2015

Heat and mass transfer during the sump development in a potash solution mine

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http://hdl.handle.net/10026.1/14084

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Appendix A: Derivation of Rectangular Interior Node

\[
\frac{\partial^2 T}{\partial x^2} = \frac{T_2 + T_4 - 2T_0}{a^2}
\]

\[
\frac{\partial^2 T}{\partial y^2} = \frac{T_1 + T_3 - 2T_0}{b^2}
\]

\[
\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = \frac{T_2 + T_4 - 2T_0}{a^2} + \frac{T_1 + T_3 - 2T_0}{b^2}
\]

\[
\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = \frac{b^2(T_2 + T_4 - 2T_0) + a^2(T_1 + T_3 - 2T_0)}{b^2a^2}
\]

\[
\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = \frac{b^2(T_2 + T_4) + a^2(T_1 + T_3) - 2T_0(b^2 + a^2)}{b^2a^2}
\]

\[
\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = 0
\]

\[
b^2(T_2 + T_4) + a^2(T_1 + T_3) - 2T_0(b^2 + a^2) = 0
\]

\[
T_0 = \frac{b^2(T_2 + T_4) + a^2(T_1 + T_3)}{2(b^2 + a^2)}
\]
Appendix B: FDM Equations for Rectangular Nodes

Interior Nodes

\[ T_0 = \frac{b^2 (T_2 + T_4) + a^2 (T_1 + T_3)}{2(b^2 + a^2)} \]

Isothermal Boundary Layer

\[ T_0 = \left( \frac{T_1}{2} + T_2 + \frac{T_3}{2} + \frac{ha}{\lambda} T_f \right) \left( 1 + \frac{ha}{\lambda} \right) \]
External Corner Node

$$T_0 = \left( \frac{T_r}{2} + \frac{T_1}{2} + \frac{ha}{\lambda} T_r \right) \frac{1}{1 + \frac{ha}{\lambda}}$$

Appendix C: Depth Calculation

$$y = 5e-6x^2 + 0.0031x + 292.67$$

When $y = 328$

$$328 = 5e-6x^2 + 0.0031x + 292.67$$

$$0 = 5e-6x^2 + 0.0031x -35.33$$

Using the quadratic equation:

$$x = \frac{-0.0031 + \sqrt{(0.0031)^2 - (4 \cdot 5e-6 \cdot -35.33)}}{2 \cdot 0.0031}$$

$$x = 2366.21 \, \text{m}$$
Appendix D: Equating of Heat Transfer Equations

\[ \dot{Q} = h \Delta T_{SL} a c \]

\[ T_b = T_t - \frac{\dot{Q} \Delta z}{\rho C_p u V} \]

Therefore

\[ \dot{Q} = \frac{\Delta T_{tb} \rho C_p u V}{\Delta z} \]

Equating the two equations gives;

\[ \frac{\Delta T_{tb} \rho C_p u V}{\Delta z} = h \Delta T_{SL} a c \]

\[ \frac{\Delta T_{tb} \rho C_p u V}{\Delta z h a c} = \Delta T_{SL} \]
### Appendix E: Fluid Properties

<table>
<thead>
<tr>
<th>Fluid</th>
<th>Density (kg/m$^3$)</th>
<th>Prandtl Number</th>
<th>Thermal Conductivity (W/mK)</th>
<th>Viscosity (pa.s)</th>
<th>Specific Heat Capacity (J/kgK)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1000</td>
<td>9.29</td>
<td>0.59</td>
<td>0.001002</td>
<td>4193</td>
<td>Haywood, 1990</td>
</tr>
<tr>
<td>Brine</td>
<td>1076.8</td>
<td>9.29</td>
<td>0.59</td>
<td>0.001002</td>
<td>4193</td>
<td>Haywood, 1990 and Lide, 2004</td>
</tr>
<tr>
<td>Diesel</td>
<td>820.8</td>
<td>27.74</td>
<td>0.14</td>
<td>0.012</td>
<td>1914.21</td>
<td>Chemical Hazards Response Information System, cited in Zen-Stoves, 1999</td>
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<tr>
<td>Gasoline</td>
<td>704.01</td>
<td>6.68</td>
<td>0.88</td>
<td>0.00041</td>
<td>2055.72</td>
<td>Chemical Hazards Response Information System, cited in Zen-Stoves, 1999</td>
</tr>
<tr>
<td>Naphtha</td>
<td>849.94</td>
<td>73.13</td>
<td>0.15</td>
<td>0.0055</td>
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<td>Chemical Hazards Response Information System, cited in Zen-Stoves, 1999</td>
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<tr>
<td>Kerosene</td>
<td>793.87</td>
<td>17.22</td>
<td>0.13</td>
<td>0.0011</td>
<td>1963.61</td>
<td>Chemical Hazards Response Information System, cited in Zen-Stoves, 1999</td>
</tr>
</tbody>
</table>
All properties taken at 20°C and 12% KCl by mass in water.