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Mechanical Integrity Considerations in LNG Depressurization A Sensitivity Analysis

By Daniel Nguyen

Emergency depressurizing systems (EDPs) are designed to reduce pressure by expelling the fluids and/or inventory from the protected equipment, thereby reducing the risk of equipment failure. Typical scenarios considered for emergency depressurization are external fire, uncontrolled reactions, and process vessel leaks.

In the event of a pool fire or jet flame impingement, not only do the system contents experience a rise in temperature and pressure, but the temperature of the system's walls rises as well. As the temperature of the metal increases, its mechanical strength decreases. Since the portion of the vessel filled with liquid predictably absorbs most of the heat, the main area of concern would be the unwetted or dry wall exposed to fire. As heating continues, the tensile strength is further reduced. Eventually, the wall metal temperature will reach the vessel's ultimate tensile strength, causing equipment failure.

“Depressurization systems in typical LNG installations often experience this phenomenon, known as auto-refrigeration, which may compromise the equipment’s mechanical integrity and pose a risk of material embrittlement.”

Much literature[1,3,4] has been devoted to addressing system depressurization for fire scenarios; this paper focuses on the scenario of a vessel leak, alternatively referred to as a non-fired or cold depressurization. Due to expansion cooling and condensation of light ends, rapid depressurization can cause cryogenic temperatures in both upstream and downstream connected process equipment and piping. Depressurization systems in typical LNG installations often experience this phenomenon, known as auto-refrigeration, which may compromise the equipment’s mechanical integrity and pose a risk of material embrittlement. As system walls are exposed to temperatures below the minimum design metal temperature (MDMT), permanent damage is possible. The potential for brittle failure is even more pronounced for a non-fire scenario. Its severity depends on the initial pressure, temperature, content inventory, depressurizing rate, fluid composition, surrounding conditions, and heat transfer mechanisms.

Emergency depressurizing valves (EDPV) must therefore be sized to ensure a reasonable compromise between the impact of pressure and temperature. For example, in the event of fire or abnormal heating, a larger EDPV size would generally lower pressure faster, likely meeting the established pressure reducing criteria (e.g.,100 psi or 50% of the initial pressure) in the specified amount of time (often at 15 minutes). However, a larger EDPV size would also generate a higher depressurizing rate, exacerbating the cryogenic effect, which ultimately leads to a lower metal temperature. Likewise, a larger liquid inventory may provide a better liquid contact for heat absorption and sustain the vessel integrity for longer in the event of abnormal heating. However, the larger liquid inventory may also expose the metal wall (at the bottom in contact with the cryogenic liquid) to the lower temperature longer, creating a higher probability of embrittlement failure., Darby/API, DIERS/AIChE, and Pentair to name a few.

This paper examines the impact of different liquid levels, depressurizing valve sizes, vessel thicknesses, and fluid compositions. The primary objective is to identify and illustrate the key factors that that influence the mechanical integrity of a typical LNG installation, particularly at the mid to lower end of methane fluid compositions and their impacts on carbon steel.

Basis for Sensitivity Analysis

The system chosen for this paper’s sensitivity analysis study entails a horizontal cylindrical vessel with 2:1 Elliptical heads with Carbon Steel SA-516-G70. Unless stated otherwise, the basis and mixture composition considered in all vessel wall dynamics analyses are summarized in Table 1 and Table 2.

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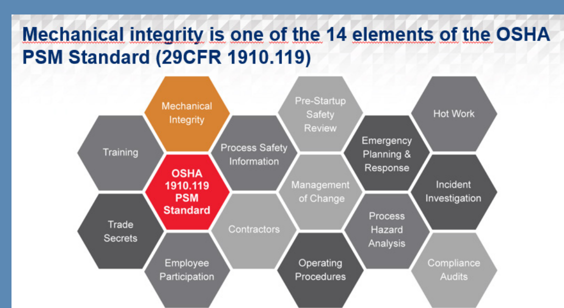

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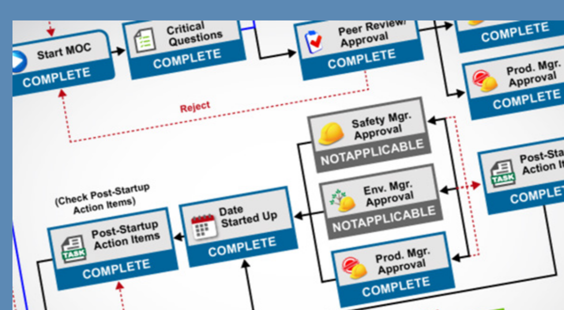

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