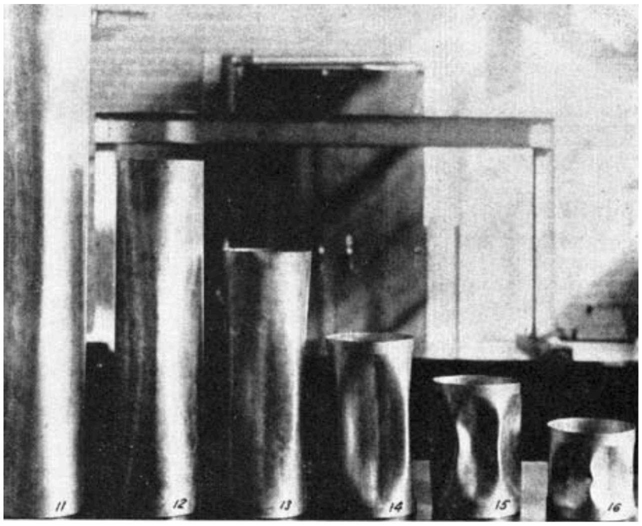
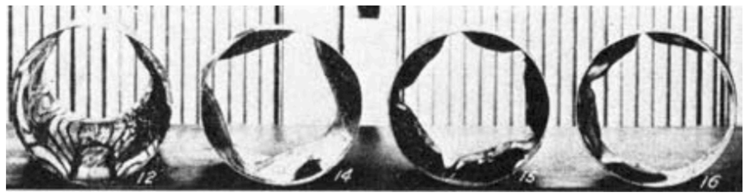

From: Henry L. Langhaar and Arthur P. Boresi, "Snap-through and post-buckling behavior of cylindrical shells under the action of external pressure", University of Illinois Bulletin in cooperation with the Office of Naval Research, Engineering Experiment Station Bulletin No. 443, 1957

Professor Henry Louis Langhaar (1909 – 1992)

See:
http://www.worldcat.org/identities/lccn-n88053509/

From http://de.wikipedia.org/wiki/Henry_L._Langhaar :
Born 14 October 1909 in Oklahoma; Died 28 September 1992. Professor Langhaar was an American engineer scientist of Mechanics and Civil Engineering. He studied mechanics at Lehigh University, where he received his doctorate in 1940 under Clarence Albert Shook (Steady flow in the transition length of a cylindrical conduit). He became professor of mechanics at the University of Illinois at Urbana-Champaign. In 1979 he received the Theodore von Karman Medal.

Most Significant Publications (from Wikipedia):
Dimensional Analysis and Theory of Models, Warrior 1980
Energy Methods in Applied Mechanics, Wiley 1962
With Arthur Boresi, Robert E. Miller, Jerry Brügging: Stability of hyperboloidal cooling tower, ASCE J. Eng. Mech., 96, 1970, 753-779
with Boresi: Buckling and post-buckling behavior of a cylindrical shell subjected to external pressure, TAM Report 93 1956
Buckling of a cylindrical shell subjected to external pressure, Austrian engineer Archives 1960

Selected Publications:
Langhaar, Henry Louis and Boresi, Arthur Peter, "Buckling and post-buckling behavior of a cylindrical shell subjected to external pressure", TAM Report 93, Dept. of Theoretical and Applied Mechanics (UIUC), April 1956, http://www.ideals.illinois.edu/handle/2142/18754.
ABSTRACT: In an earlier report (TAM Report No. 80), the authors considered the buckling and post-buckling

behavior of an ideal elastic cylindrical shell loaded by uniform external pressure on its lateral surface, and by an axial compressive force. Assumptions were introduced which reduced the shell to a system with one degree of freedom. The present investigation is a generalization and a refinement of this theory. The shell is treated as a system with 21 degrees of freedom. By the imposition of constraints on the 21 generalized coordinates, various end conditions can be realized; for example, simply supported ends with flexible end plates (no axial constraint), simply supported ends with rigid end plates, and clamped ends. Also, effects of reinforcing rings have been incorporated in a more general way than in TAM Report No. 80. The restrictive assumption that the centroidal axis of a ring coincides with the middle surface of the shell has been eliminated. A pressure-deflection curve for an ideal cylindrical shell that is loaded by external pressure has the general form shown in Figure 1. The falling part of the curve (dotted in the figure) represents unstable equilibrium configurations. Also, the continuation of line OE (dotted) represents unstable unbuckled configurations. Actually, the shell snaps from some configuration A to another configuration B, as indicated by the dashed line in Figure 1. Theoretically, point A coincides with the maximum point E on the curve, but initial imperfections and accidental disturbances prevent the shell from reaching this point. Point E is the buckling pressure of the classical infinitesimal theory (called the "Euler crítical pressure", since Euler applied the infinitesimal theory to columns). To some extent, point A is indeterminate, but it is presumably higher than the minimum point C unless the shell has excessive initial dents or lopsidedness. In TAM Report No. 80. a hypothesis of Tsien was used to locate point A. In the present investigation, point A is not considered. Rather, attention is focused on the development of a theory that will determine the en tire load-deflection curve. For short thick shells, such as the inter-ring bays of a submarine hull, the Euler critical pressures, determined by TAM Report No. 80, are too high, presumably because the assumption that the shell buckles without incremental hoop strain is inadmissible in this range. The present report corrects this error. Numerical data on the Euler critical pressures of shells with simply supported ends and flexible end plates have been obtained with the aid of lhe Illiac, an electronic digital computer. The data are tabulated at the end of this reporto For short shells without rings, the buckling pressures are appreciably lower than those determined by von Mises' theory. The numerical data for the Euler buckling pressures of sheUs with uniformly spaced reinforcing rings are sufficiently extensive to permit interpolation to estimate effects of various ring sizes. Some exploratory numerical investigations of post-buckling behavior have been conducted with the Illiac. lt is not feasible, at the present time, to handle nonlinear equilibrium problems for systems with 18 degrees of freedom. Consequently, for the numerical work, some higher harmonics were discarded so that the system was reduaed to 7 degrees of freedom. Even then, the numerical problem is formidable. The calculations were confined principally to the determination of the minimum point C on the post-buckling curve (Figure 1). The pressure at point C is the minimum pressure at which a buckled form can exist. It is found that the ordinate of point C, determined by TAM report No. 80, is somewhat too high. The two theories are compared by a table anq curves at the end of this report.

Langhaar, H. L,, and Boresi, A. P., "Snap Through and Post Buckling Behavior of Cylindrical Shells under the Action of External Pressure," Univ. of Ill. Eng. Exp. Station, Bull. No 443, 1957.

H. Langhaar, "Buckling of a cylindrical shell subjected to external pressure", Osterreichishes Ingenieur-Archiv, 1960

Langhaar, H. L., **Energy Methods in Applied Mechanics**, New York, John Wiley and Sons, 1962

Henry L. Langhaar (1), Arthur P. Boresi (1), Robert E. Miller (1) and Jerry J. Bruegging (2)
(1) Department of Theoretical and Applied Mechanics, University of Illinois, Urbana, Illinois, USA
(2) The Marley Co., Kansas City, Missouri, USA

“Stability of Hyperboloidal Cooling Tower”, ASCE Journal of the Engineering Mechanics Division, Vol. 96, No. 5, September/October 1970, pp. 753-779
ABSTRACT: An infinitesimal theory of instability of an elastic orthotropic shell of revolution subjected to uniform external normal pressure is developed. The theory leads to a linear eigenvalue problem for determination of the buckling pressure. Illustrative numerical calculations based on piecewise-polynomial approximations and the partition method are given for the Fort Martin tower erected in West Virginia by the Marley Co. The tower is a reinforced concrete hyperboloidal shell of revolution, 370 ft. high and 5.5 in. thick for most of its height.