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Original Research Article

Introduction of Risk Management Method Based on Hierarchy Risk Management and Surface Data to Eliminate Operational Risk (Second Development)

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Abstract

Industrial operations in high H2S gas wells can cause serious environmental, financial & health consequences. Risk management is important, especially when the world is at war with the SARS-COV-2 pandemic; we should have stronger boundaries to protect lives. One of the common methods is the hierarchy method. In this study, by combining this method and designing a new correlation to calculate static bottom hole pressure at gas wells, we tried to have strong risk management with the final goal of replacing the industrial operation. In the past, time-consuming and imprecise trial and error methods& expensive operations were used to calculate static bottom-hole pressure for gas wells. So, a general equation was modified based on field observations to obtain more accurate static bottom-hole pressure predictions. For this purpose, a unique adjustable parameter, based on the history matching of wells, has been proposed for each reservoir. The accuracy of this equation was investigated in three Iranian gas reservoir information. Good agreement was obtained between the field observations and this proposed equation. The precision of this method depends on field data, and with increasing numbers of field tests, the model becomes more accurate.

Keywords: H2S gas wells; hierarchy method; risk management; SARS-COV 2 pandemic; Operational Risk; Second Development.

1. Introduction

Periodic measurement of static bottom-hole pressure (SBHP) of wells is essential to monitor the reservoir depletion and gather information, and also, accurate SBHP values are essential for gas reservoir engineering calculations. The gas reservoir pressure has been calculated from wellhead pressure for many years [1]. The success of pressure transient analysis often depends on accurately measuring or estimating the bottom-hole pressure [2]. Pressure measurement is an appropriate method, but it is time-consuming and costly, especially with deep wells, high-temperature reservoirs, and the presence of highly corrosive gases. Therefore, the estimation of static pressure via an accurate method is necessary. The equations, based on the average properties of the gas, can be developed to determine SBHPin gas wells. The methods discussed in the literature for calculating gas gradient pressure in tubing and reservoirs are based on the properties of the fluid column in the well with some simple assumptions.

In 1945, Rzasa and Katz developed three methods to calculate the static pressure gradient in gas wells using the trial-and-error method. They developed charts from which pressure gradients may be read when the wellhead pressure, the well fluid gravity, depth, and the average well temperature should be given [1]. Messer et al. considered the z-factor a linear function of reduced pressure, Pr, between 10 - 30 for reduced temperatures, and Tr, between 1.1 – 3. They used a numerical integration method to solve their suggested equation [3]. Economides presented two correlations for calculating static bottom-hole gas pressure in saturated or slightly superheated vapor. Also, he suggested that the vapor density is a linear function of pressure [2]. Bender and Holden used different temperature distribution functions to determine the average temperature in the good column for average z-factor calculation [4]. Moreover, other researchers developed some methods to calculate static bottom-hole pressure for gas wells using simplifying assumptions [5]. In this paper, a new equation has been suggested and used for comparison with field observations.

2. Theory

2.1 Derivation of Formula

The basis of the SBHP calculation technique is energy balance in the wellbore. The general differential form of the energy balance equation describing steady-state flow in pipes [6]:

$$\frac{144}{\rho}dp+\frac{g}{g_c}dL+\frac{v}{g_c}dv+dF=-dw_s \tag{1}$$

Where:

ρ is the fluid density, p is pressure, gis local acceleration, gis dimensional constant, v is flow velocity, F is energy loss resulting from friction, and ws is the total shaft work done by the system.

In a static gas column, the kinetic energy, shaft work, and friction effects are zero and can be eliminated from Eq. (1).

$$\frac{144}{\rho}\mathrm{dp}+\frac{\mathrm{g}}{\mathrm{g_c}}\mathrm{dL}=0 \tag{2}$$

In American Engineering Unit g=g_c, therefore, Eq. (2) is rearranged as below:

$$\mathrm{dp}=-\frac{\rho}{144}\mathrm{dL} \tag{3}$$

Using the real gas equation of state (EoS), the gas density can be intended as a function of pressure:

$$\rho_g=\frac{\mathrm{pM}}{\mathrm{zRT}}=\frac{28.97\gamma_g\mathrm{p}}{\mathrm{zRT}} \tag{4}$$

Where M is the molecular weight of gas ($\frac{lb_{mass}}{lb_{mole}}$), Z is the gas compressibility factor, R is the universal gas constant, 10.732 ($\frac{psi.ft^3}{lb_{mole}\cdot{}^{\circ}R}$), γ_g is gas specific gravity, and $T$is absolute temperature ($^{\circ}R$).

Substitution of Eq. (4) in Eq. (3) yields:

$$\mathrm{dp}=-\frac{0.01875\ \gamma_g\mathrm{p}}{\mathrm{zT}}\mathrm{dL} \tag{5}$$

Figure 1 illustrates the schematic of a vertical well geometry. Gas density and compressibility factors are functions of pressure and temperature. In addition, temperature and pressure change with depth. Therefore, solving the differential equation (Eq. (5) is complicated. To simplify the solution, the z-factor and temperature were assumed to be constant and can be represented by average values. Typically, these average values are determined in an arithmetic average of the surface and bottom-hole temperature and pressure [6].

Substituting an average temperature,$\overline{T}$, and an average z-factor,$\overline{z}$, into Eq. (5), integration from bottom to top of the wellbore, SBHPcan be derived as follows [6]:

$$\int_{\mathrm{ps}}^{\mathrm{pwhs}}\frac{\mathrm{dp}}{\mathrm{p}}=-\frac{0.01875\gamma_g}{\overline{\mathrm{z}}\overline{\mathrm{T}}} \tag{6}$$

$$P_{\mathrm{ws}}=P_{whs}\times exp\left(\frac{0.01875\gamma_g H_t}{\overline{z}\overline{T}}\right) \tag{7}$$

Where H_t is the total depth of the well (ft), P_{ws} and P_{whs} are static bottom-hole and static wellhead pressures (psi), respectively.

Eq. (7) is a general form for calculating the SBHP using surface field data. Because $\overline{z}$ depends on P_{ws}, the solution to Eq. (7) involves a time-consuming iterative process.

In this study, a new method has been proposed to solve Eq. (7) for reducing time and improving the accuracy of results.

3. Proposed Equation and Method

To improve the correlation results, a positive adjustable and dimensionless parameter,α, which is unique for each reservoir, was considered in Eq. (7). In fact, this parameter is adjusted to eliminate the trial-and-error calculations and can be obtained by matching the measured pressure of the reservoir. Thus, the proposed equation is:

$$P_{\mathrm{ws}}=P_{whs}\times exp\left(\alpha\times\frac{0.01875\gamma_g H_t}{\overline{z}\overline{T}}\right) \tag{8}$$

To solve this equation, some steps must be done as follows:

I- Give the basic information about the reservoir, such as initial reservoir pressure, P_i, initial reservoir temperature, T_i, and mole fraction of components representing the reservoir fluid sample.

II- Use the available information of wells in the reservoir such as static wellhead pressure, P_{whs}, measured Static bottom-hole pressure, $P_{ws\text{-}gauge}$, static wellhead temperature, T_{whs}, and well depth, H_t, which was measured previously.

III- Calculate the average pressure and temperature for each well as follows:

$$\overline{\mathrm{P}}=\frac{\mathrm{P_i}+\mathrm{P_{whs}}}{2}$$

$$\overline{\mathrm{T}}=\frac{\mathrm{T_i}+\mathrm{T_{whs}}}{2}$$

IV- Calculate the z-factor of each well. In this work, Wichert and Aziz's correlation accounted for inaccuracies in the Standing and Katz chart when the gas contains significant fractions of CO_2 and H_2S [7]. Also, for the effect of high molecular weight gas correction, Sutton’s correlation has been used [8].

V- A range for α from 0 was considered.

VI- For the first value of α, static bottom-hole Pressure, P_{ws_calc}, was calculated for each well by available data of reservoir (T_i, $P_i$and γ_g) and wells (P_{ws_gauge}, $P_{whs,}$ and H_t) with Eq. (8).

VII- Calculate the Root Mean Square Deviation, *RMSD*, of the reservoir for consideration as follows:

$$\mathrm{RMSD}=\sqrt{\frac{\sum_{\mathrm{n}}\left(\mathrm{P_{wscalc}}-\mathrm{P_{wsgauge}}\right)^2}{\mathrm{n}}} \tag{9}$$

Where n is the number of wells in the reservoir that has been reported P_{ws_gauge} for each of them.

VIII- In this step, by the new value of α (previous $\alpha+\varepsilon$), steps VI and VII would be repeated until α reaches the maximum value in the range.

IX- *RMSD* vs. α is plotted. The optimum value of α of the reservoir causes to have minimum *RMSD*.

Using optimum α, the static bottom-hole pressure of any wells in the reservoir has been computed by Eq. (8) without the necessity to use the pressure gauges anymore.

Table 1. Mole fraction of components for three reservoirs.

component	**Mole fraction**		
	Reservoir 1	**Reservoir 2**	**Reservoir 3**
N_2	0.06	0	0.2
Co_2	2.35	10.77	2.42
H_2S	0	24.46	0.07
C1	85.65	63.07	86.85
C2	6.35	0.79	5.81
C3	2.42	0.28	2.57
i-C4	0.56	0.07	0.42
n-C4	1	0.11	0.86
i-C5	0.43	0.07	0.25
n-C5	0.39	0.08	0.25
C6	0.41	0.08	0.15
C7+	0.38	0.22	0.15

Table 2. Initial pressure and temperature of reservoirs.

Reservoir	**Pi(psia)**	**Ti (°F)**
1	12750	285
2	7531	220

Table 3. Initial pressure and temperature of reservoirs.

Parameter	**Well 1**			**Well 2**		**Well 3**		
	Test 1	**Test 2**	**Test 3**	**Test 1**	**Test 2**	**Test 1**	**Test 2**	**Test 3**
P_{ws_gauge} (psia)	12746	12734	12558	12558	12332	11378	11053	10523
P_{whs} (psia)	9389	9400	9336	9296	9035	8178	7927	7390
H_t (ft)	15958	15958	15958	15925	15925	15917	15917	15917
T_{whs} (°F)	195.5	197.5	195.5	199.1	205	209	210	196

Table 4. Measured information of wells in reservoir 2.

Parameter	**Well 1**	**Well 2**	**Well 3**	**Well 4**
P_{ws_gauge} (psia)	2404	2529	2544	2572
P_{whs} (psia)	1495	1664	1609	1630
H_t (ft)	13650	13284	13690	13595
T_{whs}(°F)	70	68	75	73

Table 5. Measured information of wells in reservoir 3.

Parameter	**Well 1**	**Well 2**	**Well 3**		**Well 4**
			Test 1	**Test 2**	
P_{ws_gauge} (psia)	2961	3024	3026	3017	3011
P_{whs} (psia)	2350	2310	2325	2330	2360
H_t (ft)	8010	8772	8482	8482	7868
T_{whs}(°F)	130	131	121	121	118

Table 6. Calculated values of α for each reservoir.

reservoir	**Average P_{ws}**	**α**
1	11985	1.580
2	2509	1.089
3	3008	1.267

Table 7. Comparison between Pws-gauge and calculated Pws of each well in reservoir 1 by α=1.580.

well	**$P_{wsgauge}$ (psi)**	**Calculated P_{ws} (psi) by Eq. 8**	**RAE (%) Eq. 8**	**Calculated P_{ws} (psi) by Eq.7**	**RAE (%) Eq. 7**
Well 1	2404	2362	1.736	2172	9.649
Well 2	2529	2591	2.454	2412	4.629
Well 3	2544	2532	0.461	2343	7.882
Well 4	2572	2559	0.502	2372	7.745

Table 8. Comparison between Pws-gauge and calculated Pws of each well in reservoir 2 by α=1.089.

well		**$P_{wsgauge}$ (psi)**	**Calculated P_{ws} (psi) by Eq. 8**	**RAE (%) Eq. 8**	**Calculated P_{ws} (psi) by Eq.7**	**RAE (%) Eq. 7**
Well 1	Test 1	12746	12809	0.495	11509	9.703
	Test 2	12734	12818	0.666	11518	9.547
	Test 3	12558	12677	0.948	11451	8.808
Well 2	Test 1	12332	12337	0.044	11721	6.662
	Test 2	11378	11243	1.180	11108	9.918
Well 3	Test 1	11053	10922	1.186	10165	10.657
	Test 2	10523	10259	2.506	9887	10.543
	Test 3	12558	12743	1.470	9310	11.522

Table 9. Comparison between Pws-gauge and calculated Pws of each well in reservoir 3 by α=1.267

well		$P_{wsgauge}$ (psi)	Calculated P_{ws} (psi) by Eq. 8	RAE (%) Eq. 8	Calculated P_{ws} (psi) by Eq.7	RAE (%) Eq. 7
Well 1		2961	2993	1.084	2873	2.960
Well 2		3024	3010	0.450	2878	4.820
Well 3	Test 1	3026	3013.	0.397	2885	4.661
	Test 2	3017	3020	0.111	2891	4.174
Well 4		3011	3004	0.207	2885	4.169

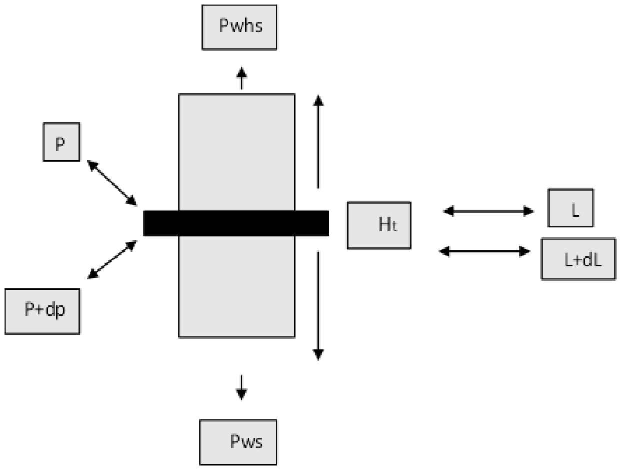

Figure 1. Schematic of a vertical well geometry.

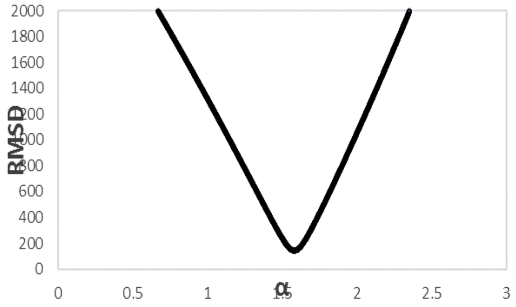

Figure 2. RMSD vs. α for reservoir 1.

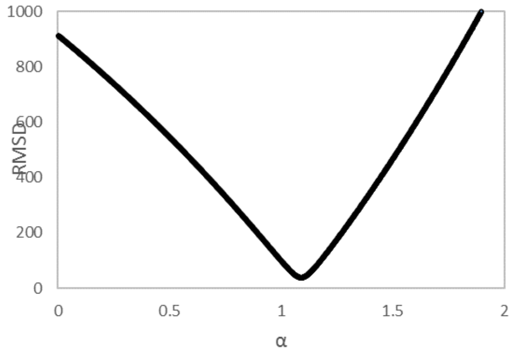

Figure 3. RMSD vs. α for reservoir 2.

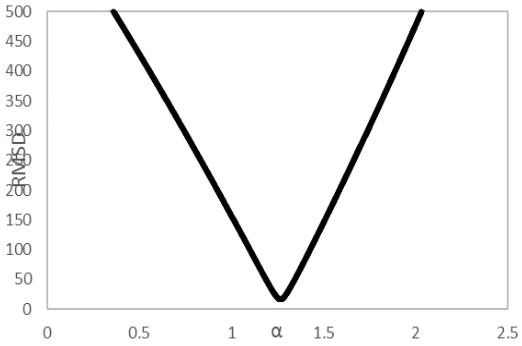

Figure 4. RMSD vs. α for reservoir 3.

4. Results and Discussion

Table I shows the component's mole fraction, and Table II presents the initial pressure and temperature of three Iranian gas reservoirs information. Measured Pwhs, Pws-gauge, Twhs, and Htof wells in each reservoir are listed in Tables IIItoV. In Figures 2 to 4, RMSD vs. α was plotted for each reservoir, and the optimum values were selected and listed in Table VI. Using the obtainedα of each reservoir, Pws_calcof wells have been calculated by Eq. (8) and also by Eq. (7) (Using trial and error method). The results are shown in Tables VII to IX. Also, the Relative Accuracy Error (RAE) of each calculated SBHP is listed in Tables VII to IX. According to tables VII to IX, the new model (Eq. (7)) has less RAE than the base model (Eq. (7)). It is important to be noted that, the accuracy of this method depends on field data and increasing numbers of field tests, the results of this model become more reliable.

5. Conclusions

This work applies a modified equation to forecast the SBHP of gas wells in different reservoirs without using the time-consuming trial and error methods by introducing an adjustable parameter, α. This parameter would be obtained by history matching and used in the proposed equation to predict SBHP in other wells or at other times. The model correlates the observed data with good accuracy and can be a good way to eliminate operational risk.

Overall, the literature on introducing a risk management method based on hierarchy risk management and surface data to eliminate operational risk offers significant value to society. Operational risks are inherent in various industries, and effective risk management strategies are essential for mitigating these risks and ensuring the smooth functioning of organizations. Through the synthesis of existing research, it becomes evident that implementing a risk management method based on hierarchy risk management and surface data can contribute to reducing operational risk and improving overall organizational performance.

Studies have highlighted that the introduced risk management method enhances the identification and assessment of potential risks systematically and structured. This enables organizations to proactively identify and prioritize risks, leading to more effective risk mitigation strategies. Using a hierarchical framework, risks can be categorized based on severity and likelihood, enabling organizations to allocate appropriate resources and focus on high-risk areas. This holistic approach provides a comprehensive understanding of operational risks and aids in developing targeted risk management strategies.

Furthermore, integrating surface data into the risk management method offers valuable insights into potential risks and their impact on operations. Surface data includes information gathered from various sources, such as incident reports, near-miss incidents, and employee feedback. Incorporating this data into the risk management process enables organizations to identify patterns and trends, facilitating proactive risk prevention efforts. By utilizing surface data, organizations can develop a deeper understanding of the root causes of operational risks, allowing them to implement effective control measures and eliminate risks before they escalate into major incidents.

The societal value of this research lies in its contribution to the overall safety and stability of organizations across various sectors. If not properly managed, operational risks can lead to financial losses, reputational damage, and, in extreme cases, even fatalities. By implementing the introduced risk management method, organizations can enhance their ability to protect their employees, assets, and stakeholders. Consequently, this contributes to the well-being of society by promoting safer working environments and minimizing the potential negative impacts of operational risks.

While the existing literature on the subject provides valuable insight, several areas of further research could enhance the understanding and application of the introduced risk management method. Firstly, empirical studies can be conducted to assess the method's effectiveness across different industries and organizational contexts. This would allow for identifying potential challenges and developing tailored strategies to optimize its implementation.

Secondly, exploring the role of technology in supporting the implementation and utilization of the risk management method presents a promising avenue for future research. Advances in data analytics, artificial intelligence, and automation could potentially enhance the identification, assessment, and monitoring of operational risks. Investigating the integration of such technologies within the introduced risk management method could lead to more efficient and comprehensive risk management practices.

In conclusion, the literature review on introducing a risk management method based on hierarchy risk management and surface data to eliminate operational risk highlights the significant societal value of this research. By offering structured and comprehensive approaches to identify, assess, and mitigate operational risks, this method enhances organizations' overall safety and stability. Further research in industry-specific applications and technological integration would contribute to improving and optimizing this risk management method, ultimately benefiting society.

6. References

[1] Badri, S. Nadeau and A. Gbodossou, "A new practical approach to risk management for underground mining project in Quebec", Journal of Loss Prevention in The Process Industries, Vol. 26, pp. 1145-1158, 2013, doi: https://doi.org/10.1016/J.JLP.2013.04.014.

[2] D. Woong Shin, Y. Shin and G. W.H.Kim, “Comparison of Risk Assessment for a Nuclear Power Plant Construction Project Based on Analytic Hierarchy Process and Fuzzy Analytic Hierarchy Process", Vol. 04, pp. 157-171, 2016, doi: https://doi.org/10.4236/JBCPR.2016.43010.

[3] D. Z. Zeng, H. Qiyao, Y. Zhiming, W. Jia, S.W. Zhang and Q.Liu, "Risk assessment of sustained casing pressure in gas wells based on the fuzzy comprehensive evaluation method," Journal of Natural Gas Science and Engineering, Vol. 46, pp. 756-763, 2017, doi: https://doi.org/10.1016/J.JNGSE.2017.08.019

[4] G.W. Meng, J. Huang, B. Wu, Y. Zhu, S. Xu and J. Hao, "Risk Assessment of Deep Foundation Pit Construction Based on Analytic Hierarchy Process and Fuzzy Mathematics," Advances in Civil Engineering pp. 1-12, 2020, doi: https://doi.org/10.1155/2020/8840043.

[5] E. Topuz and C. A. V. van Gestel,"An approach for environmental risk assessment of engineered nanomaterials using Analytical Hierarchy Process (AHP) and fuzzy inference rules", Environment international, Vol. 92-93, pp. 334-47, 2016, doi: https://doi.org/10.1016/j.envint.2016.04.022.

[6] M. N. Amar and N. Zeraibi,"A combined support vector regression with firefly algorithm for prediction of bottom hole pressure," SN Applied Sciences, Vol. 2, 2019, doi: https://doi.org/10.1007/s42452-019-1835-z.

[7] L. Zhang, S. Wu, W. Zheng and J. Fan, "A dynamic and quantitative risk assessment method with uncertainties for offshore managed pressure drilling phases," Safety Science, Vol. 104, pp. 39-54, 2018, doi: https://doi.org/10.1016/J.SSCI.2017.12.033.

[8] B. Ma, Y.M. Han, S. Cui, Z. Geng, H. Li and C. Chu,"Risk early warning and control of food safety based on an improved analytic hierarchy process integrating quality control analysis method," Food Control, Vol. 108, 2020, doi: https://doi.org/10.1016/J.FOODCONT.2019.106824.

[9] S. Wu, L. Zhang, J. Fan and Y. Zhou, "Dynamic risk analysis of hydrogen sulfide leakage for offshore natural gas wells in MPD phases," Process Safety and Environmental Protection , 2019, doi: https://doi.org/10.1016/J.PSEP.2018.12.013.

[10] E. Khamehchi and A. Bemani. "Prediction of pressure in different two-phase flow conditions: Machine learning

applications," Measurement, 2020 [In Persian]. doi: https://doi.org/10.1016/j.measurement.2020.108665

[11] X. Wang, S.i Li, X. Zhenhao, X. Li, P. Lin and C. Lin, "An interval risk assessment method and management of water inflow and inrush in course of karst tunnel excavation," Tunneling and Underground Space Technology , 2019, doi: https://doi.org/10.1016/J.TUST.2019.103033.

[12] M. Zhao, H. Geng, J. Zhang, J.F. Xie and K. Wang, "Research on Fast Semi-Quantitative Risk Assessment Method for High Temperature and High Pressure Gas Wells, " World Journal of Engineering and Technology, Vol. 9, pp. 100-108, 2021, doi: https://doi.org/10.4236/WJET.2021.91008.