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Capillary Pressure Equations

Buoyancy Forces Definition

\[ \Delta \rho g \Delta h \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\Delta \rho)</td>
<td>In-situ difference in density between water and oil</td>
<td>[kg/m³]</td>
<td>[lb/cuft]</td>
<td>[g/cc]</td>
</tr>
<tr>
<td>(g)</td>
<td>Acceleration due to gravity</td>
<td>[m/s²]</td>
<td>[ft/s²]</td>
<td>[cm/s²]</td>
</tr>
<tr>
<td>(\Delta h)</td>
<td>Height above engineering oil-water contact</td>
<td>[m]</td>
<td>[ft]</td>
<td>[cm]</td>
</tr>
</tbody>
</table>

Capillary Forces Definition

\[ \frac{2\sigma \cos \theta}{r} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\sigma)</td>
<td>Surface tension between oil and water</td>
<td>[kPa/m]</td>
<td>[dyne/cm]</td>
<td>[dyne/cm]</td>
</tr>
<tr>
<td>(\theta)</td>
<td>Contact angle between oil, water and rock</td>
<td>[°]</td>
<td>[°]</td>
<td>[°]</td>
</tr>
<tr>
<td>(r)</td>
<td>Pore throat radius</td>
<td>[m]</td>
<td>[micron]</td>
<td>[μm]</td>
</tr>
</tbody>
</table>

As the all three unit systems are inconsistent, a conversion factor is technically required to equate the buoyancy forces with the capillary forces. These calculations are most easily done in laboratory units, which only requires a shift in decimal point.

Largest Pore Throat

\[ r = a_0 \frac{2\sigma \cos \theta}{P_e} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>(r)</td>
<td>Pore throat radius</td>
<td>[m]</td>
<td>[micron]</td>
<td>[μm]</td>
</tr>
<tr>
<td>(\sigma)</td>
<td>Surface tension between oil and water</td>
<td>[kPa/m]</td>
<td>[dyne/cm]</td>
<td>[dyne/cm]</td>
</tr>
<tr>
<td>(\theta)</td>
<td>Contact angle between oil, water and rock</td>
<td>[°]</td>
<td>[°]</td>
<td>[°]</td>
</tr>
<tr>
<td>(P_e)</td>
<td>Threshold pressure</td>
<td>[kPa]</td>
<td>[psi]</td>
<td>[dyne]</td>
</tr>
<tr>
<td>(a_0)</td>
<td>Unit Conversion factor</td>
<td>[calc]</td>
<td>[calc]</td>
<td>[10⁴]</td>
</tr>
</tbody>
</table>

Saturation Height

\[ \Delta h = a_1 \frac{P_c}{\Delta \rho g} \]
<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δh</td>
<td>Height above engineering oil-water contact</td>
<td>[m]</td>
<td>[ft]</td>
<td>[cm]</td>
</tr>
<tr>
<td>P_c</td>
<td>Capillary pressure</td>
<td>[kPa]</td>
<td>[psi]</td>
<td>[dyne]</td>
</tr>
<tr>
<td>Δρ</td>
<td>In-situ difference in density between water and oil</td>
<td>[kg/m³]</td>
<td>[lb/cuft]</td>
<td>[g/cc]</td>
</tr>
<tr>
<td>g</td>
<td>Acceleration due to gravity</td>
<td>[m/s²]</td>
<td>[ft/s²]</td>
<td>[cm/s²]</td>
</tr>
<tr>
<td>a₁</td>
<td>Unit Conversion factor</td>
<td>[1000.0]</td>
<td>[32.174/144.0]</td>
<td>[Calc]</td>
</tr>
</tbody>
</table>
Relative Permeability Equations

**Oil Relative Permeability Definition**

\[ k_{ro} = \frac{k_o}{k} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k_{ro} )</td>
<td>Oil relative permeability</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>( k_o )</td>
<td>Oil effective permeability</td>
<td>[mD]</td>
<td>[mD]</td>
<td>[D]</td>
</tr>
<tr>
<td>( k )</td>
<td>Absolute permeability</td>
<td>[mD]</td>
<td>[mD]</td>
<td>[D]</td>
</tr>
</tbody>
</table>

**Water Relative Permeability Definition**

\[ k_{rw} = \frac{k_w}{k} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k_{rw} )</td>
<td>Water relative permeability</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>( k_w )</td>
<td>Water effective permeability</td>
<td>[mD]</td>
<td>[mD]</td>
<td>[D]</td>
</tr>
<tr>
<td>( k )</td>
<td>Absolute permeability</td>
<td>[mD]</td>
<td>[mD]</td>
<td>[D]</td>
</tr>
</tbody>
</table>

**Oil Relative Permeability Calculation**

\[ q_o = \frac{k_{ro}kA\Delta p}{\mu_o\Delta L} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( q_o )</td>
<td>Oil rate</td>
<td>-</td>
<td>-</td>
<td>[cm³/sec]</td>
</tr>
<tr>
<td>( k_{ro} )</td>
<td>Oil relative permeability</td>
<td>-</td>
<td>-</td>
<td>[ ]</td>
</tr>
<tr>
<td>( k )</td>
<td>Absolute permeability</td>
<td>-</td>
<td>-</td>
<td>[D]</td>
</tr>
<tr>
<td>( A )</td>
<td>Cross-sectional area perpendicular to flow</td>
<td>-</td>
<td>-</td>
<td>[cm²]</td>
</tr>
<tr>
<td>( \Delta p )</td>
<td>Pressure drop in flow direction</td>
<td>-</td>
<td>-</td>
<td>[atm]</td>
</tr>
<tr>
<td>( \Delta L )</td>
<td>Length in flow direction</td>
<td>-</td>
<td>-</td>
<td>[cm]</td>
</tr>
<tr>
<td>( \mu_o )</td>
<td>Oil viscosity</td>
<td>-</td>
<td>-</td>
<td>[cP]</td>
</tr>
</tbody>
</table>
### Water Relative Permeability Calculation

\[ q_w = \frac{k_{rw}kA\Delta p}{\mu_w\Delta L} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>(q_w)</td>
<td>Water rate</td>
<td>-</td>
<td>-</td>
<td>[cm³/sec]</td>
</tr>
<tr>
<td>(k_{rw})</td>
<td>Water relative permeability</td>
<td>-</td>
<td>-</td>
<td>[ ]</td>
</tr>
<tr>
<td>(k)</td>
<td>Absolute permeability</td>
<td>-</td>
<td>-</td>
<td>[D]</td>
</tr>
<tr>
<td>(A)</td>
<td>Cross-sectional area perpendicular to flow</td>
<td>-</td>
<td>-</td>
<td>[cm²]</td>
</tr>
<tr>
<td>(\Delta p)</td>
<td>Pressure drop in flow direction</td>
<td>-</td>
<td>-</td>
<td>[atm]</td>
</tr>
<tr>
<td>(\Delta L)</td>
<td>Length in flow direction</td>
<td>-</td>
<td>-</td>
<td>[cm]</td>
</tr>
<tr>
<td>(\mu_w)</td>
<td>Water viscosity</td>
<td>-</td>
<td>-</td>
<td>[cP]</td>
</tr>
</tbody>
</table>

### Water-Oil Ratio Calculation

\[ \frac{q_w}{q_o} = \frac{k_{rw}}{\mu_w B_w} \left( \frac{\mu_o B_o}{k_{ro}} \right) \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>(q_o)</td>
<td>Oil rate</td>
<td>[sm³/d]</td>
<td>[stb/d]</td>
<td>-</td>
</tr>
<tr>
<td>(q_w)</td>
<td>Water rate</td>
<td>[sm³/d]</td>
<td>[stb/d]</td>
<td>-</td>
</tr>
<tr>
<td>(k_{ro})</td>
<td>Oil relative permeability</td>
<td>[ ]</td>
<td>[ ]</td>
<td>-</td>
</tr>
<tr>
<td>(k_{rw})</td>
<td>Water relative permeability</td>
<td>[ ]</td>
<td>[ ]</td>
<td>-</td>
</tr>
<tr>
<td>(\mu_o)</td>
<td>Oil viscosity</td>
<td>[mPa.s]</td>
<td>[cP]</td>
<td>-</td>
</tr>
<tr>
<td>(\mu_w)</td>
<td>Water viscosity</td>
<td>[mPa.s]</td>
<td>[cP]</td>
<td>-</td>
</tr>
<tr>
<td>(B_o)</td>
<td>Oil formation volume factor</td>
<td>[m³/sm³]</td>
<td>[bbl/stb]</td>
<td>-</td>
</tr>
<tr>
<td>(B_w)</td>
<td>Water formation volume factor</td>
<td>[m³/sm³]</td>
<td>[bbl/stb]</td>
<td>-</td>
</tr>
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</table>
Laboratory Procedures Equations – Relative Permeability

Darcy’s Law for Oil

\[ q_o = k_o \frac{\pi \left( \frac{d}{2} \right)^2 \Delta p}{\mu_o x} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k_o )</td>
<td>Oil effective permeability</td>
<td></td>
<td>[D]</td>
<td></td>
</tr>
<tr>
<td>( d )</td>
<td>Diameter of core sample</td>
<td></td>
<td>[cm]</td>
<td></td>
</tr>
<tr>
<td>( \pi )</td>
<td>Circle constant (~3.14)</td>
<td></td>
<td></td>
<td>[dimensionless]</td>
</tr>
<tr>
<td>( \Delta p )</td>
<td>Pressure drop in flow direction</td>
<td></td>
<td>[atm]</td>
<td></td>
</tr>
<tr>
<td>( x )</td>
<td>Length in flow direction</td>
<td></td>
<td>[cm]</td>
<td></td>
</tr>
<tr>
<td>( \mu_o )</td>
<td>Oil viscosity</td>
<td></td>
<td></td>
<td>[cP]</td>
</tr>
</tbody>
</table>

Darcy’s Law for Water

\[ q_w = k_w \frac{\pi \left( \frac{d}{2} \right)^2 \Delta p}{\mu_w x} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k_w )</td>
<td>Water effective permeability</td>
<td></td>
<td>[D]</td>
<td></td>
</tr>
<tr>
<td>( d )</td>
<td>Diameter of core sample</td>
<td></td>
<td>[cm]</td>
<td></td>
</tr>
<tr>
<td>( \pi )</td>
<td>Circle constant (~3.14)</td>
<td></td>
<td></td>
<td>[dimensionless]</td>
</tr>
<tr>
<td>( \Delta p )</td>
<td>Pressure drop in flow direction</td>
<td></td>
<td>[atm]</td>
<td></td>
</tr>
<tr>
<td>( x )</td>
<td>Length in flow direction</td>
<td></td>
<td>[cm]</td>
<td></td>
</tr>
<tr>
<td>( \mu_w )</td>
<td>Water viscosity</td>
<td></td>
<td></td>
<td>[cP]</td>
</tr>
</tbody>
</table>

Oil Relative Permeability Definition

\[ k_{ro} = \frac{k_o}{k} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k_{ro} )</td>
<td>Oil relative permeability</td>
<td>[ ]</td>
<td>[]</td>
<td>[]</td>
</tr>
<tr>
<td>( k_o )</td>
<td>Oil effective permeability</td>
<td>[mD]</td>
<td>[mD]</td>
<td>[D]</td>
</tr>
<tr>
<td>( k )</td>
<td>Absolute permeability</td>
<td>[mD]</td>
<td>[mD]</td>
<td>[D]</td>
</tr>
</tbody>
</table>
Water Relative Permeability Definition

\[ k_{rw} = \frac{k_w}{k} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k_{rw} )</td>
<td>Water relative permeability</td>
<td>[ ]</td>
<td>[ ]</td>
<td>[ ]</td>
</tr>
<tr>
<td>( k_w )</td>
<td>Water effective permeability</td>
<td>[mD]</td>
<td>[mD]</td>
<td>[D]</td>
</tr>
<tr>
<td>( k )</td>
<td>Absolute permeability</td>
<td>[mD]</td>
<td>[mD]</td>
<td>[D]</td>
</tr>
</tbody>
</table>

Saturation Mass Balance I

\[ m_s = m_o + m_w + m_r \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( m_s )</td>
<td>Mass of saturated core sample</td>
<td>[mg]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( m_o )</td>
<td>Mass of oil in saturated core sample</td>
<td>[mg]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( m_w )</td>
<td>Mass of water in saturated core sample</td>
<td>[mg]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( m_r )</td>
<td>Mass of rock (solid material) in saturated core sample</td>
<td>[mg]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Saturation Mass Balance II

\[ m_s = [\rho_o \phi (1 - S_w) + \rho_w \phi S_w + \rho_r (1 - \phi)] \left( \pi \left( \frac{d}{2} \right)^2 x \right) \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Units</th>
<th>Oilfield Units</th>
<th>Lab Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \rho_o )</td>
<td>Oil density</td>
<td>[g/cc]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \rho_w )</td>
<td>Water density</td>
<td>[g/cc]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \rho_r )</td>
<td>Rock (solid material) density</td>
<td>[g/cc]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( S_w )</td>
<td>Core sample water saturation</td>
<td>[dimensionless]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \phi )</td>
<td>Core sample porosity</td>
<td>[dimensionless]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( d )</td>
<td>Diameter of core sample</td>
<td>[cm]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( x )</td>
<td>Length in flow direction</td>
<td>[cm]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>( \pi )</td>
<td>Circle constant (~3.14)</td>
<td>[dimensionless]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Laboratory Procedures Equations – Capillary Pressure

**Corrections to Laboratory Data**

\[ p_{c_{res}} = p_{c_{lab}} \times \left( \frac{\sigma_{res} \cos \varphi_{res}}{\sigma_{lab} \cos \varphi_{lab}} \right) \]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Lab Units</th>
<th>SI Units</th>
<th>Oilfield Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_{c_{res}} )</td>
<td>Capillary pressure – reservoir conditions</td>
<td>[mbar]</td>
<td>[kPa]</td>
<td>[psi]</td>
</tr>
<tr>
<td>( p_{c_{lab}} )</td>
<td>Capillary pressure – laboratory conditions</td>
<td>[mbar]</td>
<td>[kPa]</td>
<td>[psi]</td>
</tr>
<tr>
<td>( \sigma_{res} )</td>
<td>Interfacial tension - reservoir conditions</td>
<td>[dyne.cm]</td>
<td>[N.m]</td>
<td>[dyne.cm]</td>
</tr>
<tr>
<td>( \sigma_{lab} )</td>
<td>Interfacial tension – laboratory conditions</td>
<td>[dyne.cm]</td>
<td>[N.m]</td>
<td>[dyne.cm]</td>
</tr>
<tr>
<td>( \varphi_{res} )</td>
<td>Contact angle – reservoir conditions</td>
<td>[°]</td>
<td>[°]</td>
<td>[°]</td>
</tr>
<tr>
<td>( \varphi_{lab} )</td>
<td>Contact angle – laboratory conditions</td>
<td>[°]</td>
<td>[°]</td>
<td>[°]</td>
</tr>
</tbody>
</table>
Laboratory Procedures Equations – Wettability

Oil Index

\[ I_o = \frac{V_2}{V_2 + V_3} \]

\[ 0 \leq I_o \leq 1 \]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Lab Unit</th>
<th>SI Unit</th>
<th>Oilfield Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_o )</td>
<td>Oil index</td>
<td>[dimensionless]</td>
<td>[dimensionless]</td>
<td>[dimensionless]</td>
</tr>
<tr>
<td>( V_2 )</td>
<td>Oil spontaneously entering core</td>
<td>[cc]</td>
<td>[m³]</td>
<td>[bbl]</td>
</tr>
<tr>
<td>( V_3 )</td>
<td>Oil entering core under force</td>
<td>[cc]</td>
<td>[m³]</td>
<td>[bbl]</td>
</tr>
</tbody>
</table>

Water Index

\[ I_w = \frac{V_4}{V_4 + V_5} \]

\[ 0 \leq I_w \leq 1 \]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Lab Unit</th>
<th>SI Unit</th>
<th>Oilfield Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_w )</td>
<td>Water index</td>
<td>[dimensionless]</td>
<td>[dimensionless]</td>
<td>[dimensionless]</td>
</tr>
<tr>
<td>( V_4 )</td>
<td>Water spontaneously entering core</td>
<td>[cc]</td>
<td>[m³]</td>
<td>[bbl]</td>
</tr>
<tr>
<td>( V_5 )</td>
<td>Water entering core under force</td>
<td>[cc]</td>
<td>[m³]</td>
<td>[bbl]</td>
</tr>
</tbody>
</table>

Amott Index

\[ I_A = I_w - I_o \]

\[ -1 \leq I_A \leq 1 \]

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Lab Unit</th>
<th>SI Unit</th>
<th>Oilfield Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( I_A )</td>
<td>Amott index</td>
<td>[dimensionless]</td>
<td>[dimensionless]</td>
<td>[dimensionless]</td>
</tr>
<tr>
<td>( I_o )</td>
<td>Oil index</td>
<td>[dimensionless]</td>
<td>[dimensionless]</td>
<td>[dimensionless]</td>
</tr>
<tr>
<td>( I_w )</td>
<td>Water index</td>
<td>[dimensionless]</td>
<td>[dimensionless]</td>
<td>[dimensionless]</td>
</tr>
</tbody>
</table>

Modeling Equations
Modified-Corey Water Relative Permeability

\[ k_{rw} = k_{rw}^*(S_w^*)^m \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Unit</th>
<th>Oilfield Unit</th>
<th>Lab Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k_{rw} )</td>
<td>2-phase water relative permeability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( k_{rw}^* )</td>
<td>2-phase water relative permeability end-point</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( m )</td>
<td>2-phase water saturation exponent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( S_w^* )</td>
<td>Normalized water saturation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Normalized Water Saturation

\[ S_w^* = \frac{S_w - S_{wc}}{1 - S_{wc} - S_{orw}} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Unit</th>
<th>Oilfield Unit</th>
<th>Lab Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( S_w^* )</td>
<td>Normalized water saturation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( S_w )</td>
<td>Actual water saturation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( S_{wc} )</td>
<td>Critical water saturation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( S_{orw} )</td>
<td>Residual oil saturation to water</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Modified-Corey Oil Relative Permeability

\[ k_{ro} = k_{ro}^*(1 - S_w^*)^n \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Unit</th>
<th>Oilfield Unit</th>
<th>Lab Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k_{ro} )</td>
<td>2-phase oil relative permeability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( k_{ro}^* )</td>
<td>2-phase oil relative permeability end-point</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( n )</td>
<td>2-phase oil saturation exponent</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( S_w^* )</td>
<td>Normalized water saturation</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Stone’s First 3-Phase Relative Permeability

\[ k_{ro} = (k_{rw} + k_{row})(k_{rg} + k_{rog}) - (k_{rw} + k_{rg}) \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Unit</th>
<th>Oilfield Unit</th>
<th>Lab Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( k_{ro} )</td>
<td>3-phase oil relative permeability</td>
<td></td>
<td>[dimensionless]</td>
<td></td>
</tr>
<tr>
<td>( k_{row} )</td>
<td>2-phase oil relative permeability from oil-water table</td>
<td></td>
<td>[dimensionless]</td>
<td></td>
</tr>
<tr>
<td>( k_{rog} )</td>
<td>2-phase oil relative permeability from gas-oil table</td>
<td></td>
<td>[dimensionless]</td>
<td></td>
</tr>
<tr>
<td>( k_{rg} )</td>
<td>2-phase gas relative permeability</td>
<td></td>
<td>[dimensionless]</td>
<td></td>
</tr>
<tr>
<td>( k_{rw} )</td>
<td>2-phase water relative permeability</td>
<td></td>
<td>[dimensionless]</td>
<td></td>
</tr>
</tbody>
</table>

Thomeer Capillary Pressure

\[ \ln(1 - S_w) = \frac{-G}{\log \frac{p_c}{p_d}} \]

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Description</th>
<th>SI Unit</th>
<th>Oilfield Unit</th>
<th>Lab Unit</th>
</tr>
</thead>
<tbody>
<tr>
<td>( p_c )</td>
<td>Capillary pressure</td>
<td>[kPa]</td>
<td>[psi]</td>
<td>[atm]</td>
</tr>
<tr>
<td>( p_d )</td>
<td>Threshold pressure</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( G )</td>
<td>Interporosity coefficient</td>
<td></td>
<td>[dimensionless]</td>
<td></td>
</tr>
<tr>
<td>( S_w )</td>
<td>Water (or more precisely, wetting) saturation</td>
<td></td>
<td>[dimensionless]</td>
<td></td>
</tr>
</tbody>
</table>