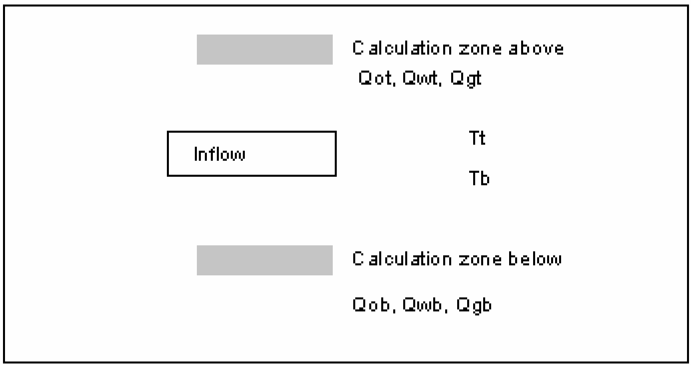
E05 • Temperature Modelling

Two distinct models are used, whether the simulation is made within, or outside inflow zones:

Within inflow zones

The temperature is calculated from enthalpy balance.



The enthalpy of the fluid at the bottom of the inflow zone is calculated as:

$$H_b = \left(Q_{ob} \times C_{po} \times \rho_o + Q_{wb} \times C_{pw} \times \rho w + Q_{gb} \times C_{pg} \times \rho g\right) \times T_b$$

Tb, the bottom temperature, is read directly from the reference temperature log. The Cp's are the heat capacities of the various fluids, defined in the PVT model.

The enthalpy at the top of the inflow zone is given by:

$$H_t = \left(Q_{ot} \times C_{po} \times \rho_o + Q_{wt} \times C_{pw} \times \rho w + Qt \times C_{pg} \times \rho g\right) \times T_t$$

It is assumed that the geothermal temperature profile is given. The incoming fluids are supposed to enter at a temperature equal to the geothermal temperature at the mid-point of the inflow zone, Tgeo. For the gas, the entry temperature is corrected for Joule-Thomson.

Joule-Thomson

For the gas, an isenthalpic process is assumed, leading to:

$$T_{gas} = T_{geo} + \frac{R \times T^2}{M \times Cp} \times \frac{dZ}{dT} \times \frac{\Delta P}{P}$$

Enthalpy balance between the top and bottom of the inflow zone gives:

$$H_t = H_b + \left(\Delta Q_{ob} \times C_{po} \times \rho_o + \Delta Q_{wb} \times C_{pw} \times \rho w\right) \times T_{geo} + \Delta Q_{gb} \times C_{pg} \times \rho g \times T_{gas}$$

Therefore:

$$T_t = \frac{Hb + \left(\Delta Q_{ob} \times C_{po} \times \rho_o + \Delta Q_{wb} \times C_{pw} \times \rho w\right) \times T_{geo} + \Delta Q_{gb} \times C_{pg} \times \rho g \times T_{gas}}{\left(Q_{ot} \times C_{po} \times \rho_o + Q_{wt} \times C_{pw} \times \rho w + Q_{gt} \times C_{pg} \times \rho g\right)}$$

Note that this equation does hold only if all the contributions are positive. Extensions are made in other situations.

Between inflow zones

With Reference to the SPE Reprint Series No 19, and more specifically the paper “Use of Temperature Log For Determining Flow Rates in Producing Wells”, by Curtis & Witterholt, the temperature above a fluid entry zone is given by:

$$T_f(z,t) = T_{Ge} - g_G \times z + g_G \times A + \left(T_{fe} - T_{Ge} - g_G \times A\right) \times e^{\frac{-z}{A}}$$

This equation was introduced by Ramey.

Tf = wellbore temperature
TGe = geothermal temperature at depth of fluid entry
gG = geothermal gradient
z = distance from fluid entry measured updwards
Tfe = wellbore temperature at depth of fluid entry
A = relaxation distance

Under certain assumptions, the relaxation distance A can be expressed as:

$$A = q \times \rho_f \times C_{pf} \frac{f(t)}{2 \times \pi \times k_h}$$

In Emeraude, the user is asked to input a “Heat loss coefficient” equal to the inverse of $\frac{A}{q \times \rho_f \times C_{pf}}$.

This is assumed a constant throughout the log.

The heat loss coefficient can be expressed using the formation heat conductivity, and diffusivity. The time function is given by Ramey and could be calculated knowing the production time. However, this coefficient can also be calculated directly from the log if the surface rates are known. It was decided to use this approach instead. This calculation is done automatically when reaching Zone Rates the first time. Also, the Heat loss coefficient can be included when matching surface conditions in the regression.