Wellbore-Reservoir Model

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Training for Engineers on
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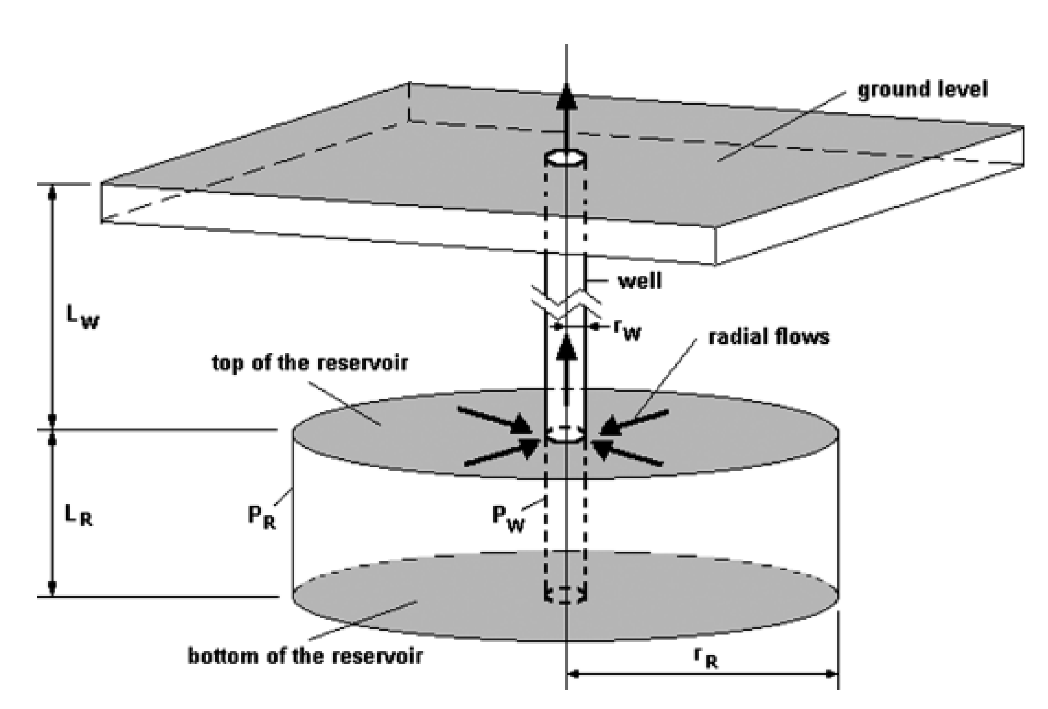
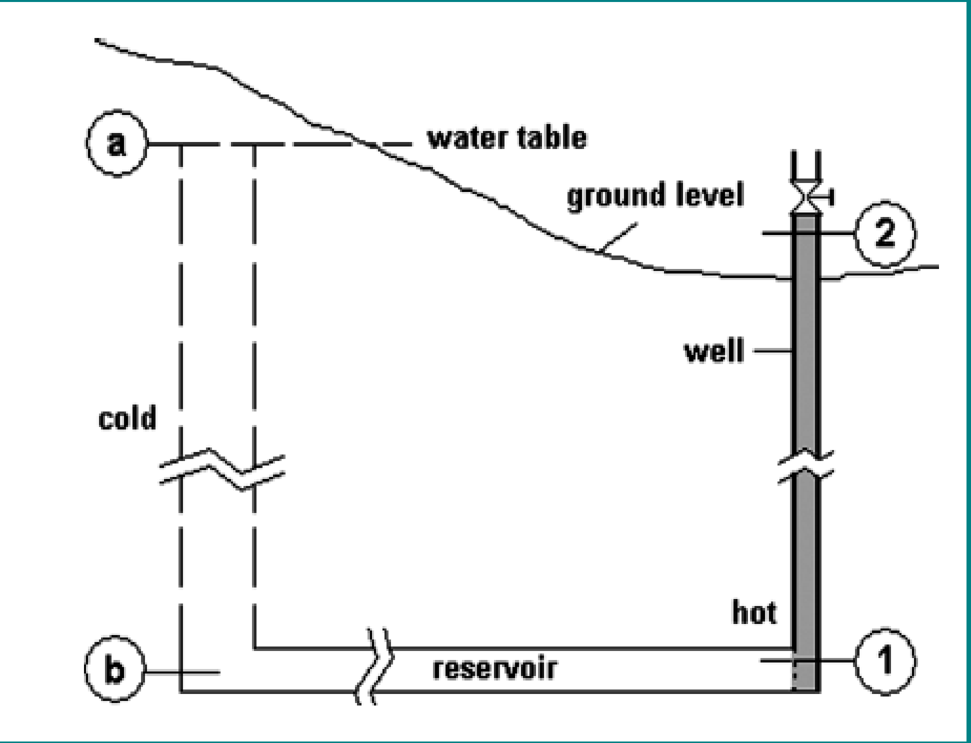
Ideal Case

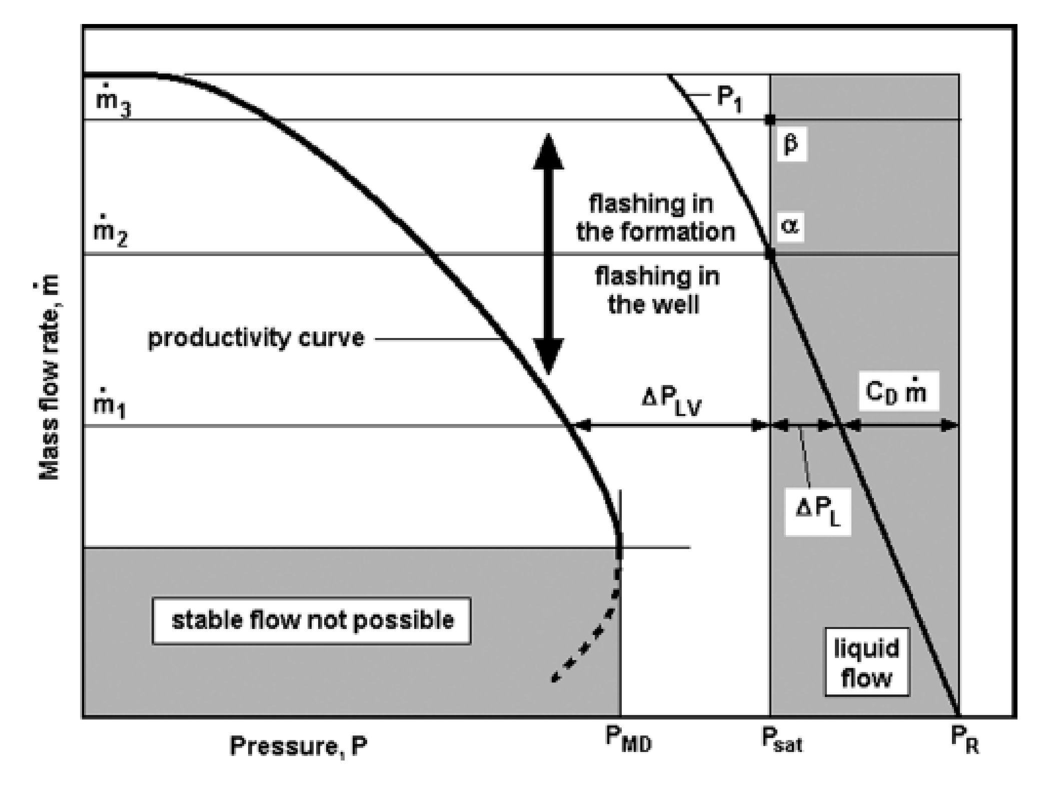

ground level
well
L_W
r_W
radial flows
top of the reservoir
L_R
P_R
P_W
bottom of the reservoir
r_R

Basic Principles

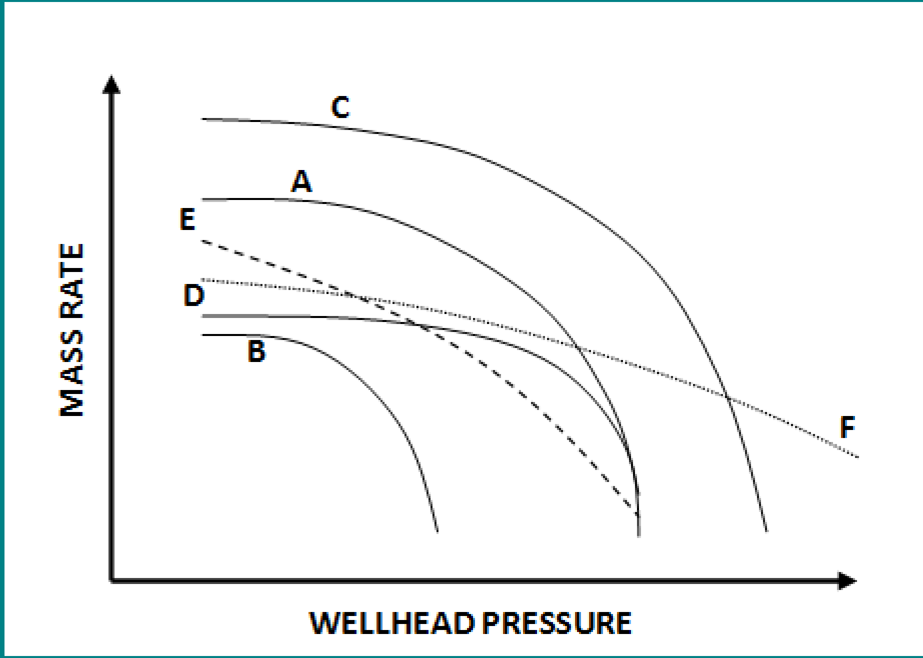


- The reservoir pressure may be assumed to be caused by a column of cold water.
- The density of the cold water exceeds that of the hot geofluid.
- Creating a natural flow when the wellhead valve is opened.
- We are interested in knowing P=P(z) and the relationship between mass flow rate and the wellhead pressure.

Mass flowrate vs Wellhead pressure

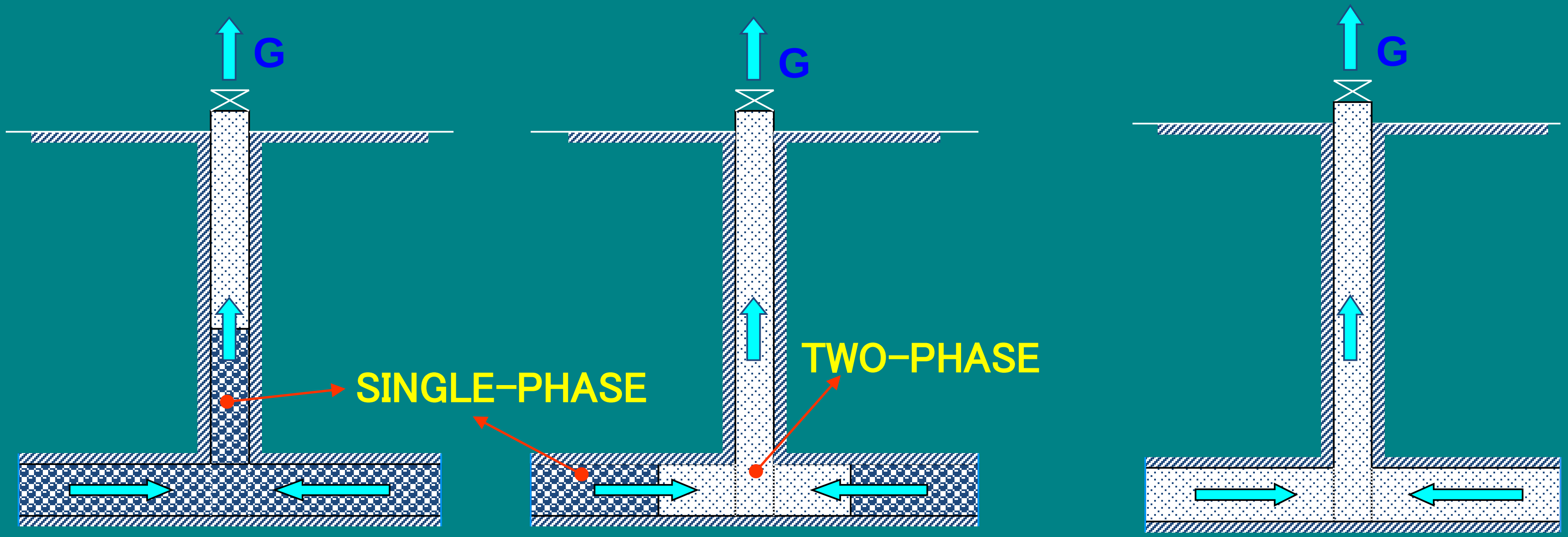


Typical Deliverability Curves



- Curve A, a basic form and represent the results obtained from wells that received liquid inflow from the reservoir with high permeability. It is assumed that water flows into the well and had flashing at a certain depth in the well.
- Curve B shows the effect of the pressure drop in the reservoir.
- Curve C shows the effect of reservoir pressure increase, or an increase in water temperature or gas content.
- Curve D illustrates the influence of scaling in the well.
- Curve E indicates the effect of low permeability. For both curves D and E deliverability curve at low flow (high wellhead pressure) did not increase because additional restriction produces little effect on the low flow rate.
- Curve F is obtained when the reservoir produces two-phase fluid (at the same pressure as in curve A).

Steady State Modeling



Governing Equations

Wellbore Model:

$$\Delta P_t = \Delta P_a + \Delta P_h + \Delta P_f$$

ΔP_t = total pressure loss (Pa)

ΔP_a = acceleration pressure loss (Pa)

ΔP_h = potential pressure loss (Pa)

ΔP_f = friction pressure loss (Pa)

Reservoir Model

Continuity Equation:

$$-\frac{1}{r}\frac{\partial}{\partial r}(ru) = 0$$

r = radial distance (m)

Momentum Equation

$$u = -\frac{k}{\nu_t}\frac{\partial P}{\partial r}$$

k = permeability (m^2)

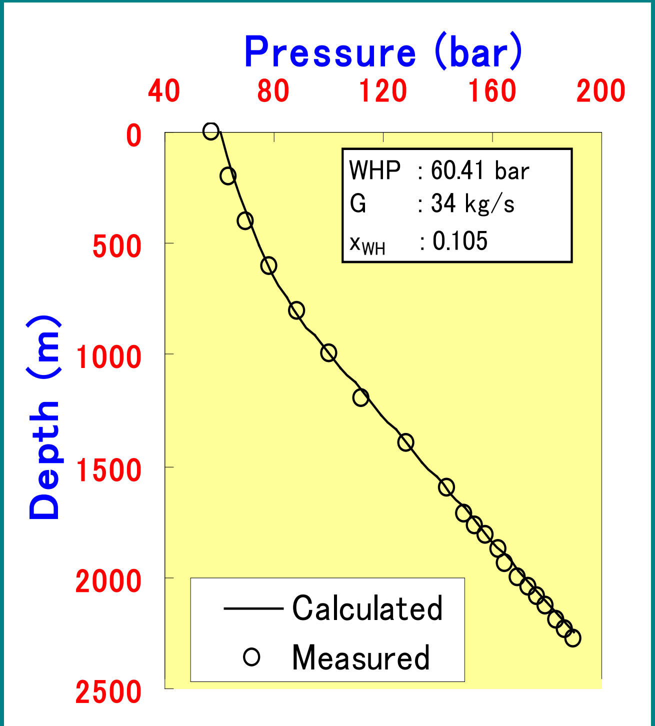
ν_t= total kinematic viscosity (m^2/s)

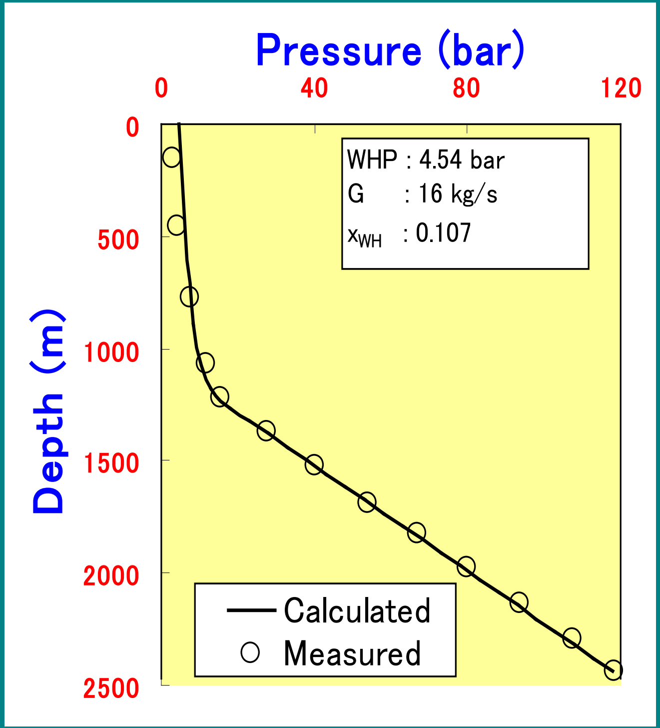
Total Kinematic Viscosity

$$\frac{1}{\nu_t} = \frac{k_{rw}}{\nu_w} + \frac{k_{rs}}{\nu_s}$$

k_{rw} = relative permeability to water (-)
k_{rs} = relative permeability to steam (-)
ν_w = kinematic viscosity of water (m^2/s)
ν_s = kinematic viscosity of steam (m^2/s)

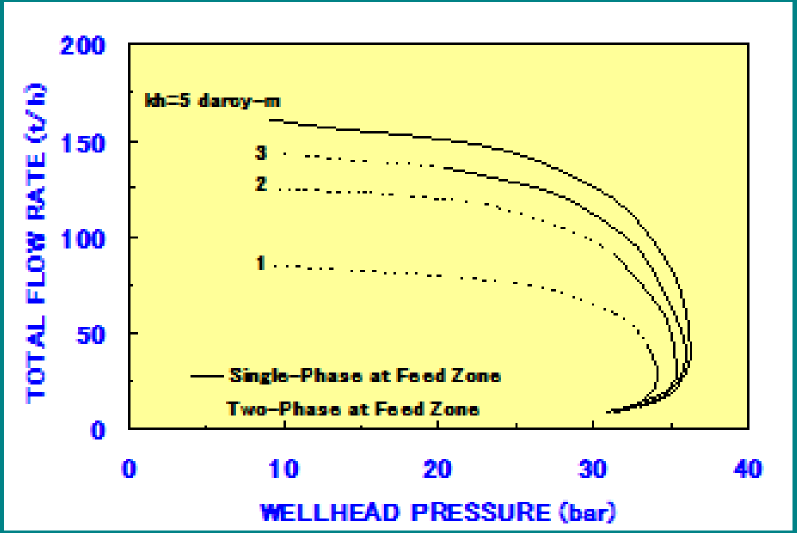
Validation

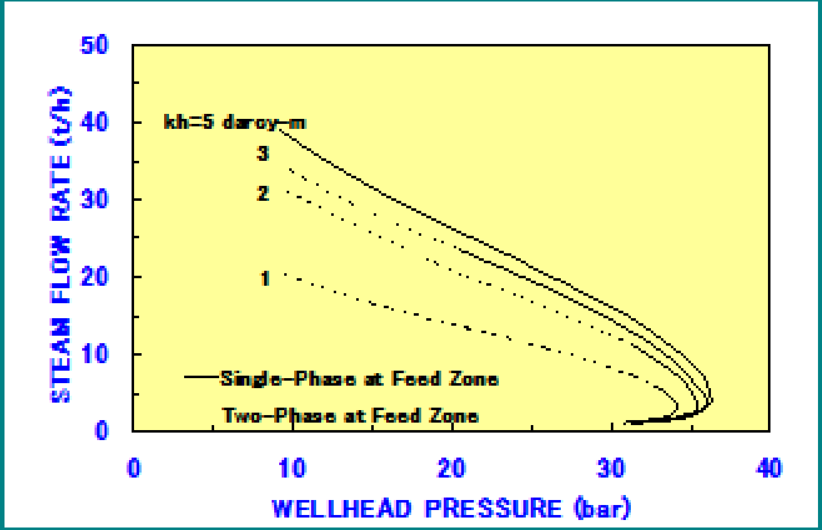

Pressure (bar)
40
80
120
160
200
0
500
1000
1500
2000
2500
Depth (m)
WHP : 60.41 bar
G : 34 kg/s
x_{WH} : 0.105
Calculated
Measured


Pressure (bar)
0
40
80
120
0
500
1000
1500
2000
2500
Depth (m)
WHP : 4.54 bar
G : 16 kg/s
x_{WH} : 0.107
Calculated
Measured

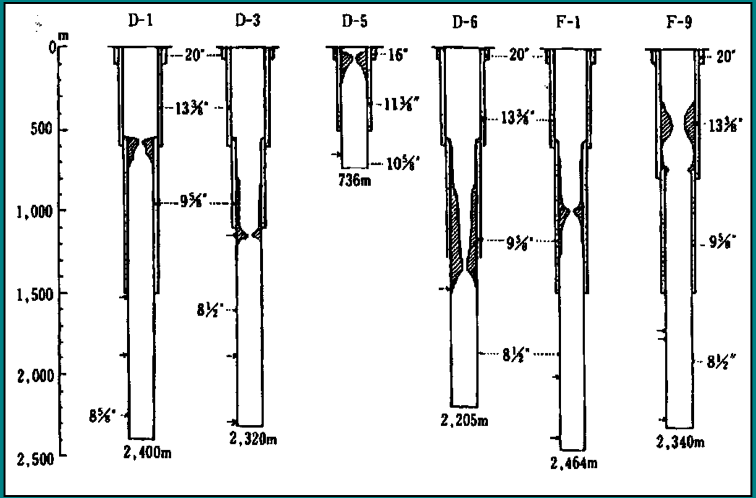
Analysis

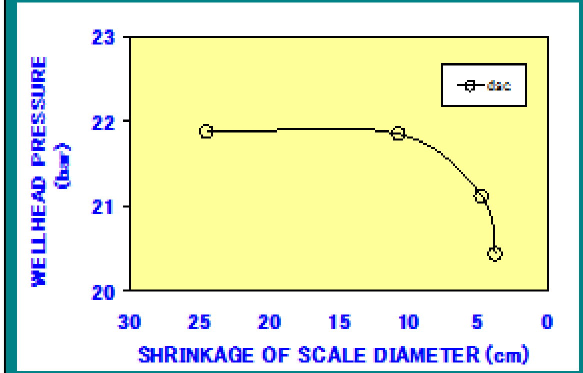
Analysis on effects of kh on well characteristics (scaling in the reservoir)

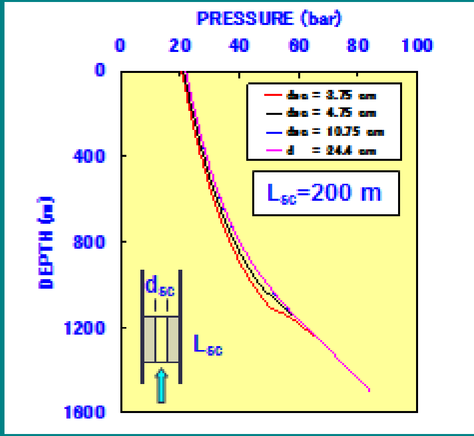


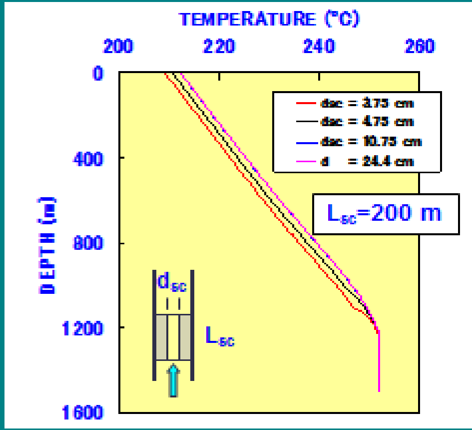


Analysis on effects of well diameter reduced by scale deposition









Transient Modeling

Advantages

- To study the behaviors of wellhead and well bottom pressure with time due to mass flow rate change with time at wellhead
- To estimate the time required for fluid flow to stabilize due to different period of time for flow rate change at wellhead
- To analysis well testing results

Governing Equations: Wellbore

Conservation of mass:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x}(\rho u) = 0$$

Equation of state:

$$\Delta \rho = \left(\frac{\partial \rho}{\partial p}\right)_e \Delta p + \left(\frac{\partial \rho}{\partial e}\right)_p \Delta e$$

Conservation of momentum:

$$\frac{\partial}{\partial t}(\rho u) + \frac{\partial}{\partial x}\left[\alpha \rho_s u_s^2 + (1-\alpha)\rho_w u_w^2\right] - \frac{\partial p}{\partial x} + \rho g - \frac{f \rho u^2}{4 r_w} = 0$$

P = pressure (Pa)

ρ = fluid density (kg/m^3)

u = fluid velocity (m/s)

α = void fraction (-)

e = specific internal energy of fluid (J/kg)

Conservation of energy:

$$\frac{\partial}{\partial t}(\rho e) + \frac{\partial}{\partial x}\left[\alpha \rho_s u_s e_s + (1-\alpha)\rho_w u_w e_w\right] = -P\left\{\frac{\partial}{\partial x}\left[\alpha u_s + (1-\alpha) u_w\right]\right\}$$

subscripts: w = water (wellbore) ; s = steam

Governing Equation: Reservoir

Diffusion equation:

$$\frac{\partial P}{\partial t} = \frac{k}{\mu \varphi C}\left[\frac{\partial^2 P}{\partial r^2} + \frac{1}{r}\frac{\partial P}{\partial r}\right]$$

t = time (s)

k = permeability (m^2)

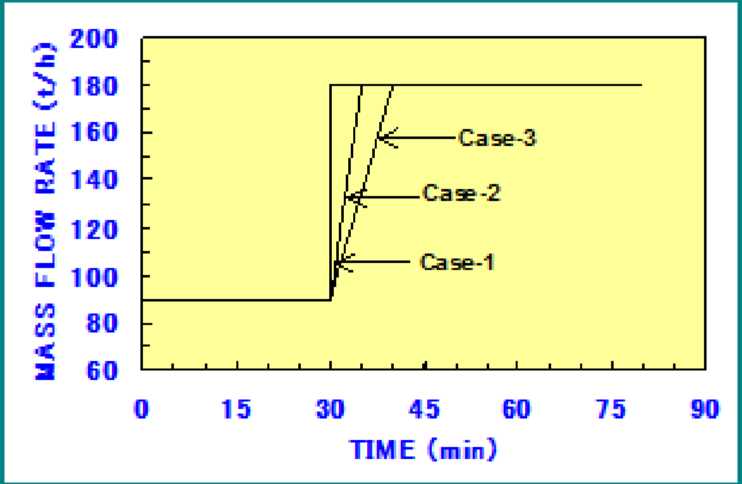
μ = dynamic viscosity (Pa.s)

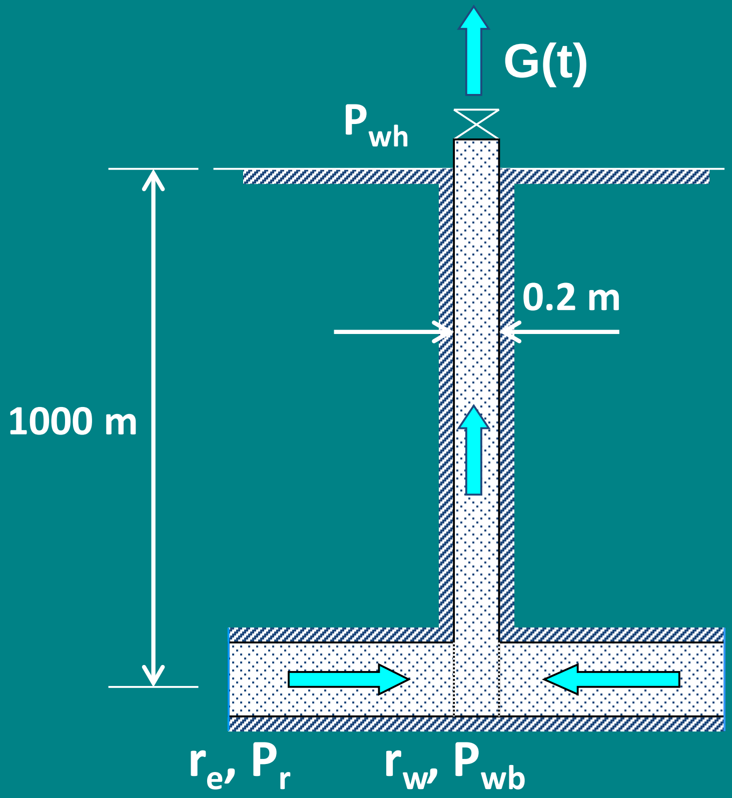
φ = porosity (-)

C = compressibility (1/Pa)

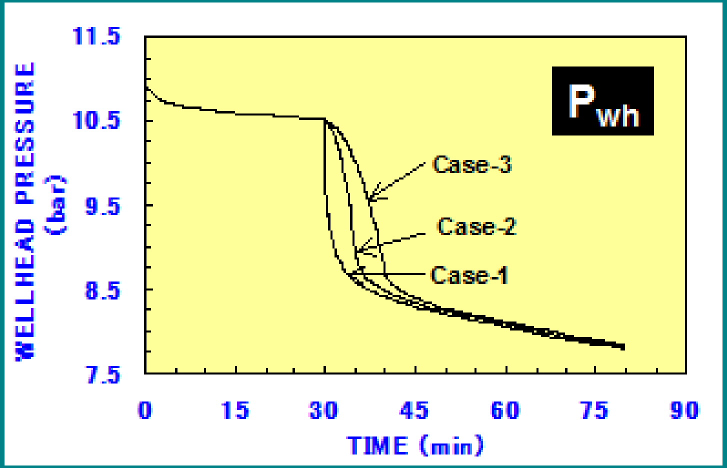
r = radial distance (m)

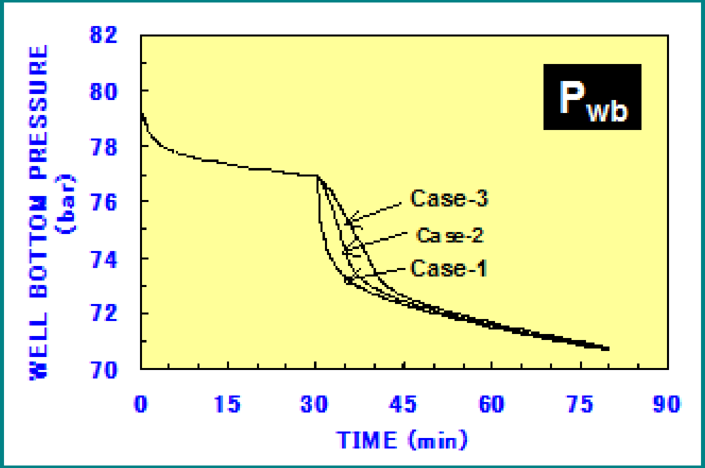
Boundary condition at wellhead:



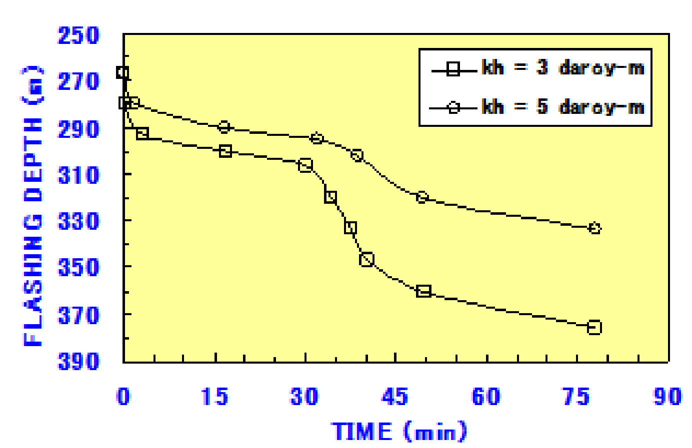


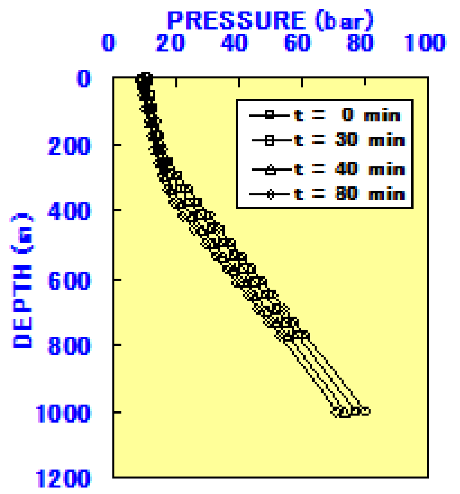
Effects of time interval required for flow rate change on well deliverability

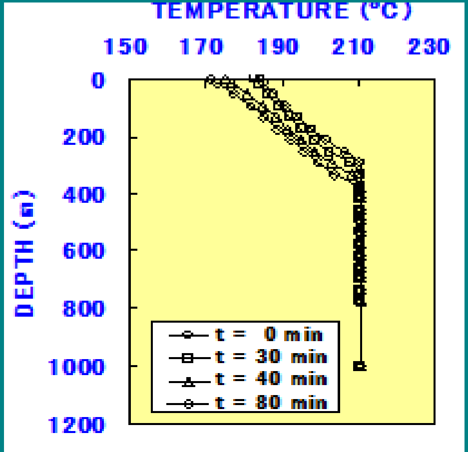




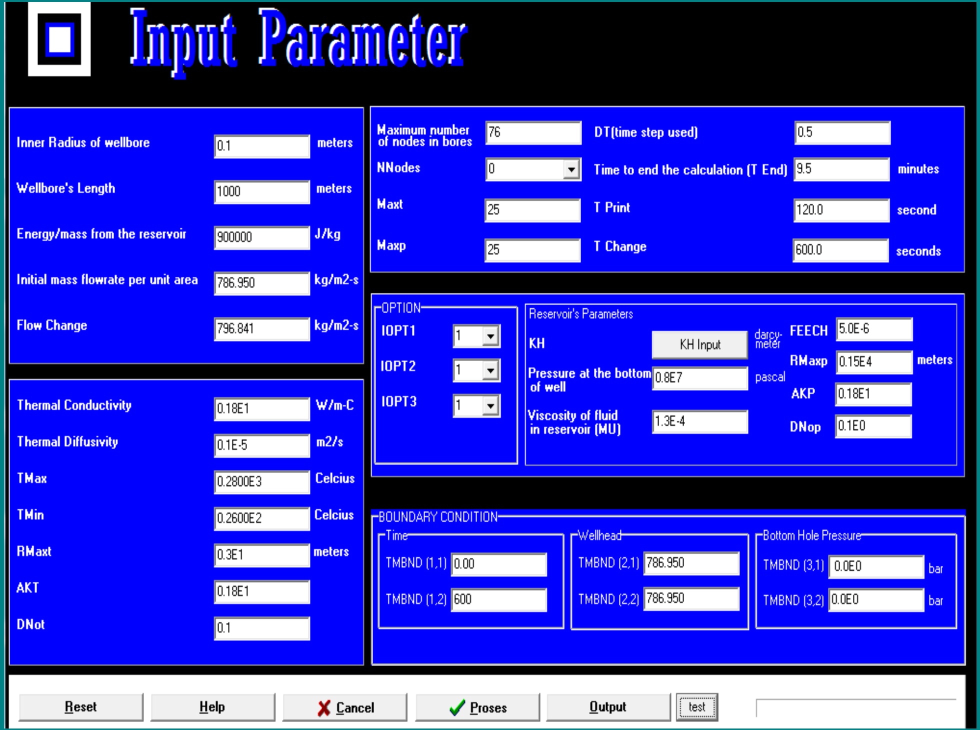
Effects of permeability thickness on flashing depth

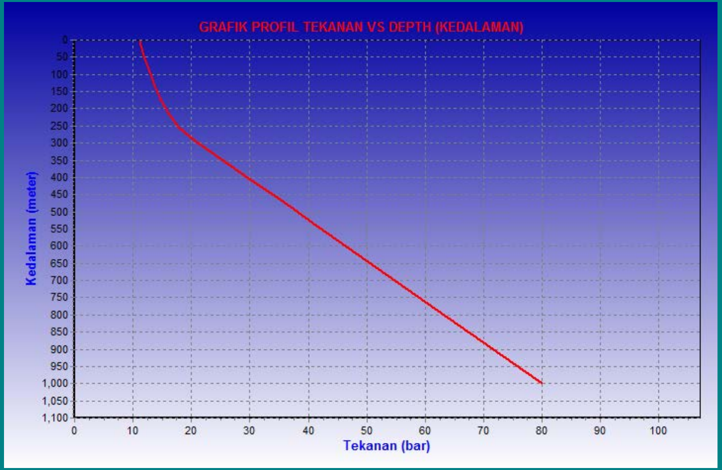


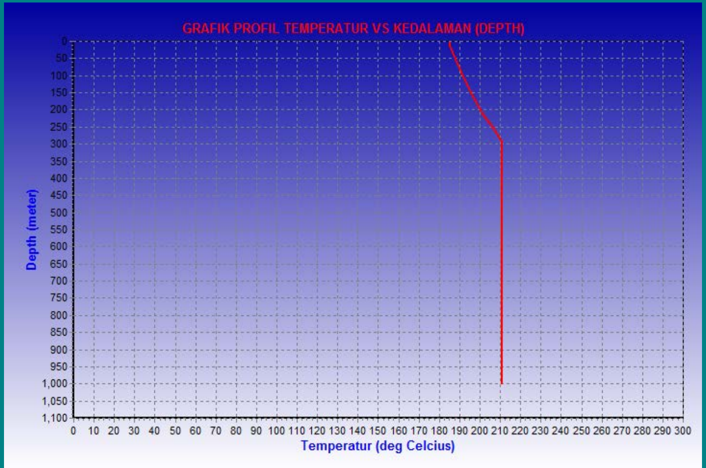




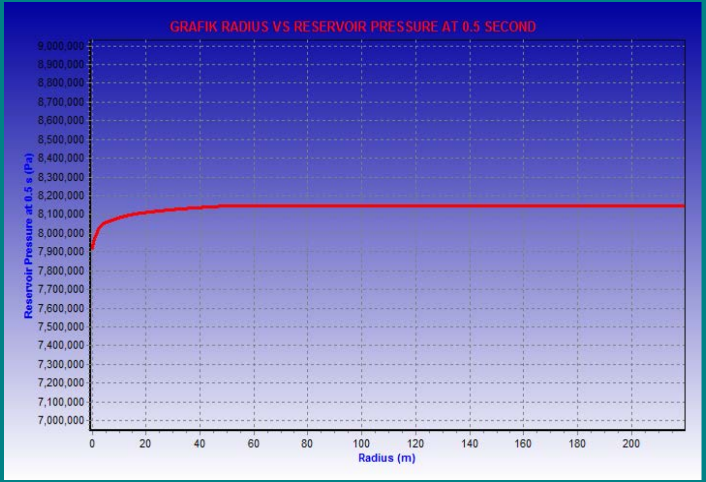
Reservoir-Wellbore Simulator




GRAFIK PROFIL TEKANAN VS DEPTH (KEDALAMAN)
Kedalaman (meter)
Tekanan (bar)


GRAFIK PROFIL TEMPERATUR VS KEDALAMAN (DEPTH)
Depth (meter)
Temperatur (deg Celcius)


GRAFIK TIME VS DOWNHOLE PRESSURE
Downhole Pressure (Pascal)
Time (s)


GRAFIK RADIUS VS RESERVOIR PRESSURE AT 0.5 SECOND
Reservoir Pressure at 0.5 s (Pa)
Radius (m)

Thank You