ABSTRACT

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Title: Liquid Storage Tanks Internal and External Pressure Studies: Yielding and Buckling Failure Modes
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The oil and gas industry depends on the ability to store its products to maintain operation and distribution tasks. Liquid product may be stored in vertical aboveground cylindrical oil storage tanks that should be able to withstand the internal hydrostatic pressure when full of product and the external wind pressure when empty without failing. The American Petroleum Institute (API) Standard 650 is commonly used to design the storage tanks with various considerations for internal hydrostatic pressure and external wind pressure. The work presented in this dissertation focuses on refining the methods of design in the API 650 standard to optimize material use, improve safety considerations, and reduce cost.

The first investigation in this study examines the approach used in API 650 for designing the varying thicknesses in stepped-wall storage tanks. Storage tanks are often designed with multiple courses, each course having a thickness related to the water column level above it. This dissertation presents a new method of specifying the thickness of each shell course based on an analytical solution that more accurately captures the effects of the bottom plate bending moment on the upper shell courses. In contrast to the current API 650 design approach, the suggested approach does not have a tank diameter to height aspect ratio limit.

The second investigation explores the buckling behavior of ring-stiffened tanks due to wind loading as recommended by API 650. The buckling of open-top cylindrical storage tanks is controlled by restraining the top edge through the use of a top stiffener ring and restraining the shell with intermediate stiffener rings, if needed. The size of the top stiffener ring is not required to be increased by the rules of API 650 for tanks with a diameter larger than 200 ft. This work recommends a new lower upper diameter limit of 170 ft, after which the size of the top stiffener ring need not be increased.
The third investigation looks into the effects of nonuniform external pressure on the in-plane buckling of elastic circular rings, which may be attached to cylindrical storage tanks as stiffener rings. The buckling of the rings is analytically studied using a perturbation approach to solve the governing differential equation describing the large deformation behavior of circular rings subjected to nonuniform pressure. This study shows that any external pressure profile, such as wind, containing a small first-mode buckling pattern will cause the first buckling mode to occur in circular rings.