PROCEEDINGS
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Management Gas Rate Production due to Liquid Loading and Erosional Rate Issue, Senoro Field, Sulawesi, Indonesia

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Abstract

As we all know that the hydrocarbon consumption is increasing by the day especially gas. Now, in order to meet this ever increasing demand it is essential for us to produce at the required rate over a specified period time. This causes the upstream industry tasked with exploiting natural resources to be forced to produce more than usual, especially gas production. Problems that often occur in gas well are the occurrence of unpredictable liquid loading and mitigation early, and also when the well's ability is considered capable of flowing a large gas flow rate, an erosive issue will emerge. The erosional aspects are particularly difficult and require special attention in high velocity area if solid particles are present.

In determining the good management gas rate, some correlation that exist for predicting the critical rate required for liquid loading in gas well include *Tuner et al* (1969), *Coleman et al* (1991), and erosional rate as the maximum limit of the rate of production using a base design from API RP14E with parameter adjustments (*Empirical Coeficient* (C) and *Pipe Roughness*) based on literature studies from several paper publications owned by SPE (*Society of Petroleum Engineers*). Based on the plotting carried out between the Future Inflow Performance Relationship (IPR), Turner/Coleman Model and also Choke Outflow Performance, using nodal analysis that integrated curves to find out the operating point of the wells.

From the results of the analysis showed that the Senoro field has a safe limit on gas production which becomes a reference later, so that the problems of liquid loading and erosive issue do not occur or can be mitigated early because we could predicted the pressure in which the problem of liquid loading may occur.

Introduction

Senoro field is the one of largest gas field producer in Indonesia with average daily production 320 MMSCFD and the condensate ± 8000 bcpd. This field has 10 production gas wells with average daily production ± 30 MMSCD.
With a large of gas production relatively, calculation and analysis will be carried out and estimates of the critical rate for problem liquid loading and erosional rates as the maximum limit of the production flow rate in Senoro Field.

The large amount of this production makes Senoro field has a several potential of problems from the gas which passes through production pipe such as potential erosion problem that causing pipe leakage. Nowadays Senoro field could transporting or carrying fluid from the subsurface to the surface. The ability come out from the reservoir pressure who has an "enough" power for lifting the liquid but, when the gas will be produced day by day so the reservoir pressure will decreasing too. When gas production is below the critical rate, the liquid cannot be brought to the surface and begins to accumulate in the wellbore, this phenomenon is called Liquid Loading.

This phenomenon makes gas flow rate will be disrupted and the worst one is our well will be shut in and cannot produce. So, here is, what we should do are determining and predicting when this probem will be happened? And what is our strategy to prevent and prepare before the problems emerge?

Data and Method

In this analysis will be used method start with collecting data from the production data, pressure, temperature, and tubing size, etc.

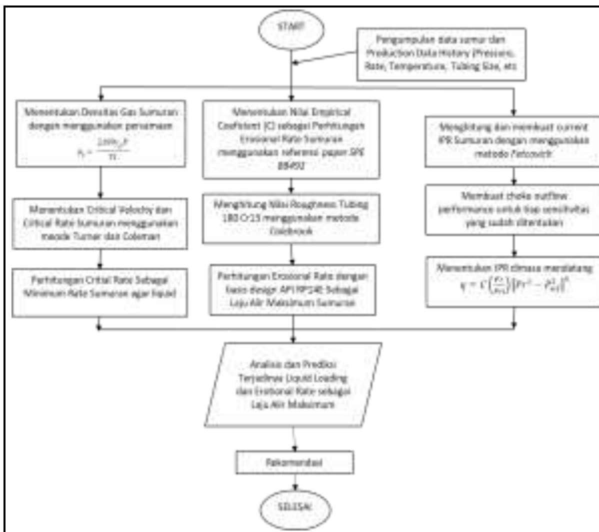

Figure 1 : Diagram Workflow

For the next step are determining of critical rate and liquid loading for each well, Erotional rate for each well, IPR Analysis, Choke Performance Relationship Anlysis, and the lastest analyzing and predicting the occurrence of liquid loading.

Result and Discussion

1. Determining of Critical Rate Liquid Loading

In determining of Critical Rate, two methods are used, Turner's Equation and Coleman Equation. Parameter data shows in below to determine Critical Rate of Liquid Loading.

Data Parameter	Nilai	Unit	Remark
Well Head Presure, Pwh	2088,22	psig	Actual Data
Well Head Temperature, T	202	F	Actual Data
Liquid Density	62,4	lb/ft3	Asume
Gas Gravity, SG	0,67		Actual Data
Deviation Gas, Z	0,890		Calculated
Interfacial Tension	60	Dyne/cm	Asume
Tubing ID	3,958	in	Actual Data
Area Tubing	0,08540	ft2	Calculated
Density Gas (calculated)	6,338	lbm/ft3	Calculated

Table 1: Parameter Data Well SNR-I

From the data table 1 then calculate the critical rate for each well in the Senoro Field using Tuner and Coleman Methods.

Turner Equation :

$$U = 1{,}92\frac{(\sigma^{1/4}(\rho_L - \rho_g)^{1/4}}{\rho_g^{1/2}} \quad \text{.....(e.q 1.1)}$$

Coleman Equation :

$$U = 1{,}59\frac{(\sigma^{1/4}(\rho_L - \rho_g)^{1/4}}{\rho_g^{1/2}} \quad \text{....(e.q 1.2)}$$

After calculating critical rate with e.q 1.1 and e.q 1.2, then calculate the production flow rate that has the same unit as the field condition with the equation below :

$$q_g = \frac{3{,}067PV_gA}{(T+460)Z}\ MMscf/D \quad \text{....(e.q 1.3)}$$

So the table 1 shows that well SNR-I has Critical velocity and critical rate as follow:

Senoro-I		Turner Model		Coleman's Model	
Density Gas	Pwf (psi)	Qg Crit. (MMSCFD)	Vcrit. ft/s	Qg Crit. (MMSCFD)	Vcrit. ft/s
	0	-	-	-	-
9,21	3000	6,32	4,75	5,24	3,94
8,60	2800	6,13	4,94	5,07	4,09
7,98	2600	5,92	5,14	4,90	4,25
7,37	2400	5,71	5,36	4,72	4,44
6,76	2200	5,48	5,62	4,54	4,65
6,14	2000	5,24	5,91	4,34	4,89
5,53	1800	4,98	6,24	4,13	5,17
4,91	1600	4,71	6,64	3,90	5,50
4,30	1400	4,42	7,12	3,66	5,89
3,68	1200	4,10	7,71	3,40	6,38
3,07	1000	3,75	8,46	3,11	7,01
2,46	800	3,37	9,49	2,79	7,86
1,84	600	2,92	10,98	2,42	9,09
1,23	400	2,39	13,48	1,98	11,17
0,61	200	1,70	19,12	1,40	15,83
0,00	0	-	-	-	-

Table 2: Critical Velocity and Critical Rate SNR-I

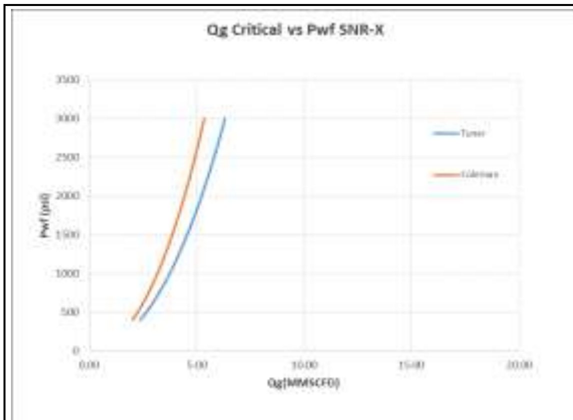

Figure 2: Graphic Critical Rate Vs Pwf

From table 1 and figure 2 shows that well SNR-I has critical rate with the variant of Pwf, so when gas production is below the critical rate, the liquid cannot be brought to the surface and begins to accumulate in the wellbore, this phenomenon is called Liquid Loading. After that we could determine Critical rate for every well in Senoro Field as follow Table 2 and Figure 3.

Well	Critical Rate Liquid Loading (MMSCFD)	
	Turner's	Coleman's
Senoro#A	14,243	11,795
Senoro#B	5,367	4,444
Senoro#C	5,381	4,456
Senoro#D	5,299	4,388
Senoro#E	5,226	4,328
Senoro#F	5,345	4,426
Senoro#G	5,414	4,484
Senoro#H	5,267	4,361
Senoro#I	5,468	4,528
Senoro#J	5,098	4,222

Table 2 : Critical Rate Result from All Wells

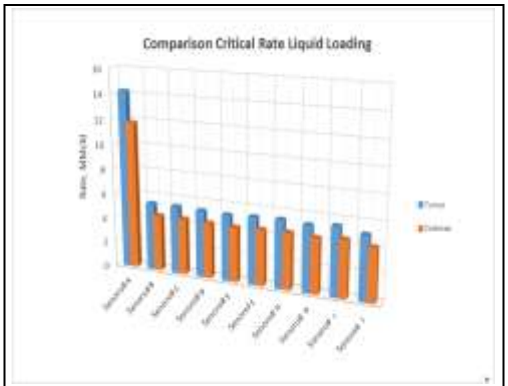

Figure 3: Comparison Critical Rate of Liquid Loading

2. Determining Erotional Rate as Maximum Flow Rate

To calculate erotional rate in the pipe reffering to API RP 14E with formula :

$$V_c = \frac{c}{\sqrt{\rho m}} \qquad \text{(e.q 2.1)}$$

Need to prepare several datas before calculating erotional rate such as fluid density (*Pm)*, and *empirical coefficient (C)*, in this analysis, calculations were without using assumptions so that the results are obtained truly and represent the real condition.

- **Determining Emperical Coefficient (C)**

On the API RP 14E said that C factor in range betwee 150-200 for well which not produce sand, if not, will be recommended by using factor C 100. In order for this analysis to be accurate, referring to SPE PAPER – 88492, the value or factor C is determined by substituting equation 2.1 to equation 2. 2.

$$f = \frac{2c\omega \, x \, gc}{\rho m V^2} \qquad \text{(e.q 2.2)}$$

Into equation 2.3 :

$$Vc = \sqrt{\frac{2gc \, x \, c\omega}{f} x \frac{1}{\sqrt{\rho m}}} \qquad \text{(e.q 2.3)}$$

So, from equation 2.3 factor C could be determined by formula below :

$$C = \sqrt{\frac{2gc \, x \, c\omega}{f}} \qquad \text{(e.q 2.4)}$$

Just because *Fanning Friction Factor (f)* calculation from above formula using several assumptions, so then *f* will be calculated by *Colebrook Equation* method with formula :

$$f = \left[1{,}14 + 2 \, Log_{10} \left(\frac{D}{E} \right) \right] \qquad \text{(e.q 2.5)}$$

So, the result of erotional rate for each well in Senoro Field could be seen as follow table 3 :

Well	Erosional Rate (MMSCFD)
	Brill and Beggs
Senoro#A	93,11
Senoro#B	95,39
Senoro#C	93,99
Senoro#D	92,27
Senoro#E	91,80
Senoro#F	94,87
Senoro#G	93,72
Senoro#H	90,99
Senoro#I	91,10
Senoro#J	95,56

Tabel 3 : Erotional Rate from All Wells

3. Inflow Performance Relationship (IPR) Analysis

Inflow Performance Relationship (IPR) is analytic relationship between bottom hole pressure and production flow rate. IPR curve is used for one phase or two phases reservoir fluid. In this case, Senoro Field using *Fetkovich equation* :

$$q = C\left[p^2 - p_{wf}^2\right]^n \text{......................(e.q 3.1)}$$

Shown on the figure 4 :

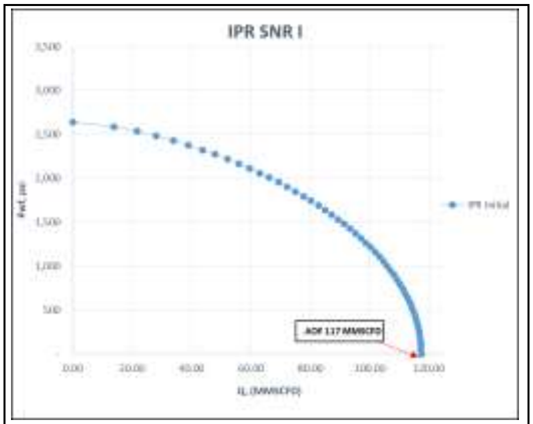

Figure 4 : IPR Curve Well SNR-I

- Determining IPR Future

Fetkovic also developing his IPR equation to predict against pressure decline with the formula as follow below :

$$q = C\left(\frac{Pr}{Pri}\right)\left[Pr^2 - P_{wf}^2\right]^n \text{........................(e.q 3.2)}$$

In this case study, IPR Future prediction using assumptions pressure 2000 psi, 1800, and 1100 psi. For the tabulation result from each pressure could be seen on the attachment A.

This is the following graphic and result from all IPR future well SNR-I.

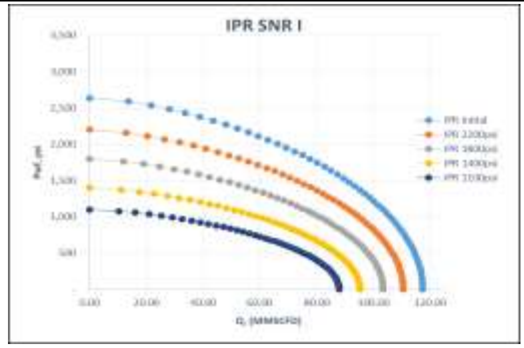

Figure 5 : Future IPR Curve SNR-I

4. Choke Performance Relationship (CPR) Analysis

Well ability analysis includes the relationship between tubing size, choke size, wellhead pressure, bottomhole pressure, and production flow rate on the IPR. In this study , choke performance relationship analysis was used as a basis for determining “real” production flow rate with several choke sizes as constraint used with data as in table 4 :

Data		Unit	Remark
Downstream Pressure	1010	psia	Actual Data
Choke size:	45	1/64 inch	Actual Data
Flowline ID:	6	in	Actual Data
Gas production rate:	60000	Mscf/d	Actual Data
Gas specific gravity:	0,67		Actual Data
Gas specific heat ratio (k):	1,28		Asume
Upstream temperature:	179	F	Actual Data
Choke discharge coefficient:	1,36		Calculated
Choke Area (A)	0,3881		Calculated
Viscosity Gas	0,0157	cp	Actual Data

Table 4 : Parameter Data Choke Performance Relationship SNR-I

Value of Coefficient Discharge 1,36 generated from :

- Determining Reynold Number Firstly

$$Re = 20{,}100\,\frac{Q_g S_g}{d\mu} \text{................................(e.q 3.3)}$$

$$Re = 20{,}100\,\frac{60000x0{,}67}{0{,}703x0{,}0157} \text{.................... (e.q 3.4)}$$

Re = 72.832.272

- Then, determining choke coefficient discharge use equation :

$$C_D = \frac{d2}{d1} + \frac{0,3167}{\left(\frac{d2}{d1}\right)^{0,6}} + 0,025\ [\log(N_{re}) - 4$$ ....(e.q 3.5)

And then calculating Upstream Pressure for each production flow rate with equation :

$$Q_{sc} = 1,248 C A p_{up} \sqrt{\frac{k}{(k-1)\gamma_g T_{up}}\left[\left(\frac{p_{dn}}{p_{up}}\right)^{\frac{2}{k}} - \left(\frac{p_{dn}}{p_{up}}\right)^{\frac{k+1}{k}}\right]}$$ …(e.q 3.6)

From the result shows that production flow rate from each pressure which using choke size 40/64 inch showed by figure 6 :

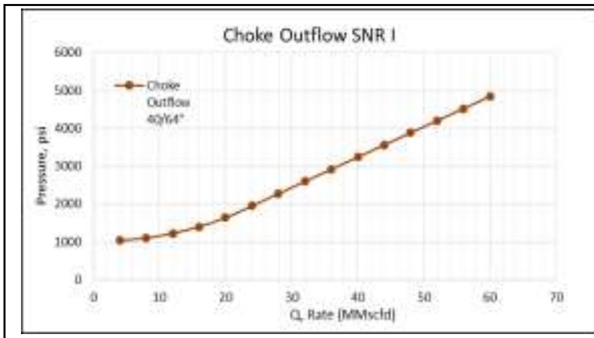

Figure 6 : Choke 40/64" Outflow SNR-I

From figure 6 can also be done for each size of the choke as follow :

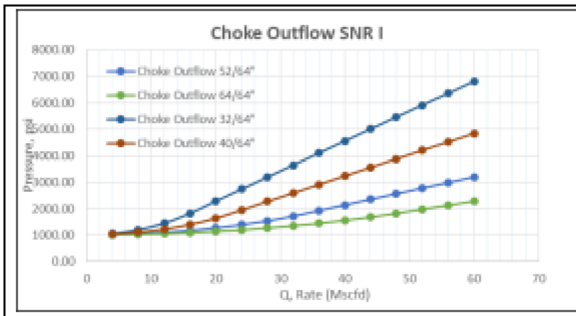

Figure 7 : Choke Outflow SNR-1

So from figure 6 data could be continued to predict when the liquid loading will be happened for gas wells in Senoro Field.

5. Liquid Loading Analysis and Prediction

After the analysis has been completed from the beginning calculation regarding liquid loading, erosional rate, IPR Future and Choke Performance Relationship then the last step is predicting when liquid loading problem will occur by plotting 3 types of graphics or charts into one graphics. The result of the prediction liquid loading have been made are shown in the figure 7 :

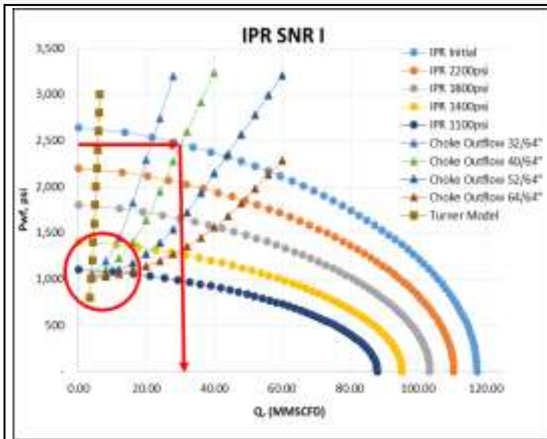

Figure 8 : Graphic Plotting IPR Vs CPR Vs Turner Model

From the figure 7 it can be concluded that there is an intersection between the IPR Future and Tuner Model and from all choke outflow sizes (shown by red circle) when the reservoir pressure in SNR-I to be at 1100 psi, this is indicated that production flow rate lower than critical rate and liquid loading problem may occurs.

Conclusions

1. Based on the result of calculations with Tuner and Coleman method , Senoro Field has average critical flow rate 5.3 MMSCFD amd 4.4 MMSCFD as minimum flow rate for each well with exisiting well completion.
2. Based on the result of calculations and basic design from API RP 14E, Senoro Field has erotional rate as maximum flow rate with average 93 MMSCFD for each well.
3. Based on *Inflow Performance Relationship Future* (IPR Future) analaysis and *Choke Performance Relationship analysis,* liquid loading problem will occur when reservoir pressure 1100 psi

Recommendation :

1. For the next study of IPR Future, it is necessary to calculate C and n factor form fetkovich equation depends on production decline.
2. Supposed to be more study about mitigation and technical analysis for liquid loading problem before these problems actually occur such as :
   - Designing for installation Well head Compressor

- Chemical for Stimulation (Soap stick)
- Resizing tubing

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