phase does not vanish during the mixing process. In this case, too, the presence of the liquid fraction with its capacity to absorb or release large amounts of heat through the change of phase levels the T_3 curve. The differences in pressure rise between the vapor and the perfect gas are smaller than in the previous case.

References

[1] Nosek, S. M. and Goldman, L. J., "Experimental investigation of nozzle critical flow characteristics of sodium vapor," NASA TN D-3183 (January 1966).

[2] Goldman, L. J. and Nosek, S. M., "Experimental nozzle expansion and flow characteristics of potassium vapor," NASA TN D-3209 (January 1966).

[3] Shih, C., "Jet compression for closed-cycle magnetoplasmadynamic electrical power generation," J. Spacecraft Rockets **3**, 1121–1123 (1966).

[4] Meisl, C. J. and Shapiro, A., "Thermodynamic properties of alkali metal vapors and mercury," General Electric Co. Rept. R60FPD358-A (1960).

Reply by Author to G. Angelino

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I APPRECIATE Mr. Angelino's comment on the neglect of cesium vapor condensation effect which appeared to exist in some test runs in my paper, "Jet Compression for Closed-Cycle Magnetoplasmadynamic Electrical Power Generation." My paper was primarily a report of the results of an experimental investigation of the feasibility of using a stream of metallic vapor of high molecular weight to entrain and compress a gaseous stream of low molecular weight. The objective of the investigation was the experimental proof of the applicability and not a theoretical treatise of the jet compression process. Since the experimental set-up employed an expansion nozzle of fixed geometry and experiments were carried out at different stagnation temperatures and pressures of the primary driving stream, a theoretical treatment of the jet compression process has to take into consideration not only the change of state of fractions of the working medium, but also the effect of underexpansion and overexpansion of the primary stream. None of such effects can really be accounted for without extensive experimental investigations.

It is well known that a vapor stream, unless disturbed, can remain fully in the vapor state under certain degrees of cooling below its saturation point. In our experimental set-up both the helium gas and the cesium system were thoroughly purged and evacuated before experimentation so as to avoid condensation by nucleation. Experiments carried out at Massachusetts Institute of Technology Lab on condensation of CO_2 and ammonia have indicated wide discrepancies in degree of supersaturation for different vapor streams expanding through convergent-divergent nozzles.[1,2] It was also observed that the more abrupt the expansion, the higher the degree of supersaturation of the expansing stream. Presumably, the molecular weight of the medium will also affect the degree of supersaturation due to difference in diffusion velocity.

Our own experience with Cs has indicated that Cs vapor in mixture with He is very difficult to condense. This was evidenced in both the MPD electrical power generation[3] experiment and the jet compression experiment. In the former case, a straight tubular type of condenser was used. However, cesium deposits in large quantity were found passing through the cooler and condenser into the He surge tank and eventually the helium compressor. In the latter program, a multitube multibaffled-type mineral-oil-cooled condenser was used. Again a large amount of Cs was condensed in the He surge tank and the heater pipe. This strongly suggests the complexity of condensation of Cs vapor. The lack of information about condensation of Cs in supersonic nozzle flow and in mixtures of Cs with noble gases negates a realistic performance analysis without extensive experimental investigation.

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References

[1] Duff, K. M., "Non-equilibrium condensation of carbon-dioxide in supersonic nozzles," Massachusetts Institute of Technology, Gas Turbine Lab. Rept. 84 (January 1966).

[2] Jaeger, H. L., "Condensation of supersaturated ammonia and water vapor in supersonic nozzles," Massachusetts Institute of Technology, Gas Turbine Lab. Rept. 86 (September 1966).

[3] "Semi-annual technical summary report of research program on closed cycle MPD electrical power generation with non-equilibrium longation," Martin Nuclear Rept. MND-3052 (July 1963).

Comments on "An Improved Finite-Difference Method for Heat-Transfer Calculation"

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GROSS[1] developed an equation for the time step interval to be applied to the explicit finite-difference technique used in transient heat-transfer calculation. Briefly, his development is as follows:

$$t_i{}^+ = t_i + \frac{\Delta\tau_i}{C_i}\left[\sum_j K_{ji}(t_j - t_i) + S_i\right] \tag{1}$$

$$t_i{}^*\left(= \sum_j K_{ji}t_j + S_i\right)/\sum_j K_{ji} \tag{2}$$

where $t_i{}^+$ = estimate of temperature of node i at the "new" time $\tau + \Delta\tau_i$; t_i = temperature of node i at the "old" time τ; C_i = thermal capacity of node i; K_{ji} = thermal conductance between node i and j nodes; S_i = energy source at node i; $t_i{}^*$ = temperature of node i if node i is in thermal equilibrium with neighboring nodes (j nodes); and $\Delta\tau_i$ = time step. The criterion for stability is given by Gross as:

$$t_i{}^+ \leq t_i{}^* \tag{3}$$

which he states results in the well known equation,

$$\Delta\tau_i \leq C_i/\sum_j K_{ji} \tag{4}$$

If a small error in temperature is allowed, Gross writes

$$t_i{}^+ \leq t_i{}^* + \Delta t \tag{5}$$

which he states results in the following criterion:

$$\Delta\tau_i \leq \frac{C_i}{\sum_j K_{ji}}\left[1 + \frac{\Delta t \sum_j K_{ji}}{\sum_j K_{ji}(t_j - t_i) + S_i}\right] \tag{6}$$

Note there is an obvious typographical error in Gross's paper in that the

$$\sum_j K_{ji}$$

in the second expression in the bracketed term of Eq. (6) [Eq. (10) in Gross's paper] is missing.

The objection to the development of Gross's is that the time step stability criterion, Eq. (6), can result in a time step less than that given by Eq. (4). This is possible since the

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