equation." The author really wonders if Lam has read this paper thoroughly.

This paper also has indicated no intension to investigate the complicated processes between the striking particles and the satellite surface, but employs only the conditions of steady state of satellite potential and constancy of satellite mass. The diameter of the satellite has been considered to be rather large, of the order of meters. In general, such a satellite is constructed as a thin conducting shell. It is obvious that the electrical current normal to the satellite surface must be zero. Spitzer[1] also stated that "if the potential of the solid surface is allowed to float, no current must flow from the plasma to the surface." In Eq. (13), $n_{oe}e^{+\varepsilon\psi_0/kT}$ and $(C_- + W\cos\theta)$ are the electron number density and their total mean speed in the direction normal to the satellite surface. The product of these two quantities is the contribution to electric current by electrons. In the same way, the left side of the equation is the contribution by ions. For zero current, Eq. (13) is established easily.

Lam's statement of "we see that Jen has a satellite made of a nonconductor" is certainly not true, since the paper has not used the term "nonconductor" at all, either explicitly or implicitly. Lastly, Lam's item 4 on Coulomb drag even contradicts his own item 1.

Reference

[1] Spitzer, L., Jr., *Physics of Fully Ionized Gases* (Interscience Publishers, Inc., New York, 1956), p. 17.

Comment on "General Instability and Optimum Design of Grid-Stiffened Spherical Domes"

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GRID-STIFFENED spherical domes subject to external pressure, as suggested by Crawford and Schwartz,[1] have been designed and built for a number of years. Shells with base diameters of over 100 ft have operated successfully as roofs, parts of space simulators, and outer walls of cryogenic vessels.

Theoretical results and experimental data for general instability and for buckling between stiffeners have been published by the author.[2–4] The theoretical results[3] for a stiffened shell give the critical buckling pressure for general instability as

$$p_{cr} = 0.365E\,(t_s/R)^2\,[1 + (12I/t_s^3b_s)]^{1/2}\,[1 + (A/t_sb_s)]^{1/2}$$

when I is the effective moment of inertia of the stiffener, and A is the area of the stiffener.

The critical buckling pressure for local instability[3] is, approximately,

$$p_{cr} = 7.42Et_s^3/Rb_s^2$$

when the torsional stiffness of the stiffeners is relatively high. When the torsional stiffness is relatively low, the local buckling pressure can be calculated by using the method previously published.[4]

The results of tests[2] indicate that if local buckling occurs at a relatively low pressure, general instability soon follows, and the theoretical general stability pressure is very low. In addition, edge effects are important in the design of stiffened shells. A series of tests conducted at the University of Missouri indicate that general instability will occur at a very low load if poor edge conditions are present. In order to reach the theoretical value of the buckling pressure, the yield strain of the material must be high enough. Even though the strain in the shell and stiffeners just prior to buckling might be relatively low (considerably below the yield strain of the material), the strains during and after buckling are relatively high (exceeding the yield strain) in a practical shell.[5] This pseudoelastic effect has been demonstrated in tests performed at the University of Missouri.

The connections between the stiffeners and between the stiffeners and the shell are of considerable interest to the engineer. A limited number of tests have shown that the general instability critical pressure is only reduced about 10% if the connections between the stiffeners are eliminated and if the attachments between the stiffeners and shell are only 50% effective.

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[1] Crawford, R. F. and Schwartz, D. B., "General instability and optimum design of grid-stiffened spherical domes," AIAA J. **3**, 511–515 (1965).

[2] Buchert, K. P., "Stability of doubly curved stiffened shells," Ph.D. Dissertation, University of Missouri, Columbia, Mo. (January 1964).

[3] Buchert, K. P., "Stiffened thin shell domes," AISC, **7**, 78–82 (1964).

[4] Buchert, K. P., "Zur Stabilität grosser, doppelt gekrümmter und versteifter Schalen," Stahlbau **2**, 55–62 (1965).

[5] Buchert, K. P., "Buckling of doubly curved orthotropic shells," Engineering Experiment Station, University of Missouri, Columbia, Mo. (November 1965).

Reply by Authors to K. P. Buchert

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STIFFENED shells of various types have been designed, built, and used in flight vehicles as well as in civil structures for a number of years; however, there still exists a potential for further reducing their weight and improving the accuracy of their analysis. Substantial improvements in vehicle performance that can be gained from such weight reductions provide the impetus for accurately defining the potential minimum weight and associated design details for the many classes of stiffened shells used in their construction.

The general instability formula presented in the previous comment is an approximation to the critical pressure for symmetric buckling with a reduction factor derived from a Karman- and Tsien-type buckling analysis. Perhaps Professor Buchert's procedure is justifiable for monocoque or sandwich shells whose symmetric and asymmetric modes of buckling have equal critical pressures; however, the subject paper shows [Eqs. (13) and (14)] that the critical pressure for asymmetric buckling is lower by a factor of $[(1 + D_3/D)/(1 + E/G_3)]^{1/2}$ for equal stiffeners in the orthogonal directions when $D_3/D < E/G_3$, as it is for the square-grid-stiffening case. In terms of parameters similar to those used by Professor Buchert previously, the small-deflection theory formula

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