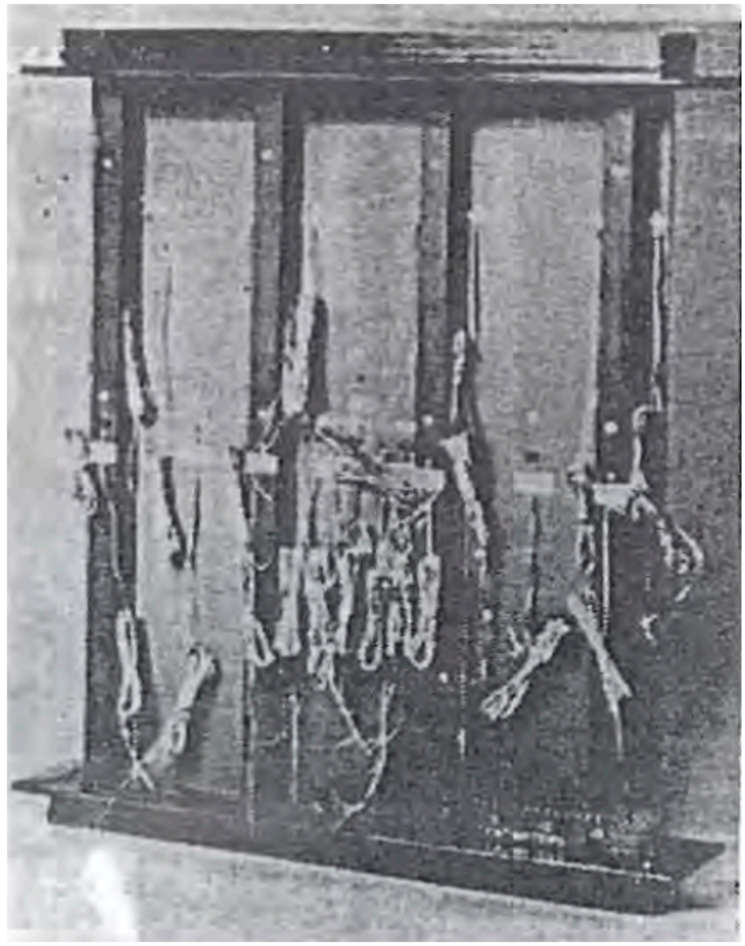
Dr. Norman F. Knight, Jr.



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Some unpublished words written by Dr. Norm Knight about buckling. Written by Norm in April, 2020:

In times past before too much FEA, structural stability was often decided by testing and then some with analysis. The old SP 8007 approach seemed to be based mostly on testing and compared to "buckling" analyses that were really eigenvalue analyses rather than nonlinear collapse analyses – not positive here but I think this is true. The so-called "buckling analysis" gave eigenvalues that were then related to "buckling loads"; however, they were way off the test "buckling load". This gave rise to the knockdown factors that accounted for in some way uncertainty in boundary condition, materials, general imperfections (surface waviness and/or thickness variations), and so on. Then the buckling analysis value was "knockdown" by the factor from SP8007. This is more of a 5,000 foot description.

What I am unsure of is what the tests cited as the basis for the SP8007 actually represented? Was it a local buckling event? Was it a global buckling event? Was it the initial drop in load? Or was it a collapse? For plates we generally see a decrease in stiffness (slope) of a load vs end shortening response but the slope stays positive and load can be increased. Not so for shells. So I wonder just what the test data for SP8007 really represented (local "buckles", global "buckles" or collapse)?

Anyway jump ahead a decade or two and we then started using nonlinear FEA and incorporated geometric imperfections and even used linear combination of the eigenvectors as an assumed imperfection for the structure. Riks' method came in and we could go further along on some unstable paths with the assumption that the response was all statically connected – no mode jumping.

Now it seems to me, and I may be wrong, that the current generation of analysts have forgotten about buckling eigenvalue analyses and probably courses on structural stability are infrequently offered. When I was in academia, I was only able to populate (4 students!)and teach a buckling course once in 8 years. Fundamental mechanics courses were difficult to populate, my experience. Now it seems detailed FEA models are built and then executed using a combination of implicit and explicit solution schemes. A nonlinear analysis is started statically and when convergence is slow, they switch to a dynamic analysis (perhaps an implicit scheme with inherent damping or an explicit scheme that only required the internal force vector and no a ‘tangent’ stiffness matrix.

So when the design spec calls for an assessment of “buckling”, what does the analyst do? Eigenvalue analysis of a detailed FEA? Standard nonlinear analysis until convergence stops or negative eigenvalues are detected? Or peak load from an implicit/explicit nonlinear analysis? How I have read and understood the standards is that I think it should be an eigenvalue analysis of a perfect structure based on minimum design thicknesses combined with the factors from SP8007. Then we augment our understanding with additional analysis. On the other hand, maybe it is like the effort that Mark Hillburger and company have been doing to assess what it means. To me, the old SP8007 type of approach really “protected” us from some of the “unknown” unknowns and as we drive out the “known” unknowns ((e.g., load introduction issues, boundary effects, imperfections) we increase risk.