



## Module 3: Internal Flows

### Lecture 17: Some Practical Applications

#### The Lecture Contains:

-  Summary of the Solutions for Various Flow and Heat Transfer Situation in Internal Flows A
-  Convection correlations for non-circular tubes:

 **Previous**    **Next** 

### Summary of the Solutions for Various Flow and Heat Transfer Situation in Internal Flows

A marvelous compilation of different results due to various investigations are available in **Shah and London (1978)** [Shah, R. K., and London, A. L., **Advances in Heat Transfer, Laminar Flow Forced Convection in ducts, Academic Press, New York, 1978**]. **Figure 3.12** provides the results in a comprehensive manner



$$\frac{x/D}{Re Pr}$$

$Nu_D$  is plotted against the **dimensionless parameter**  $\frac{x/D}{Re Pr}$  **or reciprocal of Graetz number**. (Graetz number  $G \equiv \frac{D Re Pr}{x}$ ). Fully developed values are independent of Prandtl number. Fully developed conditions are reached for  $\frac{x/D}{Re Pr} \approx 0.05$ .

For the constant surface temperature condition, it is desirable to know the average convection coefficient (in the entry length) **for use with equation (3.40)**  $q_{conv} = \bar{h} A_w \Delta T_{l,m}$ . Hausen presents the following correlation for hydrodynamically fully developed flow (laminar) in tubes at constant wall temperature

$$\overline{Nu}_D = 3.66 + \frac{0.0668(D/L)Re_D Pr}{1 + 0.04[(D/L)Re_D Pr]^{2/3}}$$

Module 3: Internal Flows

Lecture 17: Some Practical Applications

Because the above result is for thermally developing flow, it is not generally applicable. For simultaneously developing flow, a suitable correlation due to **Sieder and Tate (1936)** is of the form:

$$\overline{Nu}_D = 1.86 \left[ \frac{Re_D Pr}{L/D} \right]^{1/3} \left( \frac{\mu}{\mu_w} \right)^{0.14}$$

All properties are evaluated at  $T_m = (T_{m,0} + T_{m,i})/2$ ,  $\mu_w$  is the viscosity of the fluid at wall temperature.





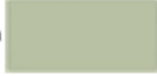

Cross section	$\frac{b}{a}$	$Nu_D = (hD_n)/k$	
		Constant $q'_s$	Constant $T_w$
	-	4.36	3.66
	1.0	3.61	2.98
	1.43	3.73	3.08
	2.0	4.12	3.39
	3.0	4.79	3.96
-	4.0	5.33	4.44
-	8.0	6.49	5.60
(parallel plate)	$\alpha$	8.23	7.54
		3.00	2.35

Table 3.1: Nusselt numbers for fully developed laminar flow intubes of differing cross section.

## Module 3: Internal Flows

## Lecture 17: Some Practical Applications

**Convection correlations for non-circular tubes:**

To a first approximation, many of the circular tube results may be applied by using hydraulic diameter as characteristic length which is

$$D_h = \frac{4A_c}{P}$$

Here,  **$A_c$  flow cross sectional area and  $P$  wetted perimeter**

However, in a non-circular tube, the convection coefficients vary around the periphery,

**38 approaches zero in the corners.**

For turbulent flow [ i.e., for  $Re_{D_h} > 2300$ ] often it is reasonable to use the modied ( $D \rightarrow D_h$ ) circular tube correlations. However, for laminar flow, the use of circular tube correlations are less accurate. For such cases **Nusselt number corresponding to fully developed condition may be obtained from Shah and London's book. Some results are shown in Table 3.1.**

◀ Previous   Next ▶

**Module 3: Internal Flows****Lecture 17: Some Practical Applications****References**

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