Table 1.5: Summary of improtant relations for internal forced convection

Condition	Equations
Hydrodynamic entry length, laminar flow	$\left(\frac{x_{fd,h}}{D}\right)_{lam} = 0.05Re_D$
Hydrodynamic entry lenght, turbulent flow	$\left(\frac{x_{fd,h}}{D}\right)_{turb} \approx 10$
Thermal entry length, laminar flow	$\left(\frac{x_{fd,t}}{D}\right)_{lam} = 0.05Re_D Pr$
Thermal entry length, turbulent flow	$\left(\frac{x_{fd,t}}{D}\right)_{turb} \approx 10$
Mean temperature or mixing cup temperature	$T_m(x) = \frac{2\pi\rho}{\dot{m}}\int_0^{r_o} ru(r)T(r,x)dr$
Thermally fully developed condition	$\frac{\partial}{\partial x}\left[\frac{T_s(x)-T(r,x)}{T_s(x)-T_m(x)}\right]_{fd,t} = 0$
For thermally fully developed condition	$h \neq f(x)$
Relation between temperature derivatives: fully developed, constant surface heat flux	$\frac{\partial T_s(x)}{\partial x} = \frac{\partial T(r,x)}{\partial x} = \frac{\partial T_m(x)}{\partial x}$
Energy balance for pipe flow	$\frac{dT_m(x)}{dx} = \frac{2\pi r_0 q_w}{\dot{m}\hat{c}_p}$
Length wise mean temperature variation, constant wall temperature	$\Delta T_o = \Delta T_i \exp\left(-\frac{A_T\bar{h}}{\dot{m}\hat{c}_p}\right)$
Total rate of heat transfer, constant wall temperature	$\dot{Q}_{tot} = A_T\bar{h}\Delta T_{lm}$