We have a partial differential equation:

$$\theta \frac{\partial u}{\partial t} = \frac{\kappa}{r}\frac{\partial u}{\partial r} + \kappa \frac{\partial^2 u}{\partial r^2} + Q(t,r) \tag{1}$$

with boundary conditions:

$$\left.\frac{\partial u}{\partial r}\right|_{r=0} = 0, \quad \kappa \left.\frac{\partial u}{\partial r}\right|_{r=R} = -hT(t,R) \tag{2}$$

We distretise the r variable first to get:

$$\theta \frac{du_j}{dt} = \frac{\kappa}{r} \cdot \frac{u_{j+1} - u_{j-1}}{\delta r} + \kappa \frac{u_{j+1} - 2u_j + u_{j-1}}{\delta^2} + Q_j \tag{3}$$

This can be arranged into:

$$\theta \frac{du_j}{dt} = \frac{\kappa}{\delta r^2} \left[\left(1 + \frac{\delta r}{r}\right) u_{j+1} - 2u_j + \left(1 - \frac{\delta r}{r}\right) u_{j-1} \right] + Q_j \tag{4}$$

This is a vector equation in the u_j's.

$$\theta \frac{d\mathbf{u}}{dt} = \frac{\kappa}{\delta r^2}\mathbf{A}\mathbf{u} + \mathbf{Q} \tag{5}$$

Here $\mathbf{A}$ is a tri-diagonal matrix. Now we apply the Crank-Nicholson method:

$$\theta(\mathbf{u}^{i+1} - \mathbf{u}^i) = \frac{\kappa \delta t}{2\delta r^2}(\mathbf{A}\mathbf{u}^{i+1} + \mathbf{A}\mathbf{u}^i) + \frac{\delta t}{2}(\mathbf{Q}^{i+1} + \mathbf{Q}^i) \tag{6}$$

Upon denoting $\alpha = \kappa \delta t/(2\delta r^2)$, the equation then becomes:

$$(\theta \mathbf{I} - \alpha \mathbf{A})\mathbf{u}^{i+1} = (\theta \mathbf{I} + \alpha \mathbf{A})\mathbf{u}^i + \frac{\delta t}{2}(\mathbf{Q}^{i+1} + \mathbf{Q}^i) \tag{7}$$

In terms of indecies, this stencil becomes:

$$(\theta \delta_{jk} - \alpha A_{jk})u_{i+1,k} = (\theta \delta_{jk} + \alpha A_{jk})u_{i,k} + \frac{\delta t}{2}(Q_{i+1,j} + Q_{i,j}). \tag{8}$$

The k takes values $j-1, j, j+1$. To tackle the boundary at $r = 0$, write $u = A_1 + A_2 r^2$, then

$$\frac{1}{r}\frac{\partial u}{\partial r}\left(r \frac{\partial u}{\partial r}\right) = 4A_2$$

and $A_1 = u^1$ and $A_2 = (u^2 - u^1)/\delta r^2$ and the equation becomes:

$$\theta \frac{du^1}{dt} = \frac{4u^1 - 4u^2}{\delta r^2} + Q_1 \tag{9}$$

Which makes the first row of the matrix $\mathbf{A}$ to be $A(1,:) = (-4, 4, 0, \ldots, 0)$. To include the final boundary condition examine the $j = N$th node:

$$-\alpha A_{N,N-1}u_{i,N-1} + (\theta - \alpha A_{N,N})u_{i,N} - \alpha A_{N,N+1}u_{i,N+1}$$

The boundary condition is written as:

$$\kappa \frac{u_{i,N+1} - u_{i,N-1}}{2\delta r} = -h u_{i,N} \Rightarrow u_{i,N+1} = u_{i,N-1} - \frac{2h\delta r}{\kappa} u_{i,N}$$

The row becomes:

$$-\alpha(A_{N.N-1} + A_{N,N+1})u_{i,N-1} + (\theta + 2h\delta r/\kappa - \alpha A_{N,N})u_{i,N} \tag{10}$$