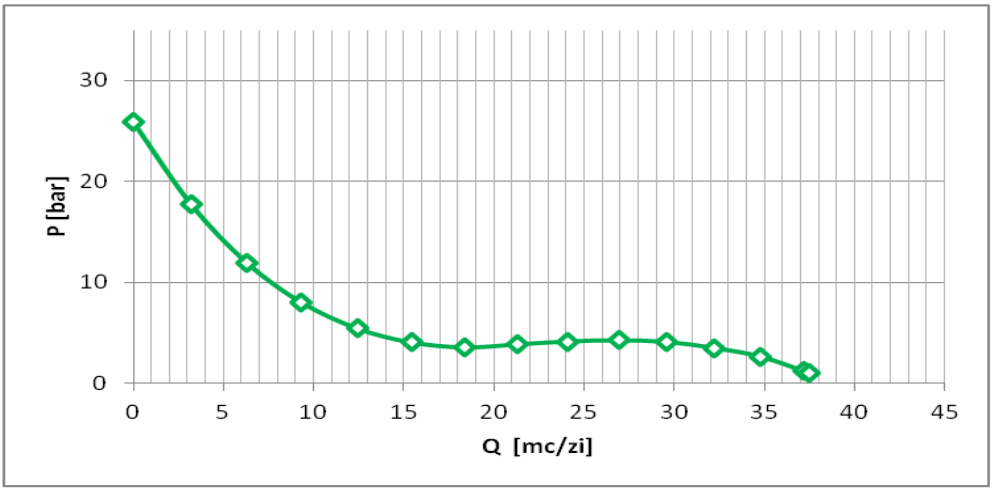

Fig. 12. The variation of the flow depending on the pressure- Beggs and Brill correlation (diameter of the perforations is 40 mm and the length of a perforation is 1270 mm)

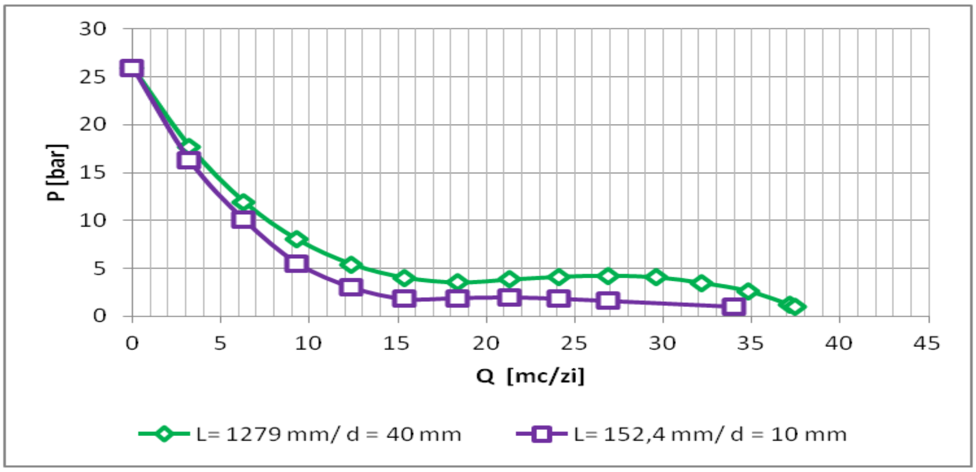

Fig. 13. The variation of the flow depending on the pressure - Beggs and Brill correlation

In the adjacent figure, the behavior curves made with the help of the 4 correlations are superimposed:

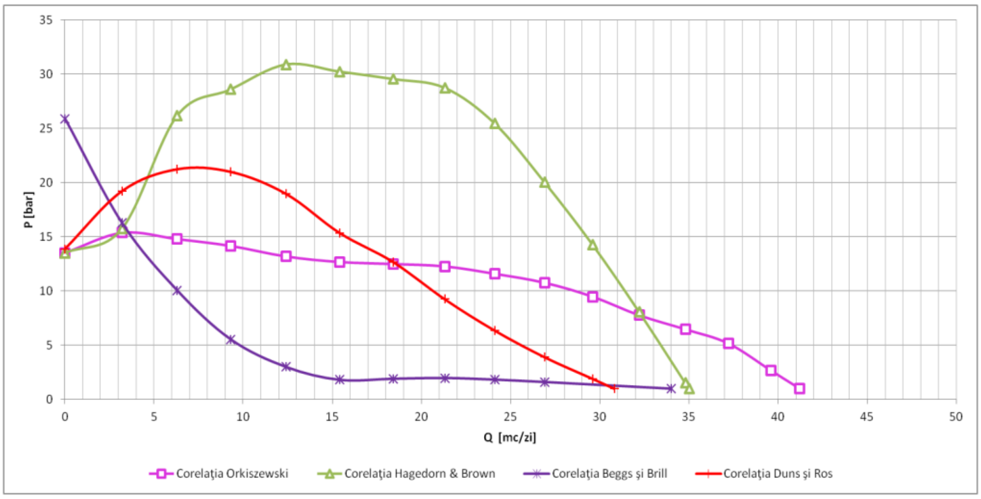

Fig. 14. The variation of the flow depending on the pressure (the diameter of the perforations is 10 mm and the length of the perforations is 152.4 mm)`

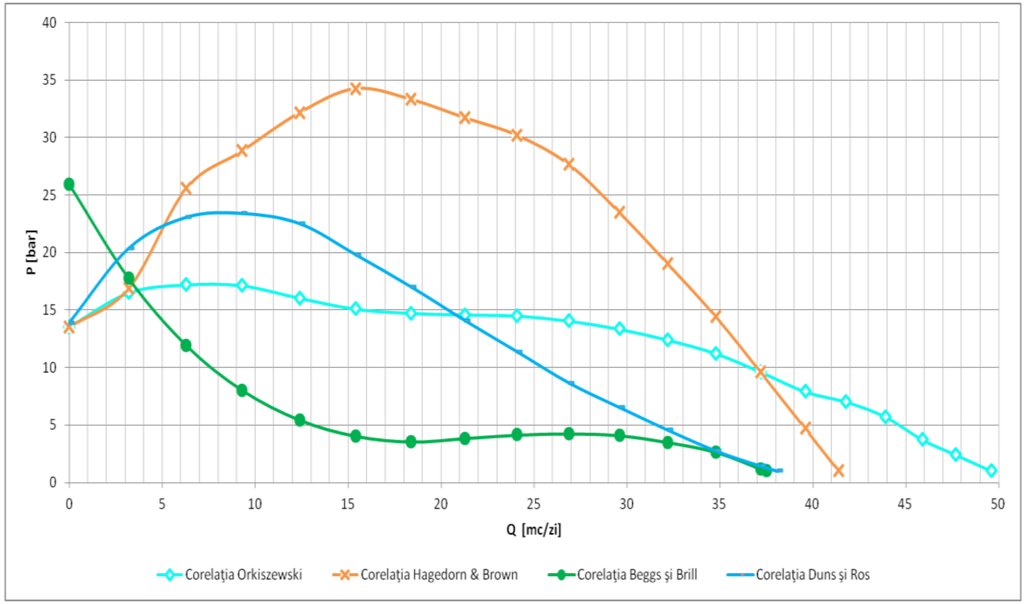

Fig. 15. The variation of the flow depending on the pressure (the diameter of the perforations is 40 mm and the length of the perforations is 1270 mm)

4. CONCLUSION

Based on the results obtained representing the behavior curves of the layer, considerable differences are found between them, therefore a careful correlation with the production data of the well is required.

In all the situations presented, the maximum flow of crude oil produced was obtained when communication with the probe layer was achieved using the Penedrill perforation system, with a perforation length of 1270 mm and a diameter of 40 mm.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. Ahmed G, Horne RN, Brigham WE. Theoretical Development of flow into a well through perforations, final report, DOE/BC/ 14126–25, Bartlesville, Oklahoma; August 1990.
2. Almaguer J, Manrique J, Wickramasuriya S, Habbtar A, Lopez-de Cardenas J, May D, et al. Orienting Pertorations in the Right Directions, Oilfield Review Spring. 2002; 14(1):16-31.
3. Atkinson C, Monmont F, Zazovsky A. flow performance of perforated completions, Transport in porous media. 80:305-328. ISSN: 0169-3913.
4. Beggs HD. Production optimization using nodal analysis, OGCI and Petroskills Publications, Tulsa, Oklahoma; 2003.
5. Brown KE, James FL. Nodal systems analysis of oil and gas wells, JPT. October 1985;37.
6. Cosad C. Choosing a Perforation Strategy, Oilfield Review. October 1992;4(4): 54-69.
7. Crawford HR. Underbalanced perforating design, the 64-th SPE Annual Technical Conference and Exhibition, San Antonio, Texas, USA; October 8-11, 1989.
8. Stoianovici D, Chis T. Well production with casing sand bridge**,** Romanian Journal of Petroleum & Gas Technology (LXXV) NO. 1/2023;IV.

Peer-review history:
The peer review history for this paper can be accessed here:
https://www.sdiarticle5.com/review-history/118666