Ref. 2 for entry at circular velocity ($\bar{z}_e = 0$). The equivalence of the two solutions indicates that elimination of the term referred to by Nayfeh is based, in the limiting case $f_e' \to 0$, on restricting the effect that the small but nonzero entry density has on the solution.

Approximate solutions to physical problems must be judged on their accuracy and their utility. Figures 1 and 2 and the additional results of Ref. 2 provide a basis for assessing the value of the solution obtained in Ref. 2.

References

[1] Nayfeh, A. H., "Comments on 'An analytic solution for entry into planetary atmospheres'" AIAA J. **4**, 758 (1966).

[2] Citron, S. J. and Meier, T. C., "An analytic solution for entry into planetary atmospheres," AIAA J. **3**, 470–475 (1965).

[3] Eggers, A. J., Jr., "The possibility of a safe landing," *Space Technology* (John Wiley & Sons, Inc., New York, 1959), Chap. 13, pp. 13–18 and 13–19.

Comments on "Simplified Solutions for Ablation in a Finite Slab"

Andrzej Wortman*

Northrop Corporation, Hawthorne, Calif.

IN a recent note, Chen[1] presents a solution of a differential equation, which is assumed to present a model of a charring ablator. The model used assumes that the original material is decomposed at a known ablation temperature T_m (all nomenclature used here are the same as those used by Chen) and a known surface temperature T_0. The latter assumption does not recognize the fact that the solution of the problem of charring ablation is governed by heat balance rather than by an imposed surface temperature. The net heat transferred to the material must equal the heat stored plus the heat absorbed by decomposition. Specification of the surface temperature presupposes the knowledge of the heat balance, which can be obtained only after the complete problem is solved. The surface boundary condition for negligible radiation therefore should be written as: heated conducted into the material = aerodynamic heat input − heat blocked by injection of gases into the boundary layer. Neither the net heat transfer into the material nor the surface temperature is known a priori.

This, however, is a minor point in comparison with the assumption implied in Chen's basic equation [Eq. (1)]. The equation neglects the convective effects, i.e., the heat transferred from the char to the gaseous products of decomposition. A simple order of magnitude analysis yields the ratio

$$\frac{\text{Heat absorbed by the gases}}{\text{Heat absorbed by the decomposition}} \approx \frac{(T_0 - T_m)}{L} C_{pg} \frac{(\rho_u - \rho_c)}{\rho_u}$$

where C_{pg} = specific heat of the gases. In any practical application of any common charring ablator for which a reaction temperature is assumed, this ratio is about one or greater. There are indications that some materials have a very low heat of depolymerization, so that the ratio actually can be much greater than one. Thus, Chen's solution neglects an effect that is as important as the one that is retained in his boundary condition.

It seems, therefore, that Chen's simplifying assumptions lead to a steady-state solution for a constant temperature sink (reaction zone) with known surface heat transfer and surface temperature, rather than for a charring ablator.

Reference

[1] Chen, N. H., "Simplified solutions for ablation in a finite slab," AIAA J. **3**, 1148 (1965).

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* Engineering Specialist, Gas Dynamics Research, Norair Division.

Reply by Author to A. Wortman

Ning Hsing Chen*

Thiokol Chemical Corporation, Brunswick, Ga.

ABLATION is a complicated phenomenon. It deals with conduction, diffusion, chemical reaction (or combustion), kinetics, etc. The products of the combustion are char and multicomponent gaseous mixtures. In addition, the heat input from the environment to initiate the ablation in a rocket motor also is concerned with multicomponent exhaust gaseous mixtures. Because of this complex nature, it is certainly impossible to obtain a closed form solution to account for all these effects. Hence, in order to have an approximate analytical expression, "simplified assumptions" must be made.

With these simplified assumptions in mind, the following "heat" terms, as indicated by A. Wortman, already have been considered in my recent note.[1] The heat blocked by injection of gases into the boundary layer was eliminated because of assumption 7 in my note.[1] The heat absorbed by the gases from the decomposition was neglected on account of assumption 3.[1] The heat absorbed by the gases from the environment was taken into consideration in the char-gas layer.

In regard to the surface temperature T_0, it is true that it varies with time. However, for a particular instant, there exists such a temperature. This temperature is not known, as indicated by A. Wortman, but is determined from the heat balance equations in my note.[1]

Moreover, T_m was defined as the ablation temperature in my note, but not as the reaction temperature. These two temperatures may not be equal. The latter one, as suggested by A. Wortman, does not fit into my proposed model.

Reference

[1] Chen, N. H., "Simplified solutions for ablation in a finite slab," AIAA J. **3**, 1148–1149 (1965).

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* Principal Engineer; now Staff Engineer, Chrysler Corporation, Space Division, Huntsville, Ala.

Comments on "Calibration of Preston Tubes in Supersonic Flow"

Edward J. Hopkins* and Earl R. Keener*

NASA Ames Research Center, Moffett Field, Calif.

SIGALLA[1] has noted an interesting application of the reference-temperature method for compressible boundary layers to a calibration formula for Preston tubes. The writers

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* Research Scientist. Member AIAA.