Establishing IPR in Gas-Condensate Reservoir: An Alternative Approach

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Abstract—**Inflow performance relationship (IPR) accuracy in the condensate reservoir is a long-standing problem in the oil industry. This paper presents a new approach to project the gas phase IPR in condensate reservoirs. IPR is estimated by Rawlins and Schellhardt equation whereas the gas pseudo-pressure function is solved by two methods and their IPRs are compared. Additionally, an average of both IPR's is estimated and compared. At the reservoir pressure, the difference between both flow rates is negligible i.e. at 6750 psi, the flow rate difference is 0.55 MMSCF/D. As pressure declines the difference is increasing at one stage, it is observed approximately 15 MMSCF/D.**

Keywords-gas; condensate; condensate reservoir; Pseudopressure; Well productivity; Relative Permeability; Permeability; IPR

I. INTRODUCTION

The gas condensate reservoirs are difficult to predict due to its multiphase behavior. Petroleum industry is struggling to obtain the accurate Inflow Performance Relation (IPR) in condensate reservoirs for decades. There is not much research conducted in the case of calculating gas phase IPR in a condensate reservoir. It is possible to calculate IPR by using gas phase pseudo-pressure function without using the relative permeability data. Pseudo-pressure equation is solved using effective permeability data which can be obtained by pressure buildup test [1]. In the solution gas drive reservoir, two phase flow causes the curvature in IPR due to the reduction in the relative permeability of the oil phase with the depletion [2]. Two phase pseudo-steady state equation was solved [3] based on Weller's approximation of constant gas oil ratio (GOR) and constant de-saturation [4]. In this study, the proposed approach is compared with the conventional method. To generate the IPR, the relative equation in [5] is preferred. In several case studies, it has been shown through production data and well test data that condensate blockage may reduce the production from two to four times. The major cause of production loss is condensate blockage near the wellbore [6]. To understand the condensate behavior, it is divided into three regions. Region-1 (near wellbore), where both phases are presented and mobile, Region-2 where both phases are present but only gas phase is mobile, and Region-3 (above dew point pressure) where only the gas phase is present and mobile [7]. Experimental work on the long core of sandstone formation outcome shows that the mobility is increased with capillary number near the wellbore region [8]. Authors in [9] verified the existence of the three regions by using a compositional simulator. The estimation of total well productivity in condensate reservoir is complicated. Condensate extent must be known to identify the blockage effect so that remedial action can be taken [10]. In [11], common problems associated with the condensate reservoirs were investigated and several proposed solutions were reviewed. This paper provides key improvements in the calculation of gas phase pseudo-pressure function using the integral effective permeability technique proposed in [12].

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II. MODEL DESCRIPTION AND WORKING EQUATIONS

A. Gas Pseudo-Pressure Function

It completely depends on the pressure. To calculate real gas pseudopressure function linearly, Kirchhoff integral transformation is used as follows [13]:

$$m(p) = 2\int_{P_{wf}}^{P} \frac{p}{\mu Z}\, dp \qquad (1)$$

where P: pressure, μ: viscosity, and Z: compressibility factor. Authors in [7] modified and introduced the pseudopressure equation in form of three regions [7]. The total gas pseudopressure equation is:

$$m(p) = \int_{P_{wf}}^{P_r} \left(\frac{k_{ro}}{\mu_o B_o} R_s + \frac{k_{rg}}{\mu_g B_g}\right) dp \qquad (2)$$

where k_{ro}: relative permeability of oil, μ_o: viscosity of oil, B_o: oil formation volume factor, *Rs:* the solution gas-oil ratio, and *g*: gas. Authors in [12] modified the pseudopressure equation to calculate it with the single-phase effective permeability of either gas or oil by using well test data. They proposed the following equation, using gas PVT properties:

$$m(P)_g = \left[\int_{P_{wf}}^{P_r} \left(\frac{k.k_{rg}}{B_g \mu_g}\right) \frac{R_p(1-R_o R_s)}{R_p - R_s} (P)\, dp\right] \quad (3)$$

where *Rp*: producing gas-oil ratio and *Ro*: oil vapors in gas. Calculations of the classic and the proposed method are given in Table VI and VII respectively.

B. Derivative of Gas Pseudo-Pressure Function

Time dependent derivative of the pseudopressure function is required in order to obtain the integral of effective permeability. To calculate the derivative, it is necessary to obtain a pseudopressure equation. At first, the pseudopressure equation was calculated by ignoring the permeability data. Then, the derivative of pseudopressure equation is calculated.

C. Integral of Effective Permeability

The effective permeability data were calculated from the semi log straight line (SSL) from Shut-in versus time in Figure 1. The start of SSL shows the MTR (Middle Time Region) on PBU (Pressure Build-up) plot. The following equation is used to calculate the integral of effective permeability:

$$\int_{P_{wf}}^{P} (k_{eg})\, dp = \int_{P_{wf}}^{P} (k.k_{rg})\, dp = 162.6 \left(\frac{q_{g,meas}}{h}\right) \frac{1}{\Delta m(p)'} \quad (5)$$

where k_{eg}: gas effective permeability, $q_{g,meas}$: flow rate of gas measured, h: bed thickness and $\Delta m(p)'$: change in pseudopressure derivative. Now, extrapolate the integral of effective permeability versus pressure to zero using curve fit software. The equation from curve is used to calculate its integral on the desired pressure (Figure 4).

D. Effective Permeability

Once the integral of effective permeability is calculated, we take its derivative using a two-point numerical derivative as a function of pressure:

$$k_{eg} = \frac{(\int k_{eg})_2 - (\int k_{eg})_1}{(P_2 - P_1)} \quad (6)$$

This effective permeability is used to calculate the final pseudopressure function as shown in Table VII.

E. Gas Flow Rate for IPR

To establish gas phase IPR, the equation from [5] is used. Additionally, both gas pseudopressure equations are solved and their IPRs are plotted and compared. Figures 6 and 8 show the classic and the proposed IPR whereas Figure 9 shows the comparison of both IPRs with their average.

$$q_g = C \times \left[\left(m(p)_g\right)_{pi}^2 - \left(m(p)_g\right)_{pwf}^2\right]^n \quad (7)$$

where *C*: flow coefficient, *n*: deliverability exponent, $m(p)_g$: gas pseudopressure function, pi: initial pressure and p_{wf}: wellbore flowing pressure.

III. STEP-BY-STEP PROCEDURE TO GENERATE IPR

This method of calculating IPR is slightly different from the classic one. Its steps are:

1. Calculate gas properties (viscosity, density, compressibility) by conventional equations.
2. Convert well test data into gas pseudopressure function, ignoring permeability terms.
3. Calculate the derivative of the time log $\left(\frac{d\Delta m(p)}{d\ln(t)}\right)$ of pseudopressure data.
4. Plot well test data pressure versus time on semi-log and find the straight-line.
5. Estimate the integral of effective permeability following the straight line from the previous step.
6. Plot the estimated integral of effective permeability versus pressure extrapolated to zero limits. To get good curve fit the equation's both limits should be extrapolated to zero.
7. Calculate the integral of effective permeability values using the generated equation from the curve obtained in Step 6.
8. Calculate the effective permeability using a two-point numerical derivative as a function of pressure from the previous step.
9. Calculate the pseudopressure function again this time including the effective permeability data.
10. Finally, establish condensate well performance by using the equation from [5].

IV. CONCLUDING INTERPRETATION

IPR is often used to predict the natural flow of the well so it should be properly selected. This study presents a new approach to estimate IPR in a gas condensate reservoir. Furthermore, it concludes with the following observations:

- A method is proposed to calculate pseudopressure equation for plotting IPR in gas condensate reservoir. It does not require relative permeability data, as effective permeability can be easily calculated from its integral.
- Effective permeability must be used before solving the pseudopressure integral. The comparison of IPR with the classic method shows that as pressure declines the flow rate difference in classic method and the proposed one increases. It can reduce the error by 1-15MMSCF/d.

V. RECOMMENDATIONS

IPR can obtain optimum flow of the well. It is highly recommended to use the proposed method to reduce errors in IPR calculations. The error percentage shows the reliability of this work. For additional research, three-phase reservoir should be considered, and optimum flow can be obtained by plotting TPR vs. IPR.

A. Abbreviations and Acronyms

PPF = Pseudopressure function
GOR= Gas Oil Ratio
SSL = Semi-log-straight-line
R-1 = Region-1

R-2 = Region-2
R-3 = Region-3
B_g = Gas formation volume factor
μ_g = Gas viscosity
K_{eg} = Gas effective-permeability
K_{rg} = Gas relative-permeability
q_g = Gas flow-rate
q_o = Oil flow-rate
R_p = Producing gas-oil ratio
R_{so} = Solution gas-oil ratio
$m(p)$ = Pseudo-pressure function
$m(p)'$= Derivative of pseudo-pressure function
$\Delta m(p)$= Change in pseudo-pressure function

B. Figures and Tables

TABLE I. RESERVOIR AND FLUID DATA [14]

Symbol	Value	Unit	Symbol	Value	Unit
Pi	6750	Pisa	qg	75.4	MSCF/D
Pd	6750	Pisa	qo	2.8	STB/D
Rp/GOR	10417	SCF/STB	h	216.5	ft
T	814	°R	Φ	0.062	
Gas SG	0.94		rw	0.54	ft
MW	27.17		API	50	[Assumed]
ΔT	2.85	°F/100ft			

TABLE II. WELL TEST DATA [14]

Time (hrs)	*P* (psi)	Time (hrs)	*P* (psi)	Time (hrs)	*P* (psi)
0	1083.1	6	2759.4	50	6487.3
0.167	1174.5	8	3246.5	58	6507.6
0.333	1226.7	12	4210	68	6526.5
0.5	1303.6	16	5162	82	6556.9
1	1490.6	22	6161	97	6574.3
2	1751.6	28	6336.5	112	6587.3
3	2046	34	6406.1	141	6601.8
4	2279.4	42	6452.5	Pr	6750

TABLE III. GAS PVT PROPERTIES AT WELL TEST PRESSURE

P psi	Z	B_g bbl/SCF	ρ_g gm/cc	μ_g cc	R_s SCF/STB	R_o STB/SCF
1083.1	0.9145	0.0034	0.0539	0.0080	297.945	1.4E-05
1174.5	0.9101	0.0031	0.0585	0.0082	327.131	1.55E-05
1226.7	0.9075	0.0030	0.0611	0.0083	343.959	1.63E-05
1303.6	0.9038	0.0028	0.0649	0.0085	368.948	1.75E-05
1490.6	0.8947	0.0024	0.0742	0.0090	430.644	2.04E-05
1751.6	0.8820	0.0020	0.0872	0.0097	518.739	2.41E-05
2046.0	0.8672	0.0017	0.1019	0.0105	620.549	2.82E-05
2279.4	0.8716	0.0015	0.1135	0.0113	702.899	3.14E-05
2759.4	0.8807	0.0013	0.1374	0.0130	876.247	3.81E-05
3246.5	0.8899	0.0011	0.1617	0.0151	1056.97	4.54E-05
4210	0.9157	0.0008	0.2097	0.0200	1426.45	6.22E-05
5162.0	0.9962	0.0007	0.2572	0.0273	1804.60	8.39E-05
6161.0	1.0806	0.0007	0.3069	0.0376	2213.14	0.000115
6336.5	1.0954	0.0007	0.3157	0.0397	2286.02	0.000121
6406.1	1.1013	0.0007	0.3192	0.0406	2315.01	0.000124
6452.5	1.1052	0.0007	0.3215	0.0413	2334.36	0.00012
6487.3	1.1082	0.0007	0.3232	0.0417	2348.89	0.00012
6507.6	1.1099	0.0007	0.3242	0.0420	2357.37	0.000128
6526.5	1.1115	0.0006	0.3252	0.0422	2365.27	0.000129
6556.9	1.1140	0.0006	0.3267	0.0427	2377.98	0.000130
6574.3	1.1155	0.0006	0.3275	0.0429	2385.26	0.000131
6587.3	1.1166	0.0006	0.3282	0.0431	2390.70	0.000131
6601.8	1.1178	0.0006	0.3289	0.0433	2396.77	0.000132
6750.0	1.1304	0.0006	0.3363	0.0454	2458.94	0.000138

TABLE IV. PPF, ITS DERIVATIVE AND INTEGRAL OF EFFECTIVE PERMEABILITY

P psi	$\Delta m(p)$ MMpsi²/cp	$\Delta m(p)'$	$\int Keg$
1083.1	19.87139		
1174.5	23.33366		
1226.7	25.40711		
1303.6	28.58367	7.475785	
1490.6	36.87831	11.75797	
1751.6	49.68891	29.24621	
2046	65.64563	38.57398	
2279.4	79.14166	55.36694	
2759.4	108.0837	75.90609	
3246.5	138.2613	107.2502	
4210	196.2917	139.7734	
5162	246.5346	135.301	
6161	287.666	93.06389	SSL
6336.5	293.6161	56.13135	0.001008854
6406.1	295.8697	15.22777	0.003718756
6452.5	297.3387	8.76812	0.006458438
6487.3	298.423	5.343989	0.010596647
6507.6	299.0485	4.866248	0.011636966
6526.5	299.6263	4.524248	0.012516635
6556.9	300.5464	3.375618	0.016775701
6574.3	301.0679	3.658003	0.015480678
6587.3	301.4551	2.58145	0.021936645
6601.8	301.8845		
6750	306.1246		

TABLE V. PVT PROPERTIES AT ASSUMED PRESSURE

P psi	Z	B_g bbl/SCF	ρ_g gm/cc	μ_g cc	R_s SCF/STB	R_o STB/SCF
100	0.98995	0.04061	0.0049	0.0062	19.08302	1.4E-05
300	0.97359	0.01331	0.0149	0.0065	67.76515	3.4E-06
600	0.94906	0.00648	0.0298	0.0070	150.7455	4.83E-06
900	0.92348	0.00421	0.0448	0.0076	240.6389	1.09E-05
1200	0.90888	0.00310	0.0597	0.0083	335.3379	1.59E-05
1500	0.89428	0.00244	0.0747	0.0090	433.7788	2.05E-05
1800	0.87969	0.00200	0.0896	0.0098	535.3081	2.48E-05
2100	0.86826	0.00169	0.1046	0.0107	639.48	2.89E-05
2400	0.87393	0.00149	0.1195	0.0117	745.9688	3.31E-05
2700	0.87962	0.00133	0.1345	0.0128	854.5257	3.73E-05
3000	0.88530	0.00121	0.1494	0.0140	964.9535	4.16E-05
3300	0.89099	0.00110	0.1644	0.0153	1077.092	4.62E-05
3600	0.89668	0.00102	0.1793	0.0168	1190.809	5.11E-05
3900	0.88955	0.00093	0.1943	0.0184	1305.991	5.63E-05
4200	0.91490	0.00089	0.2092	0.0202	1422.542	6.2E-05
4500	0.94025	0.00085	0.2242	0.0222	1540.379	6.82E-05
4800	0.96561	0.00082	0.2391	0.0244	1659.429	7.49E-05
5100	0.99096	0.00079	0.2541	0.0268	1779.628	8.23E-05
5400	1.01632	0.00077	0.2690	0.0295	1900.917	9.05E-05
5700	1.04167	0.00075	0.2840	0.0324	2023.246	9.94E-05
6000	1.06702	0.00073	0.2989	0.0357	2146.567	0.000109
6300	1.09238	0.00071	0.3139	0.0393	2270.839	0.00012
6750	1.13041	0.00068	0.3363	0.0454	2458.946	0.000138

The curve in Figure 4 is obtained from the equation generated by the curve fit. The smooth curve is an indication of accuracy and it should be used to calculate the other required data. The curve in Figure 6 shows the trend of effective permeability of gas against pressure. As the pressure is increased, the effective permeability of the gas is also increased. The graph trend in Figure 9 shows that error is reduced by 1-15 MMSCF/d. The difference between average IPR and classic IPR is 0.5-7.5 MSCF/d.

TABLE VI. FINAL PPF AND FLOW RATE - CLASSIC METHOD

P psi	$m(p)_g$ MMpsi²/cp	$\int K_{eg}$	$m(p)_g$ (Final) MMSCF	q_g MMSCF/D
100	0.196978075	6.50266E-05	1.28088E-05	94.05954
300	1.742696934	8.13784E-05	0.00014181	94.04973
600	6.778583051	0.000100002	0.00067787	94.009
900	14.82858679	0.000117101	0.001736445	93.92854
1200	25.52693376	0.000134243	0.003426806	93.80002
1500	38.4846738	0.000152154	0.005855598	93.61529
1800	53.3722675	0.000171361	0.009145922	93.36488
2100	69.85112141	0.000192357	0.013436386	93.03811
2400	87.42029189	0.000215685	0.018855232	92.62498
2700	105.6132162	0.000241992	0.025557541	92.11336
3000	124.1582217	0.000272102	0.03378372	91.48445
3300	142.8181289	0.000307105	0.043860203	90.71261
3600	161.3865833	0.000348495	0.056242486	89.76188
3900	179.8151745	0.000398395	0.071637542	88.57631
4200	197.7524845	0.000459941	0.090954501	87.08307
4500	214.7604013	0.000537981	0.11553694	85.17347
4800	230.77076	0.00064044	0.147794924	82.65125
5100	245.7339194	0.000781243	0.191977821	79.16496
5400	259.6153259	0.000987312	0.256321205	74.01772
5700	272.3926848	0.001318394	0.359120865	65.6006
6000	284.0536412	0.001939033	0.550789526	49.10788
6300	294.5938878	0.003527854	0.811762171	27.12217
6750	308.3105787	0.003211887	0.990258889	0

TABLE VII. PPF AND FLOW RATE - PROPOSED METHOD

P (psi)	k_{eg}	$m(p)_g$ (MMpsi²/cp)	q_g (MMSCF/D)
100	0	3.9E+08	80.29606
300	8.17589E-08	1.41E+08	80.40645
600	6.2078E-08	4.88E+08	80.25238
900	5.69979E-08	9.64E+08	80.04083
1200	5.71385E-08	1.57E+09	79.76904
1500	5.97042E-08	2.33E+09	79.43118
1800	6.4023E-08	3.26E+09	79.01951
2100	6.99885E-08	4.36E+09	78.52535
2400	7.77579E-08	5.66E+09	77.94393
2700	8.76901E-08	7.17E+09	77.26862
3000	1.00368E-07	8.91E+09	76.48462
3300	1.16677E-07	1.09E+10	75.572
3600	1.37967E-07	1.33E+10	74.50349
3900	1.66333E-07	1.61E+10	73.23101
4200	2.05152E-07	1.94E+10	71.71536
4500	2.60132E-07	2.34E+10	69.90629
4800	3.41533E-07	2.82E+10	67.69041
5100	4.69341E-07	3.42E+10	64.87688
5400	6.86896E-07	4.22E+10	61.11419
5700	1.10361E-06	5.35E+10	55.66273
6000	2.0688E-06	7.17E+10	46.58986
6300	5.29607E-06	1.1E+11	25.98219
6750	7.0215E-07	1.45E+11	0

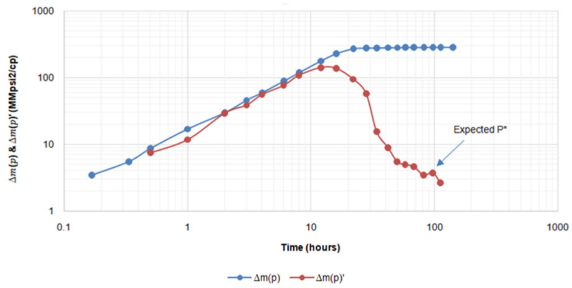

Fig. 1. Pseudopressure function and its derivative vs. time

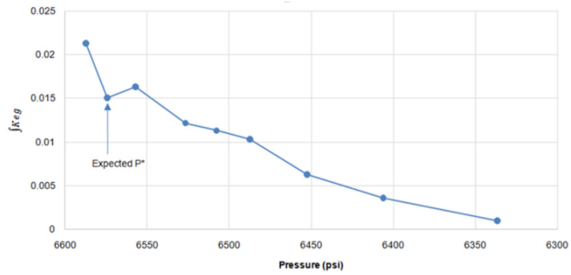

Fig. 2. Integral of gas effective permeability as a function of pressure

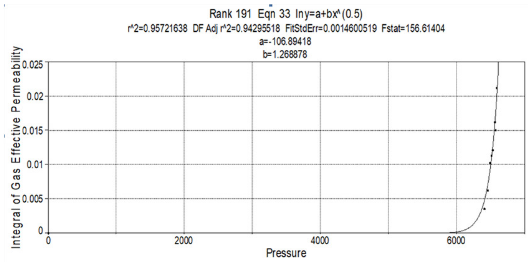

Fig. 3. Integral of gas effective permeability as a function of pressure extrapolated to zero

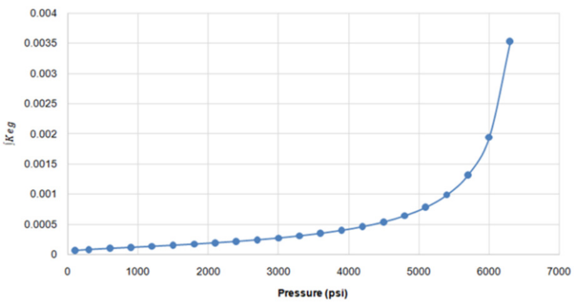

Fig. 4. Integral of effective permeability versus pressure at assumed pressure points

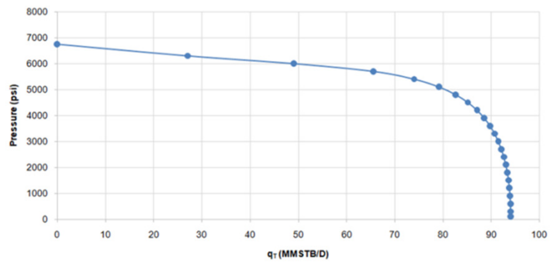

Fig. 5. IPR via classic method

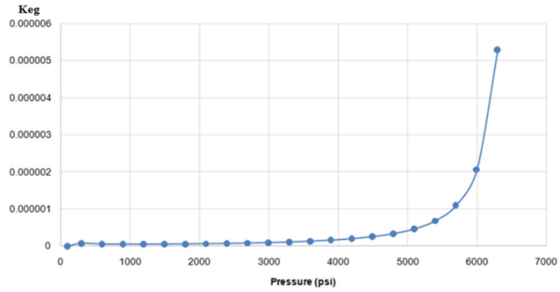

Fig. 6. Gas effective permeability vs. pressure

TABLE VIII. PROPOSED AND CLASSIC METHOD COMPARISON

P (psi)	q_g (MMSCF/D)	q_g (MMSCF/D)	q_g (difference) (MMSCF/D)	q_g(avg) (MMSCF/D)
100	94.05954	80.29606	13.76348	87.1778
300	94.04973	80.40645	13.64328	87.22809
600	94.009	80.25238	13.75662	87.13069
900	93.92854	80.04083	13.88771	86.98468
1200	93.80002	79.76904	14.03098	86.78453
1500	93.61529	79.43118	14.18411	86.52323
1800	93.36488	79.01951	14.34537	86.1922
2100	93.03811	78.52535	14.51276	85.78173
2400	92.62498	77.94393	14.68105	85.28445
2700	92.11336	77.26862	14.84475	84.69099
3000	91.48445	76.48462	14.99984	83.98453
3300	90.71261	75.572	15.14061	83.1423
3600	89.76188	74.50349	15.25839	82.13268
3900	88.57631	73.23101	15.3453	80.90366
4200	87.08307	71.71536	15.36771	79.39921
4500	85.17347	69.90629	15.26718	77.53988
4800	82.65125	67.69041	14.96084	75.17083
5100	79.16496	64.87688	14.28808	72.02092
5400	74.01772	61.11419	12.90353	67.56595
5700	65.6006	55.66273	9.937865	60.63167
6000	49.10788	46.58986	2.518028	47.84887
6300	27.12217	25.98219	1.139977	26.55218
6750	0	0	0	0

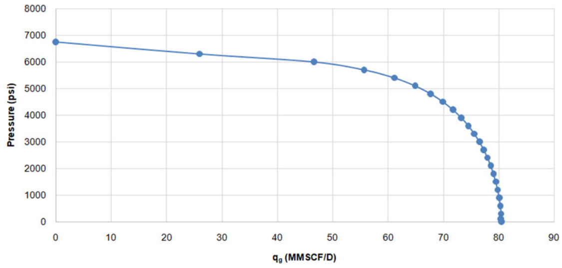

Fig. 7. IPR via the proposed method

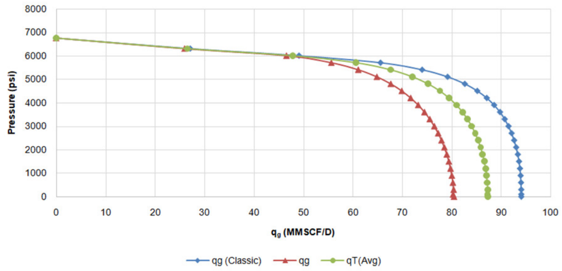

Fig. 8. IPRs via classic and proposed method and their average

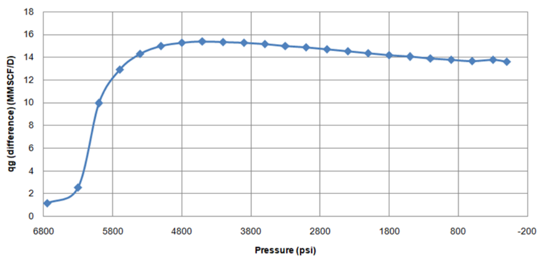

Fig. 9. Variation in gas flow rate versus pressure

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REFERENCES

[1] S. A. Jokhio, D. Tiab, "Establishing inflow performance relationship (IPR) for gas condensate wells", SPE Gas Technology Symposium, Calgary, USA, 30 April-2 May, 2002

[2] H. H. Evinger, M. Muskat, "Calculation of theoretical productivity factors", Transactions of the AIME, Vol. 146, No. 1, pp. 126-139, 1942

[3] J. T. Vogel, "Inflow Performance Relationships for solution-gas drive wells", Journal of Petroleum Technology, Vol. 20, No. 1, pp. 83-92, 1968

[4] W. T. Weller, "Reservoir performance during two phase flow", Journal of Petroleum Technology, Vol. 18, No. 2, pp. 240-245, 1966

[5] E. L. Rawlins, M. A. Schellhardt, Backpressure data on natural gas wells and their application to production practices, Literary Licensing, 1935

[6] D. Afidick, N. J. Kaczorowski, S. Bette, "Production performance of a retrograde gas reservoir: a case study of the Arun field", SPE Asia Pacific Oil and Gas Conference, Melbourne, Australia, November 7-10, 1994

[7] O. Fevang, C. H. Whitson, "Modeling gas condensate deliverability", SPE Reservoir Engineering, Vol. 11, No. 4, pp. 221-230, 1995

[8] R. Mott, A. Cable, M. Spearing, "A new method of measuring relative permeabilities for calculating gas-condensate well deliverability", 1999 SPE Annual Technical Conference and Exhibition, Houston, USA, October 3–6, 1999

[9] A. C. Gringarten, A. Al-Lamki, S. Daungkaew, R. Mott, T. M. Whittle, "Well test analysis in gas-condensate reservoirs", SPE Annual Technical Conference and Exhibition, Dallas, USA, October 1-4, 2000

[10] M. S. Abdallah, M. A. Al-Zawad, M. L. Fraim, "Common misinterpretations of gas condensate reservoirs", SPE Kingdom of Saudi Arabia Annual Technical Symposium and Exhibition, Dammam, Saudi Arabia, April 24-27, 2017

[11] M. H. Chachar, S. A. Jokhio, A. H. Tunio, "Investigating gas phase productivity in gas condensate reservoir: a review", Engineering Science & Technology International Research Journal, Vol. 2, No. 3, pp. 95-99, 2018

[12] S. A. Jokhio, D. Tiab, S. Baladi, A. H. Tunio, "Estimating pseudopressure function without relative permeability [kr(Sw)] for two and three phase gas condensate systems", SPE Asia Pacific Oil and Gas Conference and Exhibition, Melbourne, Australia, October 8-10, 2002

[13] R. Al-Hussainy, H. J. Ramey, P. B. Crawford, "The flow of real gases through porous media", Journal of Petroleum Technology, Vol. 18, No. 5, pp. 624-636, 1966

[14] P. Gherson, C. Faruk, "Gas-condensate well test analysis with and without relative permeability curves", SPE Annual Technical Conference and Exhibition, Dallas, USA, October 1-4, 2000

[15] V. N. Gopal, "Gas Z-factor equations developed for computer", Oil and Gas Journal, Oil and Gas Journal, Vol. 75, No. 8, pp. 8-13, 1977

[16] A. L. Lee, M. H. Gonzalez, B. E. Eakin, "The viscosity of natural gases", Journal of Petroleum Technology, Vol. 18, No. 8, pp. 997-1001, 1966