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Spills and Fires from LNG Tankers in Fall River (MA)

By Professor James A. Fay, Massachusetts Institute of Technology
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Introduction:

The events of September 11, 2001 have raised concerns about the potential for terrorists attacks on the energy system infrastructure of the United States. In particular, the possibility of the use of a boat bomb, such as was used against the USS Cole in 2000 and the oil tanker Limburg in 2002, to attack a marine liquid fuel tanker in a U.S. harbor, was publicly discussed in Massachusetts, where both LNG (liquefied natural gas) and oil product tankers land cargoes in Boston harbor. The consequences of such an incident could be severe, and present a potential problem of great magnitude for public safety officials.

The safety concerns for the public stem from the effects of the burning of the tanker's combustible liquid cargo, which would certainly escape from cargo holds punctured by the force of an explosion. The ensuing fire can spread on the sea surface toward nearby shorelines, and its thermal radiation could produce bodily harm to exposed individuals on shore and possibly set fire to shoreside buildings.

The fire that would ensue from a boat bomb attack on a tanker would be of unprecedented size and intensity. Like the attack on the World Trade Center in New York City, there exists no relevant industrial experience with fires of this scale from which to project measures for securing public safety. Lacking such experience, we must rely on scientific understanding to predict their characteristics, based upon laboratory and field experiments of much smaller fires.

The author has developed a mathematical model for the spills and fires from liquefied fuel marine tankers which is based upon published scientific papers in peer-reviewed journals (Fay, *Model of Spills and Fires from LNG and Oil Tankers*, Journal of Hazardous Materials,

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B96, 171-188, 2003). The purpose of this article is to apply this research to the case of Fall River (MA) harbor.

Weaver's Cove Energy LLC has proposed to construct and operate a marine LNG import terminal on the Taunton River in Fall River (MA) (Weaver's Cove Energy LLC, *Weaver's Cove Energy LNG Import Terminal,* Fall River, June 30, 2003). To reach this terminal, ocean-going LNG tankers must move through Narragansett and Mount Hope Bays and enter the Taunton River, passing within 1000 feet of downtown Fall River waterfront and near commercial and residential areas. A tanker spill fire at any location along this route would have serious consequences for persons and property on the shore adjacent to the stricken vessel.

LNG Tanker Spills and Fires:

The liquid fuel carried in sea-going LNG tankers is stored in separate holds, each of which may be as large as 25,000 cubic meters holding 10,500 tons of cargo. A powerful explosion close along side the tanker can puncture at least one hold and allow the cargo to drain out upon the surrounding sea surface. The upper part of the cargo fluid that is higher than the sea surface level will first leak out, but additional cargo may also be ejected. Given an explosively formed hole of sufficient size, such cargoes can be disgorged within minutes.

LNG is lighter than sea water. Once spilled, it floats, unmixed, on the sea surface. Most importantly, it speedily spread sideways, exposing the fuel to the air above. Once ignited, as is very likely when the spill is initiated by a chemical explosion, the floating LNG pool will burn vigorously. The time to burn spills of the size mentioned above can be less than five minutes.

Fires that burn thousands of tons of fuel in a few minutes are extraordinarily large, lying well outside the range of domestic firefighting experience. Such fires can be damaging to people and can set afire combustible buildings.

Maximum Pool Size and Fire Duration:

To illustrate the characteristics of such spills in Fall River harbor, we consider a typical spill of LNG. (The relevant spill parameters are listed in Table 1.) The LNG spill volume is 14,300 cubic meters or 3.8 million gallons. Provided the vessel hole area is greater than ten square meters, the maximum pool fire area is 180,000 square meters (44 acres) and radius is 340 meters (1115 feet), while the fire duration is 3.3 minutes.

Table 1: Physical parameters of a typical LNG tanker spill	
Spill volume	14,300 cubic meters = 3.8 million gal.
Fire duration	3.3 minutes
Maximum pool area	180,000 square meters = 44 acres
Maximum pool radius	340 meters = 1115 feet

Average heat release rate	1,500,000 megawatts
Distance to average heat flux of 5 kilowatts per square meter	1100 meters = 3600 feet

The pool fire, initiated at the time of the explosion, grows in area in proportion to the time since initiation, reaching maximum extent at the end of the burning process. Maximum pool size for an LNG spill located at the proposed LNG terminal: the outer edge of pool fire extends to both east and west shores of the Taunton River. For a spill anywhere along the path of an LNG tanker approaching the terminal, the pool fire would reach Fall River shore. It is most certain that combustible buildings long the waterfront would be ignited by contact with the pool fire.

The extent of the pool fires, which spread to distances greater than the ship length in a short time, would make it impossible to move the stricken vessel away from the waterfront areas. The potential for retarding the pool spread is nonexistent.

Pool Fire Thermal Radiation:

Burning LNG emits thermal radiation that, if intense enough, can cause skin burns on humans exposed to the radiation and can ignite combustible materials on buildings. The more intense the radiation, the shorter is the exposure time needed to cause a skin burn or combustible material ignition.

For human skin exposure to flame thermal radiation, a thermal flux of 5 kilowatts per square meter will result in unbearable pain after an exposure of 13 seconds and second degree burns after an exposure of 40 seconds. Exposure to twice that level, 10 kilowatts per square meter, for 40 seconds is the threshold for fatalities (K.S.Mudan, *Thermal radiation hazards from hydrocarbon pool fires*, Progress in Energy Combustion Science, 10, 59-80, 1984). Wood can be ignited after 40 seconds exposure at a thermal flux of 5 kilowatts per square meter.

We have chosen a thermal flux of 5 kilowatts per square meter a a criterion for the limit for significant damage to humans and combustible materials and have calculated the distance from the spill site at which that flux would be experienced (These distances are based upon an analysis contained in Fay, *Model of large pool fires*, submitted to the Journal of Hazardous Materials). As listed in Table 1, this distance is 1100 meters (3600 feet or 0.68 mile) for an LNG spill.

For an LNG spill, the thermal radiation damage zone encloses 940 acres, including about 400 acres of land area in Fall River. Within this zone, extending 3600 feet from a spill site in the main channel of the Taunton River, skin burns to humans exposed for only a fraction of a minute will occur, and building fires can be induced. Beyond the shorefront, at 1600 feet from the spill site, where the thermal radiation flux is 10 kilowatts per square meter, fatalities can ensue.

One cannot exaggerate the thermal intensity of the LNG pool fire. It's average heat release rate is about twice the average thermal power consumption of all U.S. fossil fuel electric power plants.

Conclusion:

The analysis summarized in this report, based upon studies published in peer-reviewed scientific journals, sets forth the physical characteristics of the fires to be expected from a boat bomb attack on an LNG tanker in Fall River harbor. The major conclusions are:

- The magnitude of the resulting liquid cargo pool fires are unprecedented in scale. There is no possibility of ameliorating the fire's effects, much less extinguishing it, during the short time (several minutes) of burnout.
- At any point along the inner harbor route of ship travel from sea to berth, pool fire thermal radiation that can burn and even kill exposed humans, and ignite combustible buildings, will be experienced along and well inland from the waterfront.

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