mined experimentally. The scatter gives a measure of the accuracy of the photoelastic technique in determining strain and also indicates the variation of stress in the shell. The usual procedure is to plot stress ratio (σ/σ_{cr}) vs end deformation of the shell. However, the author simply wanted to illustrate a typical test run using the photoelastic method of computing strain.

Recent results from several photoelastic shells tested by the author have confirmed the fact that buckling loads within 10% of the classical value are obtainable. Although the shells employed had relatively low ratios of radius to thickness (i.e., $100 \leq R/t \leq 170$), the buckling loads represent an increase (about 10%) over the data in Fig. 1 of the preceding comment for the same value of R/t. The author admits that the results of Ref. 2 represent a "significant improvement over the general body of existing data" because of the higher R/t ratio of the shells tested.

In the concluding remarks of Ref. 1, the author wished to point out the following:

1) Of the two existing competitive theories explaining the lower buckling loads (well below the classical value), Tsien's energy criterion, as well as having no logical basis,[3] appeared to have no experimental basis. Tsien's lower buckling load, as stated by the author,[1] was achieved only by applying a lateral disturbance to the shell.

2) When isotropic elastic shells are made sufficiently free of imperfections and loaded axially in a rigid test machine, buckling loads very close to the classical value can be achieved. The author never intended his note to constitute unique evidence of the importance of imperfections on the buckling load of a shell loaded axially in compression. Furthermore, his *tentative* conclusion was proposed knowing full well that further investigation of both end effects and imperfections on the shell buckling phenomena was necessary.

The author recognizes the fact that the classically predicted critical buckling load of a circular cylindrical shell can be attained only within certain limits. He also accepts the fact that classical theoretical solutions have assumed shell edges that are free to expand radially, and, since his cylinder edges were clamped, this posed a limit on the observed buckling loads. The theoretical analysis of Ref. 4 for the case of simply supported ends clearly indicates that the end conditions do play a role in reducing the critical buckling stress of a shell. However, end constraints did not appear to produce a serious effect on the clamped shells used by the author. Buckling loads were repeatable and always near 10% of the computed value. No appreciable end effect has been observed by the author in the photoelastic analysis of the shells, either in the prebuckled state or in the buckled configuration. Any bending deformations should appear as color striations at the ends of the loaded shell.

In conclusion, the author agrees with Leonard that very convincing experimental evidence of the effect of imperfections on the lowering of buckling loads is offered by the results of Ref. 2. However, it must be noted that the works of both Refs. 2 and 4 did not appear until December 1962, after the author had submitted his note (August 1962) for publication.

References

[1] Tennyson, R. C., "A note on the classical buckling load of circular cylindrical shells under axial compression," AIAA J. **1**, 475–476 (1963).

[2] Babcock, C. D. and Sechler, E. E., "The effect of initial imperfections on the buckling stress of cylindrical shells," NASA TN D-1510, pp. 135–142 (December 1962).

[3] Fung, Y. C. and Sechler, E. E., "Instability of thin elastic shells," *Proceedings of the First Symposium on Naval Structural Mechanics 1958* (Pergamon Press, New York, 1960).

[4] Stein, M., "The effect on the buckling of perfect cylinders of prebuckling deformations and stresses induced by edge support," NASA TN D-1510, pp. 217–227 (December 1962).

Comment on "Flight Mechanics of the 24-Hour Satellite"

Leon Blitzer* and G. Kang†
Space Technology Laboratories Inc., Redondo Beach, Calif.

In his article on the flight mechanics of the 24-hr satellite, Perkins[1] refers to an unpublished manuscript by Blitzer, Boughton, Kang, and Page[2] as having "shown that the rate of longitudinal drift of the 24-hr equatorial satellite due to equatorial oblateness is sufficiently large to be of concern to system designers." He further states that "With the exception of the period for the case of small amplitude oscillation, Blitzer's work did not present any closed-form analytical expressions for the mean path motion of the satellite."

The object of this note is to update Perkins' reference and inform the reader of two papers by Blitzer et al.[3,4] which appeared prior to Perkins' article and in which the restrictions to equatorial orbits and small-amplitude longitudinal oscillations were removed. In the latter paper,[4] particularly, closed-form analytic expressions are given for the period and for both radial and longitudinal motions. Diurnal and long-period components are included in the expressions. The solution for the mean motion was motivated by noting the similarity of the problem to that of the physical pendulum.

Perkins adopts an independent approach to the problem, but our results appear to be consistent. The reader will also find some other recent papers[5,6] to be of relevance.

References

[1] Perkins, F. M., "Flight mechanics of the 24-hour satellite," AIAA J. **1**, 848–851 (1963).

[2] Blitzer, L., Boughton, E. M., Kang, G., and Page, R. M., "Effect of ellipticity of the equator on a 24-hour equatorial satellite," Space Technology Labs. Inc., Los Angeles, Calif. (1961).

[3] Blitzer, L., Boughton, E. M., Kang, G., and Page, R. M., "Effect of ellipticity of the equator on 24-hour nearly circular satellite orbits," J. Geophys. Res. **67**, 329–335 (1962).

[4] Blitzer, L., Kang, G., and McGuire, J. B., "The perturbed motion of 24-hour satellites due to equatorial ellipticity," J. Geophys. Res. **68**, 950–952 (1963).

[5] Morando, B., "Libration d'un satellite de 24^h," Compt. Rend. **254**, 635–637 (1962).

[6] Frick, R. H. and Garber, T. B., "Perturbations of a synchronous satellite," J. Aerospace Sci. **29**, 1105–1111 (1962).

Received June 26, 1963.

* Consultant; also Professor of Physics, University of Arizona, Tucson, Ariz.
† Member of Technical Staff. Member AIAA.

Comment on "Dynamic Analysis for Lunar Alightment"

Robert E. Lavender*
NASA George C. Marshall Space Flight Center, Huntsville, Ala.

In a recent paper by Cappelli,[1] an analytical procedure was described for obtaining the motion during touchdown of a spacecraft landing on the lunar surface. Comparison of some

Received June 26, 1963.

* Aerospace Engineer, Aeroballistics Division. Member AIAA.