

**INTERNATIONAL AND NATIONAL EFFORTS TO
ADDRESS THE SAFETY AND SECURITY RISKS
OF IMPORTING LIQUEFIED NATURAL GAS:
A COMPENDIUM**

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ABSTRACT

The *Compendium* summarizes the principal safety and security laws, regulations, and practices under which the LNG industry operates worldwide to prevent or respond to LNG-related emergencies. It also reviews information from recently conducted safety and risk assessment studies for LNG shipping and terminal-construction projects.

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EXECUTIVE SUMMARY

Over the past three years, liquefied natural gas (LNG) project developers have announced plans to build import terminals along the West Coast, including onshore and offshore facilities in California. State and local agencies involved in reviewing and approving proposed LNG terminals are seeking objective information about the potential public safety risks posed by LNG carriers and receiving terminals and whether existing safeguards are adequate. This report is intended to help state agencies by providing them with up-to-date information on international and national LNG safeguards.

Previously, the California Energy Commission staff published *Liquefied Natural Gas in California: History, Risks, and Siting*.¹ That report summarized the properties of LNG, the potential for hazardous situations at LNG shipping, receiving, and vaporization facilities, and the key safety features of those facilities. LNG is essentially no different from the natural gas used in homes and businesses everyday, except that it has been refrigerated to minus 259 degrees Fahrenheit at which point it becomes a clear, colorless, and odorless liquid. As a liquid, natural gas occupies only one six-hundredth of its gaseous volume and can be transported overseas economically in special LNG carriers. LNG is neither stored nor transported under pressure.

In the unlikely event of an LNG release from a carrier, its contact with the water (or any warmer substance such as air) would cause the LNG to evaporate very rapidly (“vaporize”) returning to its original, gaseous state. As the LNG vaporizes, a vapor cloud resembling ground fog will form under relatively calm atmospheric conditions. The vapor cloud is initially heavier than air since it is so cold, but as the LNG absorbs more heat, it becomes lighter than air, rises, and travels downwind.

LNG vapor clouds are flammable within the portion of the cloud where the concentration of natural gas is between a five and a 15 percent (by volume) mixture with air.² To ignite, however, this portion of the vapor cloud must encounter an ignition source. Otherwise, the LNG vapor cloud will simply dissipate into the atmosphere. Close proximity to an ignited LNG vapor cloud could be very dangerous, because of its tremendous radiant heat output. Ignited clouds, however, do not explode in the open atmosphere.

Preventing spills and responding immediately to spills should they occur are major factors in the design, construction, and operation of LNG carriers and import terminals. Ocean-going carriers are equipped with LNG-cargo tanks housed inside a double-walled hull. LNG tankers are equipped with specialized systems for handling the very low-temperature gas and for combating potential hazards associated with liquid spills and fire. The ship's safety systems are divided into ship handling and cargo system handling. The ship-handling safety features include sophisticated radar and positioning systems that alert the crew to other traffic and

hazards around the ship. Also, distress systems and beacons automatically send out signals if the ship is in difficulty. The cargo-system safety features include an extensive instrumentation package that safely shuts down the system if it starts to operate out of predetermined parameters. Ships are also equipped with gas- and fire-detection systems.³ Such design features have helped to ensure that no major spill, breach, or loss of life has resulted from a shipping accident involving an LNG carrier after 40 years of shipping. LNG berths and jetties must have built-in safety features to prevent releases of LNG during ship-to-shore transfers.

A shore-based LNG terminal consists of a docking facility, LNG-storage tanks, LNG-vaporization equipment, and vapor-handling systems. A ship-to-shore emergency shutdown (ESD) system and associated shut-off valves allow rapid and safe shutdown of an LNG transfer. The ESD system will stop the ship's unloading pumps and close flow valves both on the ship and shore usually within 20 to 30 seconds, thereby limiting any potential release to a few hundred gallons of LNG. Quick-release couplings automatically disconnect the unloading arms during emergencies.

LNG is normally held on land in one or more specially designed storage tanks while it awaits regasification. The failure of one or more tanks could release an enormous volume of LNG (e.g., 100,000 cubic meters) with potentially disastrous consequences due to the size of the resulting vapor cloud. However, the design of modern storage facilities has improved from earlier designs. Modern storage tanks have no side or bottom penetrations. All penetrations, including those for LNG sendout, are through the roof. This design substantially reduces the amount of LNG spilled in the unlikely event of a rupture or leakage in the sendout piping.

New terminals typically specify full-containment storage tanks, which have a nine-percent nickel inner tank, plus a pre-stressed concrete outer tank. The outer tank, which includes a reinforced concrete roof lined with carbon steel, can be designed to withstand realistic impacts from missiles or flying objects.⁴

This consultant report provides more detailed information about the government and industry organizations and requirements that govern LNG facilities. It also reviews safety risk assessments performed for LNG facilities recently proposed or permitted in the U.S. and other countries. And, it highlights recent efforts to address the potential vulnerability of LNG carriers and terminals to terrorist attack and the possible consequences of such an attack.

A large array of laws, regulations, standards, and guidelines are currently in place to avoid and respond to all releases of LNG. These requirements affect LNG facilities' design, construction, operation, and maintenance. To address the possibility of an intentional release of LNG due to piracy, sabotage, or terrorism, new international maritime security regulations were adopted. Specifically, the International Ship and Port Facility Security (ISPS) Code was adopted in 2003 by the member countries of the International Maritime Organization (IMO), an agency of the United Nations responsible for maritime safety. The new code requires both ships and ports to

conduct vulnerability assessments and to develop security plans. It also establishes an international framework for cooperation and communication of security risks.

To protect the nation's ports and waterways from terrorist attacks, the U.S. Congress passed the U.S. Maritime Transportation Security Act of 2002 (MTSA). The act would increase security on LNG facilities at American seaports. It requires U.S. Coast Guard (USCG)-approved security plans for U.S. flag commercial vessels and U.S. port facilities. Foreign flag ships are covered by the ISPS code, which the USCG accepts as complying with the MTSA. Detailed security assessments of LNG facilities and LNG carriers are required. In addition to protecting against terrorism at U.S. ports, the act also requires that the effectiveness of anti-terrorism measures at foreign ports be assessed. New security regulations and required ship security plan certifications will help provide a safer environment for LNG facilities.

Ship classification societies have long influenced the safe design, construction, and maintenance of ship hull structures and essential shipboard engineering systems by setting industry standards and by inspecting and rating ships for marine insurance and other purposes. Their work complements the international treaties (conventions) of the IMO. The International Association of Classification Societies (IACS) and individual classification societies, such as Lloyd's Register⁵ (Lloyd's), have been proactive in enhancing LNG carrier safety, emphasizing the need for incorporating risk analyses in shipping processes. Furthermore, IACS's design guidelines for offshore LNG facilities fill a void created by the absence of specific governmental regulations.

Other non-governmental entities playing a predominant role in the safe and responsible operation of gas carriers and terminals include the Society of International Gas Tanker and Terminal Operators (SIGTTO) and the National Fire Protection Association (NFPA). SIGTTO is the LNG industry's leader in providing guidelines and recommendations to its members for safely handling liquefied gases, hazard analysis, contingency planning, and handling LNG in port areas and at sea. Despite its name, the NFPA is an *international* organization that develops, publishes, and disseminates consensus codes and standards to reduce fire risks. Its NFPA 59A Standard for the Production, Storage, and Handling of LNG has been incorporated into U.S. and Mexican safety standards for LNG facilities.

Federal safety standards for land-based LNG facilities are issued and enforced by the Department of Transportation (DOT), Research and Special Programs Administration, while regulations for waterfront facilities handling LNG are under the USCG jurisdiction. The USCG can also restrict ship traffic around LNG carriers by establishing safety and security zones while in shipping channels and in ports. The Federal Energy Regulatory Commission (FERC) may impose more stringent safety requirements than DOT's standards upon proposed projects to build or expand onshore LNG facilities that would be connected to interstate pipelines. Similarly, state agencies that have been certified by DOT to implement the federal LNG safety standards may impose more stringent requirements upon proposed facilities that would be connected only to an intrastate pipeline system.

The USCG and Maritime Administration, on behalf of the Secretary of Transportation, are now responsible for siting offshore LNG facilities and have issued interim temporary siting regulations that are in effect until October 1, 2006.

Collectively, these agencies oversee all land and sea-based LNG operations, with some overlapping authorities and some new responsibilities. The recent reactivation of U.S. LNG facilities on the Eastern Seaboard and Gulf Coast and the permitting of new facilities, have resulted in new methodologies (risk-based decision making) and processes (security workshops, scoping meetings) to assess and communicate safety risks to the public.

Public concerns about LNG safety and security make risk assessment and communication a critical part of the facility siting process. LNG organizations routinely identify new risks and update their technical design standards and operating procedures to mitigate risks. These recommended improvements are disseminated initially through organizations such as SIGTTO and IACS, but they eventually become requirements through international standards and government regulations.

In the U.S., LNG project developers perform analyses using computer models to estimate both flammable-vapor-cloud and thermal-radiation exclusion zones. The exclusion zone analyses focus on the maximum credible accident. The FERC requires that proposed onshore terminals (under its jurisdiction) meet or exceed all LNG safety code requirements, including exclusion zone distances. The projected exclusion zones are usually within the plant's boundaries so that the risk of public exposure is accepted by regulators. Modeling of large LNG releases from carriers, while not required by existing regulation, has been recently addressed through multiple independent studies and through evaluations done for specific projects.

In Europe, Mexico, and Canada, project applicants are required to conduct a safety risk assessment according to prescribed methodologies and submit their results to the permitting agency for review. The U.S. regulations do not prescribe methodologies for formal risk assessments although risk is evaluated both by the regulating entity and the project applicant.

Today, the public's concern about the possibility of terrorist attack means that LNG facility risk assessments must address the possibility of piracy, sabotage, and terrorism. Of particular concern is the potential for an LNG carrier to become a terrorist target itself or to become a weapon in an attack on another target. Terrorist attacks against maritime targets have been relatively rare, and no pirate attacks on LNG carriers have occurred. New security measures at U.S. ports (port patrols, automated shipboard communication systems, security zones around carriers) coupled with the general lack of terrorist maritime-documented activity, however, limit the potential for LNG carriers to become accessible targets in the U.S.

Recently, more than 40 U.S. LNG facilities have been planned or proposed, have started the permitting process, have been permitted to expand and resume operations, or have been approved for construction.⁶ Generally, the environmental impact statements (EIS) for onshore projects describe the safety provisions of the proposed terminal facilities and address safety issues for both the terminal and pipeline facilities. Until recently these documents, prepared by FERC in advance of project approval, tended to have similar safety-related contents including mitigation measures. They did not include risk assessment, and therefore, may not communicate risk to the level of detail desired by some members of the public. Current environmental documents, however, give a more in-depth analysis of a proposed terminal's site-specific and design-specific risks.

Documents now specifically address terrorism threats. Recent analyses indicate through conservative modeling that thermal radiation exposure would be limited to distances near an LNG carrier should a missile or another vehicle strike the carrier.

Although the permitting process for shore-side LNG facilities is documented, new ground is being broken in the permitting of offshore LNG facilities located beyond state jurisdiction (i.e., more than three miles). The USCG, rather than FERC, is the federal lead agency for environmental review for offshore LNG projects. (Offshore LNG facilities proposed within state waters would still be under FERC's jurisdiction.)

INTRODUCTION

Over the past three years, liquefied natural gas (LNG) project developers have announced plans to build LNG import terminals along the West Coast, including onshore and offshore facilities in California. Two proposals, to build LNG import terminals on Mare Island and at Humboldt Bay, were withdrawn after local citizens opposed the project due in part to their safety and security concerns.⁷ Citizens living near LNG sites proposed elsewhere in California and Baja California are also expressing fear about the possibility of an accidental release of LNG or terrorist attack involving an LNG carrier or import terminal and the potential consequences from such an upset. The California Energy Commission sponsored this study to inform its staff and the staffs of other state agencies⁸ about LNG safety and security practices and the safety analyses done for proposed projects. This overview should help state agencies and others to communicate LNG safety risks and mitigation using up-to-date information.

An earlier Energy Commission staff paper discussed the safety hazards of LNG and the safety features of LNG carriers and import terminals. Specifically, *Liquefied Natural Gas in California: History, Risks, and Siting*, noted that LNG is natural gas that has been refrigerated into a cryogenic liquid so that it can be shipped long distances. The LNG is not transported under pressure. Once an LNG carrier reaches an import terminal, the LNG is unloaded and stored in large tanks until it is revaporized and distributed as natural gas through the existing pipeline network. LNG is a hazardous liquid because it is cryogenic, and when vaporized to natural gas, is flammable at certain concentrations in air. It is not explosive unless in a confined environment.

Releases of LNG form a visible vapor cloud of natural gas, which will mix with air as it expands. The edges of a vapor cloud are flammable where natural gas concentrations in air are between five to 15 percent. If the flammable portion of the cloud meets with a strong ignition source, the cloud will likely catch fire and burn back towards the spill source from the edges. An ignited vapor cloud is a safety hazard, because thermal radiation from the fire could potentially injure nearby people and damage property. Pool fires are the other major LNG hazard. They can occur when LNG spills and forms a liquid pool and the vapor cloud edges above the pool catch fire from an ignition source. Pool fires will burn intensely until the LNG has been vaporized and completely burned.

To address these hazards, multiple safety features are integral to LNG carriers and terminals.⁹ Due to effective regulation and self-regulation, the LNG industry has had “an exemplary safety record for the last 40 years.”¹⁰ The LNG industry’s safety record, however, now includes an explosion and fire on January 19, 2004 at an Algerian gas company’s plant that refrigerates natural gas to make LNG. The accident at the facility caused deaths, injuries, and material damage within and immediately outside the plant’s boundaries. A report on the preliminary conclusions

of the accident was published in April 2004.¹¹ It is still not clear whether the accident was triggered by an LNG release. FERC representatives visited the plant site and recommended three actions to avert similar disasters at other LNG facilities: ensure that ignition sources are remote; configure integral closure of the forced draft fan and firing in boiler; and install additional detection for unexpected spills/leaks. (These facility-design and hazard-detection recommendations are applicable to onshore LNG facilities, whereas alternative controls — identified from a quantitative risk assessment — may prove to be more appropriate in minimizing risk offshore.)

Dr. Suzanne Phinney of Aspen Environmental Group identified and summarized the principal safety and security laws, regulations, and practices under which the LNG industry operates. Energy Commission staff also contributed significantly to this research and summary effort. A draft of the *Compendium* was circulated to the following LNG safety experts from government, industry, and academia: John Cornwall, Quest Consulting, Inc.; Elizabeth Drake, Emeritus Staff at Massachusetts Institute of Technology (MIT); James Fay, Professor Emeritus at MIT; Michelle Michot Foss and Fisoye Delano, Institute for Energy, Law, and Enterprise, University of Houston; Dave Glessner and Steve Meheen, Crystal Energy, LLC; Mike Hightower, Sandia National Laboratories; Ronald P. Koopman, retired Program Leader for Liquefied Gaseous Fuels Research at Lawrence Livermore National Laboratory; James Lewis, Project Technical Liaisons; and, James MacHardy, Society of Gas Tanker and Terminal Operators. Their review and comments enhanced the accuracy and clarity of the information.

The *Compendium* highlights recent international regulations and U.S. laws addressing the security risk of a terrorist attack upon LNG carriers and import terminals. After describing the regulatory framework, this paper presents information from recently conducted LNG safety and risk assessment studies for the following types of facilities:

- LNG shipping (i.e., carriers),
- Expansion projects for existing onshore LNG import terminals (i.e., receiving, storage and vaporization facilities), and
- Construction projects for new LNG import terminals.

These studies were evaluated to determine the following:

- Types of safety risk assessments conducted,
- Key hazards identified and evaluated,
- Types of analyses, modeling, and simulations performed,
- Modeling software used, and
- Recommended actions by facility operators to control and reduce key risks.

Together, these safety requirements and safety risk assessments determine under what circumstances potential safety risks posed by LNG facilities can be accepted by permitting agencies.

Offshore oil and gas facilities (now including LNG) face different risks versus those operating in an onshore environment. Thus, offshore facilities are regulated in a different manner from those to be sited onshore. The regulations and standards outlined in this *Compendium* apply primarily to onshore LNG facilities and as may not always be appropriate in the offshore marine environment to address risk.

The *Compendium* does not cover the potential risks of LNG when used as a motor vehicle fuel, in peak-shaving facilities, or in liquefaction facilities for LNG export.

Acronyms and a glossary are provided at the end of the report. Appendices provide excerpts from key reference documents.

LNG SAFETY AND SECURITY REQUIREMENTS

A significant issue regarding the construction of LNG terminals is the public's perception of the potential safety and security risks associated with these facilities. How does a permitting agency determine when to accept the safety and security risks posed by proposed LNG facilities? A first step is to ascertain whether a proposed project meets all applicable safety laws, ordinances, regulations, and standards (LORS). This chapter provides an overview of LNG safety LORS and the regulatory agencies and industry organizations that prepare and enforce them.

Safety codes exist for LNG facilities, overall, and for key facility components. These design and assessment standards address both natural and manmade hazards. Earthquakes are the principal natural hazard addressed for LNG facility piping, while earthquake and wind hazards are the focus of standards for LNG storage tanks. Safety codes also exist for manmade hazards, including blast hazards to LNG facility system reliability, piping, and storage tanks and blast¹² and cybernetic hazards to LNG facilities' electrical and mechanical equipment.

Beyond assuring LORS compliance, safety risk assessment defines potentially hazardous situations so that site-specific mitigation strategies can be added to reduce these hazards. LNG facility risk assessments now are supplemented by security assessments including vulnerability to terrorist attacks.

The intent of LNG safety regulations is to reduce the risks of human injury and asset loss. In the U.S., LNG safety regulations are largely prescriptive in nature. That is, they provide specific details about how to design a facility so that it is safe. In other parts of the world, such as Europe, LNG safety regulations are based on performance standards that identify outcomes rather than specific technical requirements. They set the level of safety or risk reduction required and the methods for verifying that the design meets the required performance standard. Performance-based standards allow engineers more design flexibility in meeting safety objectives, but prescriptive standards are easier to apply and conform with. Performance-based standards are not necessarily more protective. An example of performance standards is the earthquake standards for LNG terminals. Using these standards, the LNG terminal must be designed to withstand a site-specific maximum credible earthquake (MCE).

Since September 11, 2001, an increasing awareness and concern for terrorist attacks against energy infrastructure such as LNG facilities have prompted heightened maritime security. Recently developed maritime security laws and regulations now join the many rules, regulations, and guidelines put forth by the International Maritime Organization (IMO), U.S. Department of Homeland Security, the U.S. Coast Guard, and ship classification societies to regulate LNG shipping facilities. These measures are supplemented by non-mandatory operational guidelines issued by professional and trade organizations.

Regulations, Standards, and Guidelines Relating to Marine Security

Shipping is perhaps the most international industry in the world. The best way of ensuring safety at sea is by developing international regulations that are followed by all shipping nations. The IMO is the agency of the United Nations responsible for adopting and updating international treaties (called conventions) for shipping safety and security. IMO has 163 shipping nations as members that are responsible for implementing IMO-adopted conventions and regulations.

IMO has adopted approximately 40 conventions and protocols, including the International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IMO Gas Code) and the International Maritime Dangerous Goods Code. Of current interest to the safety of LNG carriers and shipping is the 2003 edition of the International Ship and Port Facility Security (ISPS) Code, which amended the 1974 International Convention for the Safety of Life at Sea (SOLAS). The ISPS Code is the first multilateral security standard ever created to strengthen maritime security and to prevent and suppress acts of terrorism against shipping and ports. Implemented in July 2004, all nations are now required to develop, monitor, and enforce port and ship security plans.

The ISPS Code is not prescriptive with respect to the security plans outlined below. Instead, the ISPS Code follows a risk management approach, providing a standardized, consistent framework for evaluating risk and enabling governments to determine how to reduce vulnerabilities. Security plans must suit the individual company, the ship, and the conditions under which the company is trading.

The Code amendments have important implications for all ship and terminal owners as listed below:

- Ships are required to:
 - Carry an automatic identification system (AIS),
 - Show the IMO ship identification number externally and internally,
 - Have a ship security alert system,
 - Appoint a ship security officer, and
 - Create and implement a Ship Security Plan.

- Ship operators are required to:
 - Appoint a company security officer,
 - Carry out a ship security assessment,
 - Ensure security drills and exercises are carried out, and
 - Provide appropriate resources.

- Ports are required to:
 - Carry out port facility security assessments,
 - Develop port security plans, and
 - Designate a port facility security officer.

The Code amendments also:

- Establish an international framework for co-operation between contracting governments (i.e., governments that have ratified SOLAS and are parties to SOLAS), government agencies, local administrations, and the shipping and port industries to detect security threats and take preventive measures against security incidents affecting ships or port facilities used in international trade;
- Establish the respective roles and responsibilities of the contracting governments, government agencies, local administrations, and the shipping and port industries, at the national and international level, for ensuring maritime security;
- Ensure the early and efficient collection and exchange of security-related information; and
- Provide a methodology for security assessments so that plans and procedures are in place to react to changing security levels.

To achieve its objectives, the Code requires the following functions be performed:

- Gather and assess information with respect to security threats and exchange such information with appropriate contracting governments;
- Maintain communication protocols for ships and port facilities;
- Prevent unauthorized access to ships, port facilities, and their restricted areas;
- Prevent introducing unauthorized weapons, incendiary devices, or explosives to ships or port facilities;
- Provide a means for raising alarm in reaction to security threats or security incidents;
- Require ship and port facility security plans based upon security assessments; and
- Require training, drills, and exercises to ensure familiarity with security plans and procedures.

Flag states (countries) are required to exercise control over administrative, technical, and social matters of the ships flying their flags. If a flag state does not wish to exercise this control, it may delegate classification societies to act on behalf of the flag state. Port states (i.e., those countries whose ports are visited by vessels flying the flag of other states) may have their own requirements to ensure that vessels in their national waters meet their own safety and other standards. Countries are free to impose more stringent regulations.

The U.S. Marine Transportation Security Act of 2002¹³ (MTSA) parallels the ISPS Code but is somewhat broader in that it creates “families” of plans. Individual facility plans fit into larger, port-wide screening plans. The MTSA also mandates uniform biometric identification and background checks for maritime transportation workers. The Act expands the USCG’s role in providing port security to reduce the threat of terrorism including against vessels transporting oil, compressed natural gas, and LNG. The MTSA also extended the Deepwater Port Act of 1974¹⁴ to apply to offshore LNG facilities.

On July 1, 2003, the U.S. Department of Homeland Security (DHS) published security regulations,¹⁵ implementing significant portions of the MTSA. The DHS stated in its July 1, 2003 press release on the new security regulations, that “by requiring completion of security assessments, development of security plans, and implementation of security measures and procedures, these regulations will reduce the risk and mitigate the exposure of our ports and waterways to terrorist activity.”

Provisions of the MTSA, which would apply to ports with LNG facilities and to LNG carriers, are summarized in Appendix A.

Ship Design Standards by Classification Societies

LNG carriers represent a blend of conventional ship design with specialized materials and advanced systems for handling cryogenic cargoes.

Classification societies are independent technical organizations that establish and administer standards for the design, construction, and periodic re-survey of ships to aid in the insurance process and for meeting international regulatory and some domestic, commercial-documentation requirements. Their classification of ships assures ship owners, buyers, or other interested parties, that a ship is structurally sound and mechanically fit to carry crew and cargo. In addition to ship classification, societies conduct another level of approval called certification. While classification continues throughout the life of the vessel (unless it fails a survey), certification attests to the condition only at the time of delivery. To keep a ship "in classification," it must be inspected on a regular basis, usually annually, or whenever changes or damage to it might affect the classification.¹⁶

The International Association of Classification Societies (IACS) provides technical support, compliance verification, and research and development for its classification-

society members. More than 90 percent of the world's commercial (ocean-going cargo, process, and passenger) vessels are covered by the classification design, construction, and compliance rules and standards set by IACS' ten member societies and two associate members.

Member Societies and the number of LNG vessels they class, if applicable, are:

- American Bureau of Shipping (24),
- Bureau Veritas (20),
- China Classification Society,
- Det Norske Veritas (17),
- Germanischer Lloyd,
- Korean Register of Shipping (8),
- Lloyd's Register (50),
- Nippon Kaiji Kyokai (33),
- Registro Italiano Navale, and
- Russian Maritime Register of Shipping.

Associate members are the Croatian Register of Shipping and the Indian Register of Shipping.

These societies stress safety and incorporate risk analyses in shipping processes. Three prominent classification societies for LNG shipping are the following:

Lloyd's Register

Lloyd's Register is one of the leading classification societies for LNG shipping and the oldest classification society in existence. Currently, 37 percent of the world's LNG carrier fleet is classified by Lloyd's Register and more than 60 percent of new LNG carriers will be built to Lloyd's Register classification standards.¹⁷ Lloyd's Register was called upon to review the safety of LNG transport into Boston Harbor after the September 11, 2001 events. The results of this evaluation are summarized in the Risk Assessment Findings Section, below.

Classification societies also independently certify offshore LNG installations. For example, Lloyd's Register has published rules for floating offshore installations at fixed locations. These rules include the option to use risk assessment to identify critical elements of design and to determine performance standards in lieu of designing and constructing the installation to Lloyd's Register Rules and Regulations. Because floating, offshore LNG terminals differ from normal LNG carriers due to the fact that they require additional facilities on the deck be provided, Lloyd's Register recommends that a Fire and Explosion Risk Assessment be undertaken.

Det Norske Veritas

The stated mission of Det Norske Veritas (DNV) is to support its customers' efforts to mitigate the risk and improve quality, safety, and environmental performance. DNV was the first classification society to issue an International Ship Security Certificate. (By July 1, 2004, all ships must have this certification under the new ISPS Code.) It issued the certificate on July 1, 2003 to the LNG tanker *Berge Boston*, which serves the Distrigas terminal in Everett, Massachusetts. DNV has also issued preliminary design rules for offshore LNG terminals.

American Bureau of Shipping

The American Bureau of Shipping (ABS) has guidance notes on risk assessment applications for the marine and offshore oil and gas industries. ABS has also published guidance notes for floating LNG terminals. According to ABS, a key design issue for floating LNG terminals will be the relative motion between the terminal and the LNG carrier during offloading operations.¹⁸

Shipping Guidelines by Professional and Trade Organizations

Professional and trade organizations such as the Society of International Gas Tanker and Terminal Operators (SIGTTO), the Oil Companies International Maritime Forum (OCIMF), the International Association of Ports and Harbors (IAPH), the World Shipping Council, and the International Navigation Association (PIANC) also play major roles in the safe and responsible operation of gas carriers and terminals.

SIGTTO is a major voice for the liquefied gas tanker and terminal industry. Its members represent both the LNG and liquefied petroleum gas industries, and SIGTTO members collectively represent nearly all of the world's LNG carrier and terminal operators.

Its members cooperatively develop SIGTTO's core output of written guidance documents and "best-practice" recommendations for the safe and responsible operation of gas tankers and terminals. Examples of recent SIGTTO publications include the following:

- *A Guide to Contingency Planning for Marine Terminals Handling Liquefied Gases in Bulk* (second edition) – This guide includes direction on how to identify and control of potential hazards and incidents. The guide describes the expected changes and requirements for safety management systems over the next decade and the future role of risk assessment within the gas industry.
- *Guidelines for Hazard Analysis as an Aid to Management of Safe Operations in Port*;

- *Human Error and the Environment – Management Systems for the Gas Industry*;
- *Contingency Planning for the Gas Carrier at Sea and in Port Approaches* (1998 update);
- *Contingency Planning for the Gas Carrier Alongside and Within Port Limits* (1998 update);
- *Guide to Safety Self-Assessment*;
- *LNG Operations in Port Areas*. This publication outlines the risks associated with handling LNG and analyzes the methodology for minimizing such risks.
- *Crew Safety Standards and Training for Large LNG Carriers*; and
- *Liquefied Gas Fire Hazard Management*.

In April 2001, the general manager of SIGTTO stated in an interview with Lloyd's List that the challenges to maintaining the LNG industry's strong safety record would increase in the future. In particular, he noted that LNG shipping patterns are changing. Traditionally, LNG carriers were dedicated to serving specific terminals. In the future, carriers would be changing routes more frequently due to "cross-trades" and "gas swaps."¹⁹

The OCIMF issues guidelines for the safe operation of terminals and oil tankers. The IAPH is a forum for safety and environmental protection in port operations. The World Shipping Council established a Security Advisory Committee to address how the industry could assist the U.S. government in improving port and maritime security. A list of security recommendations were developed and presented in a white paper, "Improving Security for Liner Shipping," to Congressional committees and Executive Branch agencies responsible for port and maritime security.

PIANC's report, "Handling of Dangerous Cargoes in Ports²⁰," recommends that risk assessment be undertaken to detect weak points; both the deterministic method and the probabilistic method for assessing risks are suggested approaches. (See Glossary.)

U.S. LNG Safety Requirements

Numerous rules and regulations apply to U.S. LNG import facilities. The Energy Commission staff publication, *Liquefied Natural Gas in California: History, Risks, and Siting*, sets out the basic federal and state permitting processes for new terminal projects.²¹ The federal government also sets the safety requirements for existing LNG facilities; these are detailed below.

FERC requirements for applications to construct, operate, or modify onshore facilities that are used for exporting or importing natural gas, are defined in the Code

of Federal Regulations, Title 18, Part 153 (The short form for this code reference is 18 CFR 153.). These regulations request information concerning the applicant, pipeline interconnections, facility safety features, and potential environmental impacts. In §153.8(5)(6) of these regulations, Exhibit E stipulates that the application contain detailed engineering and design information. In areas of seismic concern, Exhibit E-1 requires that a report on earthquake hazards and engineering be submitted to FERC. An environmental report pursuant to the National Environmental Policy Act (NEPA) must be prepared.

Thirteen resource (subject-area) reports must be submitted to FERC; these reports generally follow the resource subject areas covered in an EIS and are listed below:

- Resource Report 1 – General Project Description,
- Resource Report 2 – Water Use and Quality,
- Resource Report 3 – Fish, Wildlife, and Vegetation,
- Resource Report 4 – Cultural Resources,
- Resource Report 5 – Socioeconomics,
- Resource Report 6 – Geological Resources,
- Resource Report 7 – Soils,
- Resource Report 8 – Land Use, Recreation and Aesthetics,
- Resource Report 9 – Air and Noise Quality,
- Resource Report 10 – Alternatives,
- Resource Report 11 – Reliability and Safety,
- Resource Report 12 – PCB Contamination, and
- Resource Report 13 – Engineering and Design Material.

With respect to LNG safety, Resource Report 11 Reliability and Safety, addresses the potential hazards to the public from failure of facility components resulting from accidents or natural catastrophes, how these events would affect operational reliability, and what procedures and design features have been used to reduce potential hazards. Resource Report 13, Engineering and Design Material, requires extensive design information on major terminal components, LNG storage tanks in particular. It must contain detailed plot plans; layouts of fire protection, hazard detection, and spill containment systems; and identification of how the facility will comply with federal safety standards (49 CFR 193) for LNG facilities and industry standards for the production, storage, and handling of LNG.

In Resource Report 13, the LNG terminal developer must also provide thermal-radiation and vapor-dispersion exclusion zone calculations (described below). FERC prepares a summary of its analysis of the proposed facility's engineering and cryogenics designs in the safety section of the EIS.

Federal safety standards for the onshore components of LNG facilities are contained within 49 CFR 193. Section 193.2013 mandates compliance with National Fire Protection Association (NFPA) Standard 59A for LNG. In March 2004, DOT updated Part 193 to reference the 2001 version of NFPA 59A. The 2001 version differs from the 1996 edition of NFPA 59A in the following ways:

- Bases design on the concept of maximum credible earthquake, in line with building codes used throughout the country; and,
- Requires formal, risk-based evaluation of fire protection systems and equipment.

The NFPA 59A requirements are, for the most part, prescriptive as to the siting and design of an LNG facility. They require any LNG container, process area, vaporization area, or transfer area to have an impoundment system capable of containing the quantity of LNG that could be released by a credible incident involving the component served by a particular spill-impounding system.

Siting requirements under NFPA 59A include an analysis of two scenarios: tank penetration leading to a ground spill and a 10-minute spill out of the storage tank. A “vapor dispersion exclusion zone” and a “thermal radiation exclusion zone” must be calculated for these volumes of spilled LNG. Exclusion zones are the areas surrounding an LNG terminal in which the operator legally controls all activities. These zones are intended to assure that public activities and structures outside the immediate LNG facility boundary are not at risk in the event of an on-site LNG fire or the formation of a flammable, but unignited vapor cloud. Thermal radiation exclusion zones protect the public from exposure to the thermal radiation from LNG fires, while a vapor dispersion exclusion zone protect the public from LNG clouds that have not ignited but could migrate to an ignition source while still in a potentially flammable state (i.e., LNG concentrations between 5 and 15 percent in air).

Chapter 2 of the NFPA 59A standard identifies the computer models that are approved for use in determining these exclusion zones. The approved models include DEGADIS (for vapor-cloud dispersion) and LNGFIRE (for thermal radiation).

Part 193 Subpart C of the LNG safety code identifies design requirements such as the capacities for impoundment areas around LNG storage tanks in the event of tank failure and LNG release from the tank. Specifically, the impoundment areas must be able to contain 110 percent of the LNG tank’s maximum liquid capacity. The outer concrete shell of a double or full containment tank qualifies as the spill impounding system for the tank. Subparts D and E lay out construction and equipment requirements. Subpart F requires operations and requires emergency procedures and investigation of any failures. Maintenance procedures are defined in Subpart G. Personnel qualifications and training are prescribed in Subpart H and fire protection in Subpart I. Subpart J lays out requirements for security, protective enclosures, communications, lighting, monitoring, alternative power, and warning signs. The regulations also identify requirements for security at LNG plants. Leaks and spills of LNG must be reported to the National Response Center.²²

Regulations in 33 CFR Part 127, Liquefied Natural Gas Waterfront Facilities, apply to all waterfront facilities that transfer LNG in bulk to or from vessels. The regulations specify equipment, operations, maintenance, personnel training, firefighting, and security requirements. USCG jurisdiction over onshore LNG facilities is generally limited to the marine transfer area, which extends from the waterfront to the last valve or manifold prior to the receiving tank.

Currently, all LNG carriers making deliveries to U.S. terminals operate under a foreign flag with foreign crews. Safety Standards for Self-Propelled Vessels Carrying Bulk Liquefied Gases, in 46 CFR 154, address hull structure and cargo tank design and specify examination requirements for foreign flag ships to ensure their compliance with U.S. safety standards. The USCG will not issue a Letter of Compliance to a foreign ship unless it has met the U.S. standard. In some instances, 46 CFR 154 requires higher safety standards than does the IMO Gas Code. For example, the USCG requires enhanced grades of steel with enhanced crack arresting properties in the structural framework of carriers (e.g., shear strake, deck stringer, and bilge strake). In general, however, the regulations follow the IMO Gas Code.²³

Regulated Navigation Areas and Limited Access Areas, in 33 CFR 165, designate safety and security zones surrounding key waterfront facilities and vessels in the U.S. Other vessels may not enter these zones unless authorized by the USCG. Their purpose is to prevent damage from sabotage or accidental collisions to these vessels and facilities. Safety zones for waterfronts with LNG receiving terminals include Boston Harbor, Cove Point, and the waters surrounding the EcoElectrica facility in Puerto Rico. Moving LNG carriers may also have designated safety zones. The sizes of these moving safety zones vary, depending on which terminal the LNG carrier is approaching.

FERC is the overall federal lead agency for siting onshore LNG terminal facilities that would tie into an interstate pipeline and for issuing construction and operation permits for these facilities. As required by NEPA, FERC prepares an EIS for a proposed onshore LNG facility. In California, a state lead agency under the California Environmental Quality Act will cooperate with FERC in publishing a joint EIS/Environmental Impact Report (EIR). The environmental review process is an opportunity for the public to learn about a project's plans, to raise issues, and to work with the project developers and regulatory-agency staffs in resolving those issues. In California, proposed LNG facilities will not necessarily interconnect with interstate pipelines. When proposed LNG facilities do not connect with interstate pipelines, the California Public Utilities Commission, which is a DOT-certified state agency, must issue a certificate of public convenience and necessity for the proposed LNG facility before construction may begin. FERC and CPUC hold opposing views on siting authority of LNG facilities in California. The CPUC has asserted jurisdiction over the proposed onshore LNG facility in the Port of Long Beach.

Additional safety and security issues are addressed in non-public proceedings, usually with the police, fire, emergency–response personnel, and other pertinent stakeholders. This limitation is consistent with the general policy of restricting information that might be helpful to terrorists. The degree to which these meetings are held depends on the level of perceived risk. For example, special security sessions were conducted for the Everett, Massachusetts and Cove Point, Maryland facilities, but similar sessions were not held for the Lake Charles, Louisiana; Elba Island, Georgia; or Hackberry (renamed Cameron), Louisiana LNG facilities.

Within the DOT, the Research and Special Projects Administration (RSPA) regulates the safety of existing onshore facilities such as LNG tanks, cryogenic piping, and vaporization equipment. Specifically, the Office of Pipeline Safety (OPS) within RSPA is responsible for enforcing federal safety standards for LNG facilities. On August 6, 2002, RSPA published a final rule that defines high consequence areas (HCAs) where a gas pipeline accident could harm people and property. On December 15, 2003, RSPA published a subsequent final rule improving the integrity of gas transmission pipelines in the HCAs. In September 2002, DOT’s OPS issued non-public guidelines that direct LNG operators to develop new security procedures for onshore facilities.

Per a 1985 memorandum of understanding (MOU) between DOT and FERC, FERC may impose more stringent safety requirements than DOT’s standards and may impose requirements that would ensure or enhance operational reliability of its jurisdictional LNG facilities. The MOU also states that when an EIS is required as part of the FERC decision-making process on the siting, construction, and operation of LNG facilities, FERC shall describe any LNG safety matters and their impact on the environment or facility operations that warrant corrective action or further analysis. (This MOU was modified on February 11, 2004 as explained below.)

The USCG, as the federal government’s principal maritime law-enforcement agency, performs four major roles: maritime law enforcement, maritime safety, marine environmental protection, and national defense. The USCG, which was transferred from DOT to the Department of Homeland Security in 2002, is the key federal player in maintaining port security, particularly in terms of boarding and inspecting incoming commercial ships. Other federal and local agencies and terminal operators, however, also have important roles to play in port security. The local port authorities and terminal operators, for example, participate in maintaining security perimeters around port facilities.²⁴

On October 22, 2003, the USCG issued a series of six final rules, implementing MTSA requirements. These rules address implementation of the following: national maritime security initiatives, area maritime security, vessel security, facility security, continental shelf facility security, and the automatic identification system. The USCG used its risk-based decision making process to evaluate the relative risks of various target and attack mode combinations, and scenarios for high-profile facilities.

The USCG regulates the marine operations of onshore LNG facilities, including procedures for vessel operation, security, and safety. The USCG has jurisdiction over the operations and berthing of the LNG carriers once they enter U.S. waters. All LNG carriers are subject to inspections for safety. The USCG also has the primary responsibility for dealing with threats to LNG carriers in U.S. ports.

In response to the terrorist attacks of September 11, 2001, the USCG took several actions to strengthen protection of U.S. ports and waterways from potential terrorist threats. It activated port security units to help protect the ports of New York, Boston, Seattle, and Los Angeles/Long Beach. USCG personnel began boarding and inspecting inbound vessels, escorting cruise ships into and out of port, and escorting oil tankers into and out of Valdez, Alaska. The USCG instituted new regulations requiring inbound ships to provide 96-hour (as opposed to the previous 24-hour) advance notice of arrival, thus providing more time to conduct vessel, crew, and cargo background checks before vessels arrive in U.S. waters. USCG armed sea marshals began boarding and riding inbound commercial ships during transits into all major California ports.

To reduce the risk of a terrorist attack upon critical energy infrastructure, the USCG can designate safety and security zones around high-interest vessels in specific harbors and channels. For example, it instituted the following three security zones related to LNG terminal operations in Boston Harbor:

- All waters within a 500 yard radius around the Distrigas Everett, Massachusetts terminal pier at all times;
- A moving zone 2 miles ahead, 1 mile astern, and 1,000 yards on either side of all LNG vessels transiting Boston Harbor; and,
- All waters within a 500-yard radius around any LNG vessel anchored in Broad Sound and while moored at the Distrigas waterfront facility in the Mystic River.²⁵

The USCG has also developed an initiative called Qualship 21 for “quality shipping in the 21st century.” Ships and shipping companies are scored on their safety standards and crews²⁶, with the intent of keeping substandard ships out of the U.S. The USCG has identified the following characteristics of a typical “quality” vessel: one that is associated with a well-run company, is classed by an organization with a quality track record, is registered with a Flag State with a superior Port State Control record, and has an outstanding Port State Control history in U.S. waters. Using these general criteria, only approximately 800 vessels are eligible for the Qualship 21 rating (approximately 8,000 individual non-U.S. flagged vessels make approximately 50,000 U.S. port calls each year).²⁷ These vessels from ten Flag States are eligible due to their detention ratio of less than one percent. Currently, almost all vessels with this Qualship 21 designation are registered to northern European countries. Ship safety standards can differ among Flag States and shipping companies.

The USCG and RSPA both regulate the location, design, construction, maintenance, and operation of onshore LNG facilities. Their responsibilities tend to be complementary; RSPA's jurisdiction over inland facilities begins where the USCG's jurisdiction ends. An MOU was signed between the two agencies in May 1986 to avoid duplicating effort in regulating onshore LNG terminals. The USCG is responsible for establishing regulatory requirements for facility site selection as it relates to managing vessel traffic in and around a facility and for all matters pertaining to structures or equipment located between the vessel and the last manifold or valve immediately before the receiving tanks. The USCG has jurisdiction for all cargo transfer systems and piping from the wharf to the first valve located outside the containment area of the LNG storage tank.

On February 11, 2004, the FERC, USCG, and DOT announced a new interagency agreement that delineates the role of each agency relative to safety and security issues at the nation's land-based LNG import terminals. The purpose of the agreement was to avoid duplication of effort and to maximize information exchange. Under the agreement, the agencies will work together to ensure that both land and marine safety and security issues are addressed in a coordinated and comprehensive manner, focusing on LNG carrier travel to the marine terminal, LNG transfer to onshore storage terminals, and terminal operations. The agencies have also agreed to identify and resolve any issues quickly during an EIS and to build "a consensus on any hazard studies or other documents that may include safety and security analyses."²⁸

Currently, the agencies are conducting a joint evaluation of hazards associated with large LNG spills on water from carriers.²⁹ As part of the joint evaluation, the FERC released the draft report, *Consequence Assessment Methods for Incidents Involving Releases from Liquefied Natural Gas Carriers*, on May 13, 2004. ABS Consulting prepared the report. The report's purpose was to identify appropriate analysis methods for estimating flammable vapor and thermal-radiation hazard distances for potential LNG vessel cargo releases during transit and while at berth. Assumptions and potential models were evaluated for the following: the rate of release of LNG from a ship, the spread of an unconfined LNG pool on water, vapor generation for unconfined spills on water, flammable vapor dispersion following spills on water, and thermal radiation from pool fires on water. Although certain generic models were recommended, ABS stressed that site specific applications should be made. A public comment period generated extensive comments, both promoting use of the results, and providing criticisms of the results. Although the final report will not be published until the end of 2004, draft conclusions were used in preparing the Freeport LNG project Final EIS issued May 28, 2004.

The Secretary of the Department of Transportation has regulatory authority over LNG facilities constructed offshore in federal waters. LNG terminals defined as deep-water ports are those located outside state boundaries, generally more than three nautical miles from shore except for the west coast of Florida and the Gulf of Mexico where it is approximately three marine leagues (equivalent to nine nautical miles). Responsibility for regulating these facilities is shared by the USCG and

DOT's Maritime Administration (MARAD). These agencies are responsible for implementing NEPA. Regulatory requirements for applications to build offshore terminals are different from those for onshore terminals (e.g., under the Deepwater Port Act, a license must be granted or rejected within 365 days). The regulations and standards applied to onshore facilities as detailed above may not always be appropriate to addressing risk in the offshore environment, given that offshore facilities face different risks to those operating in an onshore environment. Applicants for both onshore and offshore LNG facilities typically submit detailed project and environmental information to applicable regulatory bodies. The USCG published a temporary interim rule detailing the requirements for siting offshore LNG terminals in U.S. waters in the Federal Register on January 6, 2004.³⁰ This temporary interim rule is effective until October 1, 2006.

MARAD also administers federal laws and programs designed to promote and maintain a U.S. flag-Merchant Marine capable of meeting shipping and national security needs. It works with the USCG and the Transportation Security Administration (TSA), the latter created by Congress to oversee security at U.S. airports, seaports, and other land transportation facilities. TSA is a part of Border and Transportation Security, within the DHS. There are no U.S. flagged LNG carriers and very few LNG carriers are manned by U.S. crews.

Non-U.S. Codes and Standards for LNG Terminals

LNG import terminals exist in 14 countries, in addition to the U.S. Below are summaries of the LNG safety codes in some of these countries.

European Union

The European LNG code, EN 1473³¹ (Installation and Equipment for LNG - Design of Onshore Installations), is based on a risk assessment approach with fewer explicit prescriptive standards, compared to U.S. regulations. It recommends consideration of fire radiation calculations when setting minimum inter-unit separation distances within an LNG facility. The intent is to ensure that tanks and process equipment will not fail as a result of an LNG pool fire in any of the spill impounding systems. Additional codes include EN 1474 (Installation and Equipment for LNG – Design and testing of LNG loading arms) and EN 1532 (Installation and Equipment for LNG – Ship to Shore Interface).

Japan

Japan has 24 of the world's 40 operating LNG import terminals and at least two more are under construction. Most of these import terminals are owned by electric

utilities and gas utilities so the laws governing construction and operation of LNG storage, gasification, and other equipment appear in the Gas Enterprises Act and the Electric Service Enterprises Act. These acts contain the technical standards for LNG facilities, such as storage tanks, and safety policy and regulations. The safety policy and regulations address employee qualifications and training for gas facility construction, maintenance, and operation, and regular patrol and inspection of facilities.

Three Japanese regulatory agencies govern LNG terminal siting and operations:

- Ministry of Economy, Trade and Industry (METI) enforces the Gas Enterprises Act and the Electric Service Enterprises Act.
- Ministry of the Environment enforces environmental protection laws, including air pollution control, noise, and ground vibration regulations; and,
- Ministry of Health, Labour and Welfare enforces industrial safety and health laws.

While METI, a federal agency, is responsible for regulating Japanese gas and electric utilities, most LNG terminal siting, environmental and health laws are enforced by local governments.³² The Japanese Harbor Regulation Act addresses LNG carrier movement, anchorage, berthing, and unloading at receiving terminals and is enforced by the Maritime Safety Agency (Harbor Master) of each port and the Japanese Coast Guard. Twenty-four-hour guard boats are required at the Tokyo Bay and several other terminals. These boats escort an LNG carrier on its passage in and out of the port and patrol the immediate area to keep away other craft while the carrier is berthed.

Japanese technical standards for LNG facilities, contained in the gas and electric utility laws, were rewritten from prescriptive specifications to performance rules in October 2000. Recent amendments of these laws increased the utility industry's self-regulation of LNG safety standards.

Mexico

In September 2003, Mexico's Energy Ministry published "safety requirements for the design, construction, operation and maintenance" of onshore LNG facilities in Mexico. These proposed standards replaced "emergency" standards published in August 2002.

According to Alejandro Breña, director of the Mexican Energy Regulatory Commission's (CRE) Natural Gas Division, Mexico's emergency LNG safety rules were based on NFPA 59A, the American Petroleum Institute (API) Standard 620 for large welded, low-pressure storage tanks, and European liquefied natural gas standards.

Prior to constructing and operating a natural gas storage and distribution facility, an Environmental Impact Authorization (EIA) must be secured from the Secretary of the Environment and Natural Resources (SEMARNAT). This environmental “manifest” must be accompanied by a risk study if the activity qualifies as high-risk. (Details about Mexico’s risk assessment requirements are provided in the following section.) Manifests are published in SEMARNAT’s Ecological Gazette and must be made available to the public. Terminal developers must also obtain local land-use permits.

RISK ASSESSMENT FINDINGS

This chapter provides both general information on risk assessment and specific information on how risk assessment is being applied to LNG facility design, construction, and operations.

The “risk” of any action is measured by multiplying the likelihood of its occurrence (frequency) by the extent of its adverse impacts (consequence). Most human activities involve a spectrum of potential risks ranging from more frequent low-impact events to some very rare major events.

Risk assessment is the process of identifying all potential sources of risk, quantifying them, and accumulating them into an overall picture of the sources and consequences of risk for a particular facility or activity. Most risk assessments also address the uncertainties involved in making the estimates. Once risks are assessed, the major contributors to risk can be identified and risk management programs developed.

Risk communication is the interactive process of exchanging information about risk among individuals, groups, and institutions.

A fundamental principal of risk assessment is that risk may be location dependent or specific. Risk can be assessed within an accepted range of uncertainty if reliable historical and location-specific data are available. Risk assessment of a location-specific disaster event has two components: hazard and vulnerability. The hazard is a measure of the physical intensity and scope of the consequence at a particular location and the associated probability. Vulnerability is a measure of the damage that the consequence can cause to the built environment (e.g., LNG carriers and terminal facilities) at that location. Manmade structures respond to different consequences in different ways, depending on the design of their structural systems and methods of construction.

Risk assessment models can run both probabilistic and deterministic risk assessments. Probabilistic risk assessment computes damage for different events, accounting for the probability of each event. However, the hazard (consequence) assessment models used in risk assessment can also be used to examine the consequence of an arbitrarily-defined disaster event. This deterministic examination is sometimes called “What If?” analysis, or “scenario” analysis, and lacks any quantitative examination of the likelihood of the assumed scenario.

Although formal risk assessments are not required for LNG projects in the U.S., the concept of evaluating what can go wrong and implementing measures to control or eliminate those risks has been and continues to be prevalent in the LNG industry.³³

Most of the security risk assessment information developed by the regulatory agency for its evaluation of public safety impacts are not made publicly available because of security concerns. For example, FERC has removed Critical Energy Infrastructure Information (CEII) pertaining to LNG storage facilities from its website.³⁴

Quantitative Risk Assessment (QRA) is the quantitative evaluation of risk, taking into account the probability of an event and the consequences (measure of significance) of the event. It is a more mathematical approach to the identification and ranking of high-risk areas. Risks are defined as the frequency or likelihood of a certain level of harm or loss occurring in a given period of time. Risk assessments typically focus on workplace risks (i.e., potential harm to an individual's life or small number of people) and community or societal risks from major hazards (i.e., potential harm to many people from a low frequency event). Risks may be classified as: "unacceptable," "as low as reasonably practicable," or "broadly acceptable." Numerical risk criteria are used to apply these risk tolerance categories. For example, occupational hazards may be expressed in terms of the number of people within a workforce population that may be harmed, while major hazards to a community are expressed as the number of people that may be harmed once during a specified period of time (e.g., once in 10,000 years).

To be convincing to the public, an evaluation of the safety of LNG terminals must bring up all of the events that could be feared, regardless of their likelihood or seriousness, and explain for each event why one would believe that the activity (e.g., shipping, importing, storing, regasifying LNG, etc.) could not cause a disaster having physical impact upon public safety.³⁵

One of four reasons typically justifies a permitting agency's decision to allow a dangerous activity to proceed:

- The feared event is physically impossible.
- Dangerous effects of the feared event will not reach any crowded or populated areas.
- The feared event is slow enough to guarantee that the population can be kept out of harm's way, (e.g., be evacuated) or
- The probability of the feared event occurring is small enough to believe that it will likely not occur.

The most effective way to reassure people concerned about a possible LNG-related disaster is to prove that activities associated with LNG shipping and handling use inherently safe techniques and that the feared event is physically impossible.

When the event that is feared is possible, it might still be appropriate to allow the dangerous activity if one can prove that, even in the worst-case scenario, the scope of the dangerous effects is limited enough not to reach crowded or populated areas.

This type of argument may be used, for example, to accept the risk of an LNG fire following a flammable gas leak from a storage tank that is correctly equipped with means to limit the leak's flow rate and duration.

In this case, the scenario analysis approach is deterministic. Calculations that are based on the laws of physics will be used to prove the safety around the installations. Even if the calculations may be marked by great uncertainty, the key projection is the maximum distance of the flammable vapor cloud or the thermal radiation level that will not be exceeded. The proof of safety is usually based on empiricism, if the phenomenon is well known, and, if need be, on physical calculations such as spill, combustion, and evaporation rates.

The very small probability of occurrence may also be used to justify a decision that the proposed project is safe. The main reason for putting this argument in last place, however, is that it is the least convincing and most difficult to develop. It is the least convincing because:

- Aversion to risk varies greatly from one individual to the next.
- The probabilistic projections that are applied to events that are rare or never seen are only constructs of the mind.
- The available statistical data often have only tenuous connections with the case studied, and the margins of error are considerable, and
- Even a highly improbable event can nevertheless occur tomorrow.

It is also the most difficult to develop because it requires detailed analysis, strict logic, and uncertainty assessments. This approach is used frequently to improve the safety of systems such as gas pipelines and automobile transportation.

A safety study for a site considers both the causes and the effects of the feared events. The reasons for authorizing a potentially dangerous activity are always based on the risk of its engendering a disaster. The risk must always be very low and may be explained by the low probability of the accidents occurring or the low probability of exposure to the accident's effects. To make it easier to understand the reasons for authorizing an activity perceived as potentially dangerous, the arguments should always bring up the key factors that cause the probability to be very low or even nil. A comparison of the relative risks of commonly understood activities can often be helpful in the perception of risk levels.

If the probability of the accident's occurrence or exposure to its effects is strictly nil, quantitative or qualitative logic is used to prove this (deterministic approach). If neither of these two probabilities is nil, calculated probabilities are used to estimate the probability of a disaster (probabilistic approach). A disaster risk may be accepted due to the disaster's low probability, but the disaster, itself, is never acceptable.

Risk Assessment Guidance for Marine Terminal Facilities

Risk assessment has only recently become a “term of art” in the shipping industry although the general concepts of evaluating what could go wrong and mitigating against potential incidents have been an integral tool of the industry. . Formal risk assessments, however, increasingly are implemented for high hazard operations such as LNG shipping and receiving. A number of standards, guidelines, and studies addressing risk assessments for maritime operations in general, and LNG facilities specifically, have been published. The following information provides examples of risk assessment applications specific to LNG operations. The methodologies used in LNG risk assessment are varied, and each method has its benefits and drawbacks.

Risk Assessment for Gas Jetties

In 1999, SIGTTO published *A Risk Based Approach for the Evaluation of Fire Fighting Equipment on Liquefied Gas Jetties*. This publication introduced the then relatively new concept (in shipping) of risk assessment and provided general guidance for how and why a risk assessment should be conducted, using risks at liquefied gas jetties as an example. A simple risk approach would look at incident records and extrapolate into the future but would not provide an understanding of why certain risks occur or how to minimize them.

Hazards on LNG jetties were considered to fall into two general groups: generic failures (leaks, etc.) and external events (ship collisions, etc.). The likelihood of a release would be determined (e.g., from a count of the number of component parts multiplied by the likelihood that each component will fail) then, coupled with the probabilities for ignition, would be used to estimate the likelihood of a fire.

Risk Assessment of Offshore LNG Production and Storage

Classification societies have developed guidance for offshore LNG facilities. DNV Consulting described risk assessment techniques to quantify safety uncertainties associated with various design options for offshore LNG facilities.³⁶ Its paper put forth a quantitative risk assessment (QRA) methodology as a logical structure for estimating risks, particularly in advance of the development of specific codes, standards, rules, and regulations for offshore LNG.

An offshore facility was evaluated and its risks compared to an onshore facility. The analysis was structured around a standard set of major accident categories, although terrorism was not covered as an event. Fatality risks were identified; production workers had the highest exposure to risks given the combination of process risks with relatively high occupational risks. Risks associated with LNG storage were deemed exceedingly low due to LNG tank storage configuration.

Similarly, risks associated with vessel collisions were also considered low. The study concluded that risks were about the same overall for the offshore and onshore facilities.

Risk Assessment Guidance from American Bureau of Shipping

The American Bureau of Shipping (ABS) has prepared guidance notes on risk assessment applications for the marine and offshore oil and gas industries.³⁷ In their guidance document, *Guidance Notes on Risk Assessment Applications for the Marine and Offshore Oil and Gas Industries*, risk assessment is described as covering four basic steps: hazard identification, frequency assessment, consequence assessment, and risk evaluation.

ABS hazard identification methods include: hazard identification technique; what-if analysis, checklist analysis (e.g., evaluation against pre-established criteria); hazard and operability analysis; failure modes and effects analysis (considered best for reviews of mechanical and electrical hardware systems); and human factors analysis.

Frequency assessment methods include: analysis of historical data, event tree analysis, fault tree analysis, common cause failure analysis,³⁸ and human reliability analysis.

Consequence assessment methods typically involve the use of analytical models. For LNG, these include dispersion models such as DEGADIS and LNGFIRE.

Risk evaluation and presentation techniques include: subjective prioritization (e.g., high, medium, low risk); risk categorization/risk matrix,³⁹ and risk sensitivity.

ABS has identified which methods work best for different aspects of the industry. For example, event-tree analysis is often used for the analysis of vessel movement mishaps and propagation of fires, confined-space explosions, or toxic releases.

Mexican Risk Assessment Requirements for LNG Terminals

The Mexican emergency LNG safety standards described above addressed risk assessment in depth. The risk assessment process must be performed during the initial design phase of a new LNG terminal and the location of the facilities and design of a new LNG plant must be based on the risk-analysis results. Furthermore, the risk assessment must be repeated when unacceptable risks are identified. Upon completion, a copy of the final analysis must be submitted to Mexican authorities for review. The risk-analysis methodology used for the LNG plant may be probabilistic, deterministic, or both. The risk assessment may be based on conventional methods such as:

- hazard and operability study,
- failure mode effect and criticality analysis,
- event-tree analysis, or
- fault-tree analysis.

The probabilistic approach requires the following steps:

- collect data regarding failure rates,
- define potential internal and external risks to the LNG plant,
- determine and classify the probability of these risks as one of the following:
 - frequent,
 - possible,
 - rare,
 - extremely rare,
 - improbable, or
 - probability is not quantifiable.
- determine and classify the potential effects of each risk and its location using one of the following types of effects:
 - catastrophic,
 - serious,
 - significant,
 - reparable, or
 - nil.
- classify accidents according to the effects and probability of the same in determining the level of risk involved:
 - unacceptable,
 - must be improved, or
 - normal.
- verify that no risk is classified as unacceptable, and,
- justify those measures necessary to limit risks.

The deterministic approach must follow these steps:

- define potential internal and external risks to the LNG plant,
- identify credible risks,
- determine and quantify the effects of such risks, and
- justify those measures necessary to improve safety and limit risks.

Canadian Risk Assessment Requirements for LNG Terminals

The Canadian Technical Review Process of Marine Terminal Systems and Transshipment Sites (TERMPOL) code was first published in 1977. It applied to navigational risks associated with the location and operation of marine terminals for large oil tankers. A second edition, published in 1982, was expanded to include, on a voluntary basis, bulk shipments of LNG. TERMPOL was recently updated to cover operational safety aspects of dedicated ships transporting pollutants or hazardous cargoes in bulk. The code states that the selection of appropriate risk assessment models depends on the nature of the project and the characteristics of the marine terminal location. The terminal proponent must analyze any risk or risks relating to uncontrolled releases, either in route to or at a terminal. Typical scenarios include a two-ship collision, a ship grounding, a ship striking a fixed object, an improper cargo transfer incident, a fire, or an explosion.

Predictions are to be made on a worst-case, but credible-incident scenario in the terminal area and at selected positions along the coastal route. Perceived risks to populations within coastal zones along the intended route, the terminal berth and surrounding area, and the marine environment should be included.

The risk assessment should include:

- probabilities of credible incidents which result in the breaching of the ship's cargo containment system,
- risks associated with navigational and operational procedures,
- probabilities of a major cargo transfer incident at the terminal dock,
- geographical boundaries and the resulting consequences of an uncontrolled release of cargo on the marine environment and, when applicable, in the close vicinity of adjacent coastal communities, and
- risk of an incident becoming "uncontrollable."

Predictions of vapor clouds must be based on defined, worst-case, credible incidents involving LNG releases from one cargo tank. The quantification and evaluation of vapor clouds is complex and an acceptable approach would be to calculate the risk of fatalities in terms of exposed persons per unit of time.

Two dozen measures that could mitigate risks are presented as examples.

Sabotage is specifically identified as one situation that could be considered in a terminal-oriented contingency plan.

United Kingdom (UK) Formal Safety Assessment

The Formal Safety Assessment (FSA) is the basis of the “Safety Case” regime, by which the UK Health and Safety Executive judges offshore activity. FSA is a structured and systematic methodology for enhancing maritime safety. It was originally developed, in part, as a response to the 1988 Piper Alpha offshore platform explosion. It is now being applied to the IMO rulemaking process. Interim guidelines were adopted in 1997 and IMO member states are carrying out trials. Steps involved in a FSA include:

- identification of hazards,
- risk analysis,
- risk control options,
- cost-benefit assessment, and
- recommendations for decision-making.

Characterization of hazards and risks should be both qualitative and quantitative, and both descriptive and mathematical, consistent with the available data.⁴⁰

Risk Assessments by the U.S. Coast Guard

Many USCG missions involve identifying and minimizing hazards to the public, preventing mishaps, and investigating causes when mishaps occur. In 1976, the USCG published a guide entitled *Liquefied Natural Gas and Liquefied Petroleum Gas – Views and Practices, Policy and Safety, Commandant Instruction (COMDTINST) M16616.4*. This guide outlines USCG views and policies for transporting LNG and liquefied petroleum gas by water and presents generic spill scenarios.

A USCG Captain of the Port applies the risk-management standards from COMDTINST M16616.4 to decide which USCG measures should be deployed at a port to safeguard an LNG facility. Risk mitigation measures reflect the geographic location of terminals relative to population centers. Terminals in urban settings employ more safety measures than terminals in rural settings. Examples of USCG risk mitigation measures are: USCG escort, daylight transit, full or partial transfer monitoring, pre-arrival carrier inspection, USCG sea marshals, tugs for docking, and safety and security zones.⁴¹ Ports that handle LNG ships have published USCG required contingency plans concerning LNG incidents.

The USCG officially adopted the Risk Based Decision Making (RBDM) program in 2001 and has recently re-emphasized the program to identify the greatest risks and to prioritize efforts that minimize or eliminate them.⁴² RBDM consists of five major components: Decision Structure, Risk Assessment, Risk Management, Impact Assessment, and Risk Communication. The USCG used RBDM in its review of the Cove Point LNG facility. (See discussion of the Cove Point risk assessment, below.)

The RBDM process encourages USCG decision makers to ask the following questions:

- What can go wrong?
- How likely are the potential problems to occur?
- How severe might the potential problems be?
- Can the risk of potential problems be tolerated?
- And, what can/should be done to lessen the risk?

Based on its work for Cove Point, the USCG developed a detailed risk-analysis process for determining the suitability of a waterway for LNG transport. The process will be made available for future and existing LNG operations.

The approach follows elements of the Port and Waterways Safety Assessment (PAWSA) process that address risk identification and assessment steps. Example “what if” scenarios included: what if terrorists attempted to board and take control of an LNG carrier; and what if terrorists attempted to damage the LNG carrier from the shore. The goal is to begin risk assessments at as general a level as possible and to do more detailed studies only in areas where the additional risk assessment will help the decision maker. If the stakeholder team determines that a more formal assessment of risks is necessary, RBDM Guidelines provide detailed guidance on the various methods available for performing these assessments.

Terrorist Risk Assessment for LNG Facilities

Perhaps the largest uncertainty regarding LNG safety is the threat of piracy or terrorism. These activities have not been considered as thoroughly in risk assessments as have accidents or natural causes.

Piracy is a major concern in the shipping business. The three main types of piracy in global waters are harbor/anchorage attacks, attacks against vessels at sea, and hijackings of commercial vessels at sea.⁴³ Ninety to 95 percent of world freight moves by sea, providing abundant targets. Piracy attacks have included LPG carriers, with the contents sold for profit.

Pirates have not attacked an LNG carrier, although trade routes pass through piracy hotspots in Southeast Asian waters. In particular, the Malacca Strait, which is between Sumatra and the Malay Peninsula in the South China Sea, has the highest incidence rate of attacks. In 2003, a total of 445 incidents were reported, compared with 370 in 2002.⁴⁴

LNG carriers observe the IMO standard piracy watch to keep all accommodation doors locked between 6 pm and 6 am.⁴⁵ The IMO alerted ship owners to install satellite tracking systems and step up anti-piracy watches.⁴⁶ Terrorism activity in

Indonesia has prompted the Indonesian government to step up security at foreign-owned pipelines and LNG plants.⁴⁷

Terrorism is an intentional act involving unpredictable human behavior. Determining the frequency of events is based on history, science, and art. A geographical distribution of frequency would include prime targets such as tall buildings, governmental facilities, power facilities, monuments, ports and airports, and military facilities. Terrorists tend to use weapons that are relatively easy to obtain and are within their area of expertise to use effectively. Their intent is to instill terror in a community through threats and high-profile acts.

While the potential exists for an entire vessel to be used as a weapon in a terrorist strike, previous terrorist incidents involving ships have tended to target vessels rather than use them as weapons. Terrorist attacks against maritime targets are relatively rare, in part because most terrorists have little maritime experience (operating at sea requires special equipment and skills) and the many land targets offer higher visibility and greater ease of access.⁴⁸

Two large vessels were attacked in Yemen by small boats containing explosives in October 2002 and October 2003: the *USS Cole* and the French oil tanker, *MT Limburg*. An International Maritime Security (IMS) manager stated that “the only country where [the *MT Limburg* attack] may have been prevented is in the U.S. because USCG vessels now patrol port areas to stop this type of thing from happening.”⁴⁹ Following the *MT Limburg* attack, Yemen introduced new security measures, including helicopter and gunboat patrols, and bans on fishing boats from being near port entrances and shipping lanes.

MARAD issued Advisory 02-07, advising U.S. shipping interests to maintain a heightened state of alert against possible terrorist attacks. This advisory is still in effect. Advisory 03-05 alerted maritime interests to the increased threat possibilities to vessels and facilities and a higher risk of terrorist attack to the transportation community in the United States. Advisory 03-05 is no longer in effect. In July 2003, the USCG established safety and security zones around certain vessels, including those carrying LNG. According to an article in *American Maritime Officer*⁵⁰, the U.S. Navy and USCG conducted interdiction drills off the coast of San Diego to determine whether a merchant vessel being used as a weapon by terrorists could be stopped before reaching port. No advisories have been issued in 2004.

Vulnerable terrorist areas include the Strait of Malacca, where two thirds of the world’s LNG trade passes.⁵³ U.S. LNG supply, however, currently comes from more secure areas, such as Trinidad.

Although the destructive potential of LNG is great, LNG vessels tend to be expensive, are relatively modern, and are operated by reputable firms. The vessels generally have robust cargo security systems in place.⁵⁴ Since the principal risk is during loading and unloading, LNG ships would be most vulnerable when at port or awaiting transit at busy maritime choke points (eg Strait of Hormuz leading out of the

Persian Gulf). It is relatively unlikely that a terrorist group could successfully rig the destruction of an LNG vessel's cargo.⁵⁵

Immediately following the September 11, 2001, terrorist attacks, the USCG Captain of the Port of Boston (USCG) banned LNG deliveries to the terminal in Everett, Massachusetts. "I hope this decision will stimulate debate among all parties involved in ...our port safety and security...", said Port Captain Salerno. More than two years later, the dialogue continues about the potential consequences of a terrorist attack upon LNG carriers or terminals.

A study performed for the U.S. DOE Office of Fossil Energy by Quest Consultants Inc. generated considerable controversy. The Quest analysis, delivered in October 2001, was intended to be a site-specific analysis for determining whether to allow LNG carriers to resume deliveries to the Everett terminal. John Cornwell, principal author of the report, said later that his calculations were never intended to broadly examine the consequences of a terrorist attack upon LNG facilities. The analysis predicted that the maximum diameter of the LNG pool (and hence the maximum base of an LNG pool fire) would be 470 feet. And, the thermal radiation from the pool fire could cause second-degree skin burns after 30 seconds of exposure approximately one-quarter mile from the center of the fire.

Investigative reporters for the *Mobile Register* (Mobile, Alabama) questioned the assumptions and some data sources used by Quest Consultants Inc. to predict the release, spread, and vaporization rates of a terrorist-created LNG spill. The Quest study modeled a spill from a large hole in the side of an LNG cargo tank created by ramming a ship into the LNG carrier's side at a near 90-degree angle. For the ship to strike the carrier with sufficient momentum to penetrate the carrier's double hull, insulation, and one LNG storage tank, the Quest modelers determined that the terrorist incident must occur in outer Boston Harbor rather than within the narrow Mystic River near the Everett terminal. Because the terrorist attack was assumed to occur in outer Boston Harbor, the potential for public exposure to the thermal radiation from an LNG pool fire would be lower than an attack staged within Boston's inner Harbor. Furthermore, the study assumed that higher waves (relative to calmer waters within the inner harbor) would restrict the spread of LNG, thereby reducing the vaporization rate.

The *Mobile Register* reporters who raised concerns about the Quest study also questioned a similar study by Lloyd's Register for LNG shipper, Tractebel LNG of North America LLC. According to a November 2001 press release by Lloyd's Register, its study was a generic evaluation of the risks and consequences associated with transporting LNG, incorporating experiments and findings spanning more than 30 years. The study included an analysis of the consequences of the following types of deliberate attacks against LNG carriers: missiles, explosive devices, crew sabotage, collisions, and groundings. Although summaries of the report were available, the report itself was withheld from the public due to security concerns. From these summaries, the following information has been gathered.

In the Lloyd's Register's account of its report, it "concluded that if a ship were attacked, the likely consequence would probably involve a fire, not an [LNG] explosion,"⁵⁶ because an unconfined LNG vapor cloud detonation has not been demonstrated. The summary stated that an LPG or gasoline tanker attack would present a greater hazard than would LNG.

The account of the Lloyd's Register study in the *Mobile Register*, however, included the following cascading events: LNG explodes within the confined spaces of the carrier, metal portions of the ship not intended to withstand cryogenic temperatures fracture, additional storage tanks rupture and release more LNG, an un-extinguishable fire ensues, and ultimately the carrier is a total loss.

Both the Quest and Lloyd's Register studies for the Everett terminal evaluated the possible consequences of a terrorist attack by assuming the creation of a hole in an LNG storage tank onboard a carrier. The issue of whether a terrorist attack could penetrate an LNG carrier's double hull and storage tank, however, has not been determined or demonstrated. Lloyd's Register has evaluated the effects of explosives placed outside of the carrier's hull and a missile fired at an LNG carrier for a proposed LNG terminal in Nova Scotia.⁵⁷ Likely scenarios and detailed outcomes were presented. Although this report is more detailed than other documents prepared to date, it is not clear whether the analysis is based on structural tests. An engineering study might further resolve this aspect of the public debate concerning LNG carriers' vulnerability to terrorism.

FERC has attempted to review the models used to evaluate offshore releases and to recommend models for such evaluations. FERC released the draft report, *Consequence Assessment Methods for Incidents Involving Releases from Liquefied Natural Gas Carriers*, on May 13, 2004⁵⁸. The report's purpose was to identify appropriate analysis methods for estimating flammable vapor and thermal radiation hazard distances for potential LNG vessel cargo releases during transit and while at berth. Although certain generic models were recommended, the report stressed that site specific applications should be made. A public comment period generated extensive comments, both promoting use of the results, and providing criticisms of the results. Although the final report will not be published until the end of 2004, draft conclusions were used in preparing the Freeport LNG project FEIS issued May 28, 2004.

Sandia National Laboratory is currently working with the Department of Homeland Security to evaluate terrorism with respect to LNG facilities. A report has not yet been released. Using input from Sandia, however, DNV concluded in a June 2004 conference paper⁵⁹ that a 1.5 meter hole on the side of an LNG carrier could result from a terrorist action but that the energy involved in creating the hole would be so large that immediate ignition of the LNG cargo would be the most likely outcome. DNV also stated that the greater physical barriers (multiple layers within the carrier beyond the double hull) between the LNG and the outside environment make LNG carriers less vulnerable than double-hulled oil tankers to penetration.

The fundamental challenge of predicting terrorism is uncertainty. While historical information on natural disasters such as earthquakes and hurricanes exists, no comparable record for the nature, location, frequency and impact of terrorist attacks has been compiled.⁶⁰ The relative likelihood of a “show piece” scenario (missile strike, LNG carrier fire, nuclear device detonation, etc.) would be governed by a cost function, which is a measure of the overall difficulty in execution.⁶¹

Insurers are addressing terrorism by developing new computer simulation models that include information relating to counterterrorism, weapons, and security measures. Three risk management companies have recently released terrorism assessment models for the insurance industry. These include Risk Management Solutions (RMS), AIR Worldwide Corp., and EQECAT, Inc. RMS uses game theory (i.e., understanding the operational and behavioral characteristic of the terrorist organization) to help insurers quantify risk from catastrophic terrorist attacks. Its model considers approximately 1,500 possible terrorist targets in the U.S. AIR Worldwide focuses more on expert opinion and uses the Delphi Method (i.e., soliciting expert judgment), developed by RAND, to determine probabilistic estimates of the number of attacks and where they might occur. The AIR model includes a database of more than 300,000 potential targets. The EQECAT probabilistic model contains more than 10 million events and hundreds of thousands of “high probability” terrorism targets.⁶²

Risk Assessments of U.S. LNG Facilities

As of December 2004, more than 50 proposals to build onshore or offshore LNG import terminals had been announced for North America.⁶⁴ Five onshore LNG import terminals are already located in the U.S.: Cove Point, Maryland; Elba Island, Georgia, Everett, Massachusetts; Lake Charles, Louisiana; and Penuelas, Puerto Rico. FERC recently approved onshore terminals in Cameron, Louisiana (formerly called Hackberry) and Freeport, Texas. Additional projects with applications pending at FERC would be located in Long Beach, California; Corpus Christi, Texas; Sabine Pass, Louisiana, Weaver’s Cove, Massachusetts, and Providence, Rhode Island. In addition, five “pre-filings” are listed in the FERC docket: Crown Landing, Gloucester County, New Jersey; Golden Pass, Jefferson County, Texas; Vista del Sol, near Portland, Texas; and Port Arthur, Texas.

The USCG has approved two offshore LNG terminals. These are Port Pelican, which is 40 miles offshore, and the El Paso Energy Bridge, which is 116 miles offshore. Both of these projects are off the Louisiana coast in the Gulf of Mexico. MARAD issued a deepwater port license on behalf of the Secretary of Transportation to the developers of the Port Pelican LNG terminal on November 17, 2003. Developers of the El Paso Energy Bridge received notice of approval on January 15, 2004. The USCG published the Final EIS in November 2003. Two offshore terminal projects were added to the USCG docket in February, 2004: the Cabrillo Port project by BHP Billiton (21 miles offshore Southern California) and the Gulf Landing project by Shell (28 miles offshore Louisiana). More recent projects include the Pearl Crossing LNG

Terminal deepwater port, to be located approximately 41 miles southeast of Cameron, Louisiana; and the Crystal Clearwater LNG Port Project, to be located 11 miles offshore of Southern California.

Developers for many of the existing and proposed facilities have conducted studies on the risks associated with the LNG operations. The following sections detail the types of studies done, the models used to identify risks, and the general conclusions regarding risks. Examples of actions recommended in public documents to control and reduce key risks are provided in Appendix B.

Existing U.S. LNG Terminals

Cove Point, Maryland. The Cove Point terminal is located in Maryland on Chesapeake Bay and was built in 1974. The facility was deactivated and did not accept LNG shipments after 1980 because domestic natural gas supplies were cheaper. An Environmental Assessment (EA) on expanding the facility to one billion cubic feet per day (Bcfd) was prepared in 2001. Despite public concerns regarding the adequacy of the EA discussion of risk assessment, including the potential for terrorist attack on the facility, FERC approved the expansion project in October 2001. This decision was reaffirmed in December 2001. The facility has restarted operations; the USCG escorted the first LNG shipment into the facility on July 25, 2003.

As part of the permitting process, three workshops were held to assist the Captain of the Port (COTP) for Baltimore and Portsmouth in identifying and minimizing risks associated with Cove Point operations. The workshops used the Change Analysis Tool,⁶⁵ which addressed the issue of how the risk of upcoming changes in ports and waterways could be best managed. The workshops also employed “What if” analyses. Objectives of the workshops included addressing security measures by gaining a greater understanding of possible maritime security-related scenarios and developing a description of general responses should a problem develop. Risks associated with LNG transit, transfer, and differences from normal port activities were identified. Scenarios relating to LNG gas release, mutiny/loss of vessel control, violations of the safety zone, and the perceived increased threat to a moored vessel were included.

Results from the workshops were used to support the Letter of Recommendation, issued by the COTP Baltimore and Portsmouth, to cognizant state and local government agencies as to the suitability of the waterway for LNG marine traffic.

Elba Island, Georgia. The Elba Island Terminal is located near Savannah, Georgia and was built in 1978. LNG imports to the terminal stopped in 1982 due to the high costs of LNG relative to domestic natural gas supplies. It was reactivated in 2001 following the FERC-led approval process.

Prior to allowing the plant’s reactivation and expansion (from 470 MMcfd to

0.8 Bcfd), FERC prepared an EA. In that report, LNG vapor, if ignited, was identified as the primary hazard to the public. Exclusion zones were calculated as follows:

- Thermal exclusion zones — 775 feet (most intense exposure) to 1,858 feet (less intense exposure), and
- Vapor cloud dispersion exclusion zone — up to 3,970 feet, based on spilling the entire contents of the facility's single-containment storage tank (the worst-case scenario).

The report identified five hypothetical "significant incidents" involving LNG ships. The minimum striking speed needed by another ship (e.g., oil tanker) to penetrate LNG cargo tanks was calculated for both Moss (spherical-tank) and membrane-type LNG carriers. A collision or allision that ruptured a tank would most likely ignite the flammable vapors at the spill site. A rupture of more than one cargo tank was considered implausible.

The most significant risks would be created by the relative narrowness of the shipping channel and its proximity to the Elba Island terminal docks. A credible risk would be an allision with a fixed structure or the possibility of another vessel alliding with the LNG tanker while it was moored.

(Note: In September 2000, the Elba Island terminal was the site of a shipping accident. A 580-foot tanker filled with palm and coconut oil lost its steering and slammed into the LNG terminal's dock, putting a 40-foot gash in the tanker and wrecking almost half of the dock. The terminal had no LNG present, because it was still in the process of restarting, but USCG officials agreed that the consequences could have been serious.^{66,67})

Everett, Massachusetts. The Everett Terminal is located near Boston, Massachusetts. Opened in 1971, it is the oldest LNG import terminal in the U.S.

After the September 11, 2001, terrorist attacks, the USCG temporarily banned LNG carriers from entering Boston Harbor. This ban was lifted in October 2001 after the USCG reviewed results of a number of risk-assessment studies. (See discussion of these risk assessment studies in *Terrorist Risk Assessment for LNG Facilities*, above.)

Lake Charles, Louisiana. The Trunkline LNG terminal is located in Lake Charles, Louisiana with access to the Gulf of Mexico. Facility construction began in 1978 and full-scale operations began in 1982. Imports were suspended, however, between December 1983 and November 1989 and between 1994 and 1996 for economic reasons.

An EA was prepared by FERC to assess the environmental effects of a proposed expansion of the existing LNG terminal. FERC included an analysis of public safety issues.

Per 49 CFR Part 193, thermal and flammable vapor exclusion zones were modeled. The calculations of exclusion zones were based on the dimensions of the proposed impoundment systems and the design spill volumes. Exclusion distances resulting from a LNG pool fire were calculated for various thermal radiation levels using LNGFIRE III. Vapor dispersion exclusion zones (from a large quantity spill without ignition) were calculated using the DEGADIS dense gas dispersion model.

The land-based facilities incorporated features to both limit the duration of LNG spills and contain credible spill volumes. The events considered most likely to result in a significant release of LNG on water were:

- an outbound vessel colliding with an inbound LNG ship,
- an inbound LNG ship colliding with the terminal or a structure in the channel,
- a vessel colliding with an LNG ship while moored at the terminal, and
- a grounding severe enough to puncture the LNG cargo tanks.⁶⁸

In addition to using DEGADIS, the CANARY model (Quest's proprietary model) was used to calculate maximum distances for flammable vapor clouds resulting from a spill on water without ignition. However, in order to penetrate the outer hull, the inner hull and cargo containment, a triggering event would also most likely cause ignition. The analysis concluded that there is minimal risk of an incident causing hazard to the public. A section on terrorism was included.

Penuelas, Puerto Rico. The EcoEléctrica LNG Import Terminal and Cogeneration project is located at Punta Guayanilla, Penuelas, approximately nine miles west of the city of Ponce on the south coast of Puerto Rico. Construction of this project began in July 1998 and was completed in November 1999. The LNG facility, which has one storage tank that holds the equivalent of 3.6 Bcf, received its first cargo in 2000. A joint EIS/EIR was prepared by FERC and the Puerto Rico Planning Board for the EcoEléctrica LNG Import Terminal and Cogeneration project.⁶⁹ The document provides an overview of LNG facility safety and an analysis of public safety.

Sixteen specific recommendations resulted from the cryogenic design and technical review, mostly related inspections, emergency response, traffic, and tank evaluations. Thermal exclusion zones were calculated for the various thermal radiation levels for both a complete emptying of a storage tank and from various spillways. Vapor dispersion exclusion zones from onshore elements were also calculated. Marine safety was reviewed. An analysis was conducted of the damage that could result from an oil tanker striking an LNG tanker at berth. The EIS/EIR referenced a previous study in determining that a flammable vapor cloud could travel up to 3.3 miles in 25 minutes.

Other Proposed LNG Facilities in the U.S.

El Paso Energy Bridge, Offshore Louisiana. The El Paso Energy Bridge Gulf of Mexico Deepwater Port LLC applied for a license on January 23, 2003. The USCG and MARAD published a final environmental assessment in November 2003. The project (0.4 Bcfd) was approved on January 15, 2004.

El Paso Energy Bridge Vessels (EPEBVs) would be used to transport and regasify LNG. When an EPEBV reaches the deepwater port, 116 miles south of the Louisiana shoreline, it would retrieve and connect to a Submerged Turret Loading (STL) buoy. A winch located on the EPEBVs would raise the submerged buoy from its underwater location into an opening in the hull of the EPEBV. After it is secured, the buoy would serve both as the mooring system for the EPEBV and as the offloading mechanism for transferring the natural gas. The EPEBV would gasify the LNG with its onboard equipment and deliver natural gas to the STL buoy and downstream pipeline infrastructure of the deepwater port for delivery to existing, third-party pipelines. When it is not in use, the STL buoy would remain submerged in approximately 280 feet of water.⁷⁰

The risk management discussion in the environmental assessment focused on the design, engineering, and operation of the proposed deepwater port infrastructure and EPEBVs. The primary concern for potential accidents is the possibility for fire resulting from accidental releases of LNG or natural gas. The port, however, would be sufficiently far from centers of population that a serious upset would not likely affect the public.

The EPEBVs' design underwent a Lloyd's Register Safety Evaluation and a formal HAZOP assessment that showed no fatal flaws in design. The following four liquid-tight barriers between the ocean and the vessel's cargo would have to be breached before LNG could be released from the tank: double-containment cargo tanks and inner and outer carrier hulls made of carbon steel.

During offshore operations, there is a remote possibility that a passing ship collision could breach pipelines that connect at the proposed deepwater port location. A safety zone and larger "precautionary zone" would surround the deepwater port to reduce the risks of a potential collision. The most-likely worst-case accident would be the onboard rupture of an LNG line running to one of the EPEBV vaporizers. The EPEBV is designed with stainless steel sumps constructed below the cryogenic pipelines running to the vaporizers. These sumps will handle up to three times the projected release volume.

A Port Operations Manual must be prepared following project approval for USCG review and approval that addresses in detail all risk management and safety issues.

Freeport, Texas. Freeport LNG filed an application with FERC for an onshore LNG receiving terminal (1.5 Bcfd) at Freeport, Texas, at the end of March 2003. The proposed LNG marine terminal and natural gas pipeline would be located entirely on

Quintana Island in Brazoria County, Texas. The LNG marine terminal, transfer lines, and the storage and vaporization units would be located on Quintana Island, southeast of the City of Freeport.

In May 2003, FERC provided notice that its staff would be preparing an EIS on the Freeport LNG project. Issues regarding reliability and safety to be addressed in the EIS include:

- Assessment of hazards associated with the transport, unloading, storage, and vaporization of LNG,
- Assessment of potential collision of LNG ships with ships,
- Assessment of potential collisions of LNG ships with other ship traffic and structures in the port,
- Assessment of security associated with LNG ship traffic and an LNG import terminal, and
- Assessment of hazards associated with a natural gas pipeline.

The Final EIS for the Freeport LNG Project was released May 28, 2004. The section on Reliability and Safety is more detailed than past FERC LNG analyses, and includes more than 50 pages of information. The FEIS incorporates an expanded section on marine tanker safety, incorporating the results of the May 13, 2004 Draft ABS Consulting report on consequence analyses (see U.S. LNG Safety Requirements).

The most recent LNG incident at the Skikda, Algeria facility is discussed and based on this incident, design review recommendations by FERC are identified. Significant discussion is presented on “full containment” tanks, which include a concrete secondary container. These tanks serve the dual function of holding the insulation and gas pressure, and containing liquid in the event of an inner tank failure. Although the concrete wall could significantly enhance safety in the event of an attack on the facility, FERC still recommended that the Freeport facility include an external containment barrier. Despite confusion with NFPA 59A requirements, FERC applied a 10-minute spill criteria for containment sizing.

Site-specific assumptions were used in modeling thermal exclusion zones; the maximum distance of 914 feet (1,600 Btus per square foot per hour (Btu/ft²-hr incident flux level) was obtained from a storage tank release. The largest vapor dispersion zone distance (2,111 feet) resulted from a release from the process area drain sump.

The FEIS provides a detailed discussion of LNG carrier security measures and specifically discusses the possibility of a deliberate attack on an LNG ship by a terrorist group. A Security Analysis was prepared for Freeport LNG and filed under CEII. This confidential report analyzed a range of potential attack scenarios and estimated consequences. Based on this information and the results of the Lloyd’s

Register study for Weaver's Cove LNG (also confidential), a 1-meter hole was considered the "worst-case" credible damage scenario.

LNG release from a 2.5-meter hole was also modeled to serve as an upper limit of potential damage. Modeling identified thermal radiation distances of 2,870 to 5,930 feet for a 1,600 Btu/ft²-hr level, which is hazardous for persons located outdoors and unprotected. Residences on Quintana Island along the carrier route are located within these distances.

Flammable vapor dispersion calculations, based on a 1-meter hole, would result in an estimated pool radius of 459 feet. The unignited vapor cloud would extend to 11,500 feet to the lower flammability limit and 16,900 feet to ½ the lower flammability limit. The FEIS states that these estimated "worst-case" scenarios should not be misconstrued as defining an exclusion zone.

The FEIS details vessel construction and indicates that foam polystyrene is not used on LNG carriers. However, this statement has recently been disputed. The report also references the fact that other potentially hazardous cargoes traveling the same route tend to be dismissed.

The terrorism discussion identifies post September 11, 2001 security actions undertaken by the USCG and the terminal owners and operators. Pipeline safety standards were also discussed in detail.

On June 21, 2004, FERC approved the project.

Cameron (formerly Hackberry), Louisiana. The proposed Cameron LNG terminal (1.5 Bcfd) will be located at the site of an existing liquefied petroleum gas terminal in Cameron Parish, Louisiana. The EIS prepared for the project discusses, among other things, safety controls, including spill containment, hazard detection system, hazard control system, firewater system, fail-safe shutdown and pipeline thickness, corrosion protection and emergency response procedures.⁷¹ Ship movement, including grounding and collisions, within and near the terminal was also discussed.

It was determined that the principal hazard would be from the ignition of vapor arising from a release of LNG. The EIS identifies 23 recommendations regarding cryogenic design and review (see Appendix B of this document) and also recommends that a storage spill containment system be constructed in addition to the double containment tanks.

Using the scenarios developed for review of the Everett, Massachusetts terminal, the LNGFIRE III model was used to calculate the thermal radiation exclusion zone at Cameron. The maximum thermal radiation exclusion zone is 900 feet. The DEGADIS program was used to compute the vapor dispersion exclusion zone from a continuous, 10-minute spill from either the LNG storage tanks or the marine transfer area. The maximum vapor dispersion exclusion zone is 770 feet.

In contrast to previous FERC environment reports, a specific section is included on terrorism. That section included the following discussion:

“The [September 11] attacks have changed the way...regulators must consider terrorism, both in approving new projects and in operating existing facilities. However, the likelihood of future acts of terrorism or sabotage occurring at the proposed Hackberry Terminal...is unpredictable given the disparate motives and abilities of terrorist groups. The continuing need to construct facilities to support the future natural gas ...infrastructure is not diminished from the threat of such future acts. Moreover, the unpredictable possibility of such acts does not support a finding that this particular LNG terminal should not be constructed.”

Mare Island, California. The project developers, Shell and Bechtel, withdrew their plans to build an LNG terminal at this site. However, the LNG safety study prepared by a group of expert consultants for the LNG Health and Safety Committee of the City of Vallejo’s Disaster Council is useful to review. The committee, comprised of Vallejo residents and members of the Disaster Council, was formed specifically to study LNG safety risks. It disbanded once the study was published in January 2003.⁷²

The purpose of the study was to determine the safety implications from a proposed LNG release into the atmosphere on land and water. It was intended to advise the Vallejo City Council on whether to continue encouraging the terminal proponents to proceed with their proposal.

The committee’s report identified the sequence of events that would have to occur to create a “worst-case” incident involving the proposed LNG facility. First, it defined four initiating events that could lead to an LNG release: earthquakes, navigational accidents, operational accidents, and terrorism. Then, it evaluated the likelihood that a large volume of LNG would be released due to each of these initiating events.

The committee then evaluated whether the large release would ignite immediately and affect populated areas, or whether the large release would form a flammable plume instead, with the potential for igniting later over developed areas. The table below summarizes the committee’s work.

Comparison of Probabilities from Initiating Events at the Mare Island LNG Facility

| | Maritime Accident | Operations | Earthquake | Terrorism |
|--|-------------------|---------------|---------------------------|-------------------------|
| Likelihood of Initiating Event | Unlikely | Very Unlikely | Likely | Unlikely |
| Likelihood of Large LNG Release | Unlikely | Very Unlikely | Unlikely to Very Unlikely | Very Unlikely |
| Likelihood that Flammable Plume reaches Developed Areas | Very Unlikely | Very Unlikely | Unlikely to Very Unlikely | Very Unlikely |
| Likelihood that Radiant Heat affects Developed Areas | Likely | Very Unlikely | Very Unlikely | Likely to Very Unlikely |

The committee determined that earthquakes are the most likely events to initiate an LNG hazard rather than man-made causes, but the likelihood that an earthquake could lead to a large release of LNG (e.g., caused by sufficient damage to a carrier or an onshore storage tank) was unlikely to very unlikely. Other findings from the study were as follows:

- The proposed terminal and the carriers serving it are potential targets for acts of terror, but an actual attack is unlikely.
- The chance of a maritime accident in San Pablo Bay and in the vicinity of the Carquinez Strait of a severity sufficient to release LNG is unlikely.
- The authority of the USCG and the measures it applies to similar High Consequence Vessels (HCVs) in other United States LNG terminals reduces the threat from acts of terror or sabotage substantially.
- A fireball presents the worst case for radiating heat. It is very unusual for LNG to form a fireball when released and ignited, because fireball formation requires the violent mixing of fuel and air prior to ignition.
- LNG will not support a boiling liquid expanding vapor explosion (BLEVE), because it is exceedingly cold and is stored at ambient pressure in very strong tanks.
- A pool fire involving the entire contents of a storage tank, or the entire contents of a single LNG carrier cargo tank released onto San Pablo Bay at the terminal will not cause radiant heat levels dangerous to people and homes in Vallejo, because the circumstances leading to such a large LNG release are more likely to ignite the LNG before it reaches populated areas.

A large release of LNG, if not ignited, would form a large flammable vapor plume that could reach residential areas. This is unlikely because the circumstances leading to such a large LNG release are more likely to ignite the LNG before it reaches populated areas.

Port Pelican, Louisiana. The Port Pelican Terminal (1 Bcfd) will be located approximately 36 miles offshore of Louisiana in the Gulf of Mexico. The project consists of the terminal, an LNG receiving, storage and vaporization facility, and the Pelican Interconnector Pipeline to transport gas to an existing offshore gas gathering system. A Final EIS was prepared by the USCG and published August 2003.⁷³ It referenced the Lloyd's Register study done for the Everett, Massachusetts facility, but apparently no site-specific modeling was done to this project. The document stated that:

- The proposed project would be sufficiently far from centers of population that a terrorist act would not likely affect the public.
- Compliance with existing industry standards, regulations and conditions of the license (including a 500-meter safety zone around the terminal) would mitigate any potential risks.
- Detailed security measures would be developed and implemented as part of the Port Pelican Deepwater Port Operations Plan.

MARAD issued a license to build the project in November 2003. In May 2004, the U.S. Environmental Protection Agency (EPA) issued air and water permits for the project. ChevronTexaco expects the project to be operational by 2007.

Risk Assessments of International LNG Facilities

This section summarizes risk assessment information for projects proposed in Canada, India, and Belgium. (No information could be obtained about the risk assessment studies conducted for proposed LNG projects in Mexico. A better means of sharing environmental data between the U.S. and Mexico is needed.)

Cape Breton Island, Canada. A Risk Assessment Component Study was conducted for the proposed Bear Head LNG Terminal by Lloyd's Register at the request of the project applicant.⁷⁴ The first part of the assessment reviewed compliance with Canadian regulations. Results indicated full compliance.

The second part of the study evaluated the worst-case consequences from a deliberate action against a membrane LNG carrier at berth, or against a 170,500-cubic meter storage tank. Deliberate actions included a missile attack on the external hull or structure, and placement of an external explosive device next to the hull or structure. Deformation of the ship/tank structure, loss of containment, and LNG release and resulting hazards were evaluated. Results showed that a missile or explosion event would create a large number of ignition sources that could then ignite the LNG as soon as it was released.

The study also found a possibility of escalating failure of the ship structure due to embrittlement, followed by a Rapid Phase Transition (RPT) event. However, this

possibility would be minimized by water ingress through the outer hull. The possibility exists that an early internal explosion at the hull hole could occur, caused by the gas-air mixture being ignited by explosive debris. This possibility was felt to be highly unlikely, as insufficient ignition sources would be present within the ship structure.

Dahej, India. An Environmental Impact Assessment (EIA) was conducted for India's first LNG terminal. The LNG receiving and vaporization terminal was commissioned in February 9, 2004 and is located at Dahej in the state of Gujarat. An integrated risk analysis showed that the risks to the public and to workers would be very low, assuming that international design standards are met, and that the plant remained separated from control and administrative buildings, and off-site areas. The off-site individual risk was calculated to be less than one in a million outside the site boundary.⁷⁵

Zeebrugge, Belgium. The LNG terminal at Zeebrugge began operation in 1987. A paper presented at an international conference described the safety risk assessment approach used for this terminal, which is located in an urban environment.⁷⁶ Special options were adopted to increase general safety. The major risks were perceived to be the formation of a gas cloud and an LNG pool fire. Both probabilistic and deterministic approaches were taken. Using the probabilistic approach, the individual risk that could not be exceeded was one death per one million years. Possible incident scenarios were classified by their possible frequency and damage (not shown); however, the most critical scenarios were considered to be:

- complete destruction of an unloading arm with LNG spilling on the sea, and
- complete failure of a tank followed by an LNG fire, or followed by an unignited vapor cloud.

Additional safety measures were incorporated to reduce the possibility of loading arm damage.

CONCLUSIONS

The Regulations

Numerous rules, regulations, guidelines, and standards exist for LNG facilities, particularly for carriers and onshore terminals. The U.S. LNG safety regulations are largely prescriptive, requiring specific design elements (e.g., impoundment areas), and specifying the manner in which risk to the public must be addressed (e.g., exclusion zones). Collectively, they are intended to assure that proposed and existing carriers and onshore terminals address the critical safety issues associated with LNG. Environmental documents prepared for U.S. LNG facilities, however, do not describe the many LNG regulations in place.

Offshore LNG terminals have only recently been proposed as new deepwater ports. While the Classification Societies have stepped in with design guidelines, the U.S. has only recently issued regulations specific to offshore LNG import terminals.

The Agencies

A number of agencies are involved in the permitting and operational oversight of LNG facilities. The scope of this *Compendium* was limited to international and national agencies, although state and local government agencies are also involved in LNG terminal siting.

The two major federal agencies with LNG oversight in the U.S. are FERC and the USCG. The former is responsible for onshore facilities that would be connected to an interstate pipeline and the latter is exclusively responsible for offshore facilities. The regulations differ as to what must be submitted in applications to these two agencies. Different permitting approaches, including differing requirements for safety reviews, could result for offshore facilities and onshore terminals.

For onshore facilities, different federal agencies have jurisdiction over the marine and onshore components. As an example, the USCG's jurisdiction ends at the point where the discharged gas from the carrier enters the onshore storage tank. The recently enacted interagency agreement between FERC, USCG, and DOT should help prevent "gaps" in oversight or regulation, and should avoid duplication of effort.

Terrorism and the New Marine Security Regulations

New maritime security regulations and the general lack of marine experience among terrorists may reduce the potential for a terrorist attack on an U.S. LNG import terminal. In the unlikely event that a missile or another vessel hit an LNG carrier, the

conservative modeling conducted by Lloyd's Register and DNV suggests that exposure to harmful thermal radiation would be limited to distances near the carrier. The force required to penetrate the carrier's four liquid-tight barriers would likely ignite the LNG vapor cloud quickly.

Modeling conclusions would be enhanced by including more real-life details in the analysis of the structural integrity of LNG carriers.

The new IMO and MTSA regulations significantly increase port and tanker security measures, with the USCG taking a major lead in promoting a safe environment for LNG facilities. Many of the new maritime security regulations focus on the developing security and other plans. Implementation, training, and auditing of these plans will be critical to ensuring the continued operating safety of these facilities.

Risk Assessment and Risk Communication

The term "risk assessment" has various meanings ranging from a simple analysis of "What could go wrong?" to a detailed, quantitative methodology to determine risk to individuals. There is no single, comprehensive industry standard for how to conduct a risk assessment and each risk assessment method has its benefits and drawbacks.

Risk modeling used by the USCG and FERC to evaluate the potential consequences of either offshore or onshore LNG facilities should be specific to the terminal's proposed location and its design.

Terrorism risk can be the major concern of people residing near existing or proposed LNG terminals. The government agencies responsible for safeguarding public safety have a special obligation to communicate about the risk assessment process, general findings, and safeguards as the LNG risk analysis proceeds.

The Risk-Based Decision Making program used by the USCG for LNG terminals at Cove Point and Everett to provide assurances, at least to the regulatory agencies, should be incorporated for any California LNG projects. The RBDM process was conducted in workshops attended by local law enforcement and emergency response personnel and consisted of five components: decision structure, risk assessment, risk management, impact assessment, and risk communication. Risk assessment begins at a general level, followed by more detailed studies, where needed to support local decision makers.

Local agency personnel lack tailored information on LNG and its safety and permitting issues. Information developed by the state Interagency LNG Working Group should be disseminated to government organizations with permitting responsibilities.

ENDNOTES

¹ The staff white paper is available at http://www.energy.ca.gov/reports/2003-07-17_700-03-005.PDF.

² Vapor clouds are not flammable at the edge of the cloud, where the greatest mixing with ambient air occurs, because the concentration of gas is too low at the outer border. Conversely, the interior of the LNG vapor cloud will not ignite due to the lack of oxygen.

³ “LNG Frequently Asked Questions,” Dominion Cove Point LNG, LP, <http://www.dom.com/about/gas-transmission/covepoint/faq.jsp>.

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⁵ Lloyd’s Register of Shipping is an entirely separate entity from Lloyd’s of London or a variety of other financial institutions bearing the name Lloyd’s.

⁶ <http://www.ferc.gov/press-room/sp-current/3>

⁷ The community also preferred that Mare Island be redeveloped for other purposes, including light industry, open space, tourism.

⁸ The Energy Commission staff and other state agencies’ staffs comprise the LNG Interagency Permitting Work Group, whose purpose is to share information about proposed LNG terminals in California and to coordinate state permitting processes.

⁹ For more in-depth descriptions of these safety and security features, read *LNG Safety and Security*, University of Houston Law Center, Institute for Energy, Law and Enterprise, October 2003, at

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Acronyms

| | |
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| ABS | American Bureau of Shipping |
| AGA | American Gas Association |
| AIS | Automated Identification System |
| ALARP | As Low as Reasonably Practicable |
| ANSI | American National Standards Institute |
| API | American Petroleum Institute |
| Bcfd | Billion cubic feet per day |
| CAT | Change Analysis Tool |
| CCFA | Common Cause Failure Analysis |
| CEII | Critical Energy Infrastructure Information |
| COTP | Captain of the Port |
| CRE | Energy Regulatory Commission of Mexico |
| DEGADIS | Dense Gas Dispersion Model |
| DNV | Det Norske Veritas |
| DOT | United States Department of Transportation |
| DWPA | Deepwater Port Act |
| EA | Environmental Assessment |
| EIA | Environmental Impact Authorization |
| EIR | Environmental Impact Report |
| EIS | Environmental Impact Statement |
| EPEBV | El Paso Energy Bridge Vessel |
| ETA | Event Tree Analysis |
| FEMA | Federal Emergency Management Agency |
| FERC | Federal Energy Regulatory Commission |

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|-------|---|
| FMEA | Failure Modes and Effects Analysis |
| FMECA | Failure Mode Effect and Criticality Analysis |
| FSA | Formal Safety Assessment |
| FSRU | Floating Storage and Regasification Unit |
| FTA | Fault Tree Analysis |
| HAZID | Hazard Identification |
| HAZOP | Hazard and Operability Analysis |
| IACS | International Association of Classification Societies |
| IAPH | International Association of Port and Harbors |
| ICS | International Chamber of Shipping |
| IMO | International Maritime Organization |
| IMS | International Maritime Security |
| ISPS | International Ship and Port Facility Security Code |
| LNG | Liquefied Natural Gas |
| LPG | Liquefied Petroleum Gas |
| LR | Lloyd's Register of Shipping |
| MARAD | Maritime Administration |
| MOU | Memorandum of Understanding |
| MTSA | Maritime Transportation Security Act of 2002 |
| NEPA | National Environmental Policy Act |
| NFPA | National Fire Protection Association |
| OCIMF | Oil Companies International Maritime Forum |
| OPS | Office of Pipeline Security |
| OSHAS | Occupational Health and Safety Management System |
| PAWSA | Port and Waterways Safety Assessment |
| PER | Proponent's Environmental Report |

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| PIANC | International Navigation Association (formerly Permanent International Association of Navigation Congresses) |
| QRA | Quantitative Risk Assessment |
| RBDM | Risk-based Decision Making |
| RSPA | Research and Special Projects Administration |
| SEMARNAT | Secretary of the Environment and Natural Resources (of Mexico) |
| SES | Sound Energy Solutions |
| SIGTTO | Society of International Gas Tanker and Terminal Operations |
| SOLAS | International Convention for Safety of Life at Sea |
| SSCOT | State Strategic Committee on Terrorism |
| TERMPOL | Technical Review Process of Marine Terminal Systems and Transshipment Sites |
| USCG | United States Coast Guard |

Glossary

Allision – the sudden impact of a vessel with a stationary object such as an anchored vessel or a pier. Allide is the verb form of allision.

Classification Society – organization that sets standards of quality and reliability of ships affecting their design, construction, and operation

Codes – a body of regulations arranged systematically for easy reference. Codes can be a set of technical regulations, enforced by a government agency staff with engineering or construction-related expertise.

Contracting Government – a government who has ratified SOLAS and is a party to SOLAS

Cryogenics – pertaining to or causing the production of low temperatures and their effect on the properties of matter

Deterministic Risk Assessment – a risk assessment process that involves defining a disaster event (e.g., earthquake) and computing the damage associated with that event.

Double containment – a storage tank with two vertical walls, both of which are designed to contain the stored amount of liquid, with the roof resting on the inner wall.

Flag State – Country of registry of a sea-going vessel.

Full Containment Tank – a storage tank with two vertical walls, both of which are designed to contain the stored amount of liquid, with the roof resting on the outer wall.

Guidelines – Recommended practices, based on the experiences of industry representatives or reflecting government agency preferences, but without the force of law or regulation. More general than a standard.

Laws – statutes enacted by a legislative body

Liquefaction – the process by which natural gas is converted to LNG

Membrane Tank Carrier – LNG carrier where the tanks are fully integrated into the hull, which serves as a supported structure. Insulation material is installed on the inner hull to protect the hull from exposure to the low-temperature cargo.

Probabilistic Risk Assessment – a risk assessment approach that involves computing the damage for different events, accounting for the probability of each.

Qualship 21 – an initiative implemented by the Coast Guard to identify high-quality ships, and provide incentives to encourage quality operations.

Radiant flux level – a measurement of the rate of thermal radiation (heat) flowing through the atmosphere. The heat flux level, 1,600 Btus/hr-ft², defines the outer limit where a person could remain for 30 seconds before exposed skin would be subjected to second-degree burns.

Regulations – rules providing more details about how to comply with a statute. Regulations are enforced by a government agency.

Risk Assessment – the process of identifying, measuring and evaluating risk

Risk-based Decision Making – a process implemented by the Coast Guard that organizes information about the possibility for one or more unwanted outcomes to occur in order to help decision makers make more informed management choices.

Risk Management – the process of accounting for and addressing risks

Spherical Tank Carrier – LNG carrier where tanks are independent and self-supporting structures arranged inside the hull with the whole cargo liquid load borne by the membrane stress of the tank shell.

Standards – established measures by which things in the same class are compared in order to determine their quality, capacity, content, extent, value, quality, etc. Usually, standards define the minimum level of acceptability. Compliance may be voluntary, unless the standards have been incorporated by reference into regulations. Developed by a government-led or an industry-led consensus process involving both regulators and industry representatives.

Terminal – a facility where ships land to load, transfer or unload their cargo

Thermal Radiation Exclusion Zone – a specific distance from the storage tank impoundment area to the LNG property line, large enough to prevent the heat of an LNG fire from adversely affecting conditions beyond the LNG plant's property line.

Transponder – A wireless communications, monitoring, or control device that picks up and automatically responds to an incoming signal.

Vapor Dispersion Exclusion Zone – a specific distance from the tank impoundment area to the LNG property line, large enough to encompass that part of an LNG vapor cloud that could be flammable.

Vaporization – the process of returning LNG to a gaseous state by warming the LNG by passing it through pipes heated by direct-fired heaters, seawater, or through pipes that are in heated water.

Vulnerability Assessment – the assessment of exposed populations and property and the extent of injury and damage that may result from an event of a given intensity in a given area

Appendix A

Maritime Transportation Security Act 2002 Provisions Applicable to LNG Facilities and Vessels

U.S. Facility and Vessel Vulnerability Assessments

The Secretary of Transportation (Secretary), acting through the USCG, must assess all vessels and facilities on or near water to identify those at high risk of being involved in a “transportation security incident.” The criteria for designation as high risk are that if the vessel or facility were attacked, it could result in significant loss of life, environmental damage, or transportation or economic disruption.

The MTSA first requires an “Initial Assessment” to identify vessel types and facilities that pose a high risk of being involved in an “incident.” High interest vessels include vessels with cargoes, crew members or other characteristics that warrant closer examination. The USCG has completed this step and LNG vessels and facilities were so identified.

Based on the information obtained, the Secretary is required to conduct a “Detailed Assessment” of high-risk vessels and facilities. As part of this assessment, the USCG must:

- Identify and evaluate critical assets and infrastructure;
- Identify threats to those assets and infrastructure; and,
- Identify weaknesses in physical security, passenger and cargo security, structural integrity, protection systems, procedural policies, communications systems, transportation infrastructure, utilities, contingency response, and other areas specified by the Secretary.

The USCG provides detailed assessments to the vessel or facility owner. Detailed assessments are to be updated every five years. The Secretary may accept assessments prepared by, or on behalf of, the owner or operator, so long as they adequately address all of the required items.

Vessel and Facility Security Plans

The USCG must also develop the following plans: a National Maritime Transportation Security Plan, regional Maritime Transportation Security Plans for areas designated by the National Plan, and individual plans for each vessel and facility which may be

involved in transportation security incidents. The purpose of these plans is to deter such incidents to the maximum extent practicable. For the first time, all ports, waterfront facilities, and vessels would be required to operate under federally-approved security plans.

No later than January 1, 2004 (six months after the USCG promulgated the Interim Final Rule), vessel and facility plans must be submitted to the USCG for approval. They, too, must be updated, reviewed, and approved at least every five years and resubmitted for approval of each change made in the interim that may substantially affect the security of the vessel or facility.

Vessel and facility plans must be consistent with the requirements of the USCG's National and Area plans. These plans are required to:

- Identify the qualified individual authorized to implement security actions;
- Establish and maintain physical, passenger, cargo, and personnel security;
- Establish procedural policies, communications systems, and other security systems;
- Identify available security measures necessary to deter substantial transportation security threats or security incidents to the maximum extent practicable. These include developing secure areas in ports, limiting access to security-sensitive areas and conducting vessel and facility personnel background checks;
- Set up local port advisory committees to provide better coordination among federal, state and local agencies, and law enforcement. These committees would also advise on provisions of security plans; and
- Describe training, unannounced drills, and security actions of vessel and facility personnel.

No vessel or facility would be allowed to continue operation after 12 months following the publication of the interim final USCG regulations, unless the Secretary has approved the applicable plan. However, the Secretary may authorize the continued operation for one year after the submission of the plan if the [owner or] operator certifies that Secretary-approved security measures are in place to deter an incident.

Transportation Security Incident Response

The Secretary must also establish vessel and facility "Transportation Security Incident Plans" to be made available to the Director of Federal Emergency Management Agency (FEMA) for inclusion in the Director's response plan for U.S. ports and waterways.

These plans, which may be included as part of the vessel and facility security plans described above, would be required to provide for a comprehensive and coordinated response to an emergency by all of the affected agencies, including securing the facility or vessel and evacuating affected personnel.

Transportation Security Cards

The Secretary must establish regulations for issuing security cards designed to prevent access to areas of vessels and facilities designated by the Secretary as “secured areas” by persons not authorized to enter them or by persons accompanied by authorized personnel.

The Secretary is required to issue a biometric transportation security card to individuals authorized to be in such areas in accordance with a security plan, unless the Secretary decides that the individual poses a terrorism security risk. Prior to issuing security cards, the Secretary will conduct background checks on both U.S. and foreign persons who work at or arrive at U.S. ports and who seek access to vessel or facility secured areas.

Maritime Safety and Security Teams

The Secretary must establish “maritime safety and security teams” as needed to safeguard the public and protect vessels, harbors, port facilities, and cargo in waters of the U.S. from destruction, loss or injury from crime, or sabotage due to terrorist activity, and to respond to such activity in accordance with the transportation security plans required under the MTSA.

Teams are to be trained to deter, protect, and rapidly respond to threats of maritime terrorism; conduct high-speed intercepts; board, search and seize articles or things that pose a threat or a risk to a vessel, facility, or port; rapidly supplement U.S. armed forces domestically or overseas; respond to terrorist acts within a port; and assist in vulnerability assessments. These teams will coordinate their actions with law enforcement and emergency response agencies at all levels of government.

Foreign Port Assessment

The Secretary is required to assess the effectiveness of anti-terrorism measures at major foreign ports from which vessels ship cargos to the U.S. This assessment would include:

- Screening containers and cargo;
- Access to facilities, vessels, and cargo;
- Vessel security; and
- Compliance with “security standards.”

If the Secretary finds that a specific port does not maintain adequate anti-terrorism measures, the Secretary is required to notify appropriate foreign officials in the host country and may specify conditions of entry into the U.S. for any vessel arriving from that port.

Enhanced Crewmember Identification

The Secretary, in consultation with the Attorney General, must adopt identification for crew members to carry and present on demand when calling at U.S. ports. This section is consistent with existing USCG regulations.

Maritime Intelligence

A maritime intelligence system must be developed to collect and analyze information concerning vessels bound for or operating in U.S. waters and about the crew, passengers and cargos carried. A new maritime intelligence agency will be expected to work together with other intelligence entities, and collect and analyze information not available from other intelligence sources.

Automated Identification System (AIS) and Long Range Vessel Tracking System

All commercial vessels operating in waters of the U.S. are now compelled to be equipped with and operate AIS. Vessels on international voyages that include the U.S. must be equipped with a long-range tracking system, to ensure that the U.S. can affirmatively track vessel movements. Under the system, AIS transponders will automatically send out information such as the size, direction, and speed of ships.

International Seafarer Identification

The Secretary may negotiate an international agreement that provides for a uniform, comprehensive, international system of seafarer identification that will enable the U.S. and another country to authoritatively establish the identity of any seafarer aboard a vessel within the jurisdiction of the U.S. and the other country.

The section also provides that if the Secretary fails to complete the negotiation process within 24 months of the effective date of the MTSA, the Secretary must transmit the draft of the proposed agreement to the Congress that, if enacted, would establish a uniform, comprehensive system of seafarer identification.

Extension of the Deepwater Port Act to Natural Gas

The Deepwater Port Act of 1974 (33 U.S.C. 1501 et. seq.) was amended to expand the definition of deepwater ports to include offshore facilities used for the “transportation, storage, or further handling . . . of natural gas to any state, including . . . natural gas from the outer continental shelf.” As now defined, deepwater ports include both fixed or floating offshore structures located beyond state seaward boundaries, and related

components and equipment including pipelines, pumping stations, service platforms, buoys, and mooring lines located seaward of the high water mark.

Sea Marshal Program

USCG personnel are assigned to safeguard the public and protect vessels, harbors, ports, and waterfront facilities under the Sea Marshal Program. USCG maritime security and safety teams are specifically authorized to board ships entering U.S. ports to deter hijackings or other terrorist threats and enhance maritime security and safety.

Maritime Security Professional Training

Training funds were authorized for developing security training and for educating and certifying federal, state and private law enforcement and other security personnel in maritime security and safety.

Appendix B

Excerpts from *Final Environmental Impact Statement for the Hackberry LNG Project* Federal Energy Regulatory Commission, August 2003

FERC STAFF'S RECOMMENDED MITIGATION

If the Commission issues a Certificate for the proposed project, we recommend that the Commission's Order include measure 1 through 51. We believe that these measures would further mitigate the environmental impacts associated with the construction and operation of the proposed project:

1. Cameron LNG shall follow the construction procedures and mitigation measures described in its application, supplemental filings (including responses to staff data requests), and as identified in the EIS, unless modified by the Commission's Order. Cameron LNG must:
 - a. request any modification to these procedures, measures, or conditions in a filing with the Secretary of the Commission (Secretary);
 - b. justify each modification relative to site-specific conditions;
 - c. explain how that modification provides an equal or greater level of environmental protection than the original measure; and
 - d. receive approval in writing from the Director of the Office of Energy Projects (OEP) **before using that modification.**
2. The Director of OEP has delegation authority to take whatever steps are necessary to ensure the protection of all environmental resources during construction and operation of the project. This authority shall allow:
 - a. the modification of conditions of the Commission's Order; and
 - b. the design and implementation of any additional measures deemed necessary (including stop work authority) to assure continued compliance with the intent of the environmental conditions as well as the avoidance or mitigation of adverse environmental impact resulting from project construction and operation.
3. **Prior to any construction**, Cameron LNG shall file an affirmative statement with the Secretary, certified by a senior company official, that all company personnel, environmental inspectors (EIs), and contractor personnel will be informed of the EI's authority and have been or will be trained on the

implementation of the environmental mitigation measures appropriate to their jobs before becoming involved with construction and restoration activities.

4. The authorized facility locations shall be as shown in the EIS, as supplemented by filed alignment sheets, and shall include the staff's recommended facility locations. **As soon as they are available, and before the start of construction**, Cameron LNG shall file with the Secretary revised detailed survey alignment maps/sheets at a scale not smaller than 1:6,000 with station positions for all facilities approved by this Order. All requests for modifications of environmental conditions of this Order or site-specific clearances must be written and must reference locations designated on these alignment maps/sheets.

Cameron LNG's exercise of eminent domain authority granted under Natural Gas Act (NGA) section 7(h) in any condemnation proceedings related to this Order must be consistent with these authorized facilities and locations. Cameron LNG's right of eminent domain granted under NGA section 7(h) does not authorize it to increase the size of its natural gas pipeline to accommodate future needs or to acquire a right-of-way for a pipeline to transport a commodity other than natural gas.

5. Cameron LNG shall file with the Secretary detailed alignment maps/sheets and aerial photographs at a scale not smaller than 1:6,000 identifying all route realignments or facility relocations, and staging areas, pipe storage yards, new access roads, and other areas that will be used or disturbed and have not been previously identified in filings with the Secretary. Approval for each of these areas must be explicitly requested in writing. For each area, the request must include a description of the existing land use/cover type, documentation of landowner approval, whether any cultural resources or federally listed threatened or endangered species would be affected, and whether any other environmentally sensitive areas are within or abutting the area. All areas shall be clearly identified on the maps/sheets/aerial photographs. Each area must be approved in writing by the Director of OEP **before construction** in or near that area.

This requirement does not apply to route variations recommended herein or minor field realignments per landowner needs and requirements that do not affect other landowners or sensitive environmental areas such as wetlands.

Examples of alterations requiring approval include all route realignments and facility location changes resulting from:

- a. implementation of cultural resources mitigation measures;
 - b. implementation of endangered, threatened, or special concern species mitigation measures;
 - c. recommendations by state regulatory authorities; and
 - d. agreements with individual landowners that affect other landowners or could affect sensitive environmental areas.
6. **Within 60 days of the acceptance of this certificate and before construction**

begins Cameron LNG shall file an initial Implementation Plan with the Secretary for the review and written approval by the Director of OEP describing how Cameron LNG will implement the mitigation measures required by this Order. Cameron LNG must file revisions to the plan as schedules change. The plan shall identify:

- a. how Cameron LNG will incorporate these requirements into the contract bid documents, construction contracts (especially penalty clauses and specifications), and construction drawings so that the mitigation required at each site is clear to onsite construction and inspection personnel;
 - b. the number of EIs assigned per spread, and how the company will ensure that sufficient personnel are available to implement the environmental mitigation;
 - c. company personnel, including EIs and contractors, who will receive copies of the appropriate material;
 - d. what training and instructions Cameron LNG will give to all personnel involved with construction and restoration (initial and refresher training as the project progresses and personnel change), with the opportunity for OEP staff to participate in the training session(s);
 - e. the company personnel (if known) and specific portion of Cameron LNG's organization having responsibility for compliance;
 - f. the procedures (including use of contract penalties) Cameron LNG will follow if noncompliance occurs; and
 - g. for each discrete facility, a Gantt or PERT chart (or similar project scheduling diagram), and dates for:
 - i. the completion of all required surveys and reports;
 - ii. the mitigation training of onsite personnel;
 - iii. the start of construction; and,
 - iv. the start and completion of restoration.
7. Cameron LNG must receive written authorization from the Director of OEP **before commencing service** of the project. Such authorization will only be granted following a determination that rehabilitation and restoration of the right-of-way is proceeding satisfactorily.
8. **Within 30 days of placing the certificated facilities in service**, Cameron LNG shall file an affirmative statement with the Secretary, certified by a senior company official:
- a. that the facilities have been constructed in compliance with all applicable conditions, and that continuing activities will be consistent with all applicable conditions; or
 - b. identifying which of the certificate conditions Cameron LNG has complied with or will comply with. This statement shall also identify any areas along

the right-of-way where compliance measures were not properly implemented, if not previously identified in filed status reports, and the reason for non compliance.

Note: Environmental recommendations nos. 9 through 41 apply to construction and operation of the LNG Terminal.

9. Cameron LNG shall file with the Secretary a final plan for obtaining fill material for construction of the Hackberry Terminal. For each borrow site selected for use, the plan shall include:
 - a. a description of the existing land use/cover type;
 - b. documentation of landowner approval;
 - c. whether any cultural resources or federally listed threatened or endangered species would be affected; and
 - d. whether any other environmentally sensitive areas are within or abutting the borrow area.

All selected borrow sites should be clearly identified on topographic maps and aerial photographs. The borrow pit plan shall be submitted to the Director of the Office of Energy Projects (OEP) for review and approval **prior to construction**. *FEIS Section 2.4.1.3.*

10. Cameron LNG shall prepare a final compensatory wetland mitigation plan, including detailed plans and specifications, prepared in consultation with the COE, NMFS, FWS, LDWF, LDNR, and LDEQ. This plan shall include a monitoring plan and identification of success criteria and remedial measures, as necessary, to ensure mitigation success. The mitigation plan shall also include mitigative measures that would be implemented to minimize impacts to adjacent wetland areas and wetlands crossed by the temporary discharge pipelines. The wetland mitigation plan shall be filed with the Secretary for review and written approval of the Director of OEP **prior to implementation**. *FEIS Section 4.1.4.*
11. Cameron LNG **shall not begin construction** until it has received the LDNR's determination that the project is consistent with the Louisiana Coastal Zone Management Program, and has filed a copy of the consistency determination with the Secretary. *FEIS Section 4.174.*
12. Cameron LNG, in cooperation with the Louisiana Department of Transportation and Development and other responsible transportation agencies, shall prepare a Traffic Management Plan that details specific measures that would be used to control traffic and maintain traffic flow along State Highway 27 during construction of the Hackberry Terminal. Aspects of the plan may include, but are not limited to, traffic control measures, installation of a left-turn lane, traffic signage requirements, traffic control personnel, construction and delivery hours, emergency vehicle access provisions, and/or nightly shut-down procedures. *FEIS Section 4.1-8.5.*

13. Cameron LNG shall defer construction of the terminal facilities and use of all staging, storage, and temporary work areas and new or to-be-improved access roads until:
 - a. Cameron LNG files with the Secretary a cultural resources survey report for the dredge disposal areas and the borrow sites, any required treatment plan, and the SHPO's comments on the report and any plan; and
 - b. the Director of OEP reviews all cultural resources survey reports and plans and notifies Cameron LNG in writing that construction may proceed.

All material filed with the Commission containing **location, character, and ownership** information about cultural resources must have the cover and any relevant pages therein clearly labeled in bold lettering: "**CONTAINS PRIVILEGED INFORMATION--DO NOT RELEASE.**" *FEIS Section 4.1.9.4.*

14. Cameron LNG shall file a noise survey with the Secretary **no later than 60 days** after placing the Hackberry Terminal in service. If the noise attributable to the operation of the Hackberry Terminal exceeds an L. of 55 dBA at any nearby NSA, Cameron LNG shall file a report on what changes are needed and should install additional noise controls to meet that level **within 1 year** of the in-service date. Cameron LNG shall confirm compliance with this requirement by filing a second noise survey with the Secretary **no later than 60 days** after it installs the additional noise controls. *FEIS Section 4.1.10.2.*
15. Cameron LNG shall provide a barrier to prevent LNG from flowing outside the plant property in the event that the primary and secondary storage tank containers of a single tank fail. The barrier shall be designed to allow removal of rainwater (or any spill over from a storm) without open drainage. Cameron LNG shall submit the final design of this barrier to the Commission staff for review and approval **prior to construction.** *FEIS Section 4.1.11.3.*
16. A contingency plan for outer containment failure shall be included in the company's emergency response procedures. *FEIS Section 4.1.11.2.*
17. Each impounding system serving an LNG storage tank (the concrete outer wall) shall be designed for 110 percent of the tank's capacity and the tank relief capacity sized accordingly if the annular space provides the 110 percent capacity. The effect of the perlite creating flow restriction through the relief valves and/or creating a source of static electricity must also be considered. *FEIS Section 4.1.11.2.*
18. LNG tank carbon steel piping support plates and connections to piping supports shall be designed to insure that corrosion protection is adequately provided and provisions for corrosion monitoring and maintenance of carbon steel attachments should be included in the design and maintenance procedures. *FEIS Section 4.1.11.2.*

19. Horizontal and rotational movement indicators shall be provided on the primary containment tanks and instrumented for easy reading. Criteria shall be established for horizontal and rotational movement of the inner vessel for use during and after cooldown. *FEIS Section 4.1.11.2.*
20. In the event the temperature of any region of any storage tank outer containment vessel, including imbedded pipe supports, becomes less than the minimum specified operating temperature for the material, the FERC shall be notified on a timely basis and procedures for corrective action should be specified. *FEIS Section 4.1.11.2.*
21. Redundant temperature detectors shall be installed within the annular space of each tank to detect a leak from the inner wall. Particular emphasis should be given to the lower portions of the annular space. *FEIS Section 4.1.11.2.*
22. A foundation elevation survey of all LNG tanks shall be made on an annual basis. *FEIS Section 4.1.11.2.*
23. Cameron LNG shall provide metallurgical reasons supporting the use of 304 grade stainless steel over 304L grade stainless steel for high pressure piping. At the proposed location, the piping may be exposed to chloride attack from the environment and possible contact with brackish firewater. *FEIS Section 4.1.11.2.*
24. Spill containment and spill control shall be designed to drain the spill away from piping and equipment and not channel the spill under the pipe racks. *FEIS Section 4.1.11.2.*
25. Flammable gas and UV/IR hazard detectors shall be equipped with local instrument status indication as an additional safety feature. *FEIS Section 4.1.11.2.*
26. All hazard detectors shall be installed with redundancy and/or fault detection and fault alarm monitoring in all potentially hazardous areas and/or enclosures. *F. IS Section 4.1.11.2.*
27. Piping material proposed for the above ground fire water system shall be designed to avoid the potential for corrosion in the piping system and especially from the introduction of brackish water. Safeguards shall also be established to protect above ground fire water piping, including post indicator valves, from inadvertent damage. *FEIS Section 4.1.11.2.*
28. Procedures shall be developed for providing the facility with fire water coverage during such times as the fire water system would be out of service, in particular for removing and flushing brackish water from the system. *FEIS Section 4.1.11.2.*
29. Procedures shall be provided for handling off spec vaporized LNG. Information shall include the anticipated quantities of off spec vaporized product that can be handled and/or may be expected to occur during startup and shutdown. *FEIS Section 4.1.11.2.*

30. Procedures shall be developed for offsite contractor's responsibilities, restrictions, limitations and supervision of offsite personnel by Cameron LNG staff. *FEIS Section 4.1.11.2.*
31. Operation and maintenance procedures and manuals, as well as emergency plans and safety procedure manuals, shall be filed with the FERC **prior to commencement of operations.** *FEIS Section 4.1.11.2.*
32. The FERC staff shall be notified of any proposed revisions to the security plan and physical security of the facility **prior to commissioning** the proposed facilities. *FEIS Section 4.1.11.2.*
33. Progress on construction of the LNG terminal shall be reported in monthly reports submitted to the FERC. Details should include a summary of activities, problems encountered and remedial actions taken. Problems of significant magnitude shall be reported to the FERC on a timely basis. Additional site inspections and technical reviews will be held by FERC staff **prior to commencement** of operation, *FEIS Section 4.1,11-2.*
34. The facility shall be subject to regular FERC staff technical reviews and site inspections on at least a biennial basis or more frequently as circumstances indicate. **Prior to each FERC staff technical, review and site inspection,** the Company would be required to respond to a specific data request for information relating to possible design and operating conditions that may have been imposed by other agencies or organizations. Provision of up-to date detailed piping and instrumentation diagrams reflecting facility modifications and provision of other pertinent information not included in the semi-annual reports described below, including facility events that have taken place since the previously submitted semi-annual report, would be required. *FEIS Section 4.1.11.2.*
35. Semi-annual operational reports shall be filed with the FERC to identify changes in facility design and operating conditions, abnormal operating experiences, activities (including ship arrivals, quantity and composition of imported LNG, vaporization quantities, boil-off/flash gas, etc.), and plant modifications including future plans and progress thereof. Abnormalities shall include, but not be limited to: unloading/shipping problems; potential hazardous conditions from offsite vessels; storage tank stratification or rollover; geysering; storage tank pressure excursions; cold spots on the storage tanks; storage tank vibration and/or vibrations in associated cryogenic piping; storage tank settlement; significant equipment or instrumentation malfunctions or failures; non-scheduled maintenance or repair (and reasons therefore); relative movement of storage tank inner vessels; vapor or liquid releases; fires involving natural gas and/or from other sources; negative pressure (vacuum) within a storage tank; and higher than predicted boilloff rates. Adverse weather conditions and the effect on the facility shall also be reported. Reports should be submitted **within 45 days** after each period ending June 30 and December 31.

In addition to the above items, a section entitled "Significant plant modifications proposed for the next 12 months (dates)" shall also be included in the semi-annual operational reports. Such information would provide the FERC staff

with early notice of anticipated future construction/maintenance projects at the LNG facility. *FEIS Section 4.1.11.2.*

36. Significant non-scheduled events, including safety-related incidents (*i.e.*, LNG or natural gas releases, fires, explosions, mechanical failures, unusual overpressurization, major injuries) shall be reported to FERC staff **within 48 hours**. In the event an abnormality is of significant magnitude to threaten public or employee safety, cause significant property damage, or interrupt service, notification shall be made immediately, without unduly interfering with any necessary or appropriate emergency repair, alarm, or other emergency procedure. This notification practice shall be incorporated into the LNG facility's emergency plan. Examples of reportable LNG-related incidents include:
- a. fire;
 - b. explosion;
 - c. property damage exceeding \$10,000;
 - d. death or injury requiring hospitalization;
 - e. free flow of LNG for five minutes or more that results in pooling;
 - f. unintended movement or abnormal loading by environmental causes, such as an earthquake, landslide, or flood; that impairs the serviceability, structural integrity, or reliability of an LNG facility that contains, control, or processes gas or LNG;
 - g. any crack or other material defect that impairs the structural integrity or reliability of an LNG facility that contains, controls, or processes gas or LNG;
 - h. any malfunction or operating error that causes the pressure of a pipeline or LNG facility that contains or processes gas or LNG to rise above its maximum allowable operating pressure (or working pressure for LNG facilities) plus the build-up allowed for operation of pressure limiting or control devices;
 - i. a leak in an LNG facility that contains or processes gas or LNG that constitutes an emergency;
 - j. inner tank leakage, ineffective insulation, or frost heave that impairs the structural integrity of an LNG storage tank;
 - k. any safety-related condition that could lead to an imminent hazard and cause (either directly or indirectly by remedial action of the operator), for purposes other than abandonment, a 20 percent reduction in operating pressure or shutdown of operation of a pipeline or an LNG facility that contains or processes gas or LNG;
 - l. safety-related incidents to LNG trucks or LNG vessels occurring at or in route to and from the LNG facility; or

- m. the judgment of the LNG personnel and/or management even though it did not meet the above criteria or the guidelines set forth in an LNG facility's incident management plan.

In the event of an incident, following the initial company notification, FERC staff will determine the need for a separate followup report or followup in the upcoming semi-annual operational report. All company followup reports should include investigation results and recommendations to minimize a reoccurrence of the incident. *FEIS Section 4.1.11-2.*

- 37. Cameron LNG shall provide a full deluge system to protect the storage tanks from thermal radiation from an adjacent tank fire. Other means such as increasing the spacing between adjacent tanks and/or other passive systems can also be considered. *FEIS Section 4.1.11.3.*
- 38. Cameron LNG shall provide detailed drawings of the transfer line impoundment systems, including dimensioned cross sections, for the review and approval of the Director of OEP **prior to construction.** *FEIS Section 4.1.11.4.*
- 39. **Prior to construction,** Cameron LNG shall provide evidence of its ability to exercise legal control over the activities that occur within the portions of the thermal exclusion zones that fall outside the site property line. Alternatively, Cameron LNG may apply to the Department of Transportation for approval of a waiver from its Title 49 CFR Part 193 regulation that specifies what alternative mitigation measures or plan Cameron LNG may provide that would afford an equal or greater level of thermal radiation protection as the requirement for control over activities within the modeled exclusion zones. *FEIS Section 4.1.11.4.*
- 40. **Prior to construction,** Cameron LNG shall provide evidence of its ability to exercise legal control over the activities that occur within the portions of the vapor dispersion exclusion zones that fall outside the site property line. Alternatively, Cameron LNG may apply to the Department of Transportation for approval of a waiver, from its Title 49 CFR Part 193 regulation, that specifies what alternative mitigation measures or plan Cameron LNG may provide that would afford an equal or greater level of flammable vapor-gas dispersion protection as the requirement for control over activities within the modeled exclusion zones. *FEIS Section 4.1.11.4.*
- 41. **Prior to commencing service,** Cameron LNG shall file with the Secretary and the U.S. Coast Guard the plan for providing dedicated tug services prior to commencing services. *FEIS Section 4.1.11.5.*

Note: Environmental recommendations nos. 42 through 51 apply to construction and operation of the 35.4-mile-long pipeline

- 42. Cameron LNG shall employ at least two EIs. The environmental inspectors shall be:
 - a. responsible for monitoring and ensuring compliance with all environmental mitigative measures required by this Order, the FERC's

Upland Erosion Control, Revegetation and Maintenance Plan (Plan) and Wetland and Waterbody Construction and Mitigation Procedures (Procedures), and other grants, permits, certificates, or other authorizing documents;

- b. responsible for evaluating the construction contractor's implementation of the environmental mitigation measures required in the contract (see recommendation no. 6 above) and any other authorizing documents;
 - c. empowered to order correction of acts that violate the environmental conditions of this Order, and any other authorizing document;
 - d. a full-time position separate from all other activity inspectors;
 - e. responsible for documenting compliance with the environmental recommendations of this Order, as well as any environmental conditions/permit requirements imposed by other Federal, state, or local agencies; and
 - f. responsible for maintaining status reports.
43. Cameron LNG shall file updated status reports with the Secretary on a bi-weekly basis until all construction-related activities, including restoration, are complete. On request, these status reports will also be provided to other Federal and state agencies with permitting responsibilities. Status reports shall include:
- a. the current construction status of each spread, work planned for the following reporting period, and any schedule changes for stream crossings or work in other environmentally sensitive areas;
 - b. a listing of all problems encountered and each instance of noncompliance observed by the EI(s) during the reporting period (both for the conditions imposed by the FERC and any environmental conditions/permit requirements imposed by other Federal, state, or local agencies);
 - c. corrective actions implemented in response to all instances of noncompliance, and their cost;
 - d. the effectiveness of all corrective actions implemented;
 - e. a description of any landowner/resident complaints which may relate to compliance with the requirements of this Order, and the measures taken to satisfy their concerns; and
 - f. copies of any correspondence received by Cameron LNG from other Federal, state, or local permitting agencies concerning instances of noncompliance, and Cameron LNG's response.
44. Cameron LNG shall incorporate the Gulf Intracoastal Waterway Route Variation A (RV-A) and the Hickory Branch Route Variation into the proposed route. *FEIS Section 3.3.2.2*

45. Cameron LNG **shall not begin** an open-cut crossing of any waterbody proposed to be crossed using HDD methods **until**:
 - a. Cameron LNG files with the Secretary the specific reasons that the HDD method is not feasible or was not successful;
 - b. Cameron LNG consults with the COE and the LDEQ and files with the Secretary a detailed site-specific, open-cut crossing plan including scaled drawings identifying all areas that would be disturbed by constructing the open-cut crossing and mitigation measures that would minimize the extent and duration of disturbance on the waterbody and associated riparian habitat; and
 - c. Cameron LNG has received written notification from the Director of OEP that an open-cut crossing may begin. *FEIS Section 4.2.3.2*
46. If a construction right-of-way width greater than 75 feet wide is required through any wetlands between Milepost 1.0 and Milepost 35. 1, Cameron LNG shall justify the modifications and shall file a site-specific construction plan with the Secretary for review and written approval by the Director of OEP **prior to construction**. The plan shall include site-specific information on soil stability as a justification for the increased right-of-way width. Absent an approved site-specific construction plan, Cameron LNG shall restrict the construction right-of-way through wetlands to 75 feet. This condition does not apply to wetlands between Milepost 0.0 and Milepost 0.7 where a variance to our 75-foot-wide restriction is approved. See table 4.2.4-2 of the *EIS*. *FEIS Section 4.2.4*
47. Cameron LNG shall coordinate construction activities within the Brown Lake Hydrologic Restoration Project with the NRCS and coordinate construction activities within the Clear Marais Shore Protection Project with the LDNR and file results of coordination, including post-construction mitigation plans, with the Secretary **prior to pipeline construction**. *FEIS Section 4.2.4*
48. Cameron LNG shall prepare a site-specific construction plan for the area between MPs 28.2 - 29.2. This plan shall include:
 - a. moving the HDD entry point and associated extra workspace for the Beckwith Creek crossing approximately 200 feet northeast off Temple-Inland's parcel;
 - b. constructing the HDD entry point and associated extra workspace for the Hickory Branch crossing entirely on the parcel north of Temple-Inland's parcel;
 - c. limiting the construction right-of-way between the above HDD extra workspaces to 75 feet in width; and
 - d. actively revegetating the disturbed areas with native species, including replanting of native trees in the temporary workspaces.

The site-specific plan shall be filed with the Secretary for review and approval by the Director of OEP **prior to pipeline construction**. *FEIS section 4.2.5*

49. Cameron LNG shall conduct surveys of suitable rookery habitat during the nesting season prior to initiation of pipeline construction. A report documenting the results of this survey shall be submitted to the FWS and LDWF for review and for further recommendations on timing restrictions. The results of the consultations with the FWS and LDWF shall be filed with the Secretary for review and approval by the Director of OEP **prior to pipeline construction**. Cameron LNG shall also include a description of wading bird rookeries and means to identify rookeries in environmental awareness training provided to contractors. *FEIS section 4.2.6.1*
50. In the event that Cameron LNG plans to use the open-cut method to construct the pipeline near the residences at MPs 16.3 and 16.4, Cameron LNG shall develop a site-specific screening plan(s) that includes specific measures to replace the trees/screening removed during construction. Cameron LNG shall file the plan(s) with the Secretary for review and written approval by the Director of OEP **prior to construction**. *FEIS section 4.2.8.2*
51. Cameron LNG shall defer construction of the natural gas pipeline facilities and use of all staging, storage, and temporary work areas and new or to-be-improved access roads until:
 - a. Cameron LNG clarifies whether the correct route was surveyed for cultural resources between MPs 29.0 and 29.5, and if not, conducts a cultural resources survey;
 - b. Cameron LNG files with the Secretary outstanding cultural resources survey reports and any required treatment plan and the SHPO's comments on the reports and any plan; and
 - c. the Director of OEP reviews all cultural resources survey reports and plans and notifies Cameron LNG in writing [hat construction way proceed.

All material filed with the Commission containing **location, character, and ownership** information about cultural resources must have the cover and any relevant pages therein clearly labeled in bold lettering: "**CONTAINS PRIVILEGED INFORMATION - DO NOT RELEASE**," *FEIS section 4.2.10.2*.

Appendix C

LNG Laws, Codes and Standards

International

International Maritime Organization (IMO)

International Convention for the Safety of Life at Sea (SOLAS), 1974

http://www.imo.org/Conventions/mainframe.asp?topic_id=250

International Ship and Port Facility Security (ISPS) Code, 2003

http://www.imo.org/Newsroom/mainframe.asp?topic_id=583&doc_id=2689#code

International Code for the Construction and Equipment of Ships Carrying Liquefied Gases in Bulk (IMO Gas Code)

http://www.imo.org/Environment/mainframe.asp?topic_id=995

International Maritime Dangerous Goods Code

http://www.imo.org/Safety/mainframe.asp?topic_id=158

European Committee for Standardization

Installation and Equipment for LNG - Design of Onshore Installations,
EN 1473

Installation and Equipment for LNG - Design and testing of LNG loading arms,
EN 1474

Installation and Equipment for LNG - Ship to Shore Interface,
EN 1532

<http://www.cenorm.be/CENORM/BusinessDomains/TechnicalCommitteesWorkshops/CENTechnicalCommittees/WP.asp?param=6263&title=CEN/TC%20282>

Japanese Ministry of Economy, Trade and Industry (METI)

Gas Enterprises Act

Electric Service Enterprises Act

Maritime Safety Agency (Harbor Master) and the Japanese Coast Guard

Japanese Harbor Regulation Act

Transport Canada

Canadian Technical Review Process of Marine Terminal Systems and Transshipment Sites (TERMPOL) code

<http://www.tc.gc.ca/MarineSafety/TP/TP743/menu.htm>

U.S.

American Petroleum Institute (API)

Standard 620. Design and Construction of large, welded, low-pressure storage tanks

http://www.ihs.com/standards/api/api_620.html

National Fire Protection Association (NFPA)

Standard for the Production, Storage, and Handling of LNG, NFPA 59A

<http://www.nfpa.org/aboutthecodes/AboutTheCodes.asp?DocNum=59A>

Federal Statutes

Pipeline Safety Law, 49 U.S.C. § 60101 *et seq.*

http://www.law.cornell.edu/uscode/html/uscode49/usc_sup_01_49_10_VIII_40_601.html

Deepwater Port Act of 1974, as amended, 33 U.S.C. § 1501 *et seq.*

http://www.law.cornell.edu/uscode/html/uscode33/usc_sup_01_33_10_29.html

U.S. Maritime Transportation Security Act of 2002 (MTSA), Public Law 107-295

<http://www.uscg.mil/hq/g-m/mp/pdf/MTSA.pdf>

Federal Regulations

Department of Transportation, Research and Special Programs Administration

49 CFR Part 193. Liquefied Natural Gas facilities: Federal safety standards

<http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=8ae43e2c94fb0ccf60742adff99c2a43&rqn=div5&view=text&node=49:3.1.1.1.4&idno=49>

Federal Energy Regulatory Commission (FERC)

18 CFR Part 153. Applications for authorization to construct, operate, or modify facilities used for the export or import of natural gas.

<http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=5a5fbcfb3e2ac59b829e9a2e4e16c1bd&rqn=div5&view=text&node=18:1.0.1.5.35&idno=18>

U.S. Coast Guard, Department of Homeland Security

33 CFR Part 127. Waterfront facilities handling liquefied natural gas and liquefied hazardous gas

<http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=a4d3dd9aee99d5e78422906d6564117a&rqn=div5&view=text&node=33:2.0.1.1.3&idno=33>

33 CFR Parts 148 -150 Regulations applicable to deepwater ports

<http://frwebgate6.access.gpo.gov/cgi-bin/waisgate.cgi?WAISdocID=821110152126+6+0+0&WAIAction=retrieve>
<http://frwebgate6.access.gpo.gov/cgi-bin/waisgate.cgi?WAISdocID=821110152126+13+0+0&WAIAction=retrieve>

<http://frwebgate6.access.gpo.gov/cgi-bin/waisgate.cgi?WAISdocID=821110152126+13+0+0&WALSaction=retrieve>

46 CFR Part 154. Safety Standards for Self-Propelled Vessels Carrying Bulk Liquefied Gases

<http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=4efb69037e927184f159ef16419ca555&rgn=div5&view=text&node=46:5.0.1.2.10&idno=46>

Liquefied Natural Gas and Liquefied Petroleum Gas – Views and Practices, Policy and Safety, Commandant Instruction (COMDTINST) M16616.4

<http://www.uscg.mil/hq/g-m/nmc/pubs/msm/v2/fch4.doc>