

AERODYNAMIC HEATING: TEMPERATURES AT A PERFECTLY INSULATED SURFACE NEGLECTING RADIATION

1. NOTATION AND UNITS

		SI	British
c_{p1}	specific heat capacity of air at constant pressure and at temperature T_1	J/kg K	ft lbf/slug K
$c_{p\infty}$	specific heat capacity of air at constant pressure and at temperature T_∞	J/kg K	ft lbf/slug K
i_H	specific enthalpy of air at temperature T_H	J/kg	ft lbf/slug
i_1	specific enthalpy of air at temperature T_1	J/kg	ft lbf/slug
i_∞	specific enthalpy of air at temperature T_∞	J/kg	ft lbf/slug
M_1	local Mach number immediately outside boundary layer		
M_∞	free-stream Mach number		
r	temperature recovery factor		
T_H	stagnation temperature outside boundary layer	K	K
T_{w0}	local surface temperature under zero convective heat transfer conditions	K	K
T_1	local static temperature immediately outside boundary layer	K	K
T_∞	free-stream static temperature	K	K
γ	ratio of specific heat capacities, assumed constant and equal to 1.4 for air		

2. NOTES

This Item gives the temperature on a perfectly insulated surface of a body moving through a fluid, where radiation is neglected, *i.e.* under zero convective heat transfer conditions (see Derivation 2). This temperature will vary around the body.

At the stagnation point the full stagnation temperature, as given by Figure 3, would occur. The stagnation temperature is obtained from the equation

$$i_H - i_\infty = \frac{\gamma - 1}{2} M_\infty^2 c_{p\infty} T_\infty, \quad (2.1)$$

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where the specific enthalpies i_H and i_∞ at temperatures T_H and T_∞ may be obtained from tables of the thermodynamic properties of air such as are given in Derivation 1. If the variation of the specific heat capacity of air with temperature can be neglected, Equation (2.1) becomes

$$T_H - T_\infty = \frac{\gamma - 1}{2} M_\infty^2 T_\infty. \quad (2.2)$$

The data in Figure 3 have been obtained by the use of Equation (2.1) so that full allowance has been made for variation in the specific heat capacity.

Away from the stagnation point the local surface temperature T_{w0} can be obtained from the formula

$$T_{w0} - T_1 = r(T_H - T_1). \quad (2.3)$$

In this formula, r is the temperature recovery factor and, within the range of conditions covered by this Item, is approximately 0.85 for laminar and 0.90 for turbulent boundary layers, independent of Reynolds number, and these values have been used in deriving the data for Figures 1 and 2 which give the local temperatures T_{w0} as functions of local Mach number and static temperature just outside the boundary layer, M_1 and T_1 respectively. The stagnation temperature T_H remains constant everywhere outside the boundary layer and has the value implied in Equation (2.1); alternatively it may be obtained in terms of the local conditions from the relation

$$i_H - i_1 = \frac{\gamma - 1}{2} M_1^2 c_{p1} T_1. \quad (2.4)$$

This Item is not applicable in regions where there is separated flow.

3. DERIVATION

The Derivation lists selected sources that have assisted in the preparation of this Item.

1. KEENAN, J.H. *Gas tables*. John Wiley, 1948.
KAYE, J.
2. DAVIES, F.V. The determination of skin temperatures attained in high-speed flight.
MONAGHAN, R.J. ARC CP 123, 1953.