INERTED VESSELS:
UNDERSTANDING HAZARDS CAUSED BY GAS BUOYANCY

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Abstract

Performing hot work on a process vessel that previously contained a flammable hydrocarbon liquid poses a significant explosion and fire hazard. To reduce the combustion hazard potential, the facility operator may choose to purge and blanket the vessel with an inert gas such as nitrogen or carbon dioxide. Numerous accidents have occurred during hot work due to inadequate inerting operations. Oftentimes the source of the problem was inadequate gas composition control caused by gas buoyancy.

A useful paradigm for analyzing the inerting process is the well-stirred control volume with a spatially uniform chemical composition (i.e., perfect mixing). Certain features of the vessel construction can interfere with the mixing process. These features include vessel openings, large aspect ratios and internal obstructions. The impact of these features is especially great if the molar masses of the chemical species are different (a frequent occurrence) or of a different temperature. These composition or temperature differences can lead to buoyancy effects. Given enough time, buoyant flows can cause density stratification of the gas possibly resulting in the formation of a flammable pocket of gas within the vessel. If an ignition source, such as those used in hot work, should contact this flammable pocket of gas, an explosion or fire could occur.

This paper discusses how to evaluate the potential for buoyant flows to disrupt and interfere with the design goal of perfect mixing. The evaluation criteria are based primarily on fluid properties and the characteristics of vessel construction. We employ dimensional and order-of-magnitude analyses to justify the proposed evaluation criteria. Additional insight is provided by computational fluid dynamics simulations of some of these specific scenarios. Finally, the utility of these criteria is demonstrated with case studies of accidents that could have been prevented had the criteria been used.