Transient, Semisteady-State, and Steady-State Flow

C.S. Matthews, SPE, Shell Oil Co.

Transient Flow

The pressure behavior at a well producing at constant flow is shown in Fig. 1. During early producing times, the pressure behavior is essentially the same as that in an infinite reservoir. This is the transient flow period. The pressure at the well can be described by the following equation for most times of practical interest:

\[ \text{well pressure} = \text{initial pressure} - A \log (\text{producing time}) - B \]

where A and B are constants.

During this period, the plot of well pressure vs. the logarithm of time will be a straight line. On Cartesian coordinates (Fig. 1) the well pressure will decline rapidly at first, then less rapidly with time.

Semisteady-State Flow

Curves of pressure in the reservoir vs. radial distance are shown in Fig. 2. If there is no flow across the drainage boundary as more producing time elapses, the pressure behavior will begin to deviate from the infinite-reservoir case. At a time shown as “late transient” in Fig. 2, the pressure at points inside the drainage boundary will begin to decline at a rate higher than that in an infinite reservoir.

Finally, as shown in Fig. 2, if compressibility is small and constant, the rate of pressure decline becomes equal through the drainage boundary. This is the semisteady-state period. All pressures in the drainage area of the well now decrease by the same amount in a given time. The difference between average reservoir pressure and wellbore pressure remains constant during this period.

The rate of pressure decline during semisteady-state flow is

\[ \text{pressure decline} = 0.0148 \times \frac{\text{producing rate} \times \text{formation volume factor}}{\text{contributory pore volume} \times \text{compressibility}} \]

![Diagram of pressure decline](https://example.com/diagram.png)

Fig. 1—Schematic plot of pressure decline at well bounded circular reservoir, constant rate case.

Journal of Petroleum Technology, April 1985
where the pressure decline is measured in psi per hour, the producing rate in barrels per day, the contributory pore volume in barrels, and the compressibility in psi$^{-1}$.

This equation is the basis for “reservoir limit testing,” which will be discussed in a future article.

**Steady-State Flow**

In steady-state flow at constant well flow rate, the pressure at every point in the reservoir will remain constant with time. This case is seldom seen in oilfield reservoirs. Cases of pressure maintenance by water or gas injection come closest to steady-state flow. In certain reservoirs, over a given period of time, it may be permissible to make the approximation that pressures do not change with time. Steady-state flow is more applicable to laboratory displacement experiments than to petroleum reservoir conditions.

**SI Metric Conversion Factors**

\[
\begin{align*}
\text{psi} & \times 16.602 \quad \text{E+00} = \text{kPa} \\
\text{psi} & \times 6.894756 \quad \text{E+00} = \text{kPa}
\end{align*}
\]

*Conversion factor is exact.*

This paper is SPE 15278. Technology Today Series articles provide useful summary information on both classical and emerging concepts in petroleum engineering. Purpose: To provide the general reader with a basic understanding of a significant concept, technique, or development within a specific area of technology.