THE ALPHA FIELD CASE STUDY

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TPG4140 NATURGASS

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- Deliverability and performances
- The Alpha gas field data
- Material balance and z-factor
- PSS flow equation for gas
- Pressure function (pseudopressure) and viscosity
- The Alpha gas pressure function (polynomial fit)
- The Alpha gas well data
- Pressure drop in gas wells
- Inflow performance and outflow performance
- Summary

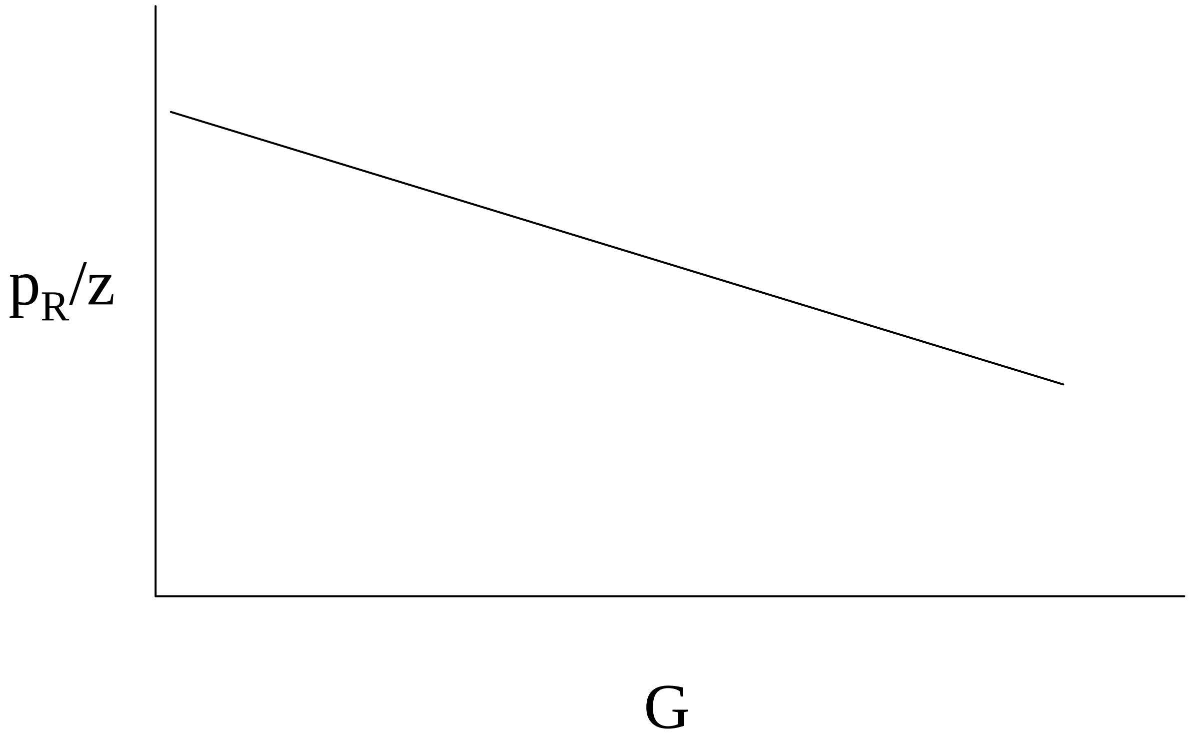
Deliverability and Performances

Analyse and Synthesis

- Pressure profile from reservoir to wellhead is analysed in terms of several performances.
- Reservoir performance gives reservoir pressure with time, which is used in inflow performance plot.
- Shape of inflow performance plot remains the same with time, unless near-wellbore damage occurs due to production.
- Tubing performance curve plotted together with inflow performance, gives the well production rate where the two curves cross each other.

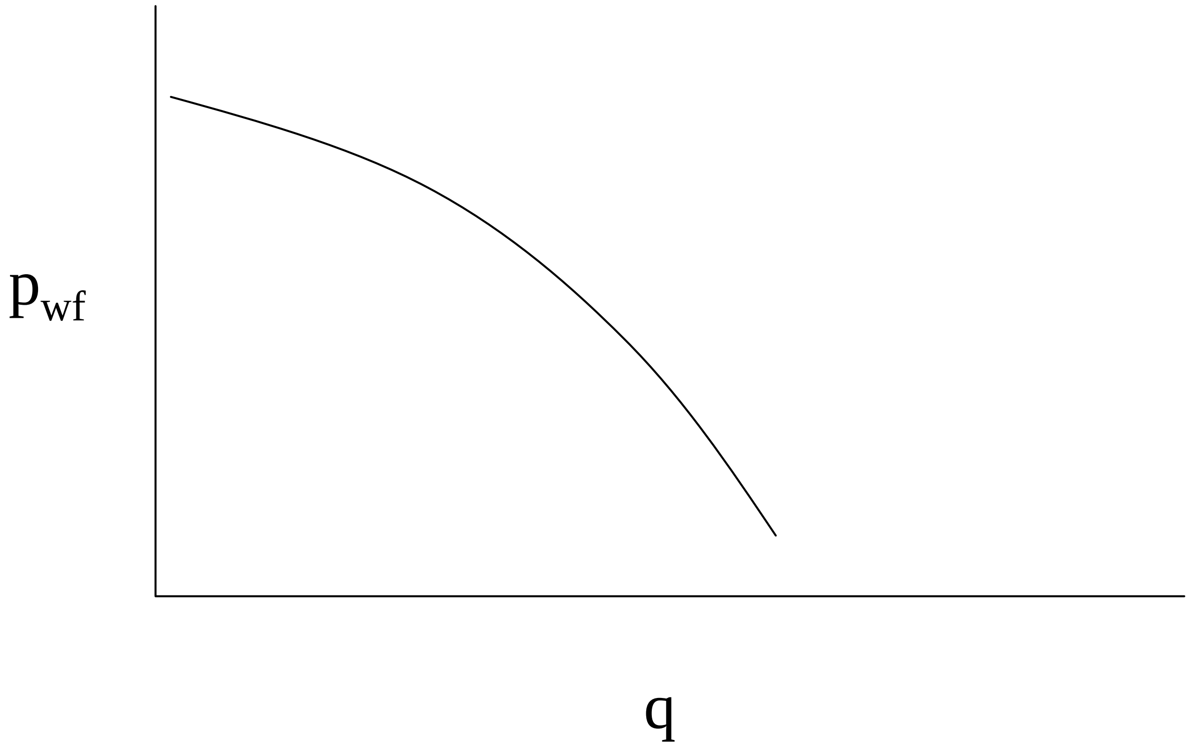
Deliverability and Performances

Reservoir Performance



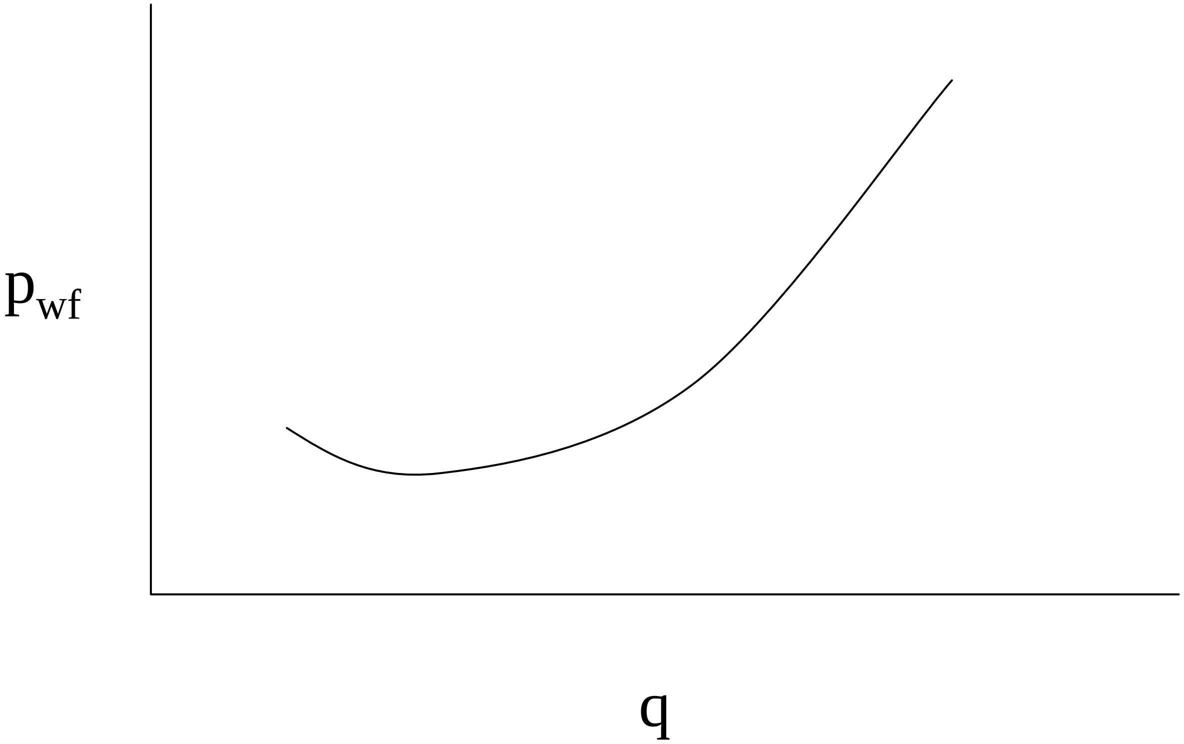
Deliverability and Performances

Inflow Performance

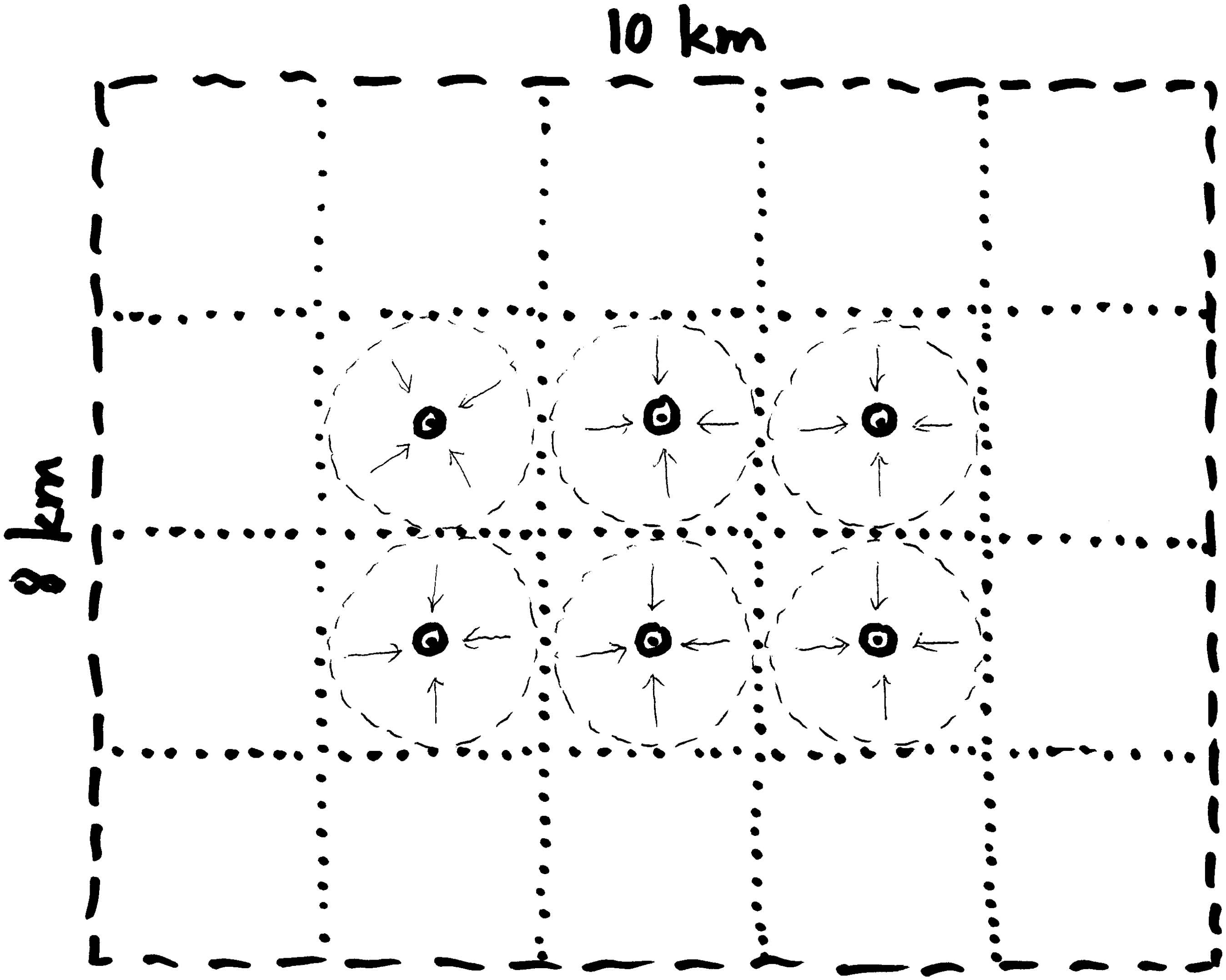


Deliverability and Performances

Tubing Performance



The Alpha Gas Field



Field data		
Areal og reservoir, AR	80	km^2
Thickness, hR	25	m
Average reservoir pressure, pR	285	bara
Average reservoir temperature, TR	88	°C
Water depth, dW	800	m
Reservoir depth, dR	2600-2650	TVD MSL
Average permeability, k	200	md
Porosity, φ	25,00 %	
Water Saturation, Sw	20,00 %	
Recovery factor, RF	60,00 %	
Z- factor	0,9334	
Spesific gravity	0,60	
Molecular weight of gas (from hysys), Mg	17,45	
Gas viscosity, μ	1,92E-02	cp
Drainage radius each well	1000	m

Material Balance for Natural Gas Fields

Volumetric Balance

Gas volumes taken at standard conditions (s.c.)

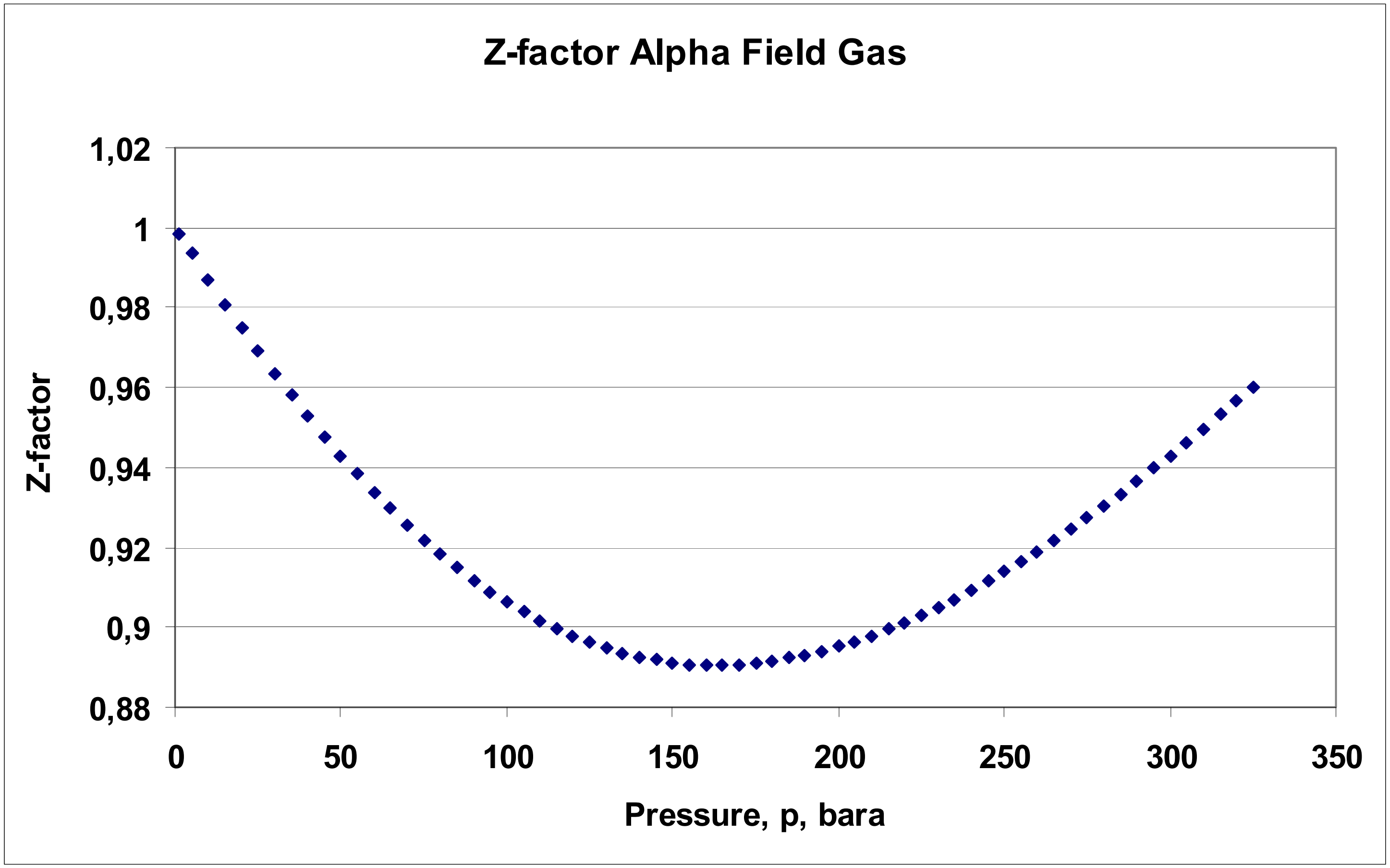
Constant volume reservoir without water influx

G_i = Gas initially in place (resource, not reserve)

G = Gas already produced (G_p in many texts)

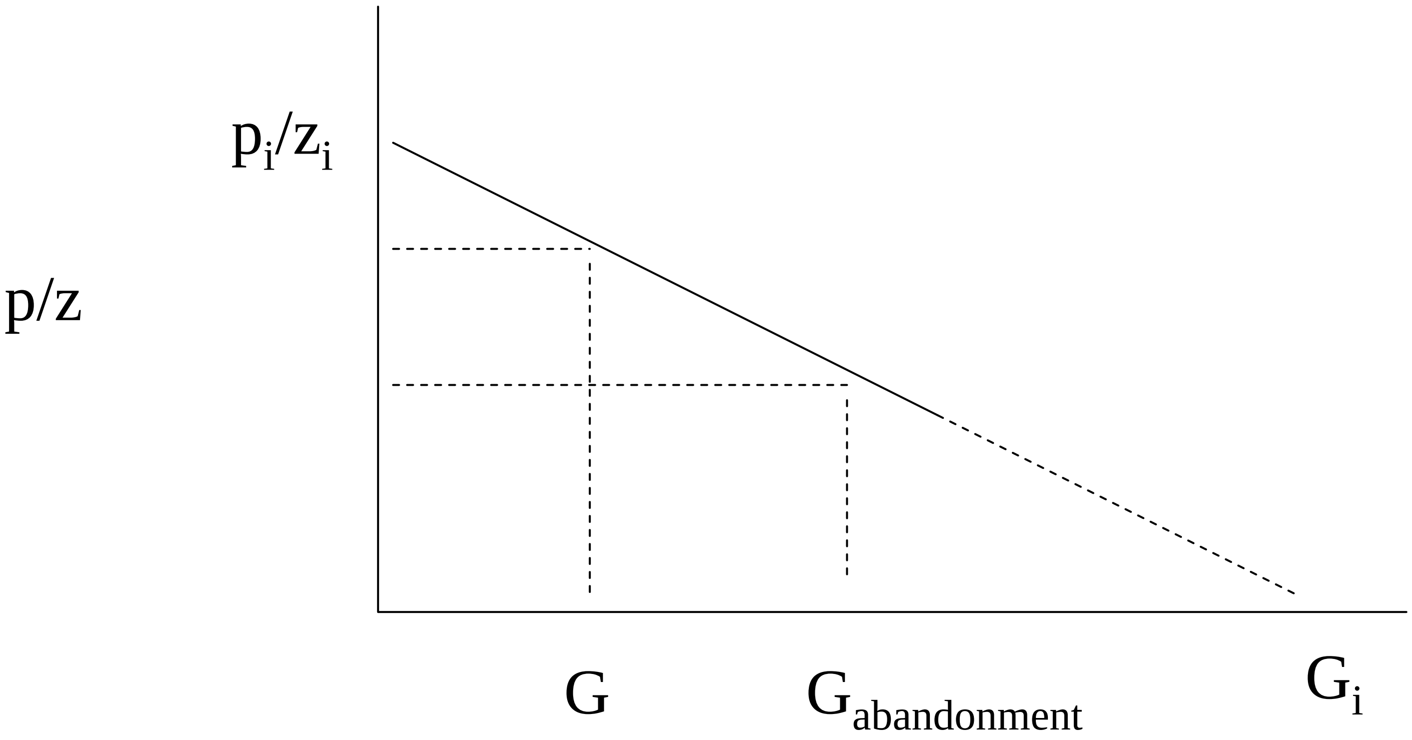
Use FVF (symbol B) for natural gas

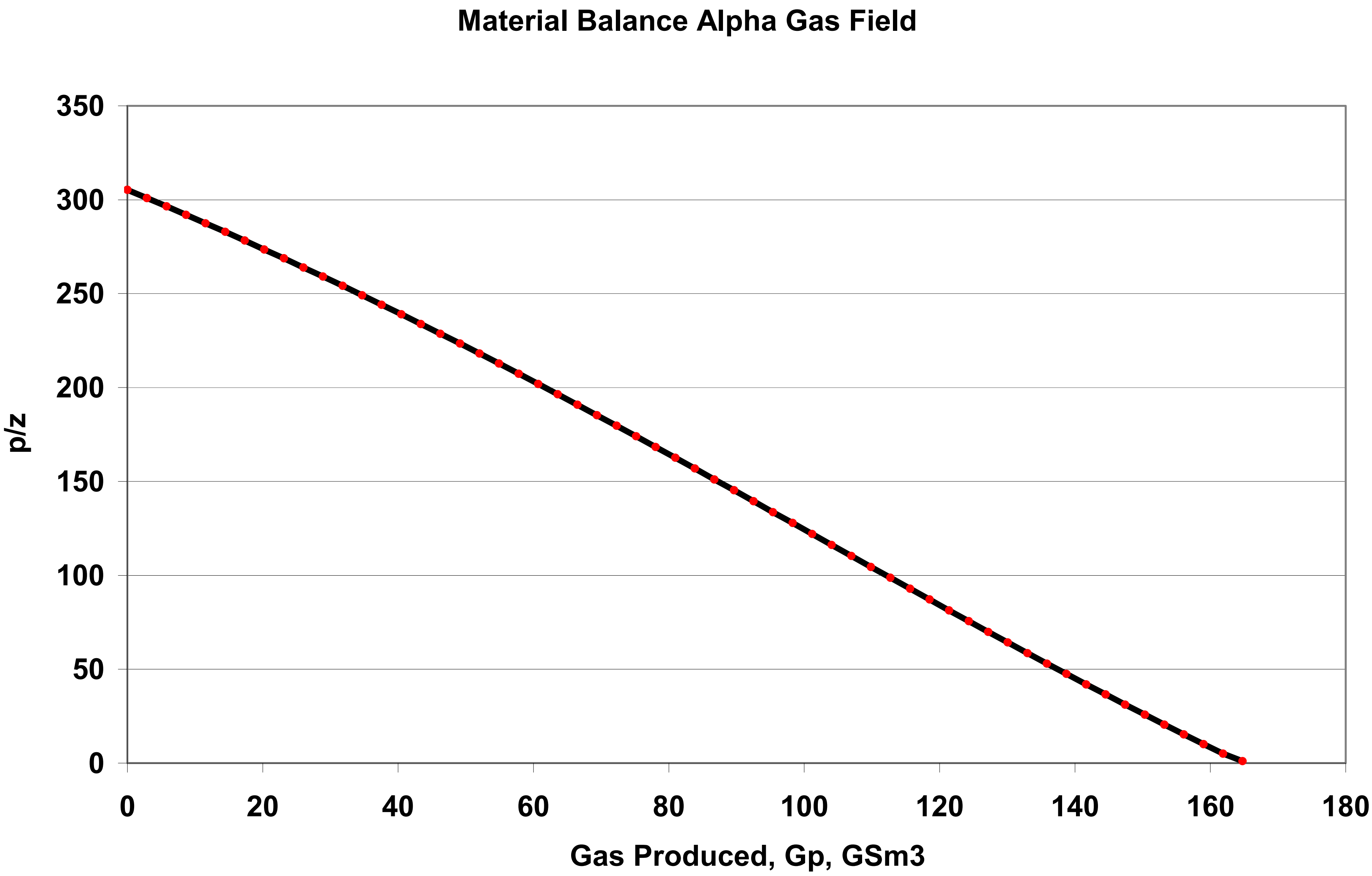
$$(p/z) = (p_i/z_i)\,[1 - G/G_i]$$


Z-factor Alpha Field Gas
1,02
1
0,98
0,96
0,94
0,92
0,9
0,88
Z-factor
0
50
100
150
200
250
300
350
Pressure, p, bara

Material Balance for Natural Gas Fields

p/z Method




Material Balance Alpha Gas Field
p/z
350
300
250
200
150
100
50
0
0
20
40
60
80
100
120
140
160
180
Gas Produced, Gp, GSm3

Flow Equations for Natural Gas in Reservoir

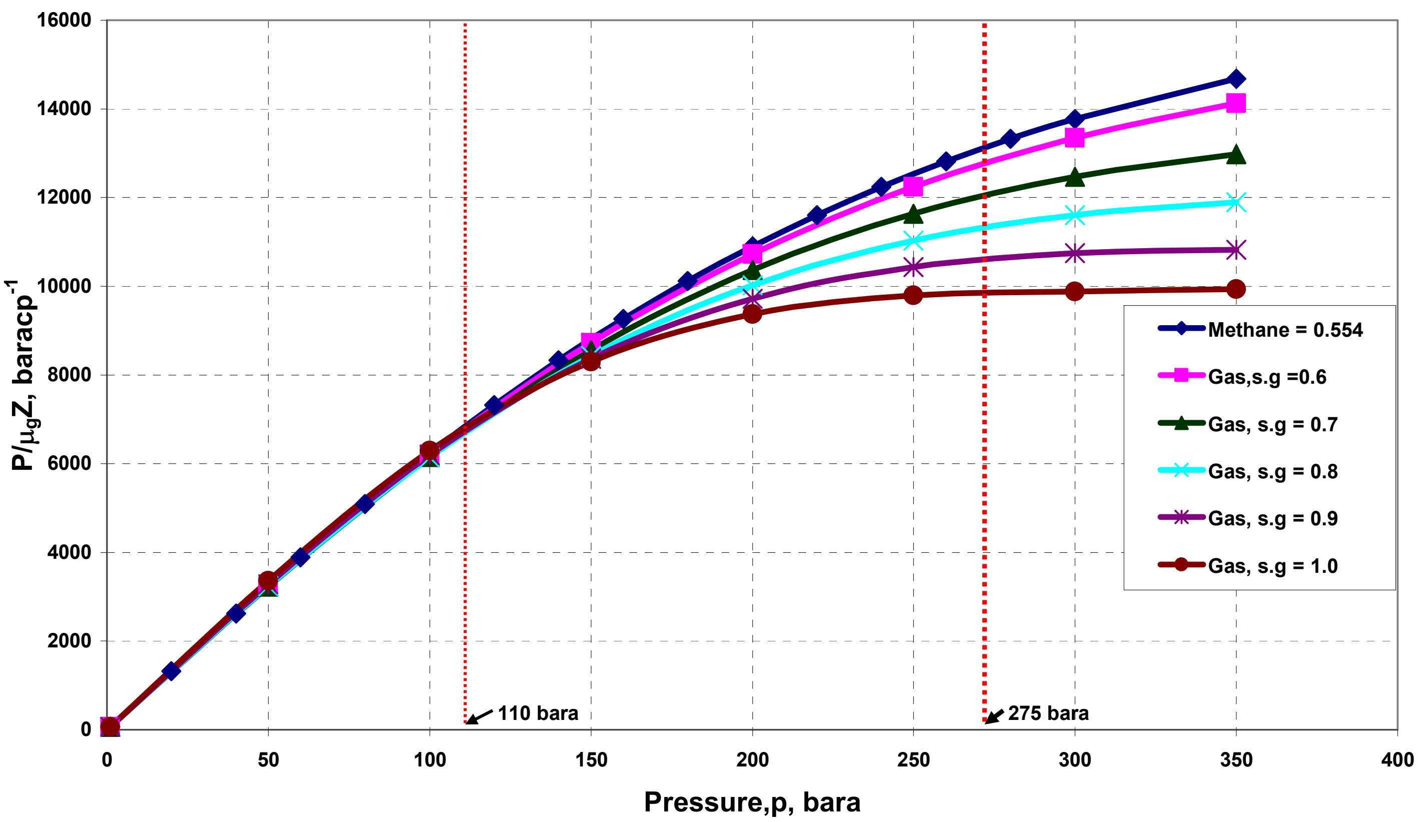
Effect of Pressure

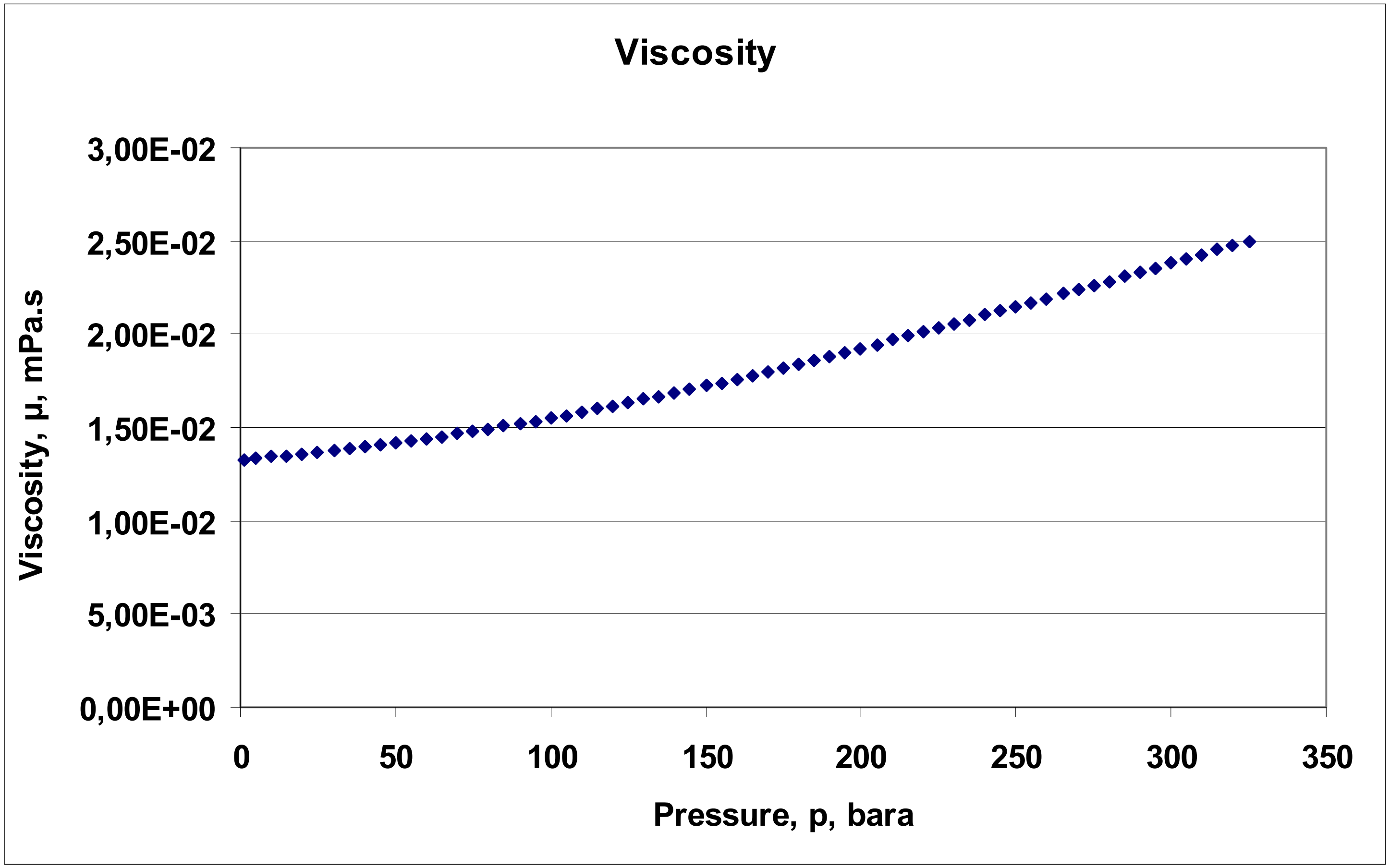
- In flow equations for low-pressure gas, pressure-squared is used, $p^2_R - p^2_w$.
- When the pressure is intermediate, the so called pseudopressure m(p) is traditionally used (from numerical integration). Same as pressure function.
- At high-pressure, the gas behaves similar to liquid and the pressure drop is expressed by simple difference, $p_R - p_w$, which is the same as for conventional oil.
- What is low-pressure, intermediate pressure and high-pressure depends on the gas composition through the pressure function $F(p)=\{p/(\mu z)\}$

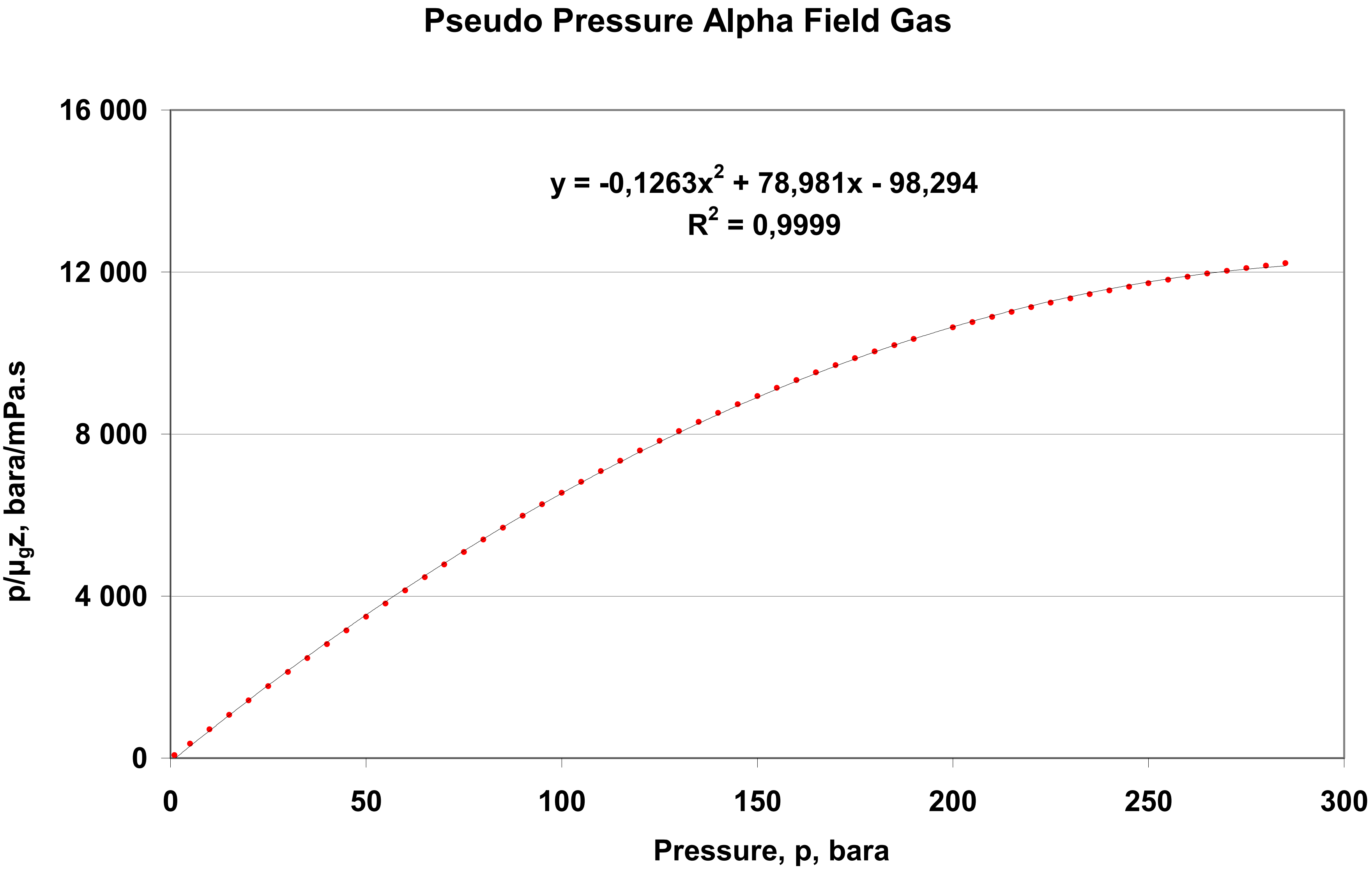
PSS Rate Equation for Gas

$$q_{s.c.} = \frac{2\pi kh}{\left[\ln\left(\frac{r_e}{r_w}\right) - \frac{3}{4} + s\right]} \left(\frac{T_{s.c.}}{T}\right) \left(\frac{1}{p_{s.c.}}\right) \int_{p_{wf}}^{p_R} \left(\frac{p}{\mu_g z}\right) dp$$

Pseudopressure and Specific Gravity




Viscosity
3,00E-02
2,50E-02
2,00E-02
1,50E-02
1,00E-02
5,00E-03
0,00E+00
Viscosity, μ, mPa.s
0
50
100
150
200
250
300
350
Pressure, p, bara


Pseudo Pressure Alpha Field Gas
y = -0,1263x^2 + 78,981x - 98,294
R^2 = 0,9999
16 000
12 000
8 000
4 000
0
0
50
100
150
200
250
300
Pressure, p, bara
p/μ$_g$z, bara/mPa.s

High-Pressure Gas and Conventional Oil

$$q_{s.c.} = \frac{2\pi kh}{\left[\ln\left(\frac{r_e}{r_w}\right) - \frac{3}{4} + s\right]}\left(\frac{T_{s.c.}}{T}\right)\left(\frac{1}{p_{s.c.}}\right)\left(p_R - p_{wf}\right)$$

$$q = PI\left(p_R - p_{wf}\right)$$

PI = Productivity Index

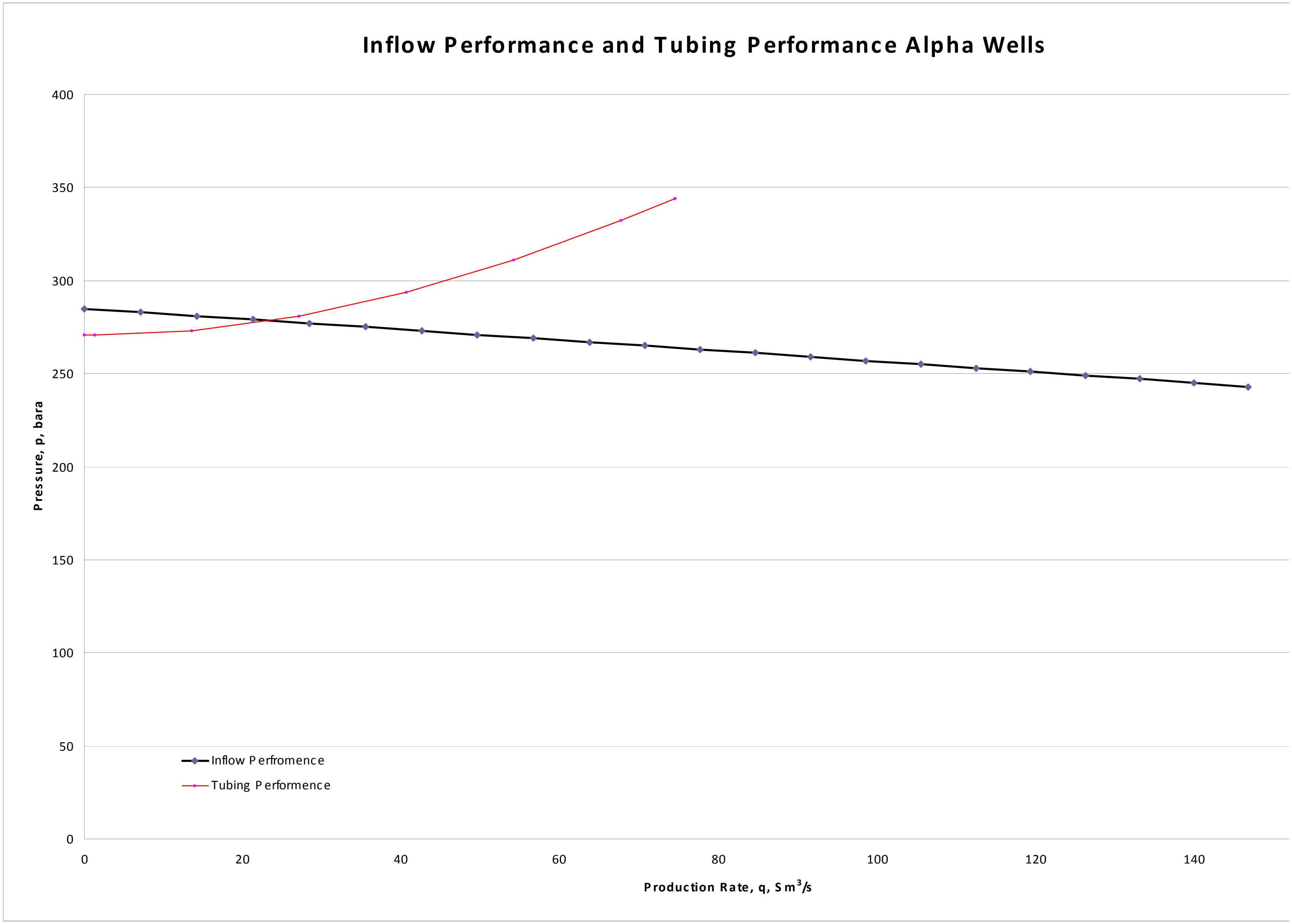
Well data ++		
Length of well, L	2600	m
Wellhead pressure, pwf, (assume 80% of pR)	228	bara
Wellhead temperature, Twh (assumes 80% of TR)	70,4	°C
Wellbore radius	0,1	m
Tubing diameter	0,15	m
Number of wells	6	
Gas density at standard conditions, Rho	0,74	kg/Sm^3
Air density at standard conditions, Rho	1,23	kg/Sm3
z- factor at standard conditions (ideal gas)	1	
Temperature at standard conditions, Tsc	15,56	°C
Pressure at standard conditions	1,01325	bara
Life time of reservoir	20	years
Molecular weight of air, Mair	28,97	kg/kmol

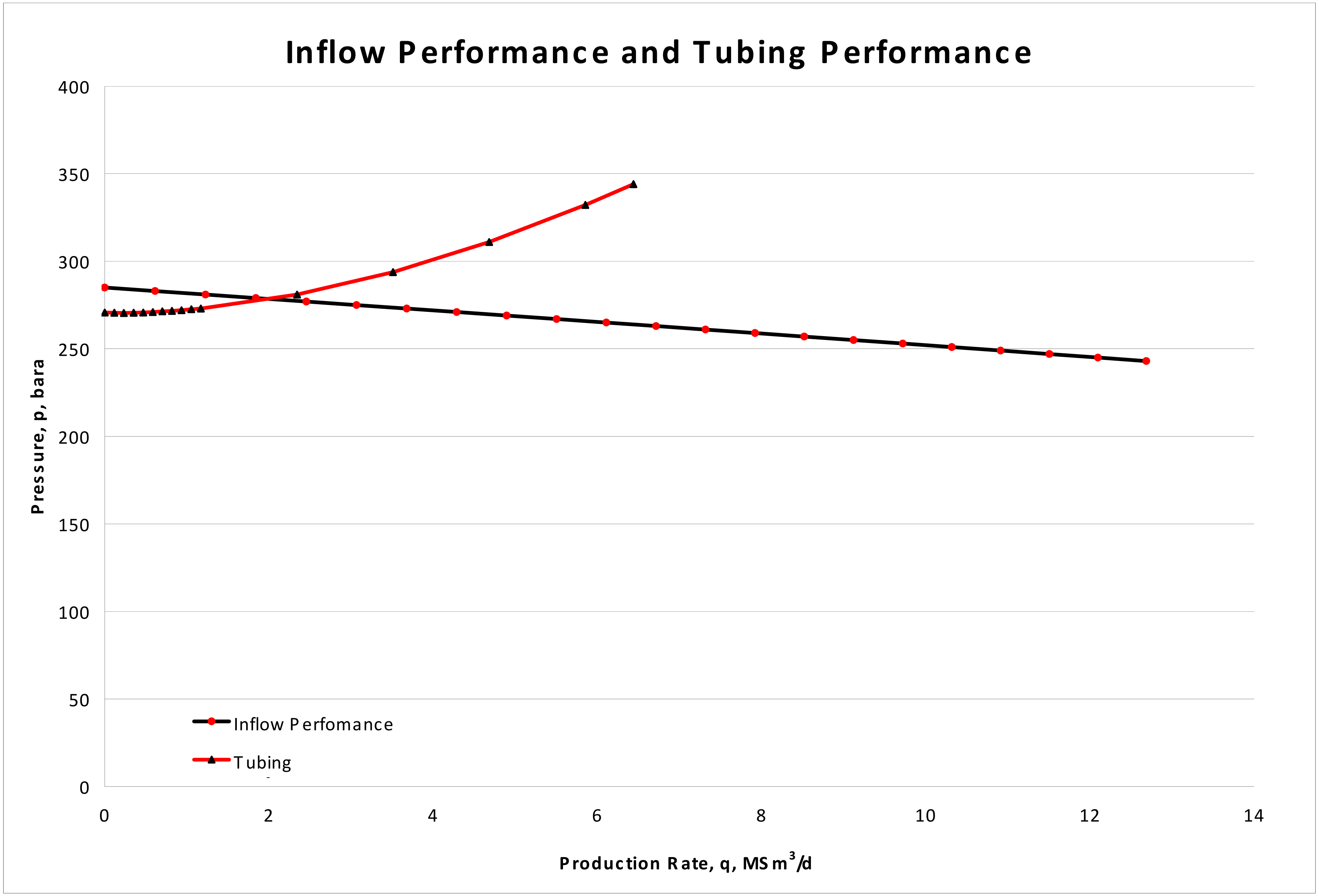
Pressure Drop in Gas Wells
Frictional and Hydrostatic

$$\Delta p = \Delta p_g + \Delta p_a + \Delta p_f$$

$$\frac{dA^2 M}{fm^2 zRT}\left(p_2^2 - p_1^2\right) - \frac{d}{f}\ln\left(\frac{p_2^2}{p_1^2}\right) + L = 0$$

$$p_2 = p_1 \exp\left[-\left(\frac{M}{zRT}\right)\left(g\sin\alpha\right)\Delta L\right]$$


Inflow Performance and Tubing Performance Alpha Wells
400
350
300
250
200
150
100
50
0
Pressure, p, bara
0
20
40
60
80
100
120
140
Production Rate, q, Sm^3/s
Inflow Perfromence
Tubing Performence


Inflow Performance and Tubing Performance
Pressure, p, bara
400
350
300
250
200
150
100
50
0
0
2
4
6
8
10
12
14
Production Rate, q, MSm3/d
Inflow Perfomance
Tubing

Summary

- Concept of deliverability can be used to estimate the production expected from a gas field from start-up to abandonment.
- The data presented for the Alpha field, the Alpha wells and the Alpha gas, is typical for a high-quality offshore resource.
- PSS rate equation using the general pressure function can be used for all inflow conditions.
- Established analytical equations for pressure drop in pipes can be used to calculate the outflow performance. (The presented outflow results were however obtained from Hysys calculations.)
- Inflow from high-pressure gas reservoirs (HPHT reservoirs, e.g. Kristin) behave similar to conventional oil reservoirs such that PI can be used.

Reelle gassloven

$$pV = znRT$$

$$pv = zRT$$

$$z_{sc} \cong 1$$

$$V_{sc} = V\left(\frac{p}{p_{sc}}\right)\left(\frac{T_{sc}}{T}\right)\left(\frac{1}{z}\right)$$

$$q_{sc} = q\left(\frac{p}{p_{sc}}\right)\left(\frac{T_{sc}}{T}\right)\left(\frac{1}{z}\right)$$

Tetthet og FVF

$$pV = znRT$$

$$M = \frac{\rho V}{n}$$

$$\rho = \frac{pM}{zRT}$$

$$B(\equiv FVF) = \frac{V}{V_{sc}}\left(\frac{m^3}{Sm^3}\right)$$

$$B = \left(\frac{T}{T_{sc}}\right)\left(\frac{p_{sc}}{p}\right)z$$

$$q = q_{sc}B$$