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LNG Pool Fires on Water (970 words)

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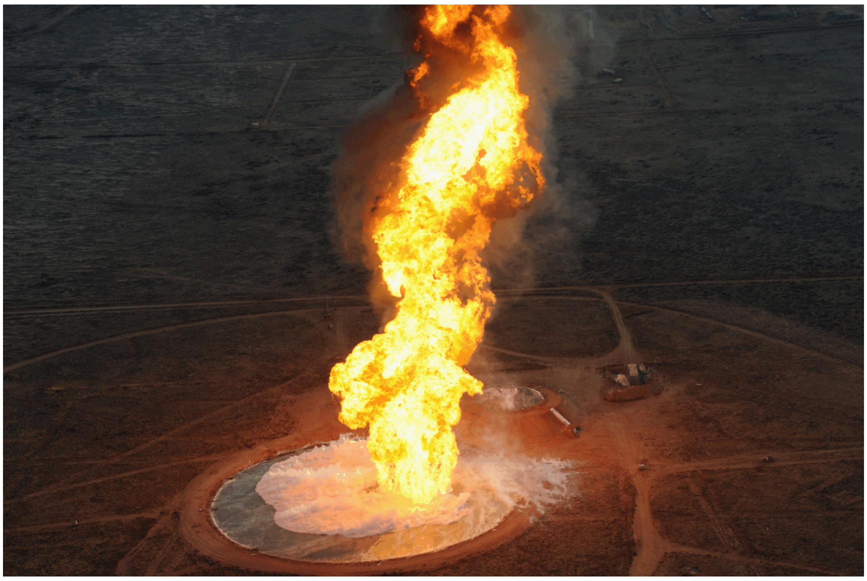

A large scale LNG spreading pool fire on water.

From June 2008 through June 2011, Sandia National Laboratories[1] (Sandia) conducted a series of large-scale liquefied natural gas (LNG) pool fire and cryogenic damage tests, as well as detailed, high performance computer modeling and simulation of LNG ship damage resulting from large LNG spills and fires on water.

This effort was in support of the U.S. Congress, the U.S. Department of Energy (DOE), and the U.S. Coast Guard (USCG) to expand LNG safety efforts to address the major LNG concerns identified in a February 2007 Government Accountability Office Report (GAO Report 07-316), "Public Safety Consequences of a Terrorist Attack on a Tanker Carrying Liquefied Natural Gas Need Clarification". The GAO convened a panel of experts on LNG safety that identified several key LNG research priorities needed to provide realistic and comprehensive large-scale spill hazard data for more accurately assessing public safety risks posed by LNG tankers transiting to near shore LNG terminals.

1 Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000.

The key pool fire issues that were addressed by these tests include:

- Determining the Surface Emissive Power (SEP) of large LNG pool fires;
- Determining the fuel vaporization rate of large LNG pool fires on water; and
- Determining the flame height to diameter ratios for large LNG pool fires.

This was accomplished through the collection of data obtained during a series of large LNG pool fire tests on water. The test site design included: 1) using soil excavated from the creation of a two meter deep, 120 m diameter pond to create a 310,000 gallon compacted soil LNG storage reservoir; 2) covering the reservoir with a double insulated cover and insulated liner to minimize LNG vaporization; 3) use of prefabricated reinforced concrete pipes to transport the LNG from the base of the reservoir to the center of the pool; and 4) use of simple, liftable plugs to allow gravity-driven high LNG flow rates from the reservoir to the pool. This approach enabled LNG flow rates representative of large spills, while minimizing the need for cryogenic rated high flow volume pumps, associated cryogenic rated hardware, and also fire rated LNG storage tanks.

Numerous cameras, spectroscopic diagnostics, and heat flux sensors were used to obtain extensive heat flux, flow rate, and fire size data from the resulting spills and fires for each test. The spreading pool fire areas were photographed with the aid of gyroscopically stabilized cameras deployed on helicopters. The tests conducted were the largest LNG pool fire tests performed on water (or land) at the time, and a summary of the measured pool fire parameters and data are provided below.

Sandia Large LNG Pool Fire on Water Data

Test	Volume Discharged (gallons)	Avg. Flame Height (m)	Flame Diameter (m)	Wind Speed (m/s)	Flame Tilt (degrees)	Vap. Rate (kg/m^2s)	Surface Emissive Power (SEP) (kW/m^2) (narrow/wide)
1	15,000	70	20.7	4.8	50	0.15	238/277
2	52,000	146	56 (83 m spill)	1.6	Negligible	Not obtained	316/286

The thermal radiation spectra as a function of height and time were acquired using a scanning mid-infrared (1.3-4.8 μm) spectrometer. Analyzed spectra determined that the dominant contributor to the thermal radiation was from broadband soot emission.

The overall thermal radiation reaching the spectrometer was attenuated by atmospheric water and CO_2 which resulted in a decrease in intensity at different wavelength bands. In LNG Test 2, at ~40 m to 103 m above the ground surface, the data is fairly consistent with spectra-derived flame temperatures of between 1300-1600°C and emissivity values between ~0.3 -0.4.

In both of the tests conducted, there was no evidence of smoke shielding. There were a few instances when small amounts of smoke were seen in LNG Test 2 during the production of large scale vortices that rolled up from the base of the flame when the fire exhibited a puffing behavior. Very little smoke shielding was also observed in pool fire data obtained from a previous, smaller scale (~10 m diameter) test conducted by Sandia in 2005. The Sandia LNG pool fire tests and other studies suggest that entrained water has the potential to reduce soot production and enhance soot oxidation, thereby reducing smoke production (Luketa 2011).

The trend in the data from these tests indicate that the SEP for LNG fires on water levels off at about ~280-290 kW/m^2 and might be expected for spreading pools with diameters in the range of 100 m. This is a reasonable value for use in hazard calculations for structures, such as the LNG vessel or shoreline areas, adjacent to or near the fire. Larger LNG fires would likely have some smoke shielding in the upper portions of the flame plume that will lower the overall flame-average SEP for far afield objects.

The collected data showed some unique and unexpected results. Specifically, the fire diameter was not the same size as the spreading pool diameter, as had been assumed by most analyses to date. Previous studies with stagnant pools in pans resulted in fire diameters the same size as the pool diameter. However, in all such studies, the pans had edges that can result in flame stabilization that would not be available in open water scenarios. The data collected further showed that in both very light and significant cross-winds, the flame will stabilize on objects projecting out of the fire, suggesting the vessel itself will act as a flame anchor.

The ultimate goal of this work was to provide recommendations on predicting thermal hazard distances resulting from LNG pool fires on water using solid flame models. An updated solid flame model that reflects the newly acquired data predicts results that are considered conservative and result in approximately 3% lower thermal hazard distances than that provided in the 2004 Sandia report. It must be emphasized, as noted in the 2004 Sandia report, that hazard distances will change depending on the surroundings conditions and the scenarios associated with the site. Thus, site-specific analyses should be performed.

Full details of the pool fire test program and test results are presented in Blanchat, et al., "*The Phoenix Series Large Scale LNG Pool Fire Experiments*," SAND2010-8676, Sandia National Laboratories. Additional references include Hightower, et al., "*Guidance on Risk Analysis and Safety Implications of a Large Liquefied Natural Gas (LNG) Spill Over Water*," SAND2004-6258, and Luketa, A., "*Recommendations on the Prediction of Thermal Hazard Distances from Large Liquefied Natural Gas Pool Fires on Water for Solid Flame Models*," SAND2011-9415.