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Note on the Effect of  
Variable Wall Temperature  
on Heat Transfer

*By*

H. B. SQUIRE, M.A.,  
of the Aerodynamics Division, N.P.L.

(Being an Addendum to "Heat Transfer Calculation for Aerofoils"  
by H. B. Squire (R. & M. 1986, November, 1942))

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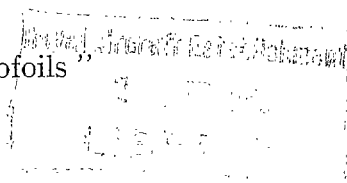
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# Note on the Effect of Variable Wall Temperature on Heat Transfer

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Two recent papers<sup>1,2</sup> have investigated the effect of variable surface temperature on heat transfer. It seems therefore worth while to record the extension of the method given in R. & M. 1986 to the case of variable surface temperature.

Using the same notation as in R. & M. 1986,  $T_1$  the surface temperature is now assumed to be a function of  $x$ , the distance along the surface from the front stagnation point. In place of the equation following (6) in R. & M. 1986 we have

$$\frac{d}{dx} \left[ U(T_1 - T_0) \delta_2 \phi \left( \frac{\delta_2}{\delta_1} \right) \right] = \frac{0.5715 \kappa (T_1 - T_0)}{\delta_2}$$

for which the integral is

$$\left[ U(T_1 - T_0) \delta_2 \phi \left( \frac{\delta_2}{\delta_1} \right) \right]^2 = 1.143 \kappa \int_0^x U(T_1 - T_0)^2 \phi^2 dx.$$

In place of (7) we get

$$\frac{\delta_2^2}{\delta_1^2} \phi \left( \frac{\delta_2}{\delta_1} \right) = \frac{0.3861}{\sigma} \frac{U^4 \int_0^x U(T_1 - T_0)^2 \phi^2 dx}{(T_1 - T_0)^2 \phi \int_0^x U^5 dx}, \quad \dots \dots \dots (7')$$

and in place of (8)

$$\frac{\delta_2^2}{\delta_1^2} \phi \left( \frac{\delta_2}{\delta_1} \right) = \frac{0.3861}{\sigma} \frac{U^4 \int_0^x U(T_1 - T_0)^2 dx}{(T_1 - T_0)^2 \int_0^x U^5 dx} \quad \dots \dots \dots (8')$$

For the case of a flat plate with uniform stream velocity the exact solutions for variable wall temperatures of the form  $(T_1 - T_0) = a_n x^n$  have been worked out by Chapman and Rubesin<sup>1</sup> for  $\sigma = 0.72$  and  $n = 0, 1, 2, 3, 4, 5$  and 10, and Lighthill<sup>2</sup> has applied his method to this case. A comparison is given in Table I between the accurate values of the surface temperature gradient and the values given by (7') or (8') for this case. It will be seen that the approxi-

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mate method gives an error of 16 per cent for  $n > 2$ . Lighthill's method gives errors of order 2 per cent for this case. However, the present method is more accurate than Lighthill's method for non-uniform stream velocity and uniform surface temperature. No comparison for a case of variable stream velocity and variable surface temperature is available at present.

TABLE I

Values of  $-\left(\frac{\nu x}{U_0}\right)^{1/2} \frac{(\partial T/\partial y)_1}{(T_1 - T_0)}$  for the flat plate with  $\sigma = 0.72$ ,  $(T_1 - T_0) = a_n x^n$

$n$	0	1	2	3	4	5	10
Exact solution	0.296	0.489	0.597	0.684	0.744	0.799	1.006
Approximate solution	0.295	0.436	0.519	0.579	0.633	0.681	0.842
Error, per cent	—	10	16	16	16	16	16

REFERENCES

No.	Author	Title, etc.
1	D. R. Chapman and M. W. Rubesin	<i>Journ. Aero. Sciences.</i> Vol. 16, p. 547. (1949).
2	M. J. Lighthill	<i>Proc. Roy. Soc.</i> Vol. A.202, p. 359. (1950).

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