calculation using an unseparated pressure correction works well over the first few steps. However a growing pressure oscillation occurs at the exit of the bend.

Our duct-flow calculation procedure introduces cross-stream pressure variations into the thru-flow momentum equation only after they have been calculated using the 3-D pressure-correction equation. The point-by-point relaxation procedure used to solve this equation allows elliptic influences to be transmitted throughout the entire flow domain each time the 3-D pressure-correction equation is solved.

An Experimental Study of the Flow-Induced Motions of a Flexible Cylinder in Axial Flow[1]

M. P. PAIDOUSSIS.[2] Although the subject of flow-induced motions of flexible cylinders is axial flow has received considerable theoretical attention, there have been very few experimental studies. Consequently, this study should be applauded both for providing added experimental information and for dealing with a particular application of considerable practical interest.

Concerning comparison between experiment and theory from the point of view of stability, it must be said that the applicability of Païdoussis' theory [1, 2] to these particular experiments is questionable. The reason for this, as the authors suspect, is due to the much higher values of L/D in these experiments, as compared to previous experiments where L/D was much smaller. Here the dynamics of the system are critically dependent on the frictional forces. Therefore, such assumptions as that of a constant value for frictional coefficients over the whole length of the body, which proved to be reasonable for shorter bodies, should be examined carefully. So should the forces at the free end. (It is recalled that in the theory the effect of the shape of the free end was accounted for by a factor f, which is the ratio of the actual lift force on the tapered end to the ideal lift that might arise if three-dimensional flow effects and separation were absent.) It is nevertheless interesting to note that Païdoussis' theory [1, 2] predicts that buckling (divergence) does *not* take place for a cantilevered cylinder with a hemispherical end ($f \leq 0.5$), if $L/D > 40$. Hence, theory predicts no divergence for the L/D involved in the experiments. This is contrary to the statement made by the authors, that the theory predicts divergence in the range of dimensionless flow velocities $1 < u < 10$; that statement is only true when applied to considerably smaller L/D than were used in Ni & Hansen's experiments.

Moreover, the situation is complicated by the fact that the aforementioned theory neglects the effect of the boundary layer, which for such lengths as those in the experiments must have been quite thick. It was recently shown [3] that the boundary layer has "an insulating effect" on the cylinder and an important stabilizing effect. In other words, when boundary layer effects are considered, divergence is even less likely to develop. In this light, the discusser wonders if the static divergence observed at $u \simeq 30$ for the Tygon tube was real or not, (i) in view of the considerable difficulty that must have been encountered in keeping these long bodies exactly neutrally buoyant and (ii) in view of the tendency of small irregularities, locked-in stresses, and non-uniformities to become exaggerated with increasing flow, as the mean flow tends to counteract the flexural restoring forces. Interestingly, similar experiments by the authors, with a propylene cable, showed no divergence [4], exactly as predicted by theory.

It should be said that the above concern but a small part of the paper and do not distract from its overall value.

Additional References

1 Païdoussis, M. P., "Dynamics of Flexible Cylinders in Axial Flow. Part 1: Theory," *J. Fluid Mechanics*, Vol. 26, 1966, pp. 717-736.

2 Paidoussis, M. P., "Dynamics of Cylindrical Structures Subjected to Axial Flow," *J. Sound and Vibration*, Vol. 29, 1973, pp. 365-385.

3 Hannoyer, M. J., and Païdoussis, M. P., "Instabilities of Tubular Beams Simultaneously Subjected to Internal and External Axial Flows," ASME *Journal of Mechanical Design*, Vol. 100, 1978, pp. 328-336.

4 Hansen, R. J., and Ni, C. C., "An Experimental Study of Flow-Induced Motions of Flexible Cables and Cylinders Aligned With the Flow Direction," ASME Paper 76-WA/FE-15.

Authors' Closure

The authors wish to thank Professor Paidoussis for his observations on their recently reported experimental study of flow-induced motions of a flexible cylinder in axial flow. As he points out, complicating factors such as a cylinder length-to-diameter ratio (L/D) much greater than 40 and a thick boundary layer distinguish his pioneering analytical studies [1, 2] from the present experimental work. Clearly, additional theoretical study is required of the fluid-structure interaction phenomena which prevail in the circumstances considered in the present experiments.

The authors do wish to emphasize that the observed "static divergence" near the downsteam extremity of the flexible cylinder appeared to be a real flow-induced deformation phenomenon and not the result of irregularities or nonuniformities in the test cylinder. The phenomenon was repeatable; the cylinder was neutrally buoyant to an excellent approximation; and permanent set in the tube wall was removed by repeatedly filling it with hot water.

Analytic Derivation of Static Pressure Distribution in Helical Flows[1]

EDWARD SILBERMAN.[2] One of the writer's students has made measurements of turbulence components in a helical flow. The writer has examined their influence on calculated radial pressure distribution using the method described by Kuzay. Data and calculated results are presented in Table 1. The data were obtained in a nominal 1 ft diameter helical corrugated pipe with air flowing. The helix made an angle of 59½ deg with the pipe axis (where 90 deg would be ordinary corrugated pipe). Turbulence measured with a split hot film anemometer was used to examine its effect on Kuzay's

[1] By C. C. Ni and R. J. Hensen, published in the December, 1978 issue of the Journal of Fluids Engineering, Vol. 100, No. 4, pp. 389-394.

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[1] By T. M. Kuzay, published in the June, 1978 issue of the Journal of Fluids Engineering, Vol. 99, No. 2, p. 1.

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