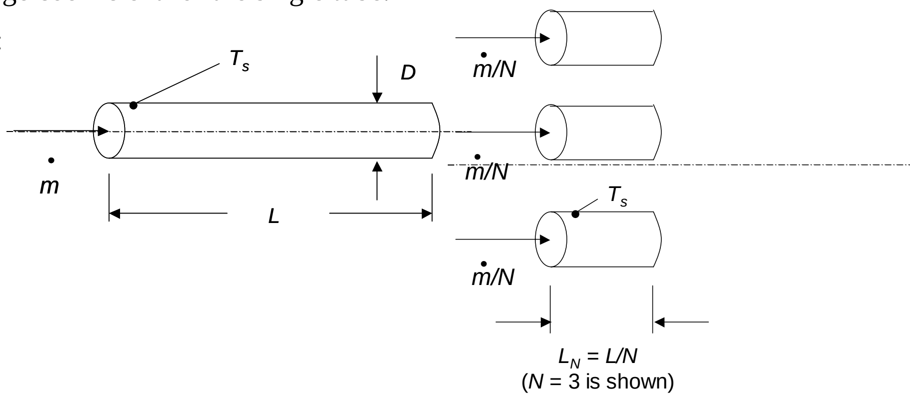
PROBLEM 8.54

KNOWN: Length of a tube with constant surface temperature and a combined entrance length, $L < x_{fd,t}$.

FIND: Expression for the ratio of the average heat transfer coefficient for N tubes each of length $L_N = L/N$ to the average coefficient for the single tube.

SCHEMATIC:



ASSUMPTIONS: (1) Combined entrance conditions, (2) Constant properties, (3) Negligible viscous dissipation.

PROPERTIES: Given: $Pr = 4$.

ANALYSIS: The Nusselt number for the combined entrance problem with $0.1 < Pr < 5$ is given by Equation 8.58 and is seen to be a function of the Graetz number, $Gz_D = DRe_DPr/L$, and the Prandtl number, Pr. For multiple tubes, each of length $L_N = L/N$ with a flowrate of $\dot{m}_N = \dot{m}/N$, observe that $Re_{D,N} = Re_{D,1}/N$, resulting in

$$Gz_{D,N} = DRe_{D,N}Pr/L_N = DRe_{D,1}Pr/L = Gz_{D,1}$$

Since the Graetz number is unchanged, and Pr has been specified as constant, the Nusselt number is unchanged. With $h = Nu_Dk/D$,

$$\bar{h}_{D,N} / \bar{h}_{D,1} = 1 \qquad <$$

COMMENTS: (1) Breaking the tube into shorter lengths has no impact on the overall heat transfer rate. Shortening the tube will, in general, tend to increase the average heat transfer coefficient, but this effect is offset by reduction of the flow rate in each of the shorter tubes. The scheme would not result in any heat transfer *enhancement*. (2) The same result holds for the thermal entrance problem, since the Nusselt number is also a function only of Gz_D.