# Problem Set 1: Examining the Energy Balance

For this problem set, I will accept submissions with one or two names.

(1) Beginning with the simplified energy balance for the shower

$$T = \frac{F_h}{F_h + F_c} T_h + \frac{F_c}{F_h + F_c} T_c$$

fill in the missing steps to derive the linearized energy balance

$$T = \frac{F_{hr}T_{hr} + F_{cr}T_{cr}}{F_{hr} + F_{cr}} + \left[\frac{T_{hr}}{F_{hr} + F_{cr}} - \frac{F_{hr}T_{hr} + F_{cr}T_{cr}}{\left(F_{hr} + F_{cr}\right)^2}\right]\left(F_h - F_{hr}\right) + \frac{F_{hr}}{F_{hr} + F_{cr}}\left(T_h - T_{hr}\right)$$
$$+ \left[\frac{T_{cr}}{F_{hr} + F_{cr}} - \frac{F_{hr}T_{hr} + F_{cr}T_{cr}}{\left(F_{hr} + F_{cr}\right)^2}\right]\left(F_c - F_{cr}\right) + \frac{F_{cr}}{F_{hr} + F_{cr}}\left(T_c - T_{cr}\right)$$

- (please use the nomenclature of the Lecture Notes)

(2) Specify practical reference conditions for each of the variables in the energy balance. For example, we know that a shower is more than a trickle and less than a torrent – what is a reasonable flowrate? We will regard these reference values as the desired operating condition for our process, and thus they should satisfy the steady state M&EB.

- (please use the nomenclature of the Lecture Notes)
- (will people look at you strangely if they see you in the dormitory shower room with a bucket and stopwatch?)

(3) The energy balance ought to tell us something useful. Compute how outlet temperature T varies with inlet hot flow $F_h$ over the domain from 0 to twice the reference value $F_{hr}$ you chose in (2). Make the computation from both the simplified and linearized energy balances in (1). Plot these results together on T vs. $F_h$ axes. Compute enough points so that you get the sort of plot Dr. Dalzell would approve.

- What do you observe about the accuracy of a linearized model?

(4) Specify practical operating ranges for each variable in the energy balance. It's the sort of decision you would make in designing an experimental apparatus – what range of gauge do I buy? How much will this variable actually vary? The Lecture Notes offer some considerations for making this decision.

- (please use the nomenclature of the Lecture Notes)

(5) Express the results of (3) as scaled deviation variables, using the reference values of (2) and the scaling ranges of (4). Make the analogous plot on $T^{*'}$ vs. $F_h^{*'}$ axes. Do you see how decisions made in (4) could affect the appearance of the dimensionless plot?

  