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# SHORTER COMMUNICATIONS

## BOUNDARY-LAYER FLOW ON A FLAT PLATE

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For steady, uniform-property, laminar, boundary-layer flow on an isothermal flat plate, with negligible dissipation and uniform free-stream conditions, the surface heat-transfer is given by:

$$Nu_x Re_x^{-1/2} = \zeta(Pr) \quad (1)$$

where $Nu_x$ and $Re_x$ are the local Nusselt and Reynolds numbers and $Pr$ is the Prandtl number. Evans [1] has tabulated numerical solutions giving values of $\zeta$ for Prandtl numbers ranging from 0.0001 to 20000. The present note provides a simple formula which is a close fit to these data over the whole range of Prandtl number.

For $Pr >$ about 0.6, $\zeta$ is often, following Pohlhausen [2], approximated by:

$$\zeta(Pr) = 0.332 Pr^{1/3}. \quad (2)$$

When the data of Evans [1] are compared with equation (2) it is seen that the equation is correct for $Pr = 1$, is in error by about 1% for $Pr = 10$ and by about 2% for $Pr >$ about 20. For $Pr < 0.6$ the error soon becomes large as $Pr$ decreases.

It may be seen from [1] that,

$$\text{for very large } Pr, \quad \zeta(Pr) \approx 0.339 Pr^{1/3}. \quad (3)$$

$$\text{for very small } Pr, \quad \zeta(Pr) \approx (1/\pi^{1/2}) Pr^{1/2}. \quad (4)$$

Thus, the expression:

$$\zeta(Pr) = \frac{Pr^{1/2}}{(A + BPr^C + DPr)^{1/6}} \quad (5)$$

would have the correct behavior for large and small $Pr$ provided $0 \leq C \leq 1$.

Equation (5) was fitted to the values given by Evans [1] by minimizing the sum of squares of relative residuals of $\zeta$. To avoid retaining excessive digits the constants were found in stages, at each of which one constant was rounded and fixed before redetermining the remaining constants. Equation (5), with the following (treated as exact):

$A = 27.8$
$B = 75.9$
$C = 0.306$
$D = 657$

has a maximum error of 0.33% over the range $0.0001 < Pr < 20000$.

The limiting values given by equation (5) and the above constants:

$$\text{for } Pr \to \infty, \quad \zeta(Pr) \to 0.339 Pr^{1/3} \quad (6)$$

$$\text{for } Pr \to 0, \quad \zeta(Pr) \to 0.575 Pr^{1/2} \quad (7)$$

may be compared with equations (3) and (4).

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2. E. Pohlhausen, Der Wärmeaustausch zwischen festen Körpern und Flüssigkeiten mit kleiner Reibung und kleiner Wärmeleitung, *Z. Angew. Math. Mech.* **1**, 115–121 (1921).

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## HEAT-TRANSFER COEFFICIENT CORRELATIONS FOR THERMAL REGENERATOR CALCULATIONS—TRANSIENT RESPONSE

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### NOMENCLATURE

- $A$, regenerator heating surface area [m$^2$];
- $C$, specific heat of storing matrix [J/kg K];
- $d$, semi-thickness of wall of heat storing matrix [m];
- $E_{g1}$, $E_{g2}$, dimensionless measure of transient response—continuous fit;
- $h$, surface heat-transfer coefficient [W/m$^2$ K];
- $\bar{h}$, bulk heat-transfer coefficient [W/m$^2$ K];
- $K$, $N\phi/3$;
- $L$, length of regenerator [m];
- $L_1$, percentage measure of response accuracy;
- $M$, mass of heat storing matrix [kg];
- $m$, mass of gas resident in regenerator [kg];