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INTRODUCTION

In its Annual Energy Outlook for 2005, the US Energy Information Administration (EIA) has projected that the country will face an 8.7 trillion cubic feet gap in domestic natural gas production by 2025. This trend is currently being felt acutely by Americans who heat their homes with natural gas, in addition to those who pay electricity bills in regions where pricing is set by landbased gas turbines.

Shipping the gas from continents with more plentiful supplies is one option. But this involves transporting and offloading the fuel in its highly concentrated liquid form (natural gas super-cooled to -259º Fahrenheit), leading to concerns over safety in the communities close to transport routes and offloading terminals. Battle lines are being drawn between those concerned about the country’s energy security and communities who fear the dangers of explosions or very large fires caused by accidents or terrorist attacks. As a result, siting of liquid natural gas (LNG) terminals is drawing an extremely high level of scrutiny over risk and safety assessments. This white paper provides an overview of this controversy, an outline of regulatory requirements, and a demonstration of how computer simulation of accidents can be used to perform risk and safety assessments.

THE CONTROVERSY OVER LNG TERMINALS

Because LNG is so dense (it takes up about 1/600th of the volume of gaseous methane), it is much more economical for transporting across large distances. When it does arrive at its destination, it goes through a re-gasification process for transport and use in the traditional manner. While some may have the impression that LNG is a new technology, more than 130 custom-designed double-hulled ships over 1,000 feet in length are currently in operation. Every year, more than 120 million metric tons of LNG are shipped between 40 LNG-receiving and re-gasification terminals. There are five such terminals in operation in the US: Everett, Massachusetts; Cove Point, Maryland; Elba Island, Georgia; Lake Charles, Louisiana; and Peñuelas, Puerto Rico. It is notable that the largest need for natural gas is on the west coast, where there
is an abundance of gas turbine based power plants, yet all of these terminals are in the East. Accordingly, terminal construction has been proposed in Humboldt Bay, California. Another terminal has been proposed for Boston Harbor on the east coast.

A typical LNG tanker holds the equivalent of 20 billion gallons of natural gas, representing an enormously large potential source of thermal energy that some worry could be a terrorist target. This has led to a great deal of controversy, widely covered by the news media. Communities have understandable fears about catastrophic explosions or large fires. Project developers have been open to providing safety information to regulators. Providing fully comprehensive safety analysis to regulators, however, requires a significant effort, and worst case scenario analyses can and have been viewed as incomplete by the public.

While fear over the possibility of a large explosion tends to receive the most media coverage, this phenomenon would require some degree of confinement coupled to a significant ignition source, an unlikely combination at LNG terminals, which are designed to avoid confinement. A large vapor cloud or pool fire caused by a spill is a more likely scenario, and could also represent a significant danger. Pool fires on open water, in particular, can grow larger than contained pools and therefore, can cause damage at larger distances.

REGULATORY REQUIREMENTS FOR LNG TERMINAL SITES
The regulatory bodies responsible for LNG terminals include the FERC (Federal Energy Regulatory Commission), the US Coast Guard, the US Department of Transportation, the National Fire Protection Association, the Transportation Security Administration, and, in some cases, additional state and local authorities. Public Utility Commissions (PUC’s) are typically the center of communication and decision making on LNG projects, interacting with federal regulators and the local community. The National Association of Regulatory Utility Commissioners has compiled a white paper providing guidance to the PUC’s on the NEPA review process and interactions with the regulatory agencies when planning LNG terminals. The process requires that the LNG facilities perform their own risk assessments.

In order to determine the hazards of such an event for any proposed terminal, where “potential impacts on public safety and property could be high and where interactions with terrain or structures can occur, modern, validated computational fluid dynamics (CFD) models can be used to improve analysis of site-specific hazards, consequences, and risks.”

Until recently, safety and security guidelines existed only for land-based LNG terminals. In order to fill this gap, the Department of Energy contracted Sandia National Laboratory to develop guidance for marine LNG terminals. The study concludes that the risk of an accidental breach of a tanker is small, and that casualties and property damage would be limited to a relatively small area. This risk can be managed using current safety practices and methods. In contrast, the risk of an intentional breach by an act of terror would be larger. This type of breach would be more likely compounded by an ignition source and ensuing fire, with a larger area of casualties and property damage.
SIMULATION TO THE RESCUE

The initial physics of the breach of the tank, the ensuing LNG flow rate through the hole, and the internal cryogenic damage to the cargo hold can be effectively decoupled from the rest of the physical processes associated with an intentional tanker breach. Exhaustive studies of these processes have been undertaken, with the conclusion that hole sizes will typically range from 2 to 12 m², with the typical sizes being between 5 and 7 m². The spreading of the cryogenic liquid on water, the evaporation process, the dispersion of dense gases, ignition, combustion, soot formation, and radiative heat transfer can all be modeled with computational fluid dynamics tools.

As a demonstration example, the breach of a generic LNG tanker has been simulated. Figure 1 shows the geometry of the scaled model, including the water surface and a hole in the side of the hull just below it. Liquid natural gas pours through the hole into the seawater, where it flashes, converts to gas, and rises to the surface with a quiescent atmosphere. This investigation assumes that there is an ignition source above the surface such that the natural gas ignites. Figure 2 shows the flame shape, colored by temperature two seconds after the flow through the hole begins, while Figure 3 depicts the flame after five seconds.

Validation of these processes is of critical importance, and an effort for simulation of LNG plume dispersion is ongoing. Nonetheless, this demonstration makes it clear that it is possible to simulate LNG accident scenarios using flow modeling tools. This type of analysis allows engineers to better understand the impact of local geography and wind patterns on the plume dispersion and thermal radiation.

SUMMARY

A natural gas shortage in the United States has led to increased public debate about construction of new LNG terminals. Because this development involving the increased presence of large amounts of combustible material coincides with rising terrorism concerns, detailed safety analyses will be critical to the process. This white paper has provided a demonstration of how fluid flow modeling can be used to understand the effect of local geography and wind patterns
on LNG plume and pool fire development. The results provide an understanding of the risk to public safety and property for various terminal siting scenarios.
