Note Title 06.11.2018

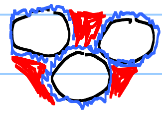
Class 8

fluid models: ~ How much $o, g, \rho_o, \rho_g, \mu_o, \mu_g$

- Black oil is used
  - → correlations are available
  - → very fast to compute (bilinear interpolation)
  - → $q_{\bar{o}} \rightsquigarrow q_o(p,T)$
    $q_{\bar{g}} \rightsquigarrow q_g(p,T)$

even if gas is dry, it will probably be saturated with water!

G + W in tubing!

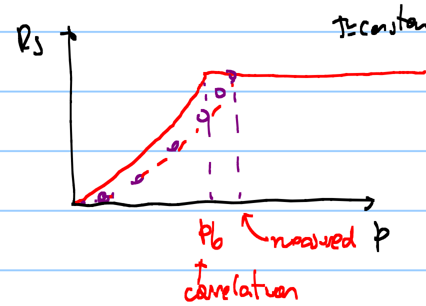


traditional BO → low GOR's 700 – 1500 scf/stb
  → non-volatile oil
  → dry gas

modified BO → volatile oil (high GOR) 1500 <
  → gas condensate

Be aware!
BO correlations must always be tuned to laboratory data!

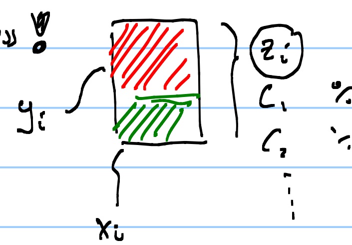
BO table contains information about
- fluid
- surface process



- compositional model $p = \frac{RT}{v-b} - \frac{a}{v(v+b)+b(v-b)}$ Peng Robinson (1976)

EOS

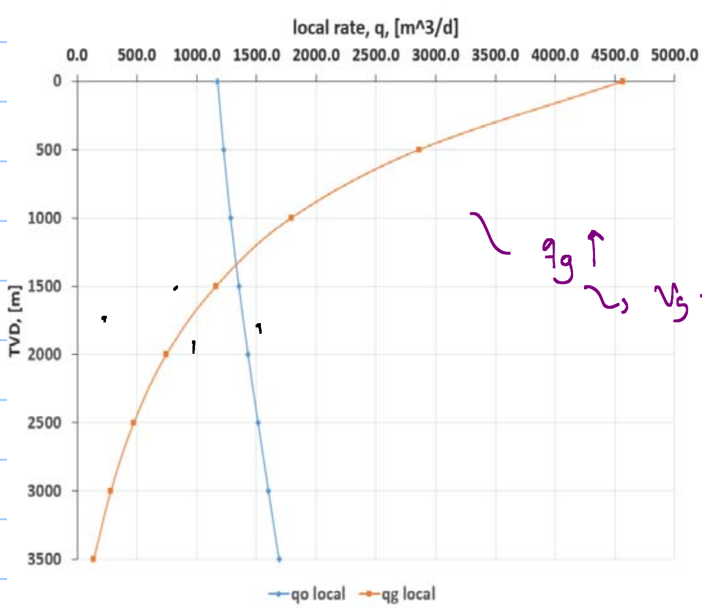
computationally expensive process!



@ p, T

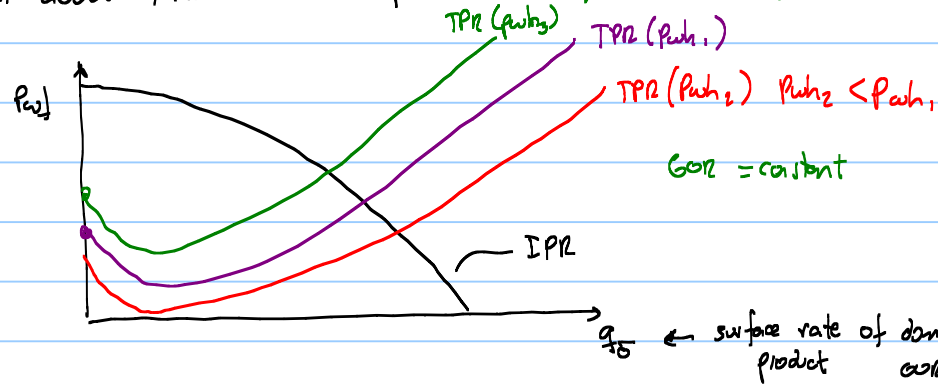
f_i f_{C_1} fugacity

$f_{C_1 L} = f_{C_1 V}$ ~ f(EOS)



→ $q_g \uparrow$ → $v_g = \frac{q_g}{A} \uparrow$ → $\Delta p_{friction} \uparrow$

Cont. discussion about TPR with multiphase flow

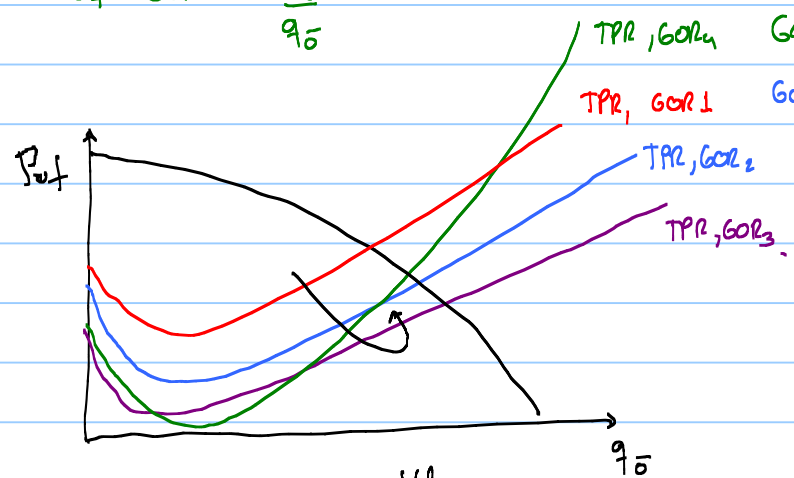


← surface rate of dominant product

GOR low → oil well $q_{\bar{o}}$

GOR ↑↑ → gas well $q_{\bar{g}}$

Effect of GOR $\frac{q_{\bar{g}}}{q_{\bar{o}}}$



$GOR_4 > GOR_3$

$GOR_2 > GOR_1$

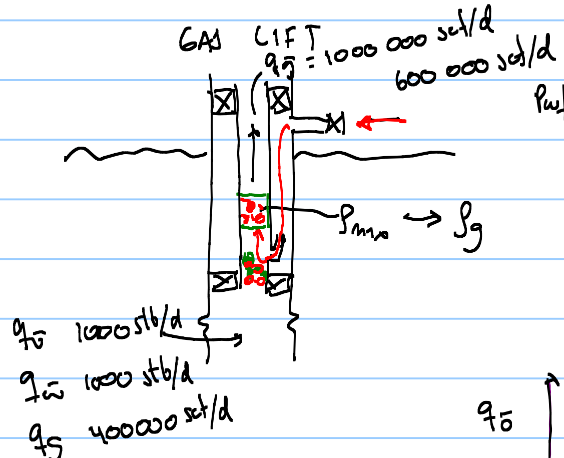
$\Delta p_{tubing} = \Delta p_{friction} + \Delta p_{hydrostatic}$

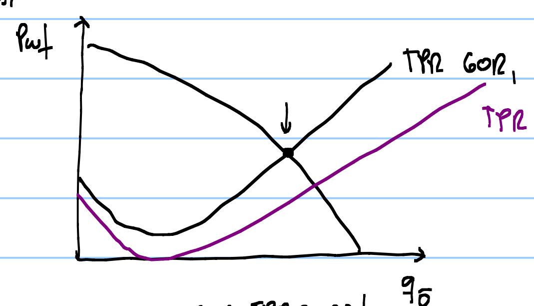
if GOR ↑

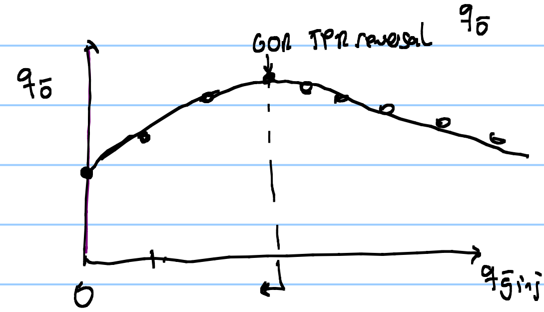
ρ_{mix} ↓ become similar to ρ_g

$\Delta p_{hydrostatic}$ ↓

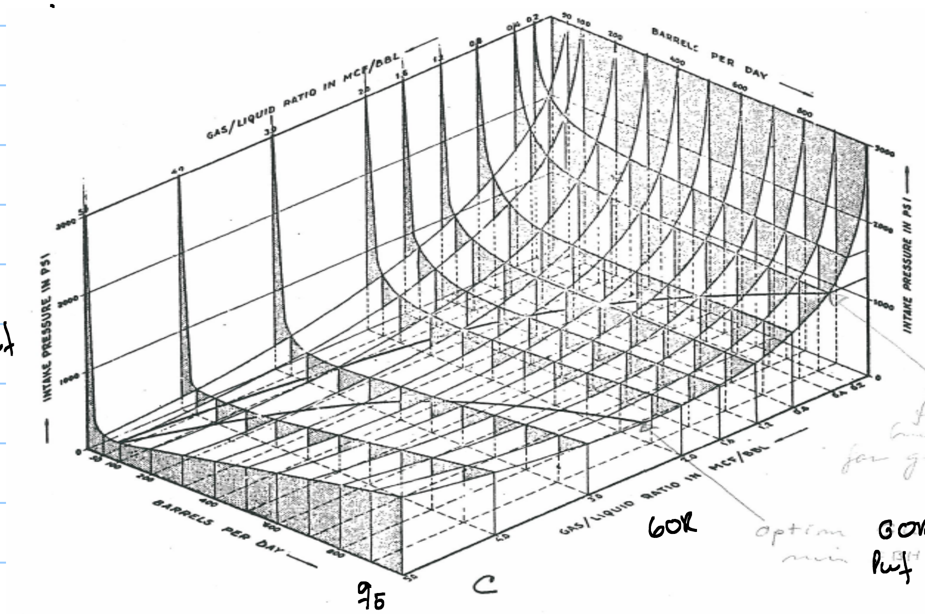
GAS LIFT







1954 (Gilbert) → choke
↘ gas lift

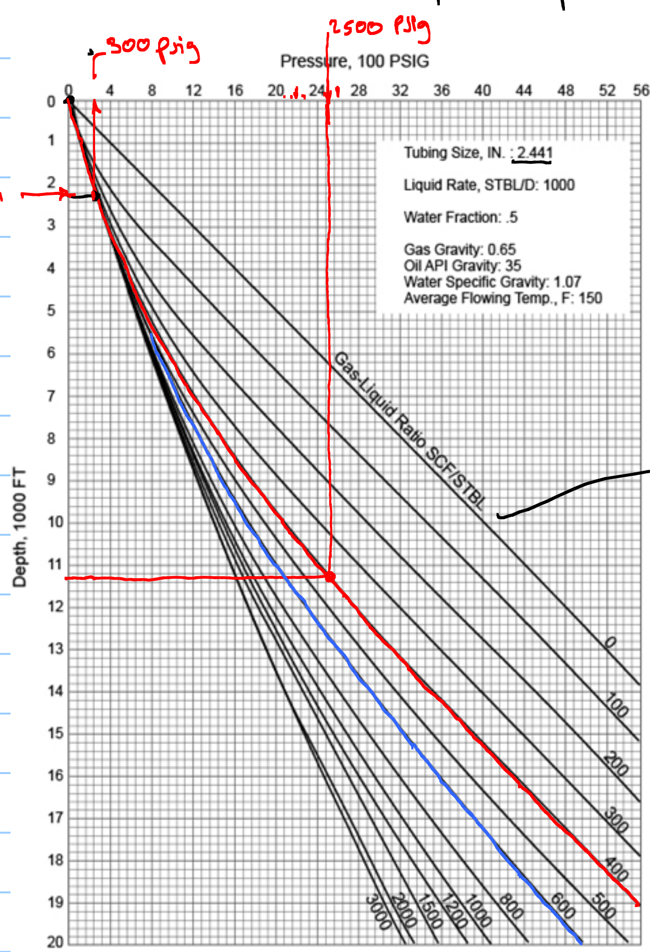


THE TWO-PHASE VERTICAL-LIFT FUNCTION
FOR 2.875 – INCH TUBING SET AT 8000 FEET
(TUBING PRESSURE = ZERO PSI GAUGE)
FIGURE 6

1954 !

- to calculate TPR for multiphase → pressure traverse curves 1960 ~ 1980's

$\frac{dP}{dx}\Big|_{P_w}$



vertical wells for a ϕ

$q_{\bar{o}}$

$wc = 50\%$

γ_o

γ_g

γ_w

$T_{av} =$

$GLR = \frac{q_{\bar{g}}}{q_{\bar{o}} + q_{\bar{w}}}$

class exercise. Case 1

$P_{wf} = 2500$ psig

$GLR = 400$ scf/stb

TVD · 9000 ft

P_{wh} ?

$TVD_{P_{wf}} = 11300$ ft

$TVD_{P_{wh}} = 11300 \text{ ft} - 9000$
2300 ft

Case 2

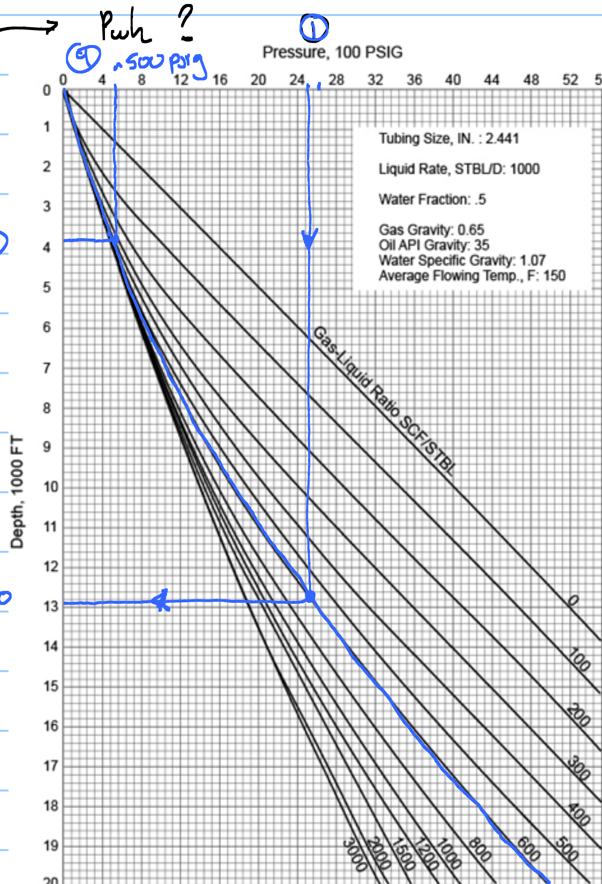
GLR = 600 scf/stb → Pwh ?

Pwf = 2500 psig

12800 – 9000

3800

12800



Case 3

Pwf = 1600 psig

GLR = 200 scf/stb

how much is Pwh ?

q_o = 1000 stb/d

q_w 1000 stb/d

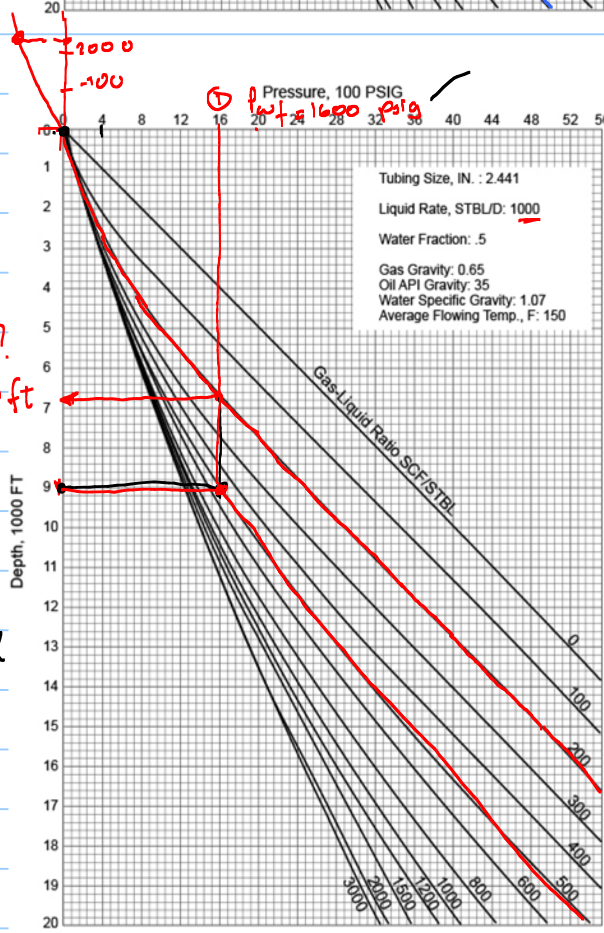
$q_g = 200 \frac{scf}{stb} (q_o + q_w)$

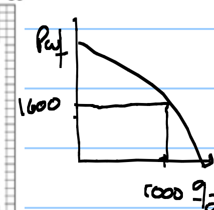
$GLR \cdot q_L = GLR (q_o + q_w)$

q_g 200 · (2000) = 400000 scf/d

6800 – 9000 ??? –2200

6800 ft





required GLR = 500 scf/stb

q_g = 500 · 2000 = 1000000 scf/d

$q_{g,inj}$ = 1E6 scf/d – 400000 scf/d

600 000 scf/d !

$q_o = 1000$ stb/d no injection

$P_{wf} = 1600$ psig GLR = 200 scf/stb

$P_{wh} = 120$ psig

GLR ?

$q_{g\,inj}$ to produce well ?

TVD = 9000 ft

9000

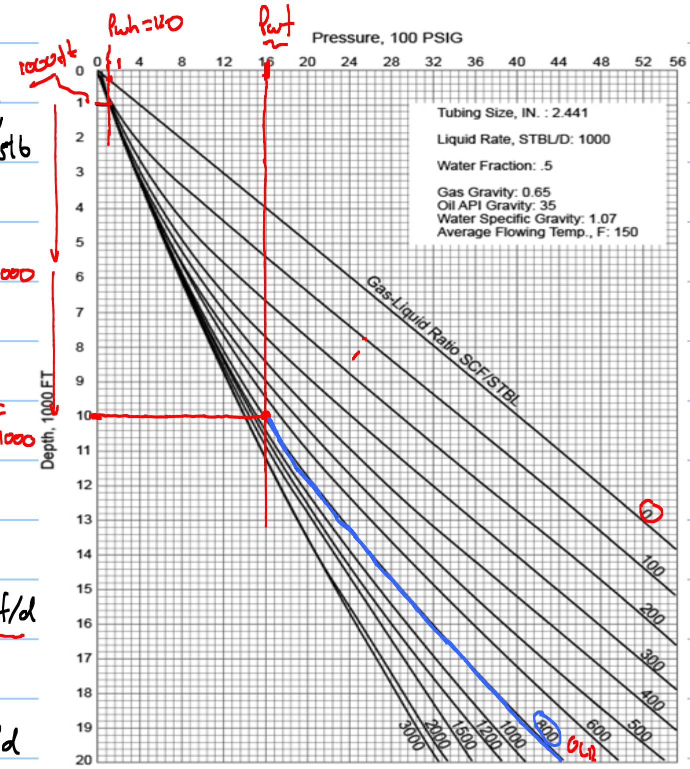
10000 = 1000 + 9000

GLR = 800 scf/stb ! to produce 1000 stb/d against 120 psig

$q_{g\,TOTAL} = GLR \cdot (q_L) = 800 \cdot 2000 = 1.6E6$ scf/d

$q_{g\,TOTAL} - q_{g\,res} = q_{g\,inj}$

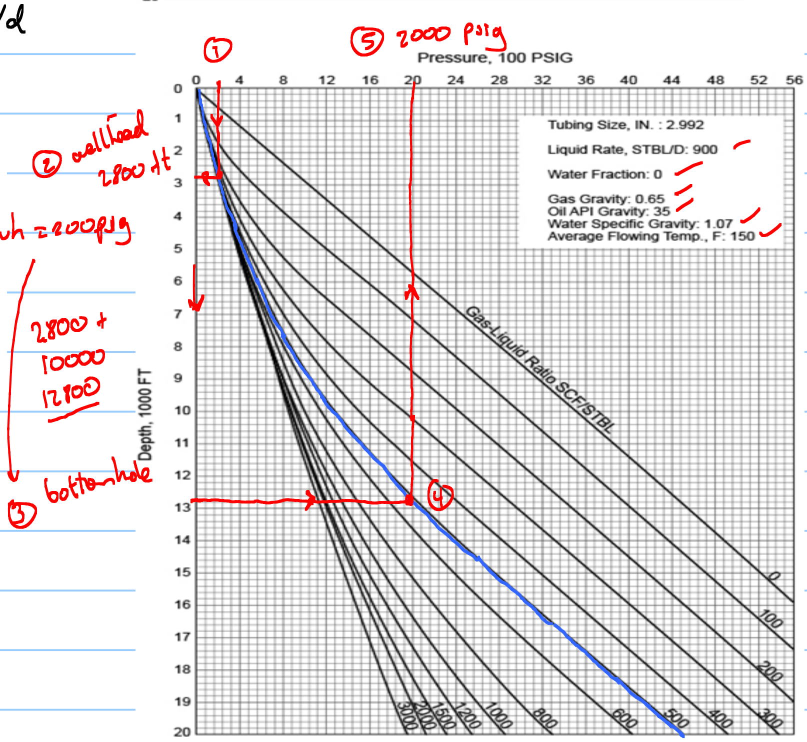
$q_{g\,inj} = 1.6E6 - 4E5$ scf/d
$= 1.2E6$ scf/d



Case 4 (290)

determine the bottom hole pressure for the follwoing oil production well
Well head pressure – 200 psi — P_{wh} = 200 psig
Well depth 10,000 ft
Tubing 2.992" ID (3 1/2")
Total Flow rate 900 bpd
Water Cut 0%
GLRp = 500 scf/bbl

2800 + 10000 = 12800



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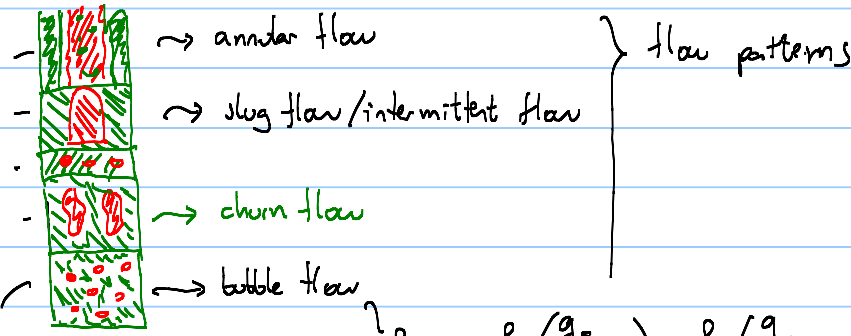
evaluation → home exercises max 3 people per group
→ exam 1 → quiz
→ exam 2 →

tentative ?

flow pattern

oil

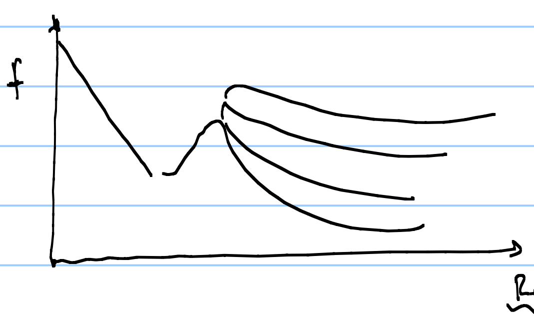


$$\rho_{mix} = \rho_g\left(\frac{q_g}{q_o+q_g}\right) + \rho_L\left(\frac{q_o}{q_o+q_g}\right)$$

very homogeneos

$\Delta p_{friction}$ $\Delta p_{hydrostatic}$

remember single phase flow



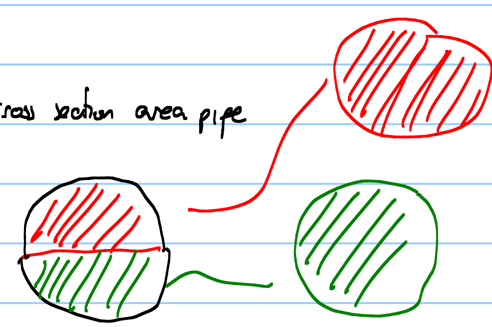
$Re = \frac{vD\rho}{\mu}$ — v: adimensional velocity

velocity

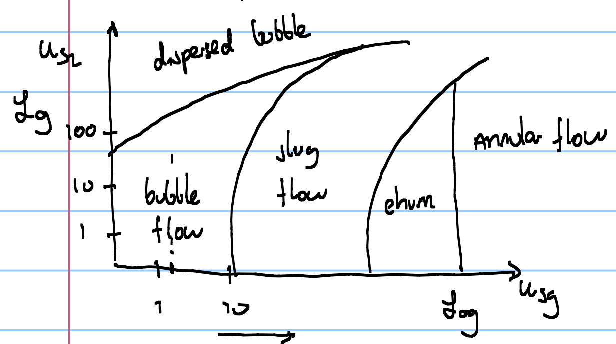
superficial velocity u_{sL} liquid, u_{sg} gas

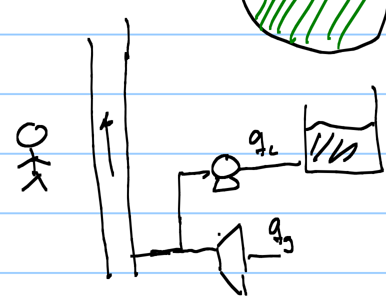
$u_{sL} = \frac{q_L}{A}$ ← cross section area pipe

$u_{sg} = \frac{q_g}{A}$



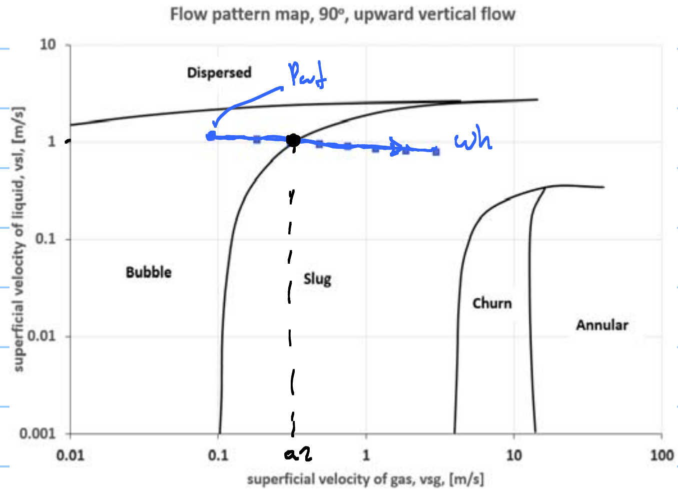
vertical pipe





the flow pattern map also depends on:

- ϕ diameter
- inclination
- fluid properties, $\rho_g, \rho_o, \mu_o, \mu_g, \sigma_{og}$
- ε pipe roughness



the transition between bubble → slug will occur at

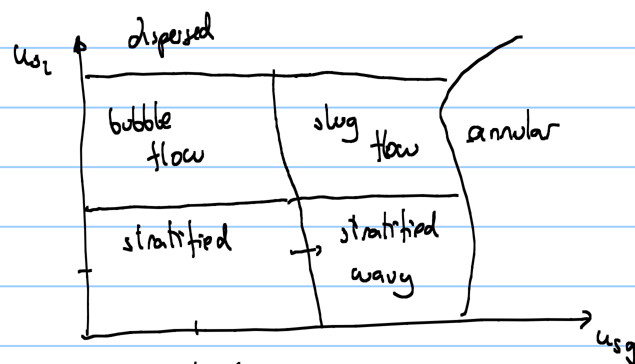
$u_{sL} \approx 1$ m/s

$u_{sg} \approx 0.2$ m/s

qo [m^3/d]	qg[m^3/d]	uso [m/s]	usg [m/s]	Flow patte
1174.3	4.566E+03	0.769	2.991	Slug
1224.4	2.862E+03	0.802	1.874	Slug
1283.1	1.791E+03	0.840	1.173	Slug
1352.5	1.161E+03	0.886	0.761	Slug
1430.1	7.452E+02	0.937	0.488	Slug
1514.4	4.721E+02	0.992	0.309	Transition
1602.1	2.803E+02	1.049	0.184	Bubble
1690.3	1.380E+02	1.107	0.090	Bubble

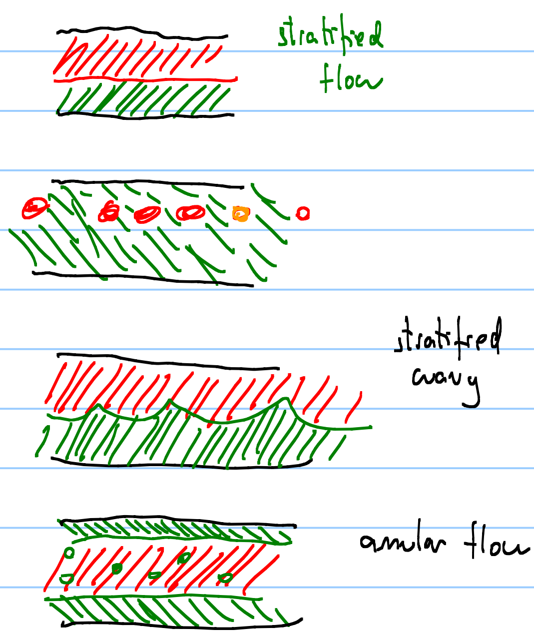
the flow patter map is very affected by pipe inclination

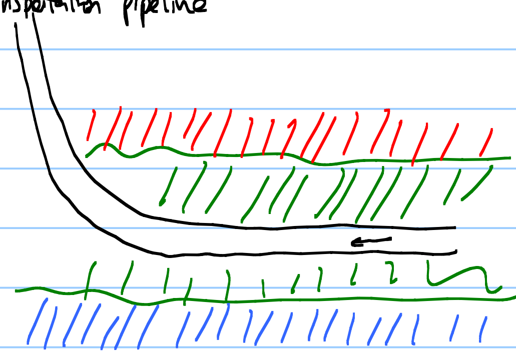
for horizontal flow :



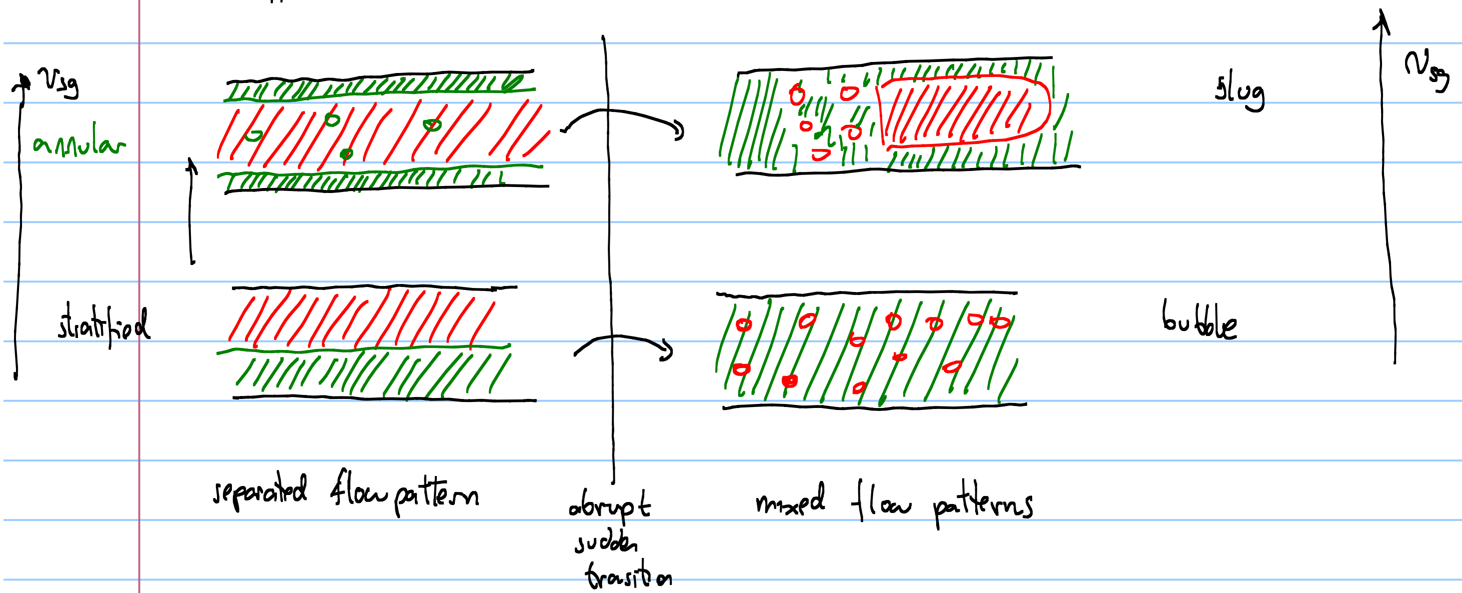
relevant for

- deviated and horizontal wells
- transportation pipeline





what affect transitions in flow pattern map?

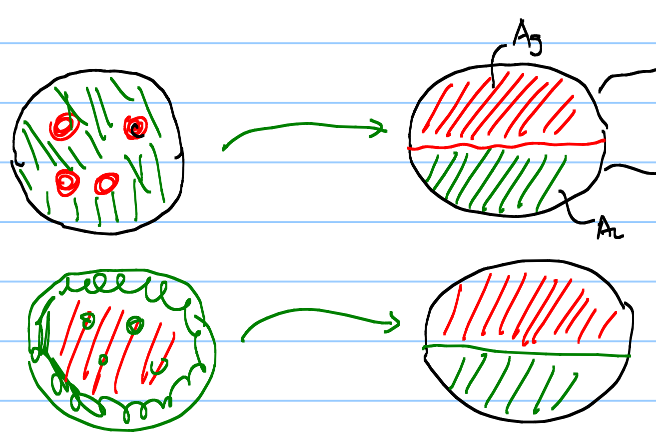


flow pattern transition is given by force balance/equilibrium on phase (oil/gas)

segregating forces ⟶ mixing forces

- gravitational acceleration ⟶ velocity ⟶ inertia
- interfacial tension ⟶ turbulence
- viscosity

$\Delta p = P_{wf} - P_{wh}$?



$v_g = \frac{q_g}{A_g}$ ← cause friction pressure drop

$v_L = \frac{q_L}{A_L}$

$\rho_m = (A_L, A_g)$

$A_g = \frac{q_g}{q_g + q_o}$ ← only if homogeneous flow