LNG (Liquefied Natural Gas) and its impact on our society

I had the opportunity to attend the International Association of Fire Chiefs (IAFC) International Hazardous Materials Response Teams Conference at Hunt Valley earlier this month. While there were a wide array of excellent workshops and presentations available for the attendees, a session on Friday evening really caught my attention. Part of the attraction were the topics, pipeline safety and LNG, but part was to view collaborative products developed by parties representing different sectors of our society but with one goal in mind, inform and educate.

As a sidelight to this month's article on LNG, I would like to make the observation that the IAFC Hunt Valley conference has evolved over the last several years. This is due to the impact of the September 11th attacks and the fact that CBRNE is now a more visible subset of Hazmat for the entire Hazmat response community. The CBRNE agents have always been there, but before Sept 2001 they took a backseat to the TICs/TIMs for which most fire service and Hazmat teams had to prepare. I have also noticed there are more law enforcement and military representatives that attend the conference than back in the 1990's.

Anyway, to get back on target, my objective is to discuss briefly the video and white paper developed by the National Association of State Fire Marshals (NASFM) in conjunction with other organizations and with funding from the US Department of Transportation's Office of Pipeline Safety (OPS). The video, on DVD, and the white paper, from which most of this discussion is taken, are available by going to the NASFM web site (http://www.firemarshals.org/) which will provide an automatic link when you click on *Programs|Liquefied Natural Gas Program* to the NASFM's Partnership in Excellence in Pipeline Safety web site (http://www.safepipelines.org/cur_proj/liquid_gas/). The White Paper is titled *Liquefied Natural Gas: An Overview of the LNG Industry for Fire Marshals and Emergency Responders*, and provides a discussion of the LNG industry and the pertinent facts of LNG as an energy resource.

My personal interest with LNG is based on the previous research that the AristaTek founders conducted at the HAZMAT Spill Center (HSC) located on the Nevada Test Site. The HSC was originally named the Liquefied Gaseous Fuels Spill Test Facility (LGFSTF) and was setup initially for testing the behavior of LNG when released to the atmosphere back in the 1980's. Many of our readers are probably familiar with the previous field research (such as the Kit Fox Series) that the AristaTek founders were involved with at the HSC during the 1980's and 1990's. Those research programs were a continuation of the initial LNG field tests originally started in 1980 at the Naval Weapons Center (NWC), China Lake, CA and then moved to the Nevada Test Site. The reason for the research then was the concern about what hazards were associated with LNG storage systems and how the LNG behaved when released from those storage containers to the environment. The questions were asked because in the late 1970's the US was experiencing a rise in energy prices and LNG importation was viewed as a partial answer to the shortage of fossil fuels.

Figure 1 - Part of the tank farm used in the Kit Fox experiments, allowed for storage of large volumes of the surrogate dense gas released during the experiments – in earlier experiments up to 66m^3 of LNG was releases in about 2 minutes from these tanks and through these lines.

Déjà vu - here we are in 2006, about 30 years later, and we're experiencing another rise in energy prices and again the importation of LNG is seen as a viable answer to the shortage of fossil energy in the US. And, even though the questions have been answered, many communities have the same concerns expressed 30 years ago about LNG facilities.

The video and White Paper available from the NASFM web site provide the industry and federal government's viewpoint of LNG technology. In the last several years, there have been recent proposals to build LNG terminals, either onshore or offshore, that have been blocked by local opposition. The opposition is not simply environmentalist or others opposed to industrial development; there are legitimate questions being asked, and some are coming from individuals with technical credentials who ask pointed questions that probably need to be answered to all parties' satisfaction.

There are multiple issues but the primary question is what is the impact of a major incident at one of these facilities? This would seem to be a straightforward question but in truth it's not.

There is considerable debate and difference of opinion on what constitutes a major incident, i.e., how much LNG could be released if a terrorist tried to blow a hole in the side of a LNG tanker while still full and sitting in port? Separate analyses by respected technical experts (see the Sandia National Laboratories report, SAND2004-6258, December 2004) provide considerable different results.

The reader can make their own assessment of the facts and the individual results, but one would hope that eventually the pro and con parties can come to an agreed to analysis basis and let that govern the permitting, design and safety monitoring processes.

Back to the topic of LNG, the federal government has three separate agencies that oversee the LNG facilities: (1) the Federal Energy Regulatory Commission (FERC), (2) the US Coast Guard (USCG), and (3) the US DOT's Office of Pipeline Safety (OPS). Through their cooperative agreement, they have the primary regulatory authorization over the siting, design, construction, and operation of the LNG facilities and the related land and marine safety and security of these facilities. FERC is responsible for permitting the LNG facilities and ensuring their safety through inspections and security reviews. DOT's OPS has the authority to enforce safety regulations and standards for transportation and storage of LNG following the NFPA's (National Fire Protection Association) Standard 59A, *Standard for the Production, Storage, and Handling of Liquefied Natural Gas*. The USCG exercises regulatory authority over LNG facilities that affect safety and security of port areas and navigable waterways.

The transport of LNG across the world's oceans has been going on for about 45 years. Currently worldwide there are 110+ million metric tons of LNG that are transported on ocean tankers annually. The tankers all have double hulls, and the LNG is carried at pressures near atmospheric pressure, i.e., these are not high-pressure cargos. Even with insulated tanks, the LNG continues to boil off, with the vapor removed to fuel the ship's engines.

The DOT regulations require exclusion zones around LNG facilities and are based on the distances being great enough so that fire hazards from potential accidents would be within acceptable limits at the LNG facility fence line or property line. This appears to be the major problem, is the required exclusion zone appropriate for a "major incident." The storage tanks are double walled and basically are designed as a container within a container. The tanks are required to meet metallurgical standards and be constructed of aluminum or 9% nickel steel. The tanks are also designed to have surrounding dikes or embankments to contain 110% of their capacity.

Since the flammability range of LNG is 5-15% by volume of gas in air, the material stored in a container is not flammable unless mixed with air. If the contents of a storage tank were lost to the containment dikes surrounding a tank, then the mixing with air could form a flammable mixture in the 5-15% range. This should be considered a significant threat but only from the standpoint of the thermal injuries from the radiant heat generated if the mixture was ignited. The rate of burn for methane (the primary component of LNG) is slow enough that the conflagration of the mixture, unless confined by some type of structure, is not rapid enough to generate an over-pressurization or blast wave as might be experienced with higher molecular weight hydrocarbons, like gasoline or oxygenated solvents.

The NASFM White Paper does provide some useful information for any firefighter or Hazmat responder that might have to deal with LNG facilities should be aware.

<u>LNG Hazards</u>

For those dealing with a LNG facility there are three primary hazards to consider: (1) flammability, (2) dispersion, and (3) cryogenic temperatures.

<u>Flammability</u>

LNG is 85-96% methane with other light hydrocarbons such as ethane, propane and butane making up the balance and with as much as 1% nitrogen. LNG has an ignition temperature of the vapor at 1004°F and a flammability range from 5-15% in air.

<u>Dispersion</u>

LNG has an expansion ratio of 1 to 600 when going from a liquid to a vapor at one atmosphere. LNG is usually stored and transported at varying pressures, usually less than 5 psig, in well-insulated containers. Since the boiling point of LNG is –260°F and as already described the tanks are maintained at less than 5 psig, the LNG is in a state referred to as "*auto-refrigeration*." This is a term some responders are not familiar with but should understand.

Materials that boil at temperatures below ambient temperature (ambient is a term meaning room temperature) are sometimes referred to as cryogenic liquids. These materials can be stored and shipped in one of two ways; either as a compressed liquefied vapor at room temperature or as a refrigerated liquid in special containers at lower pressures.

Common substances that are stored or shipped in bulk as a compressed liquefied vapor are anhydrous ammonia, chlorine, LPG, propane, and butane. These materials are contained in pressurized vessels that have no special insulation or refrigeration systems to keep the contents at a specific temperature.

This is in contrast to cryogenic materials that are shipped in special containers that have special insulation materials, there may be refrigeration units involved to maintain the liquid below a certain temperature and the containers may also be pressurized depending on the particular liquid. Examples are liquid nitrogen, liquid oxygen, liquid carbon dioxide, liquid helium and LNG. For most of the containers for these materials there is an auxiliary refrigeration system to remove heat and keep the contents at a specified temperature and its associated pressure. If the temperature rises above a certain point, a pop-off valve will release and the pressure will be relieved. As the pressure decreases, liquid will boil to reach equilibrium, and as it boils the liquid will cool. In the case of the LNG, the liquid is maintained at less than 5 psig so the LNG is continually boiling. As it boils it removes heat, which cools the remaining liquid, hence, the term *auto-refrigeration*.

The density of LNG is 3.9 pounds per gallon— about half that of water, so if it is spilled on water it will float on top and vaporize very rapidly since even at water temperatures near freezing; the water is a lot warmer than the released LNG. If it is spilled on the ground, it will initially boil rapidly and then boil slower as the ground cools. The resulting vapor cloud is very cold and will be visible because it condenses water out of the air. Initially, the vapor cloud is dense, and made visible by ice crystals from water vapor in the air. If there is no ignition source the mixture will hug the ground and spread laterally.

Cryogenic Hazards

Since LNG is a cryogenic liquid and is stored and transported at –260°F, contact with the liquid can cause severe damage to skin and eyes. Most ordinary metals are subject to embrittlement and fracture at these temperatures and therefore containers and transfer lines must be manufactured from 9% nickel steel or aluminum. These tanks and transfer lines must be insulated to protect workers from severe freeze burns if they come in contact with the equipment.

Fire Scenarios

There are three potential fire risk scenarios to be considered:

Pool Fire – In this example, the LNG is released from a storage tank or transfer line and forms a liquid pool. As the pool forms a portion of the liquid evaporates and if the vapors are ignited the flame will travel back to the source of the spill and a pool fire will be involved. If the pool is inside a properly designed dike area, the fire will remain inside the containment and burn until all the fuel is consumed. If the spill occurs outside a confined area then pool will flow based on the topography. Spraying water on the LNG pool only increases the vaporization rate and makes things worse, since spraying a gallon of water will vaporize about two gallons of LNG.

The recommended extinguishing agent for small LNG fires is dry chemical such as potassium bicarbonate. High expansion foams are not considered extinguishing agents but they are considered effective in controlling LNG fires in dikes and containment areas because they do reduce the radiant heat generated. They have also been demonstrated useful in reducing vapor from the unignited LNG. There will be some initial warming with an associated increase in vaporization but that will stabilize and eventually slows down the amount of released LNG vapor, thereby reducing the flammable region.

Jet Fire – Normally LNG facilities are operated at low pressures, and the release of a compressed natural gas or liquefied gases from storage tanks is unlikely. But jet fires could occur in pressurized LNG vaporizers and during unloading operations when pumping increases pressures. These can cause serve damage but can be localized and controlled by safety systems that stop the LNG vapor flow.

Vapor Cloud Fire – If the LNG is released and a vapor cloud forms while mixing with the air, it is possible that ignition could occur but only within the cloud that is in the flammability range between 5-15% LNG by volume. The entire cloud will not ignite a once, but a flash fire may burn back to the release point creating either a pool fire or a jet fire. The primary concern is the thermal heat injuries from the radiant heat generated and not from overpressures created unless the vapor cloud is confined.

Conclusion

To our fire service readers who may have a LNG facility in their jurisdiction, we suggest you request a copy of the video and download the White Paper. It's an excellent opportunity to inform your staff on designs for LNG facilities and the inherent hazards associated with LNG.