Readers' Forum

Brief discussions of previous investigations in the aerospace sciences and technical comments on papers published in the AIAA Journal *are presented in this special department. Entries must be restricted to a maximum of 1000 words, or the equivalent of one* Journal *page including formulas and figures. A discussion will be published as quickly as possible after receipt of the manuscript. Neither the AIAA nor its editors are responsible for the opinions expressed by the correspondents. Authors will be invited to reply promptly.*

AIAA 81-4116

Comment on "Stability Aspects of Diverging Subsonic Flows"

Gino Moretti*
Polytechnic Institute of New York, Farmingdale, N.Y.

STABLE calculations of subsonic, inviscid flows in a divergent duct can be performed using time-dependent techniques. If the flow evolves asymptotically into a steady state, the accuracy of the results can be tested, and it is found to be very high. (Errors in stagnation pressure, for example, are of the order of 10^{-4} or less.) A full discussion of the problem, both for quasi-one-dimensional flows and two-dimensional flows, requires a full-length paper. The reader interested in details will find them in Ref. 2, a report which also has been submitted to the *AIAA Journal* for publication. Since the prior statement, however, does not agree with Ref. 1, a brief comment seems to be in order.

The error growth analysis, as presented in Ref. 1, can hardly be accepted. The author tries to justify it as a "heuristic argument"; we object that the stability analysis of partial differential equations cannot be based on a finite-difference calculation, since different discretizing schemes applied to the same equations may have different ranges of stability. The fallacy of the analysis is proven pragmatically by the existence of stable calculations that tend asymptotically to that very state that is "proven" to be unstable.

I disagree with the author's statement (end of col. 2, p. 535) that his chosen boundary conditions are "correct for a well-posed problem." In brief, u cannot be specified at the inflow boundary; the correct parameter to be prescribed is the stagnation pressure.[3,4] When u is prescribed, spurious pressure waves propagate into the region of interest, and may remain trapped within. If u and p are specified from the exact solution, mesh-dependent wiggles appear. If the density is also specified, entropy waves develop.

Similar considerations can be advanced for the outflow boundary, both for quasi-one-dimensional flows and for two-dimensional flows. Some conceptual subtleties, that are not developed in Refs. 3 and 4, are necessary to understand the arguments in depth.

The most disturbing feature of the paper is the implication that erratic results of a defective numerical analysis can be used to imply physical instabilities of a flow (last paragraph in the first column of p. 537). Whatever physical "instability" (such as onset of turbulence or, with a good deal of semantic stretching, boundary-layer separation) may occur in a viscous flow, that has nothing to do with the appearance of mesh-dependent wiggles in an inviscid calculation.

References

[1] Cline, M. C., "Stability Aspects of Diverging Subsonic Flow," *AIAA Journal*, Vol. 18, May 1980, pp. 534-539.

[2] Moretti, G. and Pandolfi, M., "On the Computation of Subsonic Flows in Ducts," Polytechnic Institute of New York, Rept. M/AE 80-18, June 1980.

[3] Serra, R. A., "Determination of Internal Gas Flows by a Transient Numerical Technique," *AIAA Journal*, Vol. 10, May 1972, pp. 603-611.

[4] Pandolfi, M. and Zannetti, L., "Some Permeable Boundaries in Multidimensional Unsteady Flows," *Proceedings of the VIth International Conference on Numerical Methods in Fluid Dynamics, Lecture Notes in Physics*, Springer-Verlag, Vol. 90, 1978, pp. 439-446.

Received June 19, 1980; revision received Aug. 7, 1980.

*Professor. Fellow AIAA.

AIAA 81-4117

Reply by Author to G. Moretti

Michael C. Cline*
Los Alamos National Laboratory,
University of California, Los Alamos, N. M.

THE first conclusion of my paper[1] is that subsonic, diverging flows will separate for small angles of divergence and, therefore, inviscid methods, unable to predict or properly treat separation, cannot be expected to produce good results regardless of whether the calculations are stable or not. The second conclusion is that inviscid, subsonic, diverging flow is physically unstable. This second conclusion and its supporting research are the subject of Moretti's Comment. There are four objections presented in Moretti's Comment and these are discussed below.

The first objection (Moretti's last paragraph) concerns the implications I am using viscous flow phenomena to justify inviscid flow results. The viscous flow results,[1] which were, in the diverging case, unsteady but not unstable, were included to illustrate the accuracy, not stability, shortcomings of the inviscid equations. All of the stability discussions, results, and conclusions were intended to pertain only to the inviscid equations (see the fourth paragraph in this Reply). The term "physically unstable," used in Ref. 1, denotes the instability of the inviscid differential equations as opposed to "numerically unstable," which applies to the finite-difference equations. I must admit that the last sentence of the second paragraph of page 539[1] may be somewhat misleading. This sentence was included because at first I was surprised to find that inviscid, diverging, subsonic flow was unstable. On the other hand, after seeing how poorly the inviscid equations model the true viscous flow, I was less surprised by this result. However, I never intended there be any claims in Ref. 1 that boundary-layer separation, onset of turbulence, or any other viscous flow phenomena has any bearing on the stability of inviscid flows.

The second objection (Moretti's second paragraph) concerns the validity of my one-dimensional (1-D) stability analysis. To verify the finite-difference procedure used to solve the stability equations, two different spatial

Received Sept. 23, 1980; revision received Jan. 26, 1981.

*Group T-3. Member AIAA.