How is the next generation motivated by oil industry of 2015 in CEE region

Conference

Visegrád, 19 November 2015

Society of Petroleum Engineers

Good Luck!

Deliquification of liquid-loaded gas wells

Made by:

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Hungarian fields

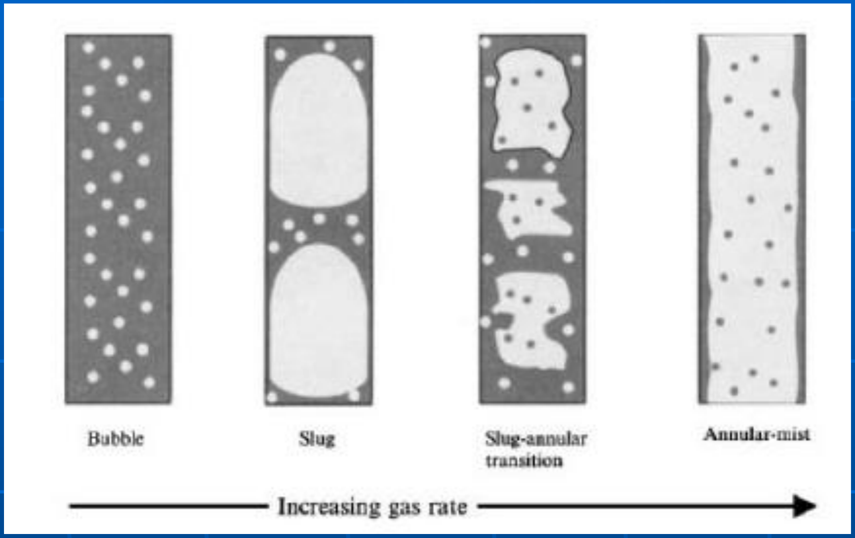
Hungary

- many matured fields (aging continuously)
- many various problems arise
- Increasing fluid production (water mainly) ⇕ Decreasing reservoir pressure and gas production

most serious problem

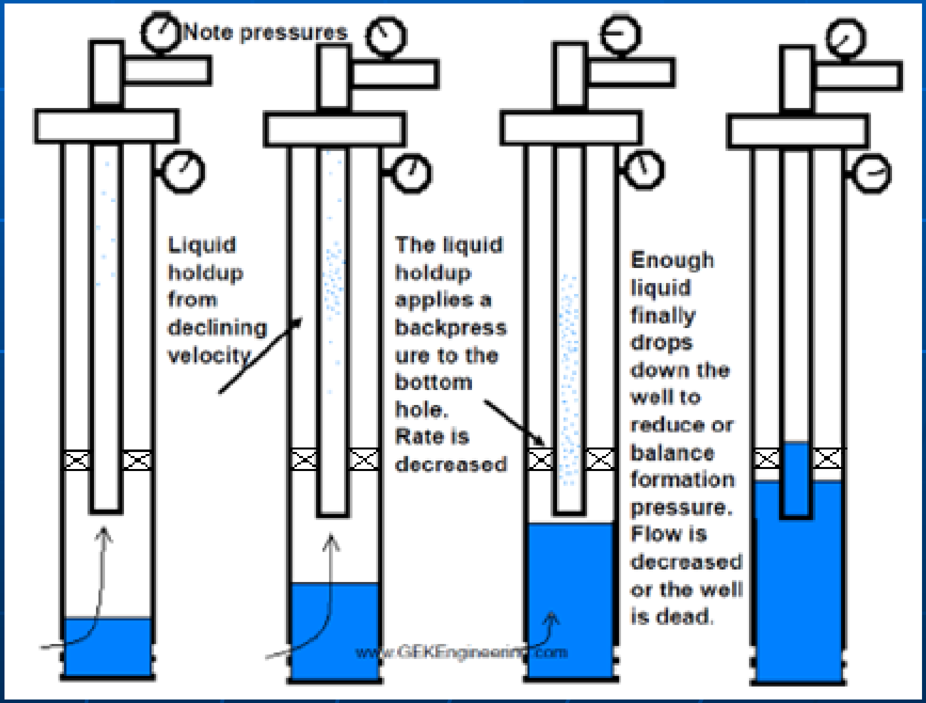
LIQUID-LOADING phenomena

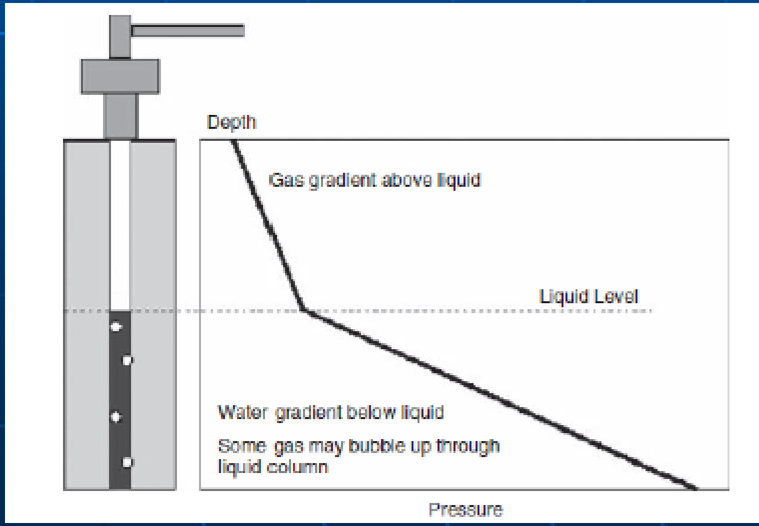
The background and process of liquid-loading phenomena



Flow regimes and their effects to the well are changing → well death

Process:





Below the liquid level → greater pressure increment

Theoretical background of the phenomena

Turner et al.'s model

$$V_{crit} = \frac{21.017 \times \sigma^{0.25}(\rho_l - \rho_g)^{0.25}}{\rho_g^{\;0.5}}$$

Nosseir et al.'s model

If the Reynolds-number lower or equal with 20.000 and the flow is turbulent:

$$V_{crit} = \frac{14.6 \times \sigma^{0.35} \times (\rho_l - \rho_g)^{0.21}}{\mu_g^{\;0.134} \times \rho_g^{\;0.426}}$$

If the Reynolds-number higher than 20.000:

$$V_{crit} = \frac{21.3 \times \sigma^{0.25} \times (\rho_l - \rho_g)^{0.25}}{\rho_g^{\;0.5}}$$

Coleman et al.'s model

$$V_{critCondensate} = 3.369 \times \frac{(45 - 0.031p)^{0.25}}{(0.0031p)^{0.5}}$$

$$V_{critWater} = 4.434 \times \frac{(67 - 0.031p)^{0.25}}{(0.0031p)^{0.5}}$$

Zhou et al.'s model

If the factor X is lower than β or equal with it:

$$V_{crit} = \frac{1.593 \times [\sigma \times (\rho_l - \rho_g)]^{0.25}}{\rho_g^{\;0.5}}$$

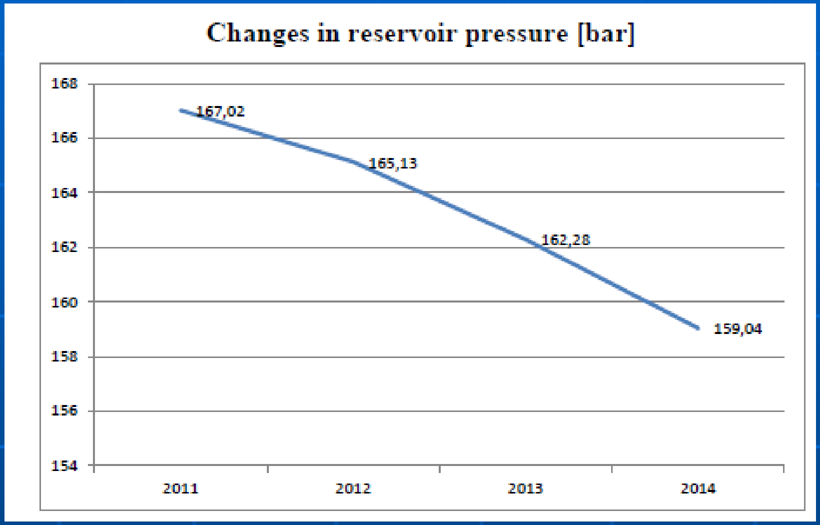
$$X = \frac{V_l}{V_g + V_l}$$

If the factor X is higher than β:

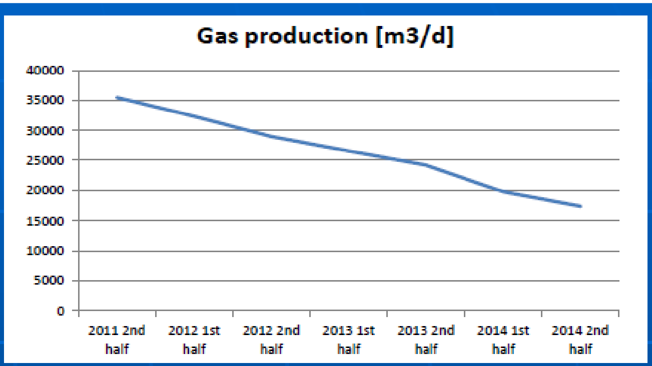
$$V_{crit} = \frac{1.593 \times [\sigma \times (\rho_l - \rho_g)]^{0.25}}{\rho_g^{\;0.5}} + \ln\frac{X}{\beta} + \alpha$$

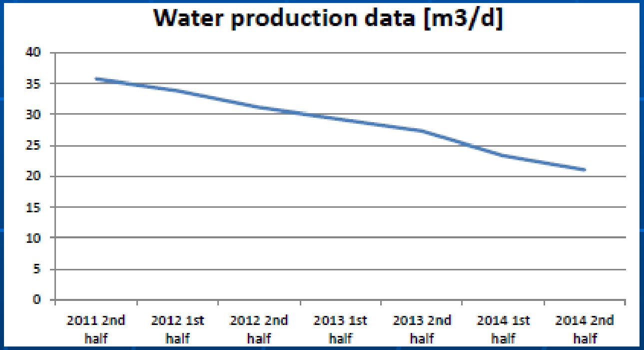
Analysis of the selected well

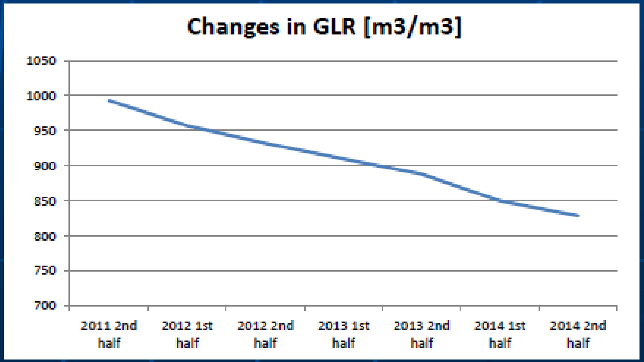
Changes in reservoir pressure:



Production data of the selected well:

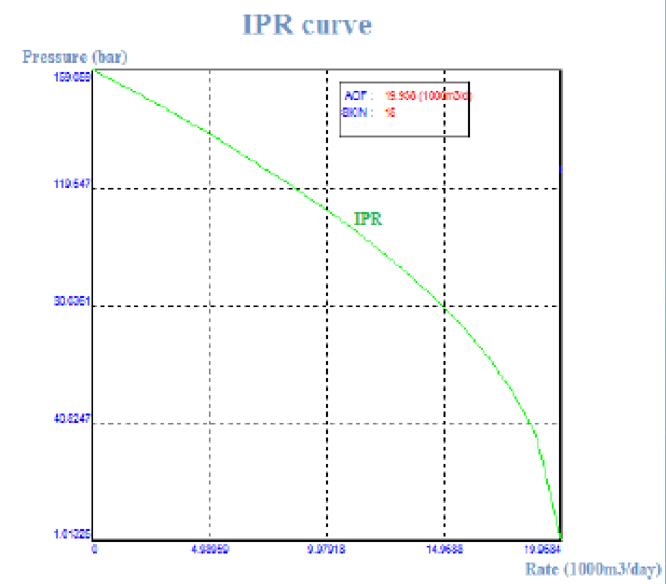






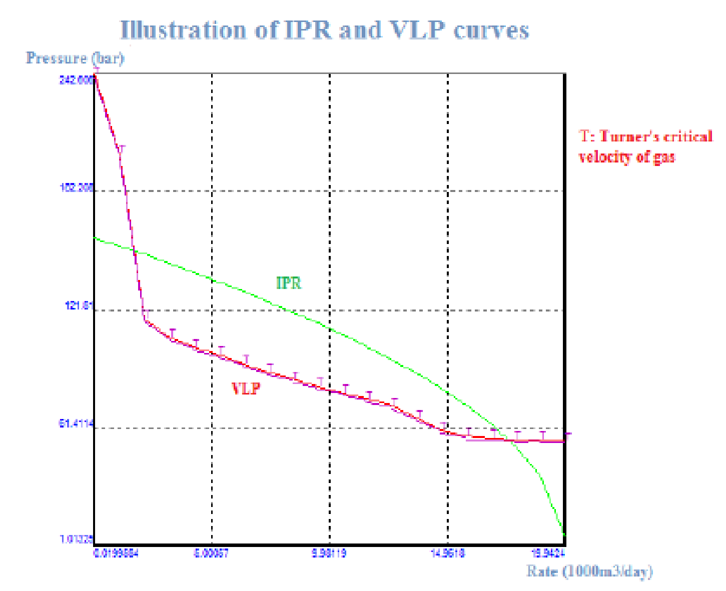
Decreasing gas production rate;
Decreasing water production rate;
Decreasing GLR;
Decreasing reservoir pressure
→
Good indicators of **liquid-loading**

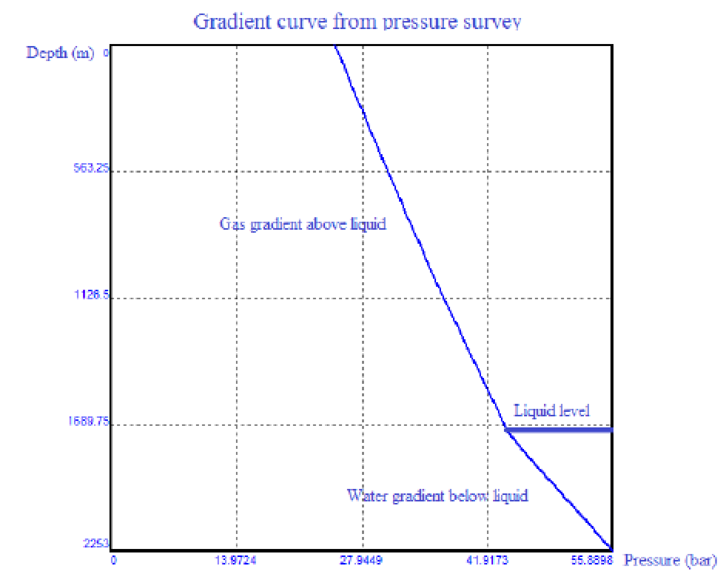
PROSPER model of the selected well



← IPR

→ IPR+VLP





Actual height of accumulated water can be found from the gradient curve

Calculation of the height of accumulated water in the selected well

Determination of the density of the liquid:

Vazquez & Beggs correlation:

$$C1_w = 0.9911 + 6.35 \times 10^{-5} \times T_{wf} + 8.5 \times 10^{-7} \times {T_{wf}}^2$$

$$C2_w = 1.093 \times 10^{-6} - 3.497 \times 10^{-9} \times T_{wf} + 4.57 \times 10^{-12} \times {T_{wf}}^2$$

$$C3_w = -5 \times 10^{-11} + 6.429 \times 10^{-13} \times T_{wf} - 1.43 \times 10^{-15} \times {T_{wf}}^2$$

$$B_{wpw} = C1_w + C2_w \times P_{wf} + C3_w \times {P_{wf}}^2$$

$$X = 5.1 \times 10^{-8} \times P_{wf} + (T_{wf} - 60) \times (5.47 \times 10^{-6} - 1.95 \times 10^{-10} \times P_{wf}) + (T_{wf} - 60)^2 \times (-3.23 \times 10^{-8} + 8.5 \times 10^{-13} \times P_{wf})$$

$$B_w = B_{wpw} \times (1 + X \times Y \times 10^{-4})$$

Bw = 1,049

Density of the liquid:

$$\rho w = \frac{\rho_{wsc}}{Bw}$$

$$\rho w = \frac{1000}{1,049} = 953,289\ kg/m^3$$

Calculation of the height of accumulated water in the selected well

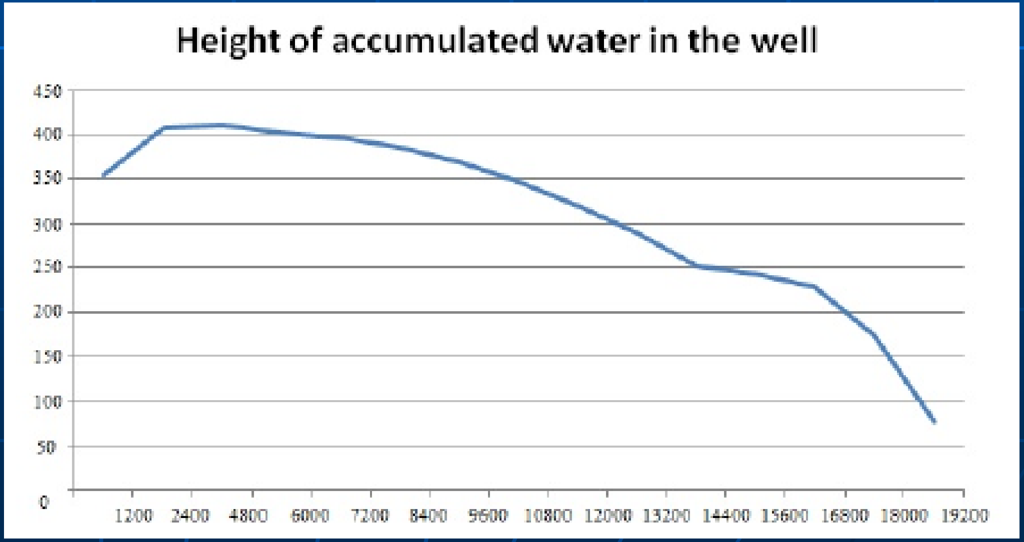
Flow rate [m^3/day]	IPR pressure [bar]	VLP pressure [bar]	Pressure difference [bar]
2117	150,3	117,1	33,2
3165	145,7	107,6	38,1
4214	141,1	102,6	38,5
5263	136,3	98,8	37,5
6311	131,3	94,3	37
7360	126,1	90,1	36
8408	120,8	86,3	34,5
9457	115,1	82,7	32,4
10505	109,2	79,3	29,9
11554	103	76	27
12600	96,4	72,8	23,6
13651	89,3	66,6	22,7
14698	81,6	60,3	21,3
15748	73,1	56,9	16,2
16797	63,4	56,2	7,2

Using a simple formula:

$$h = \frac{\Delta p}{\rho \times g}$$

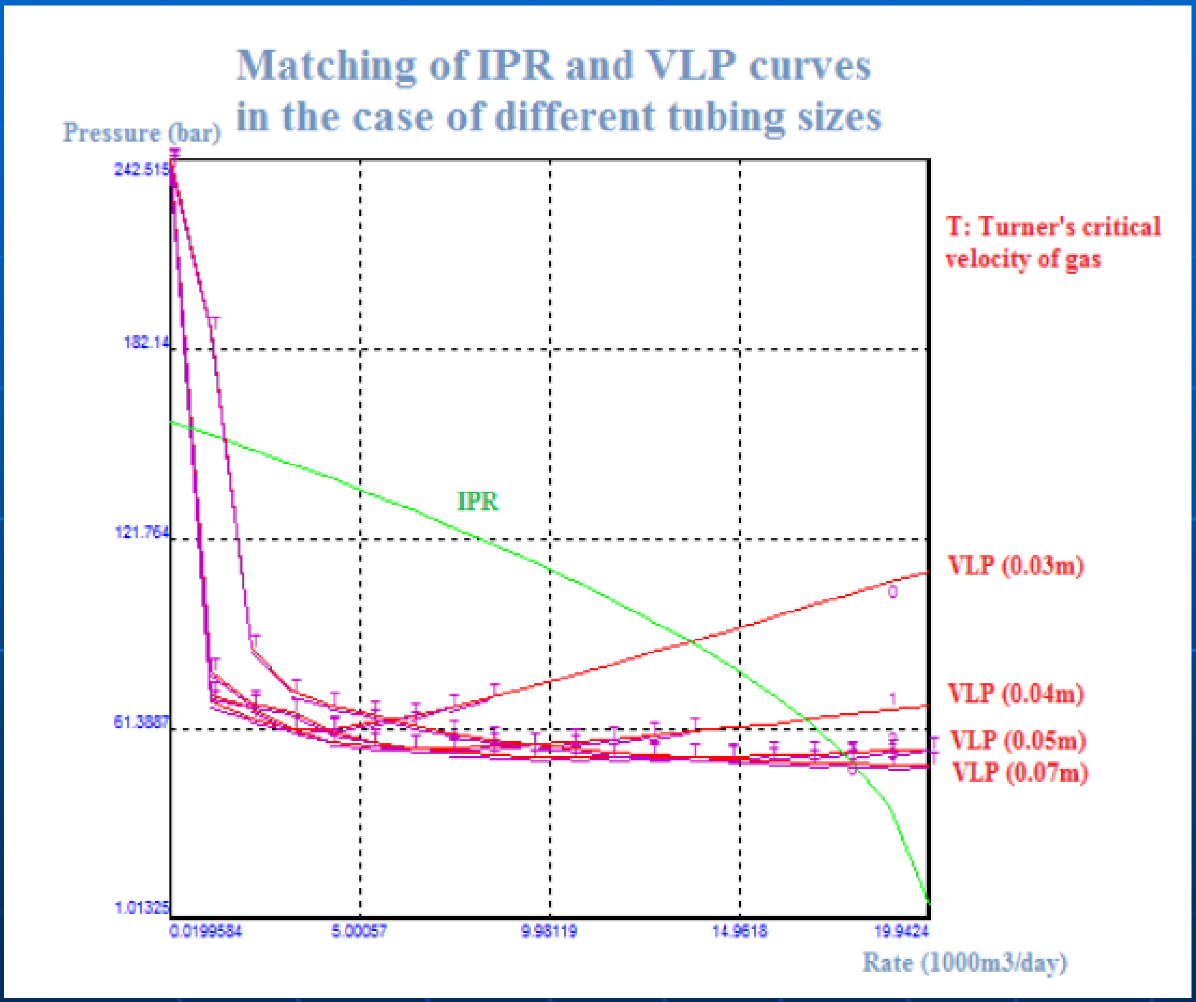
$$\rho w = \frac{1000}{1,049} = 953{,}289\ kg/m^3$$

g is known to be 9,81 m/s^2



It can be seen in the diagram, if the **gas rate is decreasing**, the **height of accumulated water is increasing**.

Possible solutions

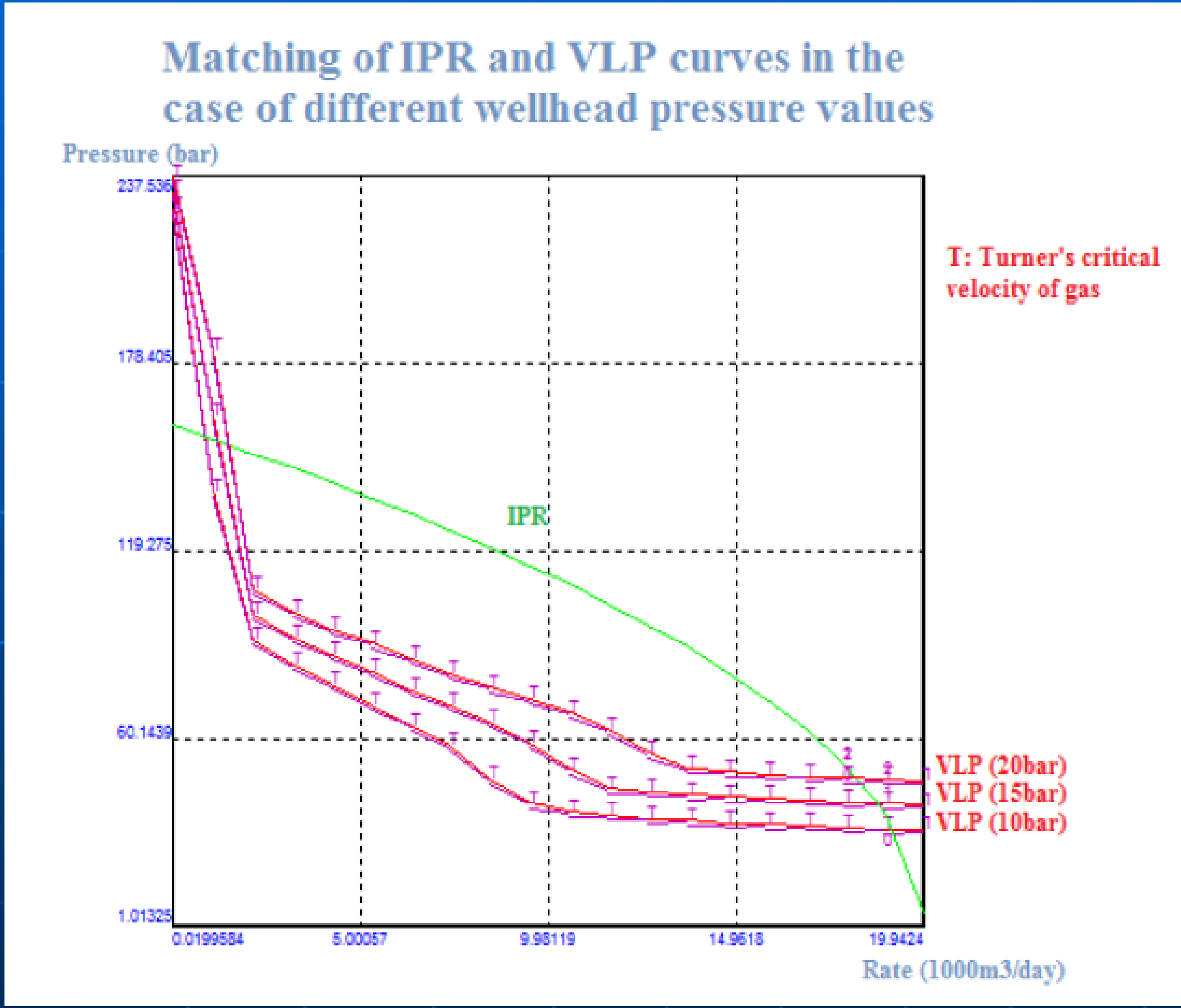


Almost the **half size** of the **original tubing** →
solution without liquid-loading

BUT!!!

The **gas rate decreases** significantly!!!

Possible solutions



Different (lower) wellhead pressures

→

will not give a solution without liquid-loading

Possible solutions

Artificial lift systems:

- Plunger lift
- SRP, ESP, PCP

→ High costs, uneconomical

Gas lift:

- Continuous
- Intermittent

→ Gas lift in a gas well? Uneconomical → Losses from original production

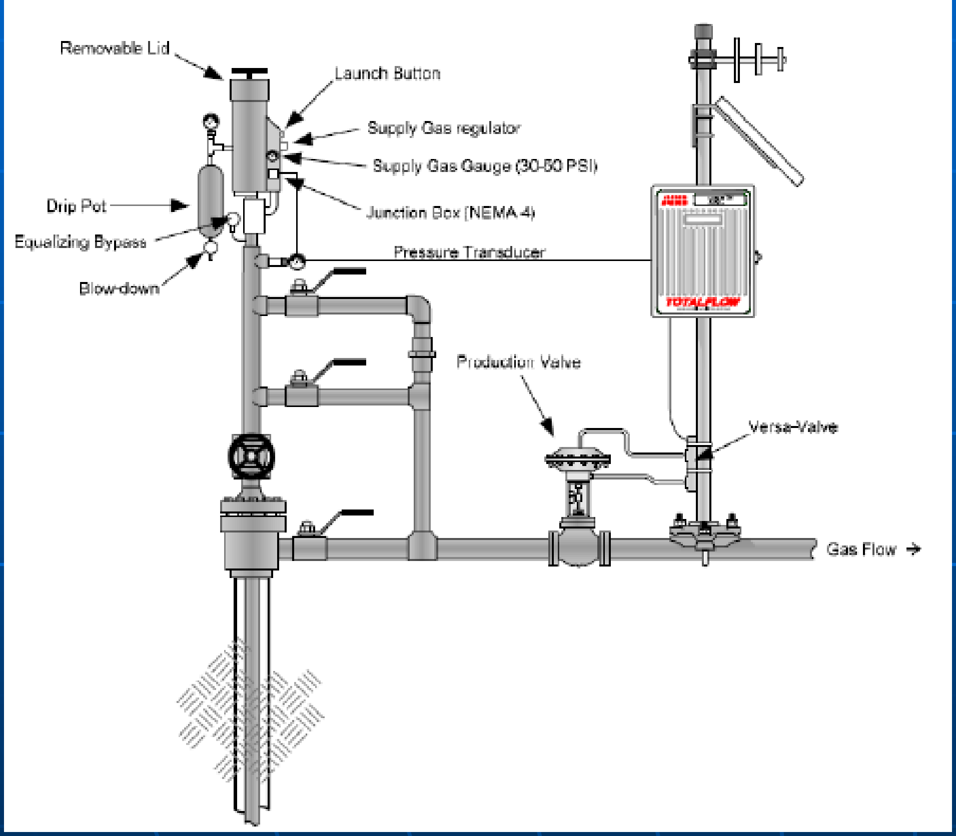
Other ways:

- Applying SURFACTANTS

→ Low costs, **could be** economical

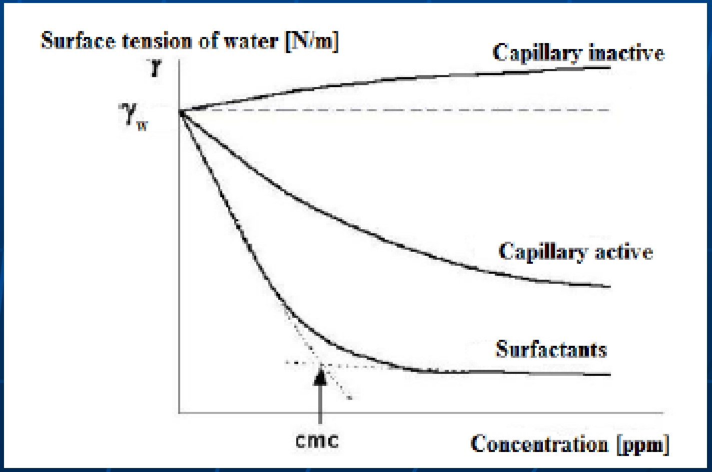
Foam Technology (using surfactants)

Injection system:



Efficiency based on:
- Concentration (CMC)
- Brine
- Hydrocarbon condensate
- Temperature

Type of surfactants:
- Anionic
- Cationic
- Nonionic
- Amphoteric



$$\sigma_m = \sigma_v - A \times \ln(1 + B \times c)$$

Calculations

Depth [m]	Value of Turner's critical velocity [m/s]
150	4,5
300	4,4
450	4,3
600	4,2
750	4,1
900	4,0
1050	3,93
1200	3,85
1350	3,77
1500	3,7
1650	3,6
1800	3,52
1950	3,4
2100	3,28
2253	3,17

Density of liquid (ρ_l): 953,3 kg/m^3, it equals with 59,5 lbm/ft^3

Density of gas (ρ_g): 34,3 kg/m^3, it equals with 2,14 lbm/ft^3

$$Vcrit = \frac{21.017 \times \sigma^{0.25}(\rho_l - \rho_g)^{0.25}}{\rho_g{}^{0.5}}$$

$$\sigma = 0.0070318 \frac{lbf}{ft} \; or \; 102,6375 \; m\,N/m$$

The new value of surface tension is:

$$\sigma_{new} = 25,66 \; m\frac{N}{m} \; or \; 0.0017579 \; \frac{lbf}{ft}$$

$$Vcrit' = \frac{21.017 \times \sigma_{new}{}^{0.25}(\rho_l - \rho_g)^{0.25}}{\rho_g{}^{0.5}}$$

$$Vcrit' = 8.096 \frac{ft}{s} \; or \; 2.468 \; \frac{m}{s}$$

Calculations

Depth [m]	Value of Turner's critical velocity [m/s]
150	4,5
300	4,4
450	4,3
600	4,2
750	4,1
900	4,0
1050	3,93
1200	3,85
1350	3,77
1500	3,7
1650	3,6
1800	3,52
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Density of liquid (ρ_l): 953,3 kg/m^3, it equals with 59,5 lbm/ft^3

Density of gas (ρ_g): 34,3 kg/m^3, it equals with 2,14 lbm/ft^3

$$Vcrit = \frac{21.017 \times \sigma^{0.25}(\rho_l - \rho_g)^{0.25}}{\rho_g^{\ 0.5}}$$

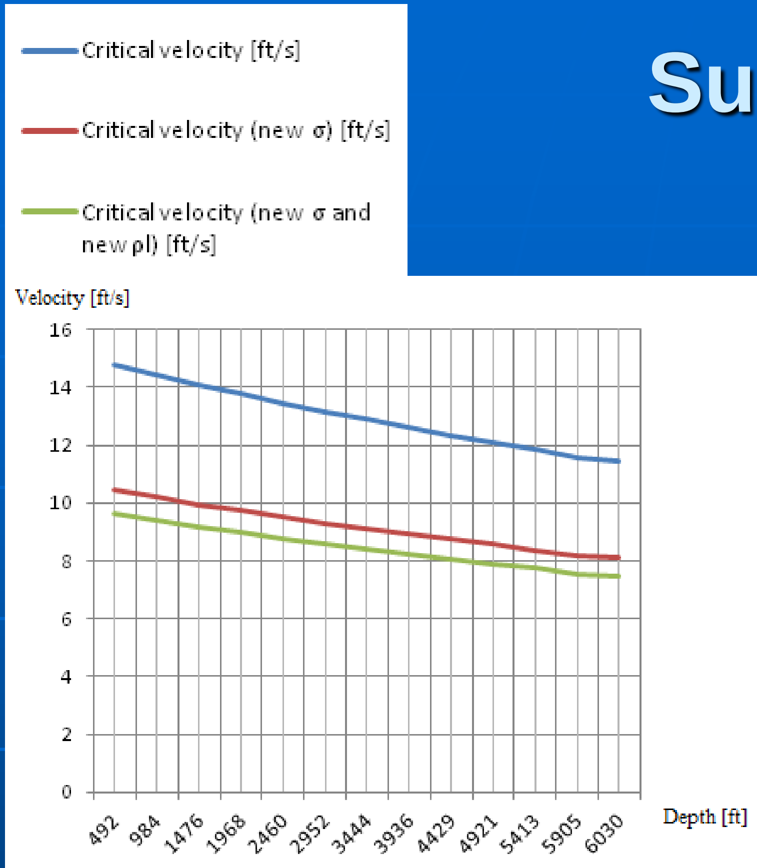
The new value of the density of liquid is:

$$\rho_{l_{new}} = 43,91 \frac{lbm}{ft3} or\ 703,37 \frac{kg}{m3}$$

$$Vcrit" = \frac{21.017 \times \sigma_{new}^{\ 0.25}(\rho_{l_{new}} - \rho_g)^{0.25}}{\rho_g^{\ 0.5}}$$

$$Vcrit" = 7.479 \frac{ft}{s} or\ 2.28 \frac{m}{s}$$

Summarizing



Depth [ft]	Critical velocity [ft/s]	Interfacial tension [lbf/ft]	New value of interfacial tension [lbf/ft]	New value of critical velocity (new σ) [ft/s]	New value of critical velocity (new σ and new ρ_l) [ft/s]
492	14,78	0,01951	0,00488	10,45	9,66
984	14,43	0,01772	0,00443	10,20	9,42
1476	14,09	0,01611	0,00403	9,96	9,20
1968	13,77	0,01471	0,00368	9,76	8,99
2460	13,46	0,01344	0,00336	9,52	8,79
2952	13,17	0,01232	0,00308	9,31	8,60
3444	12,89	0,01129	0,00282	9,12	8,42
3936	12,62	0,01038	0,00260	8,93	8,24
4429	12,36	0,00954	0,00239	8,74	8,07
4921	12,1	0,00877	0,00219	8,56	7,90
5413	11,85	0,00806	0,00201	8,38	7,74
5905	11,55	0,00728	0,00182	8,17	7,54
6030	**11,45**	**0,0070318**	**0,0017579**	**8,096**	**7,479**

By **applying foaming agents**
→
decrease the density and the interfacial tension of the liquid
→
critical velocity will **decrease** significantly!!!
→
From **11,45 ft/s** to **7,479 ft/s**

Thank you for your kind attention!

Have you got any questions?