

## Study talks of possible LNG disaster as result of accident

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A confidential study commissioned by the owner of Boston's liquefied natural gas terminal suggests that an accident involving an LNG tanker could quickly evolve into a chain reaction of explosions and fires.

Such a scenario would almost inevitably lead to a catastrophic failure of the ship and a spill of LNG that would be much larger and much more dangerous than anything so far considered in federal studies and assessments of LNG hazards.

Virtually every study used by federal regulators considers the loss of less than one-fifth of the cargo onboard a typical LNG tanker to be the "worst-case" accident scenario. Most published scientific studies estimate that such a limited spill could result in a fire a half-mile wide.

By contrast, the confidential study -- commissioned by Tractabel LNG North America LLC, which owns the Boston Distrigas LNG terminal -- proposes several scenarios in which even a relatively small rupture in one of the five cargo tanks onboard a ship could "escalate" and lead to ruptures in multiple tanks.

Described as a "generic" assessment, the study by the international maritime industry consultant Lloyd's Register of Shipping stops short of identifying how large an area could be affected by such a catastrophic failure of the ship.

LNG fires are often described as more dangerous than fires involving gasoline or other hydrocarbons, in part because natural gas burns so efficiently and intensely, and in part because each gallon of LNG has several hundred times the energy potential of a gallon of gasoline. Calculations provided to the Mobile Register by leading LNG scientists indicate that the loss of most of the contents of an LNG ship could produce a fire a mile wide and result in second-degree burns two miles away.

A fire of that magnitude would occur only under a certain set of conditions, and most scientists agree it would be unlikely unless the tanker was hit by another ship or attacked by terrorists. But the fire could be devastating if it were to occur on the western shore of Mobile Bay, where ExxonMobil Corp. has proposed building an LNG terminal about two miles south of the Mobile city limits, near a residential neighborhood and an elementary school. ExxonMobil plans to ship the highly concentrated and super-chilled liquefied gas to the facility in supertankers a thousand or more feet long.

Once docked, the tankers would offload LNG at the \$600 million facility, where the fuel would be gradually warmed and converted to the less concentrated and more conventional vaporous form of natural gas. LNG terminals recently have been proposed for more than two dozen sites around the country.

The Lloyd's study, completed in October 2001, was originally commissioned to determine whether the decades-old Distrigas LNG facility in Boston Harbor could be reopened safely. That terminal was shut down following the Sept. 11, 2001, terrorist attacks.

Since then, the study has been referenced in numerous news accounts, congressional reports, letters to members of Congress and presentations by the U.S. Department of Energy and the LNG industry. In many cases, the Lloyd's study has been cited alongside a controversial study by the Oklahoma-based Quest Consultants Inc. as proof that LNG tanker operations pose only limited threats to the public.

But the actual contents of the Lloyd's proprietary study -- titled "Explosion and Gas Release from LNG Membrane Carriers: Generic Consequence Assessment" -- apparently have never been made available to the general public.

Alabama State Docks director Jimmy Lyons said Friday that he had tried to obtain the study from Lloyd's Register in hopes of addressing safety concerns in the weeks after ExxonMobil obtained an option to buy Docks land to build its terminal. But, Lyons said, he ceased making inquiries when he was told that obtaining the study would cost \$250,000.

Last week, the Mobile Register obtained a copy of the 95-page study from sources who had been asked to review it earlier.

The newspaper attempted to reach Lloyd's Register officials to question them about the study, but they did not respond.

Julie Vitek, a spokeswoman for Boston Distrigas, said Friday that the copy of the study the newspaper obtained appeared to match the complete, original Distrigas document. Vitek said the study had never been intended for public dissemination and that Distrigas had provided it only to government officials. Vitek said Distrigas contracted with London-based Lloyd's Register (not to be confused with the insurer Lloyd's of London) because the company is "the preeminent shipping expert in the world."

The analysis that receives the most attention in the Lloyd's study is the possibility that a tanker could be lost completely as a result of multiple explosions of LNG and widespread fracturing of the hull.

While officials with the Department of Energy, ExxonMobil, the Federal Energy Regulatory Commission and the Alabama State Docks have acknowledged that an accident involving an LNG tanker could result in a fire, they have mostly scoffed at concerns that an LNG accident could result in an explosion of the cargo.

The Lloyd's study makes the case that an onboard explosion of LNG is a real and credible concern if an accident were to occur. The tankers carry more than 30 million gallons of the liquid gas.

The authors of the study noted that if a breach of both hulls in a double-hulled tanker occurred as a result of an explosives charge placed by terrorists, "there is a risk of an explosive mixture forming" within the confined spaces inside the ship. In the seconds after the deliberate blast, multiple ignitions could flare, exhaust themselves and flare again on the escaping cargo. "Ignition of this flammable mixture will result in a confinepartly restricted explosion event," states the study's "Failure Mode and Effect Analysis."

This "explosion event" could be compounded, the study continues, by a type of flameless explosion, caused when the escaping liquid natural gas comes into contact with water, warms, and in a split second expands its volume 200 times (a phenomenon often called "Rapid Phase Transition"). These flameless explosions could occur without a source of ignition.

"The explosion forces acting upon the tank sides are likely to be large," the analysis states.

The Lloyd's report considers how these explosions and the resulting shock waves and intense pressures would interact with other factors that already would have weakened the hull seriously. One of the significant dangers to the integrity of the outer hull is the extremely low temperature of the LNG itself. If the metals that frame and form the hull come into contact with a liquid that's chilled to 260 degrees below zero, the metals become brittle and fracture.

"The steel with which the structure is made is not capable of withstanding this extremely low temperature," the study says. "It will fracture extensively wherever there is contact with the liquid gas. The complete inner hull space for the complete length of the cargo tank will be in contact with the cargo and the fractures will be extensive ... The fractures will open to the extent that seawater will enter and gradually fill the space."

At this point, the study notes, an initial breach in just one of the ship's five cargo tanks could spread to the other tanks, spilling still more LNG. The cascading failures would begin to engulf the ship and its entire contents in fire.

"If ignition takes place within the inner hull, there will be a detonation type explosion," the analysis states. "The forces upon the tank sides, already weakened by fractures, will be extreme. The structure will collapse, exposing further the liquid gas inside the cargo tank. Also the explosion will collapse the structure beyond the ends surrounding adjacent cargo tanks. This structure has already fractured, but although still secure, it will not be able to withstand the blast and the adjacent cargo tanks will likely be opened, thereby releasing more liquid gas into the structure. With further ignitions and explosions following, the ship would then become a total loss with a continuous fire that would be inextinguishable until all gas had been consumed."

Many government documents and written industry presentations that refer to the Lloyd's study mention only three or four of the 19 conclusions in the executive summary, and none reviewed by the Mobile Register focus on the disastrous scenario described above.

In a November letter to Spencer Abraham, director of the Department of Energy, U.S. Rep. Ed Markey, D-Mass., raised concerns that the Lloyd's study had been used -- perhaps inappropriately -- to justify the reopening of the Boston LNG facility.

The study, he wrote, "had been used by the federal government and the facility operator to minimize the potential danger of a fire and explosion at or near the Distrigas facility" to the densely populated neighborhoods surrounding the terminal.

Vitek, the Distrigas spokeswoman, agreed that the Lloyd's study had played a key role in reopening the Distrigas facility and setting the conditions for continued LNG shipments into Boston Harbor.

"Given (Lloyd's) experience, we're confident in the company's analysis and believe that it, along with other analyses and information, has become an important tool in the safety and security planning in Boston Harbor," Vitek said Friday.

It remains unclear, however, which of the study's conclusions are being used as a basis for "safety and security planning."

Numerous industry executives and government representatives have referred to the study's conclusion that "an unconfined" LNG detonation explosion -- one that occurs as a vapor cloud spreads over open water -- "is most unlikely." But few have made reference to the study's conclusion that an "internal explosion" of gases confined in the hull "is a possibility" if a terrorist attack were to cause a spill.

Several government analyses appear to draw conclusions about the study that seem to be unsupported by the document itself.

For example, a Sept. 9 report for Congress, published by the Congressional Research Service, states that the Lloyd's study "found the risk of a public catastrophe to be small." The Mobile Register was unable to find any such conclusion in the Lloyd's study.

The same congressional report went on to refer to the terse estimate of fire size included in a summary of the Lloyd's study as further evidence that the risk to the public of an LNG release is not great.

The congressional report did not note that Lloyd's based its fire estimates solely on a 1-meter-wide hole in the hull. The Lloyd's summary, however, acknowledges that a readily transportable explosive charge would be capable of producing a much larger 5-meter-wide hole -- about 16 feet wide.

Those estimates have been confirmed by real-world events. A terrorist attack in Yemen in October 2002 punched a 26-foot-wide hole in the Limburg, a double-hulled oil tanker.

Scientists say that basing LNG spill predictions on the smaller hole size would dramatically reduce the estimated spill size, and result in calculations of smaller and less dangerous fires. Several scientists who reviewed the Lloyd's document at the Mobile Register's request noted that the fire sizes estimated by Lloyd's for a one-meter hole scenario are much smaller than those predicted by any other study, including the study by Quest Consultants, which has been widely

criticized for understating the dangers of LNG fires. Those scientists said there is not enough information in the Lloyd's study to determine how its authors arrived at their fire estimates.

But the scientists stressed that the Lloyd's study makes clear that a simple spill of LNG from a single hole in the hull is no longer the worst credible scenario, regardless of the size of the hole envisioned.

In fact, the Lloyd's study predicts that a hole much smaller than the 1-meter hole could still lead to the chain-reaction fracturing, explosions and fires that would involve the entire contents of the ship.

Jerry Havens, a leading LNG scientist who designed the standardized computer model used by federal officials to assess the dangers of chemical fires, reviewed copies of the Lloyd's Distrigas study given to him by the Mobile Register. Based on that brief review, he said he believes the Lloyd's Distrigas study is "incomplete" and that it may contain some errors, perhaps because it was done on relatively short notice after the Sept. 11 terror attacks.

In spite of those reservations, he went on to characterize the study as "very important" and said it should be "thoroughly evaluated and extended, to determine what could occur in the event of a deliberate action against an LNG ship."

Havens, a former officer in the U.S. Army Chemical Corps, said he was reluctant to address the specific findings of the Lloyd's study.

In earlier articles and conversations, Havens described scenarios very similar to the catastrophic tanker failure outlined in the Lloyd's study.

"Even the largest LNG tankers (typically more than 900 feet in length) might be completely enveloped in a pool fire following a complete spill of a single 6.5 million gallon tank," reads an August article Havens wrote for the Bulletin of Atomic Scientists. Most LNG tankers have five 6.5-million gallon tanks.

"The basic problem is that we are going to have a very intense fire that envelops the entire ship. That fire could threaten the contents of the other tanks," Havens said in an interview earlier this year. "Engulfed in fire, that tanker is out of commission. No one onboard could survive. That means it's drifting or maybe still under power, but out of control. You couldn't get close enough to it to tow it, besides there wouldn't be time. If it hits land, and the other tanks become involved, you could have an escalating situation with a fire that might burn for over an hour."

James Fay, professor emeritus at Massachusetts Institute of Technology, often described as the father of modern LNG hazard theory, has also expressed concerns that a breach in one compartment on a ship could lead to an escalating fire.

Fay said in an interview earlier this year that it would be "impossible to exaggerate" the intensity of an LNG fire.

"It would be kind of like the World Trade Center fires. After about half an hour, the steel was weakened to the point where it collapsed, and the buildings came down," Fay said. "You might have a series of failures, with the other four cargo holds disgorging their contents over an hour or so. It's difficult to say what would happen. It's a possibility that needs to be examined."