INTRODUCTION TO COMPOSITIONAL SIMULATION

So far, we have only considered so-called *Black Oil* models. These models assume that the hydrocarbons may be described as two components, *oil* and *gas*, and that hydrocarbon fluid composition remain constant during the simulation. All fluid properties are assumed to be determined by oil pressure and bubble point pressure only. All mass transfer between the two components is normally described by the solution gas-oil ratio term, R_{so} (although an oil-in-gas term to handle condensate may easily be included in the *Black Oil* formulation).

In reservoirs containing light oil, the hydrocarbon composition as well as pressures affect fluid properties. Equilibrium flash calculations using *K* values or and equation of state (*EOS*) must be used to determine hydrocarbon phase compositions. *Compositional* simulation is beyond the scope of this course, however, we will in the following give a short introduction to the subject.

In a compositional model, we in principle make mass balances for each hydrocarbon component, such as methane, ethane, propane, etc. In practice, we limit the number of components included, and group components into pseudo-components.

We still have oil and gas as flowing hydrocarbon phases. In the following we will for simplicity exclude water, which would have a form identical to its form in the Black Oil model.

We define

C_{kg} = *mass fraction of component k present in the gas phase*

and

C_{ko} = *mass fraction of component k present in the oil phase*.

Thus, we have the conditions that for a system of N_c components:

$$\sum_{k=1}^{N_c} C_{kg} = 1$$

$$\sum_{k=1}^{N_c} C_{ko} = 1$$

Then, a mass balance of component *k* may be written (in one dimension, for simplicity):

$$-\frac{\partial}{\partial x}\left(C_{kg}\rho_g u_g + C_{ko}\rho_o u_o\right) = \frac{\partial}{\partial t}\left[\phi\left(C_{kg}\rho_g S_g + C_{ko}\rho_o S_o\right)\right]$$

Darcy's equations for each flowing phase are identical to the Black Oil equations:

$$u_o = -\frac{kk_{ro}}{\mu_o}\frac{\partial P_o}{\partial x}$$

$$u_g = -\frac{kk_{rg}}{\mu_g}\frac{\partial P_g}{\partial x}.$$

Where

$$P_{cog} = P_g - P_o$$

$$P_{cow} = P_o - P_w,$$

and

$$S_o + S_g = 1.$$

Thus, we may write flow equations for N_c components as:

$$\frac{\partial}{\partial x}\left(C_{kg}\rho_g \frac{kk_{rg}}{\mu_g}\frac{\partial P_g}{\partial x} + C_{ko}\rho_o \frac{kk_{ro}}{\mu_o}\frac{\partial P_o}{\partial x}\right) = \frac{\partial}{\partial t}\left[\phi\left(C_{kg}\rho_g S_g + C_{ko}\rho_o S_o\right)\right], \qquad k = 1, N_c$$

The properties of oil and gas phases depend on pressures and composition, so that the functional dependencies may be written:

$$\rho_g(P_g, C_{1g}, C_{2g}, \ldots)$$

$$\rho_o(P_o, C_{1o}, C_{2o}, \ldots)$$

$$\mu_g(P_g, C_{1g}, C_{2g}, \ldots)$$

$$\mu_o(P_o, C_{1o}, C_{2o}, \ldots)$$

If equilibrium *K*-values are used to determine component ratios, we have:

$$\frac{C_{ig}}{C_{io}} = K_{igo}(T, P, C_{ig}, C_{io}).$$

The number of equations that must be solved in compositional simulation depends on the number of components modeled. Often, we model the lighter components individually, and group heavier components into a pseudo-component. If non-hydrocarbons are involved, these may have to also be modeled separately.

The *Black Oil* model may be considered to be a *pseudo-compositional* model with two components. Again neglecting water, if we define our components as:

- Component 1 is gas
- Component 2 is liquid

Then,

$$C_{1g} = 1 \qquad C_{2g} = 0$$

$$C_{1o} = \frac{\rho_{gS} R_{so}}{\rho_o B_o} \qquad C_{2o} = \frac{\rho_{oS}}{\rho_o B_o}$$

Substitution of these mass fractions into the *compositional* flow equation yields:

$$\frac{\partial}{\partial x}\left(\frac{kk_{rg}}{B_g \mu_g}\frac{\partial P_g}{\partial x} + \frac{kk_{ro} R_{so}}{B_o \mu_o}\frac{\partial P_o}{\partial x}\right) = \frac{\partial}{\partial t}\left[\phi\left(\frac{S_g}{B_g} + \frac{S_o R_{so}}{B_g}\right)\right]$$

$$\frac{\partial}{\partial x}\left(\frac{kk_{ro}}{B_o \mu_o}\frac{\partial P_o}{\partial x}\right) = \frac{\partial}{\partial t}\left(\frac{\phi S_o}{B_o}\right),$$

which are identical to the *Black Oil* model equations.