

2015

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

Ellard, O.

Ellard, O. (2015) 'Heat and mass transfer during the sump development in a potash solution mine', *The Plymouth Student Scientist*, 8(1), p. 41-65.

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

---

The Plymouth Student Scientist  
University of Plymouth

---

*All content in PEARL is protected by copyright law. Author manuscripts are made available in accordance with publisher policies. Please cite only the published version using the details provided on the item record or document. In the absence of an open licence (e.g. Creative Commons), permissions for further reuse of content should be sought from the publisher or author.*

## Appendix A: Derivation of Rectangular Interior Node

---

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

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

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

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

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

$$\frac{\partial^2 T}{\partial x^2} + \frac{\partial^2 T}{\partial y^2} = 0 \text{ Therefore;}$$

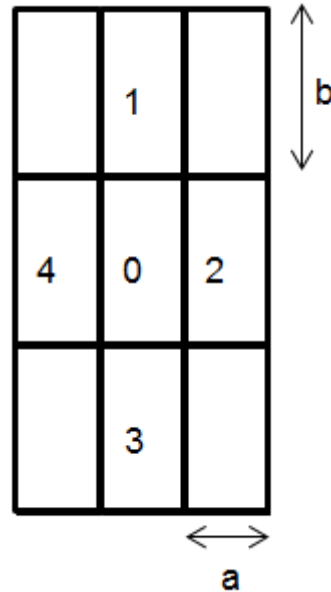
$$b^2(T_2 + T_4) + a^2(T_1 + T_3) - 2T_0(b^2 + a^2) = 0$$

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

## Appendix B: FDM Equations for Rectangular Nodes

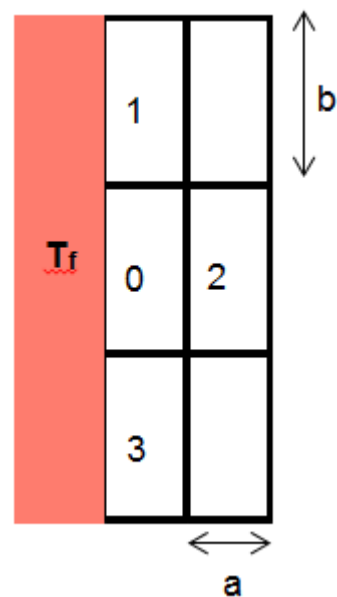
### Interior Nodes

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



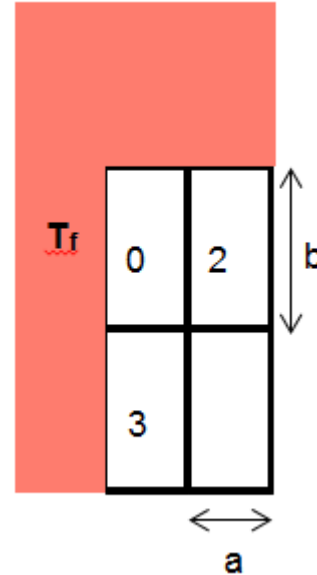
### Isothermal Boundary Layer

$$T_0 = \left( \frac{T_1}{2} + T_2 + \frac{T_3}{2} + \frac{ha}{\lambda} T_f \right) \frac{1}{2 + \frac{ha}{\lambda}}$$



## External Corner Node

$$T_0 = \left( \frac{T_2}{2} + \frac{T_3}{2} + \frac{ha}{\lambda} T_f \right) \frac{1}{1 + \frac{ha}{\lambda}}$$



## 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

$$\dot{Q} = h\Delta T_{SL} ac$$

$$T_b = T_t - \frac{\dot{Q}\Delta z}{\rho C_p uV} \text{ therefore } \dot{Q} = \frac{\Delta T_{tb} \rho C_p uV}{\Delta z}$$

Equating the two equations gives;

$$\frac{\Delta T_{tb} \rho C_p uV}{\Delta z} = h\Delta T_{SL} ac$$

$$\frac{\Delta T_{tb} \rho C_p uV}{\Delta z h a c} = \Delta T_{SL}$$

Appendix E: Fluid Properties

<b>Fluid</b>	<b>Density (kg/m<sup>3</sup>)</b>	<b>Prandtl Number</b>	<b>Thermal Conductivity (W/mK)</b>	<b>Viscosity (pa.s)</b>	<b>Specific Heat Capacity (J/kgK)</b>	<b>Reference</b>
Water	1000	9.29	0.59	0.001002	4193	Haywood, 1990
Brine	1076.8	9.29	0.59	0.001002	4193	Haywood,19 90 and Lide, 2004
Diesel	820.8	27.74	0.14	0.012	1914.21	Chemical Hazards Response Information System, cited in Zen- Stoves, 1999
Gasoline	704.01	6.68	0.88	0.00041	2055.72	Chemical Hazards Response Information System, cited in Zen- Stoves, 1999
Naphtha	849.94	73.13	0.15	0.0055	2001.29	Chemical Hazards Response Information System, cited in Zen- Stoves, 1999
Kerosene	793.87	17.22	0.13	0.0011	1963.61	Chemical Hazards Response

						Information System, cited in Zen-Stoves, 1999
--	--	--	--	--	--	---

All properties taken at 20°C and 12% KCl by mass in water.