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DILUTION JET EXPERIMENTS IN COMPACT COMBUSTOR CONFIGURATIONS

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This project concerns the effects of cooling jets on the velocity and temperature fields in a compact reverse flow combustor. The work is motivated by the need to limit the temperatures of post-combustion gases in jet engines to values within the endurance capabilities of turbine blades. The application requires not only that the temperature be kept sufficiently low but also that a suitably tailored temperature profile be provided at the combustor exit, with higher temperatures generally permissible at the blade tip than at the blade root because of higher centrifugal loads at the root.

Flows in reverse flow combustor accelerate both longitudinally because of area changes and transversely because of flow turning. The current project started with flow visualization experiments in water, using aqueous solutions of zinc bromide to model the relatively higher density of cooling jets. These flow visualization experiments were conducted in simple two-dimensional configurations designed to examine separately the effects of longitudinal and transverse acceleration. The next phase of the work consisted of temperature measurements in a model reverse flow combustor, using a rake of thermocouples which could be moved both longitudinally and transversely to provide transverse temperature profiles at a number of longitudinal stations. Single jets, and rows of cooling jets of different spacing, were injected at several locations with varying flow rates and temperatures to produce a useful range of momentum ratios and density ratios. In addition, a semi-empirical calculational model was developed to predict the behavior of a single cooling jet in the reverse flow combustor configuration.

Results of these experiments show that single jet temperature trajectories are swept toward the inner wall of the turn, whether injection is from the inner or outer wall. A widely spaced row of jets produces a trajectory similar to that of a single jet. As spacing is reduced, jet penetration is also reduced, and the cooling jets tend to remain close to the wall from which they are injected. These results suggest that suitable cooling and temperature distribution tailoring can be accomplished without injecting cooling jets upstream of the turn, and thus it appears that combustors can be made significantly smaller than current designs.

The current phase of this project is directed toward the acquisition of velocity measurements in the turn section of the combustor. To this end a combined pitot-static tube and thermocouple probe was constructed. Following successful tests of this probe, a five-probe rake using the same design was constructed. Velocity and temperature distributions are being obtained using this rake. Because of the large quantity of data required for adequate representation of the velocity and temperature fields, the data is being directly computer acquired.

An attempt to develop a semi-empirical calculational model for a row of jets, similar to that for a single jet, was limited by the absence of fundamental mixing information for rows of jets. Consequently, experiments were performed to obtain entrainment rates for rows of jets. In these experiments volume flow rates were deduced by integrating velocity distributions obtained from hot wire anemometer transverses. A Master's thesis describing these results is in preparation. In a companion effort, vortex models of a jet in cross-flows have been developed in an attempt to understand the relative importance of viscous and irviscid phenomena in determining the jet trajectories.

Throughout this work we have been fortunate to have the support and advice of Steve Riddlebaugh of the NASA Lewis Research Center, and we are pleased here to thank him.

PUBLICATIONS

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Riddlebaugh, S., Lipshitz, A., and Greber, I., "Dilution Jet Behavior in the Turn Section of a Reverse Flow Combustor", AIAA paper 82-0192, 1982.

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Karagozian, A., and Greber, I., "A Vortex Model for a Single Jet in a Cross Flow", Bulletin American Physical Society, November 1983.

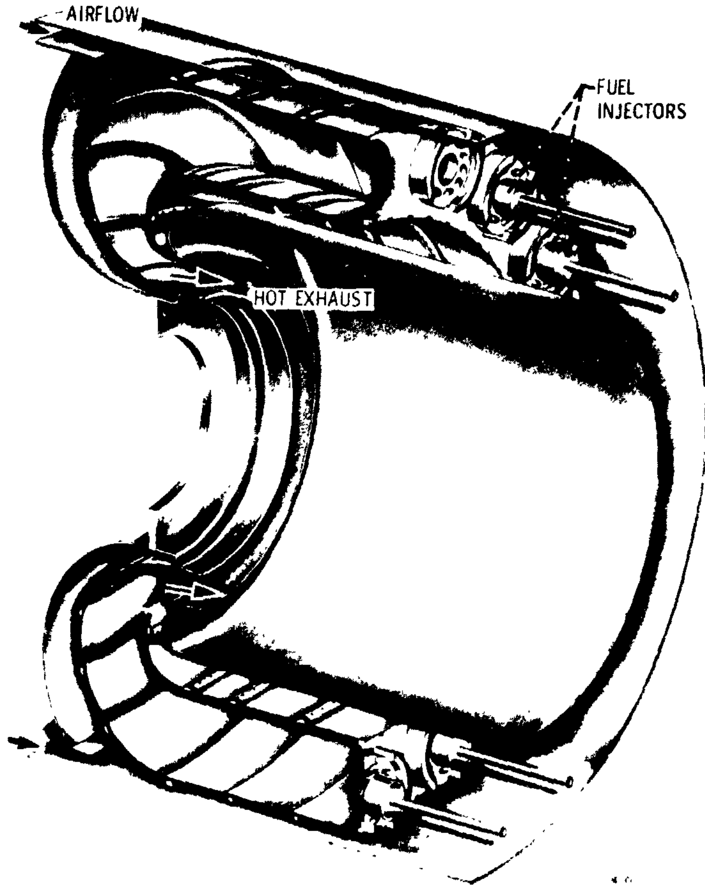

FIGURE 1. Reverse flow combustor.

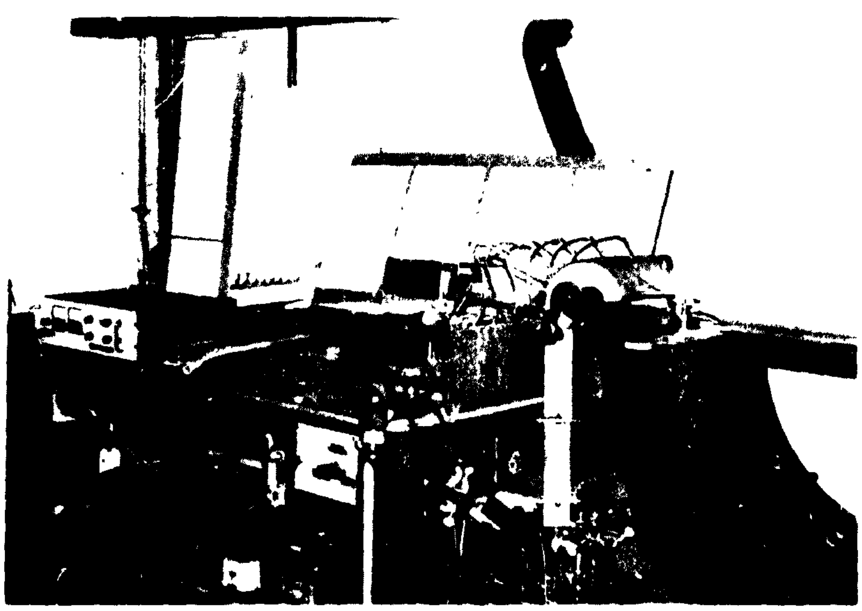

FIGURE 2. EXPERIMENTAL SETUP.

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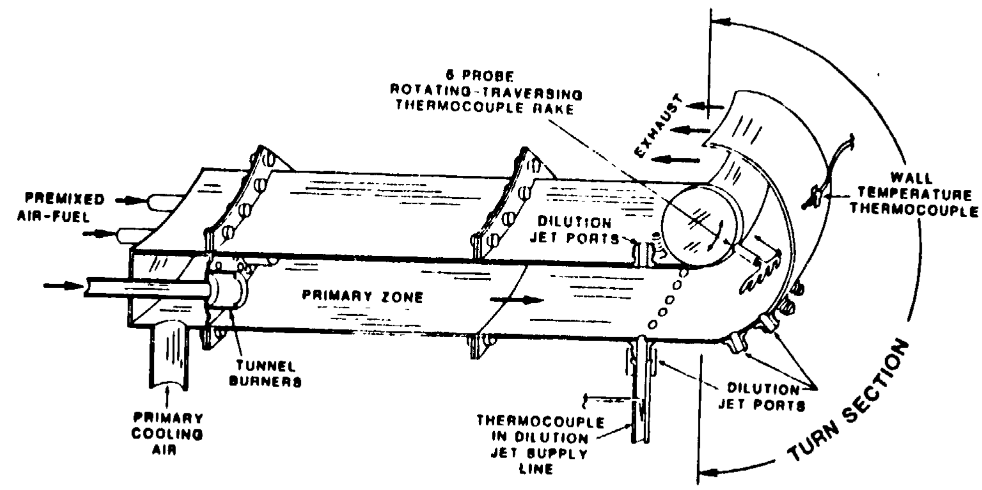

FIGURE 3. CUTAWAY SKETCH OF TEST COMBUSTOR

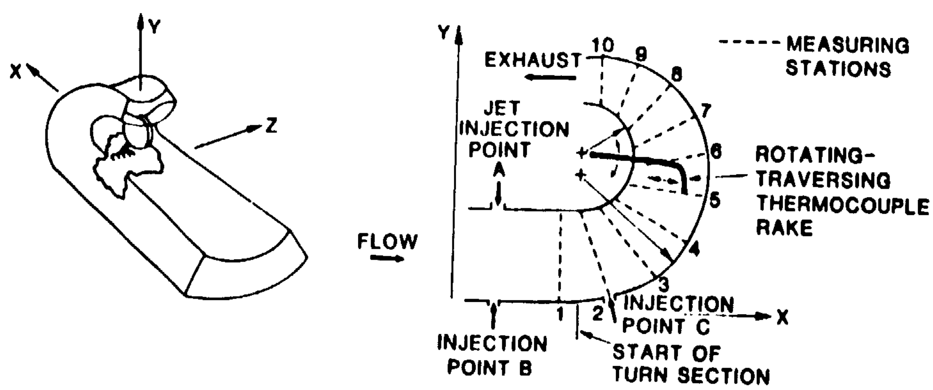

FIGURE 4. COMBUSTOR TURN SECTION GEOMETRY
AND TEMPERATURE MEASURING STATIONS

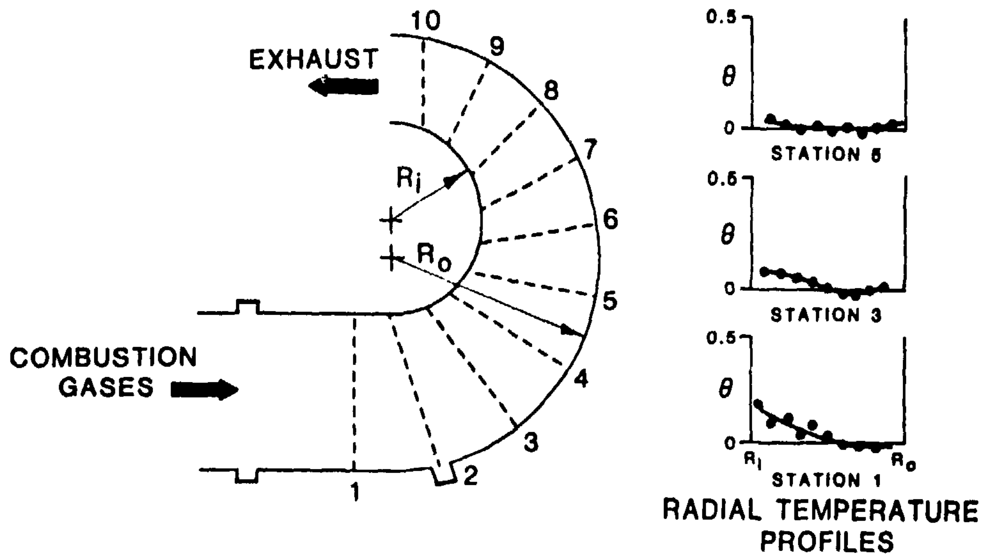

FIGURE 5. TEMPERATURE DISTRIBUTION IN THE COMBUSTOR
TURN WITHOUT DILUTION JETS

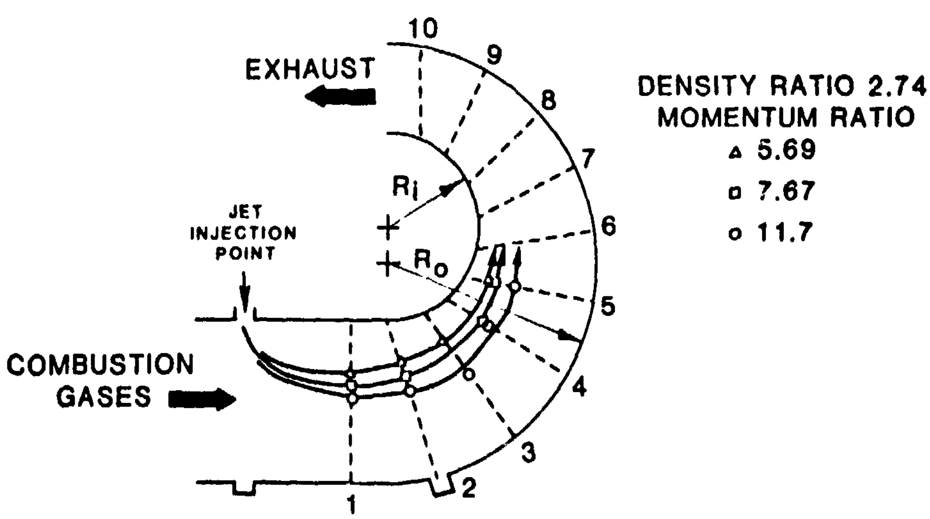

FIGURE 6. JET TRAJECTORIES SHOWING EFFECT
OF MOMENTUM RATIO ON A JET
INJECTED FROM THE INNER WALL

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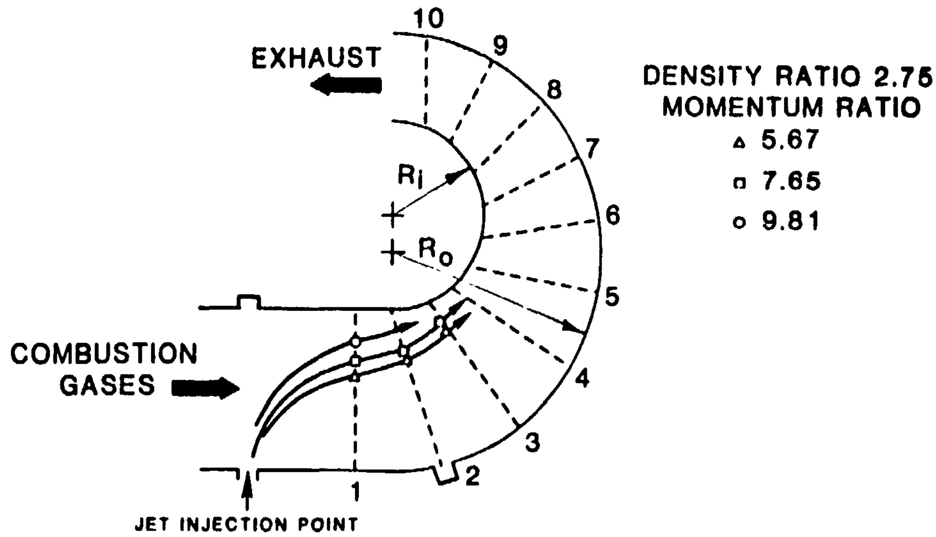

FIGURE 7. JET TRAJECTORIES SHOWING EFFECT OF MOMENTUM RATIO ON JET INJECTED FROM THE OUTER WALL

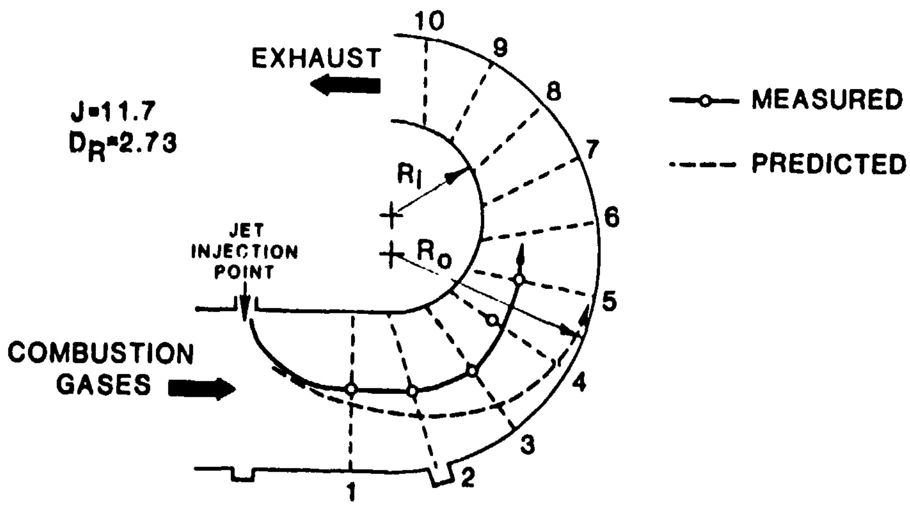

FIGURE 8. COMPARISON WITH MODEL FOR A SINGLE JET INJECTED FROM THE INNER WALL

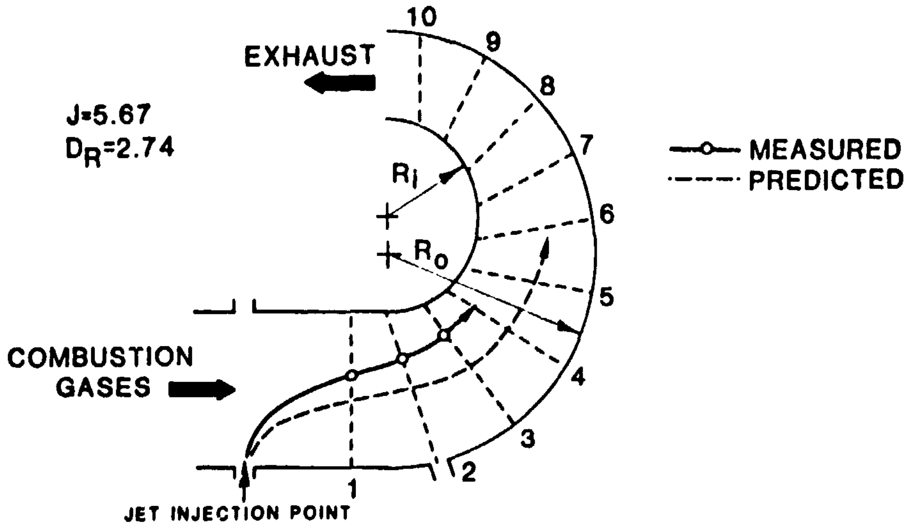

FIGURE 9. COMPARISON WITH MODEL FOR A SINGLE JET INJECTED FROM THE OUTER WALL

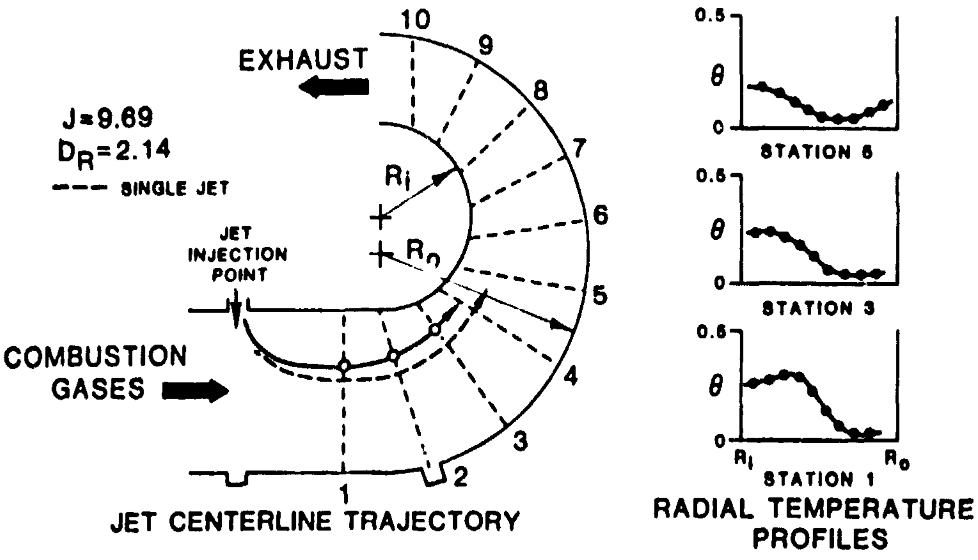

FIGURE 10. BEHAVIOR OF A WIDELY SPACED ROW OF JETS (SPACING RATIO OF 7.41) INJECTED FROM THE INSIDE WALL

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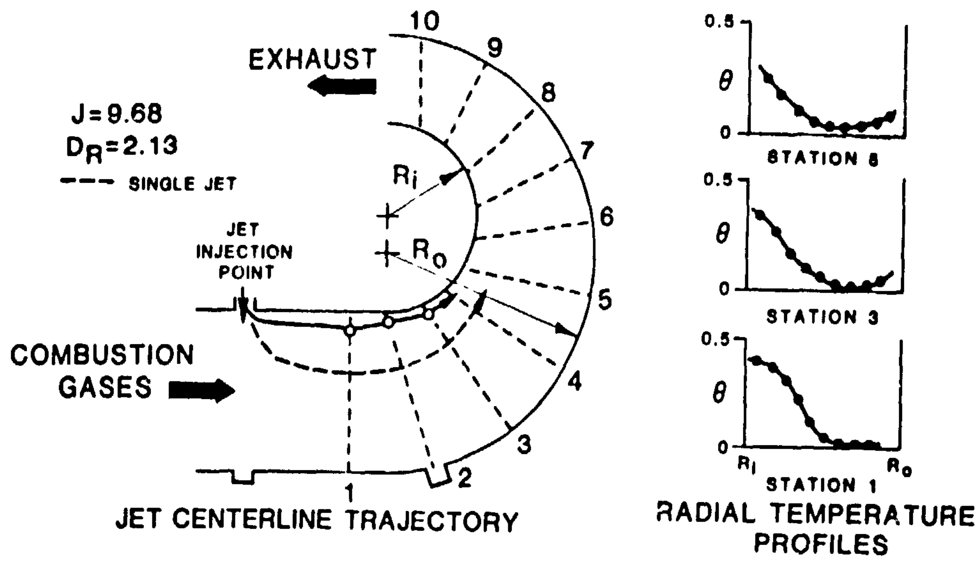

FIGURE 11. BEHAVIOR OF A CLOSELY SPACED ROW OF JETS (SPACING RATIO 2.47) INJECTED FROM THE INSIDE WALL

FIGURE 12. PITOT-STATIC/THERMOCOUPLE RAKE.

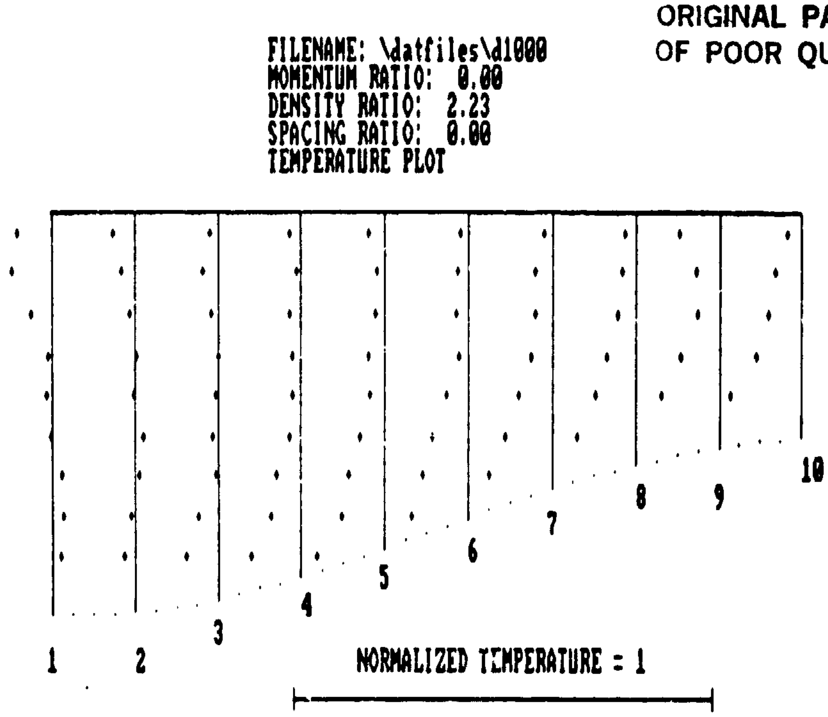

FIGURE 13. TEMPERATURE PROFILES WITH NO INJECTION.

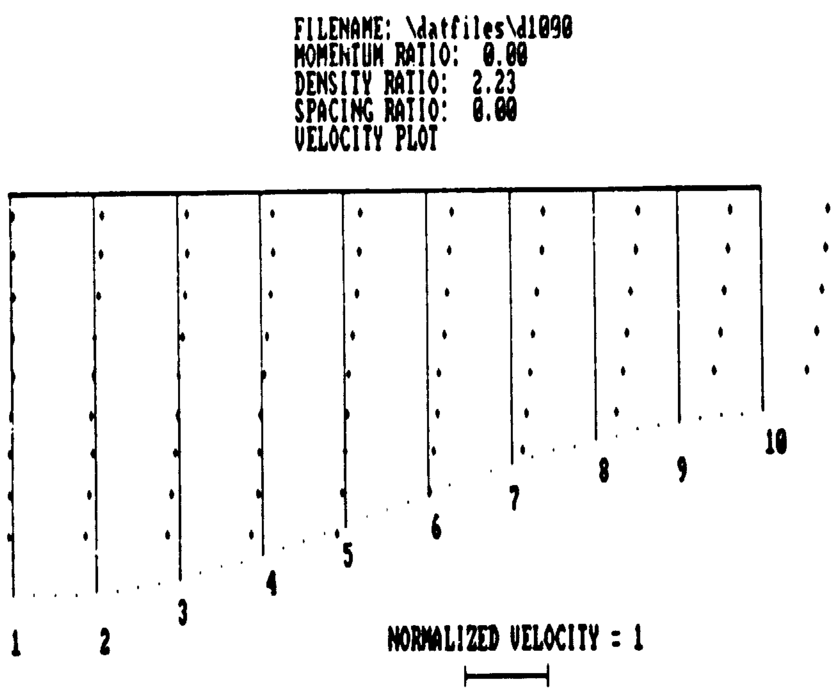

FIGURE 14. VELOCITY PROFILES WITH NO INJECTION.