



WELLBORE STORAGE

Immediately after a rate change, part of the production may be due to expansion or compression of fluid in the wellbore. It could also be due to a moving fluid contact (interface). These phenomena have been called the wellbore storage effect.

Drawdown

Many well test interpretation techniques imply the assumption of a constant rate. Suppose it is possible to keep the surface flow rate, q , constant. Then the first production comes from the wellbore and not the reservoir. The reservoir flow rate, q_{sf} , will slowly build up to become equal to the surface flow rate.

The fluid produced, q , is the sum production of fluid from the wellbore, q_{wb} , and fluid coming from the reservoir, q_{sf} .

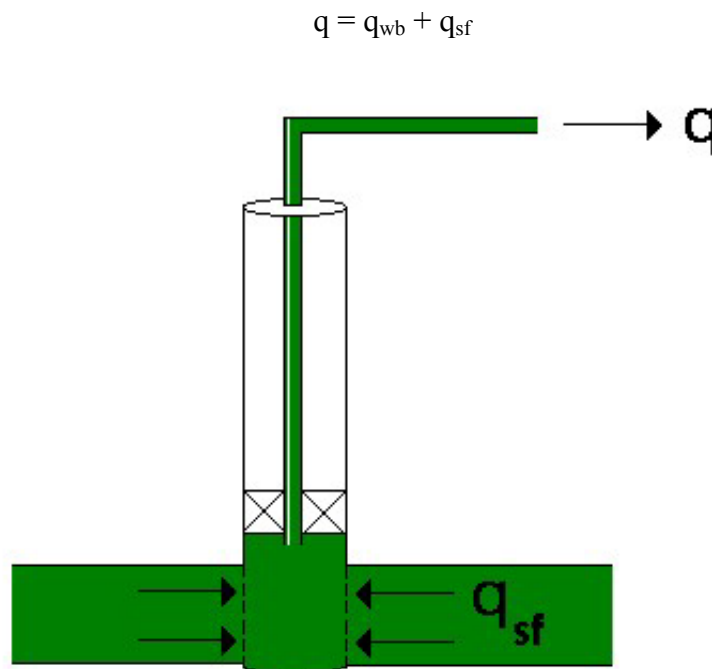


Figure 1: Surface and sandface production are not equal initially

The first production comes from the well. This is illustrated below.

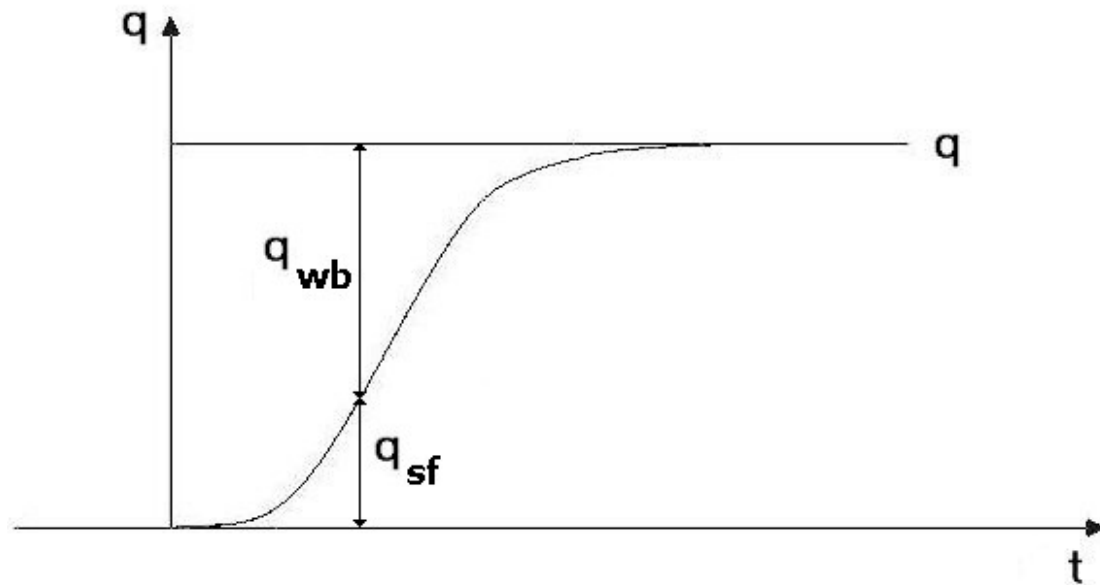


Figure 2: Surface and sandface production as a function of time

One phase in the wellbore

Semi-log analysis is possible when $q_{wb} \approx 0$. Then the wellbore storage effect has died out. The production from the wellbore is given by:

$$q_{wb} = -c_{wb} V_{wb} \frac{d\Delta p_{wf}}{dt}$$

where c_{wb} is the compressibility and V_{wb} is the volume of the compressed fluid. The pressure drawdown, Δp_{wf} , is given by:

$$\Delta p_{wf} = p_i - p_{wf}$$

For negligible sandface production, i.e. $q_{sf} \approx 0$, all the fluid produced at the surface derives from fluid expansion.

$$q = q_{wb}$$

Since the surface rate, q , is constant, the above differential equation may be integrated to yield:

$$\Delta p_{wf} = \frac{qBt}{C_s}$$

The above equation describes a straight line with slope $m = \frac{qB}{C_s}$, and intersect p_i with the vertical axis.

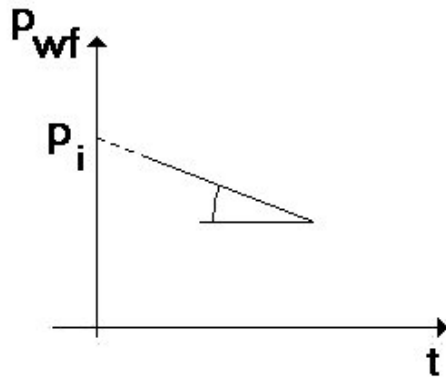


Figure 3: Well flowing pressure as a function of time

The wellbore storage constant is given by:

$$C_S = c_{wb} V_{wb}$$

Since the reservoir flow rate is zero initially, the pressure signature does not reflect any reservoir properties during this period. Only wellbore properties are reflected. If the wellbore storage constant as determined from the slope is too large, this may indicate a leak. Since V_{wb} is known from well data the wellbore storage constant may be estimated. These values should agree.

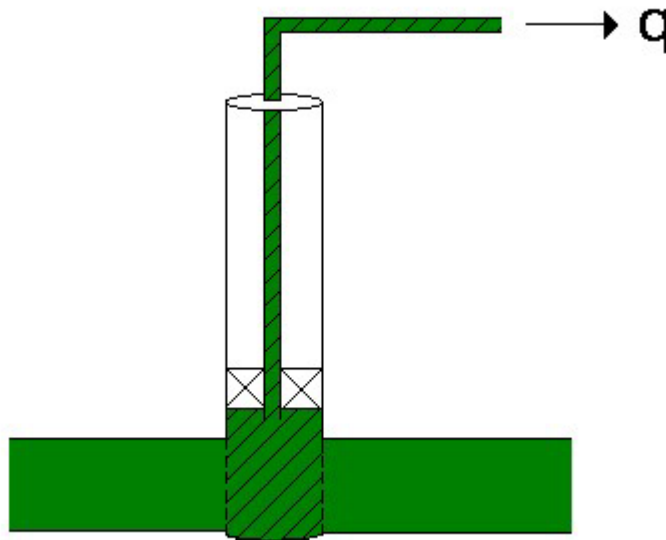


Figure 4: Volume of expanded or compressed fluid

Production by a moving fluid interface

Consider the below well which has been closed. Since pressure is decreasing with increasing height, the pressure at the top may fall below the bubble point. Then gas comes out of solution. In this case there is no packer.

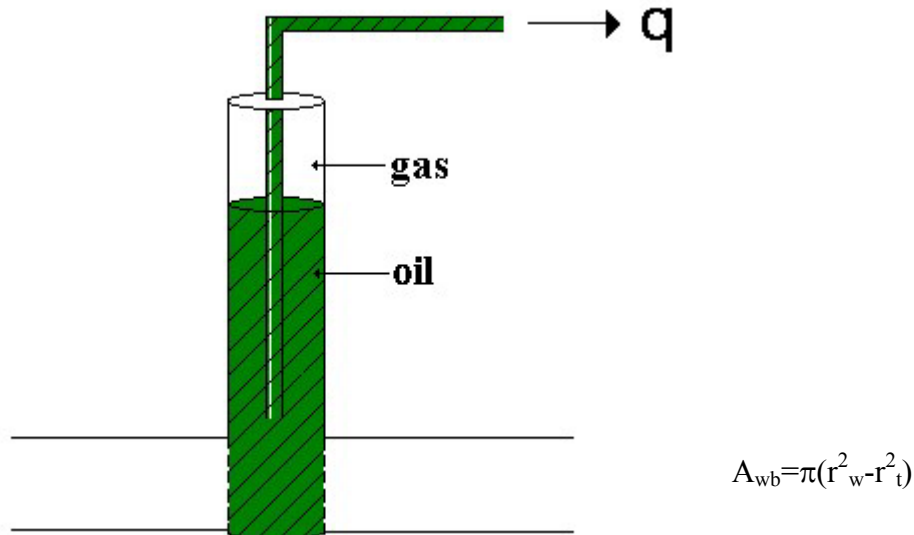


Figure 5: Oil production by a falling gas liquid interface

When production is started, the gas liquid contact will move downwards. Again the production from the wellbore is given by:

$$q_{wb} = -C_s \frac{d\Delta p_{wf}}{dt}$$

where the wellbore storage constant is

$$C_s = \frac{A_{wb}}{\rho g}$$

Since $q_{wb} = q$, the above differential equation may be integrated to yield:

$$\Delta p_{wf} = \frac{qBt}{C_s}$$

Buildup

Perfect control of the reservoir flow rate is impossible. Immediately after shutin, the wellbore pressure is lower than out in the reservoir. Fluid will continue to flow into the well after shutin. This is called afterflow. The wellbore pressure will increase as a result of fluid compression. Eventually the pressures will be equalized and the inflow into the well will stop.

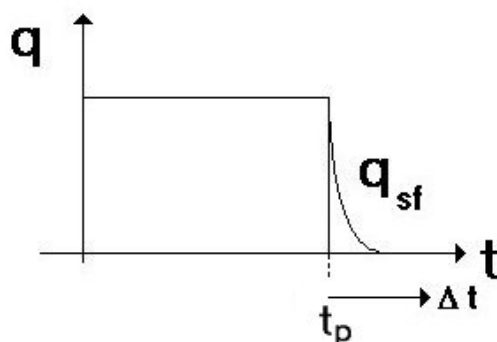


Figure 5: Surface and sandface production rates as function of time

Observations:

1. Semi-log analysis possible when $q_{sf} = 0$.
2. There is no pressure drop associated with the skin when $q_{sf} = 0$ since

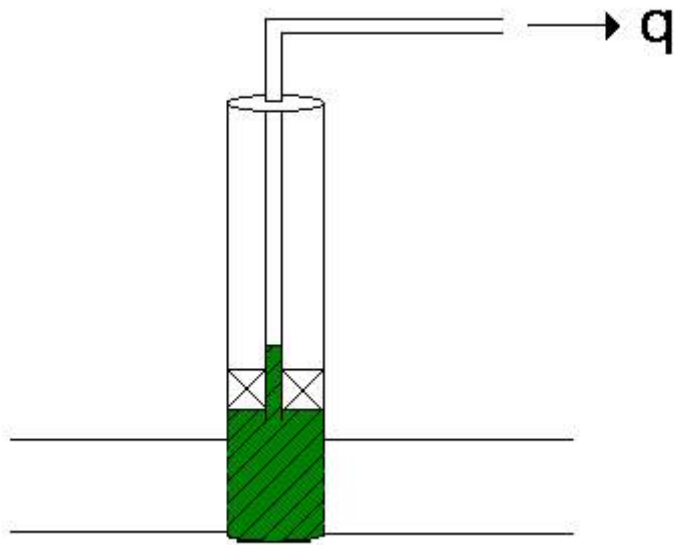
$$\Delta p_{skin} = \frac{q_{sf} B \mu}{2\pi k h} S$$

3. The pressure drop across the skin is constant when $q_{sf} = q = \text{Constant}$
4. The skin pressure drop is decreasing during the afterflow period since q_{sf} is decreasing function of time.

The effect of afterflow may be minimized by downhole shutin. If there is one phase flowing into the wellbore, the storage constant is given by:

$$C_S = c_{wb} V_{wb}$$

Downhole shutin will reduce the volume of the compressed fluid dramatically. This is illustrated in Fig.6. The compressed volume for surface shutin is shown in Fig.4. Downhole shutin is rarely done for production wells but it is common practice in drillstem tests.



Figur 6: Volume of compressed fluid, downhole shutin