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STATE OF CALIFORNIA ARNOLD SCHWARZENEGGER, *Governor*

PUBLIC UTILITIES COMMISSION
505 VAN NESS AVENUE
SAN FRANCISCO, CA 94102-3298

October 4, 2005

Via Electronic Delivery

Honorable Magalie Roman Salas
Office of the Secretary
Docket Room
Federal Energy Regulatory Commission
888 First Street, N.E., Room 1A, East
Washington, D.C. 20002

Re: Sound Energy Solutions, Docket Nos. CP04-58-000, et al.

Dear Ms. Salas:

Enclosed for filing in the above-docketed proceeding, please find an electronic filing of the "Motion of the Public Utilities Commission of the State of California to Supplement the Record and for a Hearing," which is accompanied by the "Prepared Direct Testimony of Dr. Jerry Havens (Exhibit PUC-1) and Accompanying Exhibits (Exhibits PUC-2 through PUC-4)."

Thank you for your cooperation in this matter.

Sincerely,

/s/ HARVEY Y. MORRIS

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Enclosure

UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Sound Energy Solutions	Docket Nos. CP04-58-000, *et al.*

MOTION OF THE PUBLIC UTILITIES COMMISSION OF THE STATE OF CALIFORNIA TO SUPPLEMENT THE RECORD AND FOR A HEARING

Pursuant to Rule 212 of the Rules of Practice and Procedure ("Rules") of the Federal Energy Regulatory Commission ("FERC"), 18 C.F.R. § 385.212 (2005), and section 3(e)(2)(A) of the Natural Gas Act , 15 U.S.C. § 717b(e)(2)(A) (2005), the Public Utilities Commission of the State of California ("CPUC") hereby submits its motion to supplement the record and for a hearing in this matter.

Although the CPUC is filing this motion to supplement the record with evidence that justifies the rejection of the proposed liquefied natural gas ("LNG") facilities at the Port of Long Beach, the CPUC recognizes the need for new LNG terminals along the West Coast in order to ensure sufficient supplies of natural gas, as well as to help put downward pressure on the price of natural gas. The CPUC is committed to facilitating the construction of new LNG terminals on the West Coast and has already ordered the intrastate pipelines in California to provide firm access to LNG-supplied natural gas.

Nevertheless, the evidence accompanying this motion establishes that approximately 130,000 people living or working within three miles of the proposed site at the Port Long Beach would be in harm's way, and many of them could be killed or incur second-degree burns if there were a terrorist attack, earthquake or human error, which caused the release of LNG. In addition, there is vital infrastructure that could be destroyed at the Port of Long Beach if LNG were released at or near the proposed site. This potential disaster can be and must be prevented.

Fortunately, this is not a Hobson's choice between either insufficient natural gas supplies or siting a hazardous LNG facility in a densely populated area. The evidence accompanying this motion also establishes that there are much safer alternatives to the proposed site for an LNG terminal at the Port of Long Beach. Therefore, the CPUC respectfully submits that the FERC should consider the evidence accompanying this motion as supplemental record evidence, and the FERC should reject SES's application as being contrary to the public interest, or, alternatively, the FERC should set an evidentiary hearing in this matter.

I. THE ENERGY POLICY ACT OF 2005 HAS NECESSITATED THE CPUC'S MOTION

This motion is a result of the recent enactment of the Energy Policy Act of 2005, Public Law 109-58 ("EPAct of 2005"). Prior to the enactment of the EPAct of 2005, the CPUC had maintained that it had jurisdiction over the siting of Sound Energy Solutions' ("SES") proposed LNG facilities at the Port of Long Beach. The CPUC initiated an investigation into the safety of SES's proposal and set this matter for hearing. The CPUC's Consumer Protection and Safety Division ("CPSD") staff was a participant in the CPUC's proceeding, just like FERC's staff participates in FERC proceedings. In this regard, the

CPSD entered into a contract with Dr. Jerry Havens, an expert with more than 30 years of experience in LNG safety issues, to prepare a report and testify on behalf of the CPSD in the CPUC proceedings.

In the CPUC's intervention and protest in the FERC's proceeding, the CPUC raised serious concerns as to the safety of the proposed LNG terminal site at the Port of Long Beach. However, as a decisionmaker in its own proceeding at the time the CPUC filed its intervention and protest with the FERC, the CPUC did not and could not sponsor testimony on the ultimate merits of this particular project.[1] The FERC issued orders herein claiming that it had preempted the CPUC's jurisdiction, which resulted in litigation between the FERC and CPUC in the Ninth Circuit.

With the passage of the EPAct of 2005, both the FERC and the CPUC have agreed in very recent pleadings filed with the Ninth Circuit, that the CPUC's jurisdictional issues were rendered moot. Since the CPUC is no longer contesting the FERC's authority to preempt the CPUC's jurisdiction, the CPUC acknowledges that it does not have decisionmaking authority over the siting of SES's proposed project. Because it would be pointless for the CPSD to file Dr. Havens' expert witness report in the CPUC's proceeding on SES's proposed LNG terminal (which has recently been suspended), the CPUC has decided to sponsor Dr. Havens' report in the present FERC proceeding.

The EPAct of 2005 also has certain other provisions that pertain to the FERC's authority to decide whether or not to approve an application to site and construct an LNG import terminal at a particular location. Section 311(c)(2) of the EPAct of 2005 (as codified in section 3(e)(2) of the Natural Gas Act, 15 U.S.C. §§ 717b(e)(2)) requires that

[1] Instead, the CPUC previously filed with the FERC uncontroverted evidence as to the distance between the proposed site and various neighborhoods and reports about previous LNG accidents, such as in Cleveland.

the FERC set the matter for hearing. Pursuant to this section, the CPUC requests a hearing and submits the accompanying testimony to support an evidentiary hearing herein.

Section 311(d) of the EPAct of 2005 (as codified in section 3A of the Natural Gas Act, 15 U.S.C. §§ 717bA) requires the FERC to respond to the issues raised in a State advisory report on the State and local safety considerations about a proposed LNG terminal. The California Energy Commission ("CEC") filed herein on September 7, 2005 a comprehensive State advisory report on the State and local safety considerations. Therefore, the FERC must address each of the issues in the State advisory report filed by the CEC.

In addition, section 311(d) of the EPAct of 2005 (as codified in section 3A(b) of the Natural Gas Act, 15 U.S.C. §§ 717bA(b)) has explicitly provided six factors for the location of LNG facilities. As stated in the CEC's State advisory report at 12:

> These factors mirror the six factors for the location of LNG facilities in the Pipeline Safety Act of 1979, which amended the Natural Gas Pipeline Safety Act. *See* 49 U.S.C. § 60103(a). The fifth factor in section 311(d), which involves emergency response capabilities, is a shorter paraphrase of the fifth factor in 49 U.S.C. § 60103(a). The other five factors in section 311(d) and 49 U.S.C. § 60103(a) are the exact same wording: "(1) the kind and use of the facility; (2) the existing and projected population and demographic characteristics of the location; (3) the existing and proposed land use near the location; (4) the natural and physical aspects of the location; … and (6) the need to encourage remote siting."

Relevant to each of theses factors is evidence concerning the extent to which an LNG spill can cause adverse consequences to the nearby population and/or the infrastructure. Indeed, in its analysis of these six factors, the CEC's State advisory report at 6-35, focuses precisely upon the need to carefully examine whether or not an LNG facility should be located in a densely populated area, such as the Port of Long Beach, based upon a review of these potential consequences. For example, the CEC's State advisory report points out, among other things, that:

- the area within 3 miles of SES's proposed site includes over 85,000 residents and at least 44,000 workers (CEC's State advisory report at 8);
- a 5 KW/m^2 thermal radiation flux level does not adequately protect the public, and, at a minimum, a 1.5 KW/m^2 thermal radiation flux level should be used (CEC's State advisory report at 15); and
- the petroleum infrastructure within 3 miles of SES's proposed site provides approximately 60% of the imported crude oil and 80% of imported refined petroleum products to California, which are vital to the economy and the U.S. Department of Defense (CEC's State advisory report at 17- 21).

II. THE TESTIMONY OF THE CPUC'S EXPERT WITNESS, DR. HAVENS, IS VERY RELEVANT TO THE STATE'S SAFETY CONCERNS AND SHOULD BE PART OF THE RECORD

Dr. Havens' report and sponsoring testimony goes to the crux of the State's safety concerns involving SES's proposed LNG import terminal at the Port of Long Beach, California: whether or not the proposed site would be a safe distance from the people, businesses and infrastructure in or near the Port of Long Beach. Dr. Havens is extremely qualified and has studied LNG safety issues for more than 30 years. His primary specialization is in the analysis and quantification of the consequences of releases of hazardous materials into the environment, with emphasis on the consequences that can occur as a result of toxic and/or flammable gas releases into the atmosphere. His resume and consequence assessment report to the CPUC's CPSD are exhibits accompanying his testimony. He has provided detailed analysis supporting his conclusion that there should be a minimum distance of three (3) miles between an LNG terminal and a densely populated area. Anything closer than 3 miles could put the public in harm's way.

Consistent with the CEC's State advisory report at 15, Dr. Havens has explained in his testimony and report why a 5 KW/m^2 thermal radiation flux level does not adequately protect the public, and, at a minimum, a 1.5 KW/m^2 thermal radiation flux level should be used. He also establishes why this would require an LNG terminal to be at least 3 miles from a densely populated area.

Dr. Havens' testimony and report also address other safety issues unique to SES's proposed LNG facilities at the Port of Long Beach. For example, he has provided evidence associated with the safety risks of LNG fuel trailer trucks and pointed out that SES proposes up to 45 of these trucks leaving the Port of Long Beach each day and driving through the City of Long Beach and the City of Los Angeles, as well as other cities and locations in California. This potential safety hazard was also identified in the CEC's State advisory report at 13-14.

Dr. Havens further provides evidence as to how the natural gas liquids ("NGLs") proposed to be extracted and stored on-site or transported to other locations pose additional risks for this project. This was also a hazard identified in the CEC's State advisory report at 15-16.

In addition, Dr. Havens' testimony addresses the sixth factor, the need to encourage remote siting, which Congress required to be considered in the siting of LNG terminals. *See* section 311(d) of the EPAct of 2005 (as codified in section 3A(b) of the Natural Gas Act, 15 U.S.C. §§ 717bA(b); *See also* 49 U.S.C. § 60103(a). This is also a prominent issue discussed in the CEC's State advisory report at 30–34. Providing a balanced approach to the siting of LNG terminals, Dr. Havens' testimony points to much safer alternatives in more remote siting in federal offshore waters, where LNG terminals can provide the needed supplies of natural gas without putting the public in harm's way.

Dr. Havens' testimony is therefore relevant to the issues that Congress has required the FERC to address herein. For these reasons, the FERC should accept Dr. Havens' testimony and exhibits into the record.

III. IF DR. HAVENS' TESTIMONY IS DISPUTED, THERE SHOULD BE A HEARING IN THIS MATTER

Under the above-mentioned six factors provided in section 311(d) of the EPAct of 2005, SES's proposed LNG project at the Port of Long Beach should be rejected. It is contrary to the public interest to needlessly put approximately 130,000 people, nearby businesses and critical infrastructure in harm's way when there are much safer alterative sites being pursued by others and which SES could have pursued.

To the extent that SES or others contest Dr. Havens' testimony as to why there must be a minimum 3-mile distance from the LNG terminal for the safety of the public, then there is a dispute of material fact warranting a hearing. The same holds true if SES or others contest Dr. Havens' testimony as to the hazards associated with the LNG fuel trucks or NGLs extracted at the site. There is no basis to assume SES's proposed LNG terminal would be safe or is worth the risk, given the evidence offered by the CPUC. At a minimum, a hearing would be necessary on any such disputes of material facts. *See Public Service Co. of New Hampshire v. FERC,* 600 F.2d 944, 955 (D.C. Cir. 1979).

A hearing is particularly warranted herein, because section 311(c)(2) of the EPAct of 2005 (as codified in section 3(e)(2) of the Natural Gas Act, 15 U.S.C. §§ 717b(e)(2)) requires that the FERC set the matter for hearing. Pursuant to this section and in light of the accompanying proffered testimony, the CPUC requests a hearing in this matter.

IV. CONCLUSION

For the above-mentioned reasons, the CPUC respectfully submits that the FERC should accept the accompanying testimony and exhibits into the record, and should set this matter for an evidentiary hearing.

Dated: October 4, 2005

Respectfully submitted,

RANDOLPH L. WU
HARVEY Y. MORRIS
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By: /s/ Harvey Y. Morris
HARVEY Y. MORRIS

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CERTIFICATE OF SERVICE

I hereby certify that I have this day caused the foregoing "Motion of the Public Utilities Commission of the State of California to Supplement the Record and for a Hearing," and the "Prepared Direct Testimony of Dr. Jerry Havens (Exhibit PUC-1) and Accompanying Exhibits (Exhibits PUC-2 through PUC-4)" to be served upon all known parties of record in this proceeding by mailing by first-class mail a copy thereof properly addressed to each party.

Executed in San Francisco, California, on October 4, 2005.

/s/ HARVEY Y. MORRIS

HARVEY Y. MORRIS

UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Sound Energy Solutions	Docket Nos. CP04-58-000, *et al.*

PREPARED DIRECT TESTIMONY OF DR. JERRY HAVENS (Exhibit PUC-1) AND ACCOMPANYING EXHIBITS (Exhibits PUC-2 through PUC-4)

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Filed: October 4, 2005

EXHIBIT PUC-1

Exhibit PUC-1

UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Sound Energy Solutions	Docket Nos. CP04-58-000, *et al.*

PREPARED DIRECT TESTIMONY OF
DR. JERRY HAVENS

Q. Please state your name and business address.

A. My name is Jerry Havens. I am President of Havens Associates, Inc. My consulting company's address is 809 Lighton Trail, Fayetteville, AR 72701.

Q. By whom are you employed and in what capacity?

A. I am a Distinguished Professor of Chemical Engineering at the University of Arkansas, where I have been a faculty member since 1970. In addition to my teaching responsibilities, I am the Director of the University's Chemical Hazards Research Center, where my responsibilities include the development and verification of mathematical models for prediction of atmospheric dispersion of hazardous chemicals. I am testifying here in my consulting capacity as President of Havens Associates, Inc. My remarks are not to be attributed in any way to the University of Arkansas.

Q. Please summarize your educational background.

A. I received a BS from the University of Arkansas in 1961; an MS from the University of Colorado in 1962; and a PhD from the University of Oklahoma in 1969, all in Chemical Engineering. I spent an additional one-year period as a post-doctoral fellow studying fire and explosion phenomena in the Flame Dynamics Laboratory of the University of Oklahoma before moving to the University of Arkansas in 1970.

Q. Do you have a particular area of specialization?

A. Yes, my primary specialization is in the analysis and quantification of the consequences of releases of hazardous materials into the environment, with emphasis on the consequences that can occur as a result of toxic and/or flammable gas releases into the atmosphere. Under my direction, the Chemical Hazards Research Center has been responsible for the development and validation of the DEGADIS gas dispersion model as well as for the continuing development and validation of the FEM3A computational fluid dynamics (CFD) gas dispersion model, both of which are the only gas dispersion models currently approved for the determination of vapor cloud exclusion zones as required by the Code of Federal Regulations (49 CFR 193) and the National Fire Protection Association (NFPA) 59A which govern siting of liquefied natural gas (LNG) import terminals in the United States.

Q. Do you regularly do research, publish, and speak at professional symposia on those subjects?

A. Yes. A listing of my publications, research assignments and symposia presentations is included in the Resume, which accompanies this testimony and is marked “Exhibit PUC-2.”

Q. Are you a registered professional engineer?

A. Yes. I am a registered professional engineer in the State of Arkansas.

Q. For whom are you appearing in this proceeding?

A. I am appearing for the California Public Utilities Commission (CPUC).

Q. What were you originally asked to do for the CPUC?

A. The Consumer Protection and Safety Division (CPSD) of the CPUC requested that I prepare a science-based assessment of public safety issues that should be considered regarding the proposed siting of an LNG import terminal in the Port of Long Beach, California (POLB). Subsequently, the CPUC requested that I prepare this testimony and testify as an expert witness on behalf of the CPUC. A copy of the report that I prepared for the CPSD accompanies this testimony and is marked “Exhibit PUC-3.”

Q. What are your conclusions concerning whether or not Sound Energy Solutions’ (SES) proposed LNG import terminal should be sited at the Port of Long Beach?

A. I conclude that it is not in the public’s interest to site the proposed terminal in the Port of Long Beach because of the potential severe threat to public safety and to the Port and surrounding infrastructure that could result. The details of my *consequence assessment* are contained in my report to the

CPSD, which I briefly summarize here. I specified a minimum distance of three (3) miles for the extent to which the public could be in harm's way from the initial release of approximately 3,000,000 gallons of LNG onto water at the POLB, an event which is widely considered by the scientific community to be credible. I recommend the 3 mile hazard distance as the minimum which should be considered credible to occur as a result of a terrorist attack in the Port, but I remain concerned that the fire which formed the basis for the 3 mile consequence distance would be of such severity as to make it highly likely, if not almost certain, that further failures of flammable fuel containments would occur.

Q. What are the current LNG safety regulations?

A. The regulation that specifies requirements for siting LNG import terminals in the United States is 49 CFR 193, entitled *Liquefied natural gas facilities: Federal standards*. 49 CFR 193 contains two sections that directly address the public safety issue:

193.2057 Thermal Radiation Protection, and

193.2059 Flammable vapor dispersion protection.

Q. Are the current LNG safety regulations sufficient to protect the public?

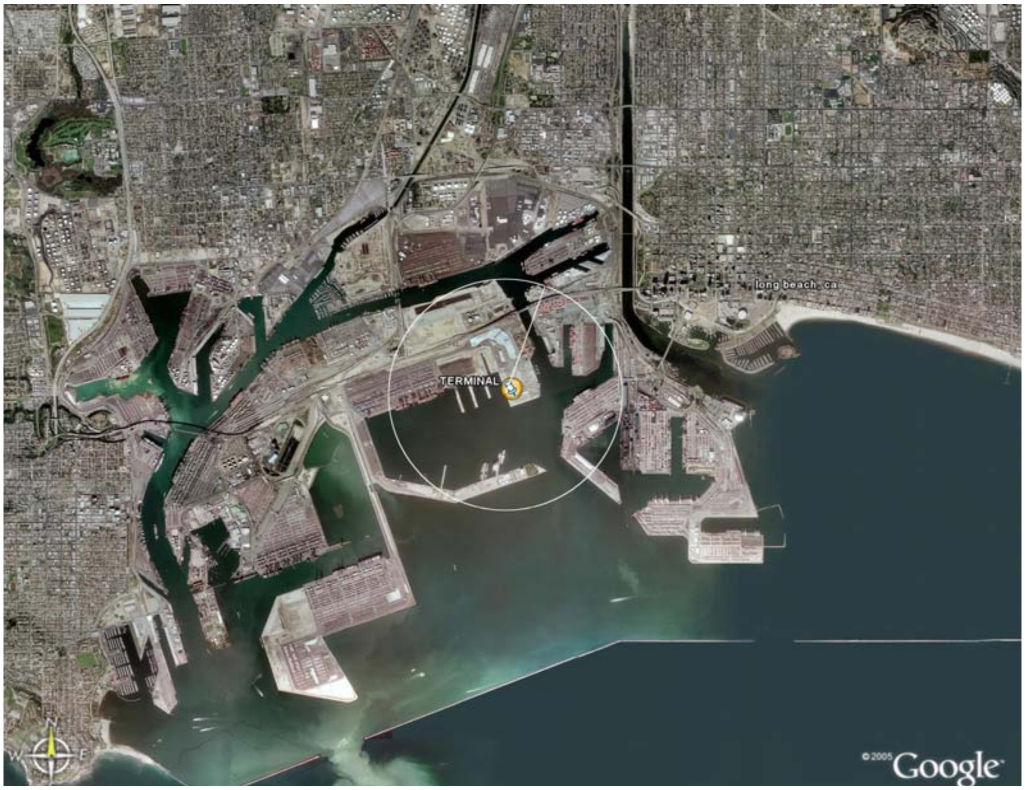
A. In my opinion they are not. I describe in detail in my report to the CPSD the deficiencies in this regard that I believe require attention in order to provide sufficient consideration of public safety. But the most important failure in my opinion of the present regulations to provide for protection of public safety stems from the fact that there are currently no requirements to provide for exclusion zones to protect the public from LNG spills on water. Since spills onto water cannot be contained, the hazards from the uncontrolled spreading of spills could extend to greater distances than would occur from spills on land, which can be contained to minimize their areal extent.

Q. Have you ever served as a consultant either to the government standard-setting agencies or to government officials working in the areas bearing on LNG safety?

A. Yes. In 1976-77, while I was on sabbatical from the University, I served as Technical Advisor to the Office of Merchant Marine Safety in U.S. Coast Guard Headquarters in Washington. I prepared a report for the U.S. Coast Guard entitled "Predictability of LNG Vapor Dispersion from Catastrophic Spills onto Water: An Assessment." That report helped to narrow the range of uncertainty in the calculations that had been made and identified for the first time the uncertainties that remained in such calculation procedures. My report was widely distributed worldwide and served, in part I believe, as the basis for Congressional authorization of $40,000,000 to initiate an LNG safety research program directed principally at the determination of consequences (fire and vapor dispersion) of major LNG spills on water. Both of the computer models currently required by 49 CFR 193 for calculating vapor cloud exclusion distances (DEGADIS and FEM3A) were the result of developments by my Associates and me at the University of Arkansas. I have also followed closely and have been involved in, if less directly, the development of the methods required by 49 CFR 193 for determining pool fire radiation exclusion zones.

Q. Please describe the location of the proposed site at the Port of Long Beach, California.

A. The satellite photo below shows the harbors of Los Angeles and Long Beach, with adjacent cities of Los Angeles to the west and north and Long Beach to the north and east. The proposed location of the LNG terminal in the Port of Long Beach is on an approximately twenty-five acre site on the east side of Pier T. For purposes of scaling, a circle with one mile radius is centered on the location of the tanker offloading site, which will be on the west side of the land parcel designated "TERMINAL".



Q. Please describe the principal components of SES's proposed LNG import terminal.

A. The principal components of the LNG terminal are:

- An LNG ship berth with 4 LNG unloading arms;
  - 2 liquid arms designed for a capacity of 24,150 gallons per minute (gpm) each, allowing ship offloading at 48,300 gpm,
  - 1 liquid/vapor hybrid arm, and
  - 1 vapor arm.

- 2 LNG receiving tanks, each with a gross volume of 42.3 million gallons of LNG at a temperature of -260 F and a normal pressure of 1 to 3 psig;
- 6 in-tank LNG pumps, each sized for 2,500 gpm;
- Seven LNG primary booster pumps, each sized for 1,830 gpm;
- Seven LNG secondary booster pumps; each sized for 1980 gpm;
- Four shell and tube vaporizers, each sized for 350 million standard cubic feet of gas per day using a primary closed loop water system heated with three direct-fired heaters and circulation pumps;
- Three boiloff gas compressors and associated condensing systems;
- An LNG trailer truck loading facility, including an LNG receiving/storage tank with a capacity of 1,000,000 gallons of vehicle quality LNG for distribution via eight trailer loading bays. An average of 45 trucks will be loaded per day.
- A natural gas liquids (NGL) recovery system, for which the final design appears to remain under consideration, will provide for the recovery and distribution off site of natural gas liquids, principally ethane and propane, via pipeline and/or trailer truck loading. (Information from Sound Energy Solutions Long Beach LNG Import Project Resource Report 1, General Project Description, Jan. 2004)

Q. Did SES's parent, Mitsubishi Corporation, contact you in the Spring of 2005 to request your help in analyzing the consequences of a terrorist attack on an LNG terminal or LNG ship?

A. Yes, they requested my technical support for a safety analysis of an LNG spill on the sea from an LNG ship that could result from a terrorist attack, including such factors as LNG spread and evaporation, and possibly FEM3A simulation of LNG vapor dispersion following such a spill. As I was already under contract with CPSD for the preparation of the report on which this testimony is based, I declined their offer since such an activity (consulting for Mitsubishi) would create for me a conflict of interest in the present matter. Their email request to me accompanies my testimony and is marked "Exhibit PUC-4."

Q. What are the primary hazards that could result from the release of LNG at the Port of Long Beach?

A. It is my opinion that the primary hazards are, in order of prioritization:

1. LNG pool fires on water
2. LNG vapor clouds resulting from spills on water
3. Unconfined vapor cloud explosions of LNG containing "hot" gases
4. Cascading failures due to the following causes, which could be combined:
    a. Confined gas explosions that can cause structural failure.
    b. Structural failure resulting from contact of cryogenic LNG with carbon steel.
    c. Failure of insulation system components resulting from extreme

fire exposure.

Q. Please explain what would be the consequence of a pool fire.

A. It is now widely accepted that spillage from a ship container of approximately 3,000,000 gallons of LNG is credible. It is highly likely that ignition sources (such as broken electrical wires, sparks resulting from friction, or open flames) would cause the LNG vapor evolving from such a spill, which would mix with air, to catch fire. Such a fire would be so large as to be completely beyond the capability of any organization to extinguish or even contain it, and it could seriously burn people to considerable distances from the fire's edge. There is a scientific consensus that such a fire could result in heat fluxes of 5 KW/m^2, which could cause second-degree burns to unprotected persons exposed for approximately 30 seconds, at a distance of approximately one mile from the center of the fire. Even more serious burns could occur at the one mile distance if exposure times were longer, and serious burns could occur at greater distances, even with lower thermal fluxes, with sufficient exposure times. In order to provide distances of separation which would ensure that unprotected persons would not be affected, I believe the criteria for safe separation should be based on a lower thermal flux value of approximately 1.5 KW/m^2. If such a criterion is used, the safe separation distance would increase, for such a spill, to approximately 1 ½ to 2 miles. Furthermore, there is good reason to believe that such a large fire could result in further failures of the containment system on the ship. As the Sandia report concludes that as many as three containers might fail, increasing the safe separation distance by approximately one third, I believe that the minimum separation distance should be considered to be approximately 2 ½ to 3 miles.

Q. What would happen if there were a vapor cloud fire at the Port of Long Beach?

A. A vapor cloud fire could result if the LNG spill vapors were not immediately ignited, and a vapor cloud formed. The cloud thus formed would drift downwind until it reached an ignition source or became diluted below the flammable concentration level – after which time it would not constitute a hazard. If the vapor cloud were ignited as it drifted downwind, the portions of the cloud which were above the lower flammability limit (~ 5%) would burn, and those persons in that area or immediately adjacent (thermal exposure could occur at some distance beyond the edge of the fire) who could not gain protection could be killed or seriously injured. In my opinion the maximum distance downwind to which portions of a cloud (sufficiently large to constitute a severe fire hazard) formed from the rapid spillage onto water of 3,000,000 gallons of LNG could be ignited is approximately three miles.

Q. To what extent have you relied upon reports by the Sandia Laboratory and the ABS Group to reach your conclusions?

A. Both the ABS Group and Sandia Laboratory reports were commissioned in 2004, following a period when there was significant controversy about the state of knowledge for making consequence assessments for LNG spills on water. I welcomed the reports, and I believe that they now provide us an opportunity to move forward in a rational decision making process to consider siting of LNG terminals in the United States so as to protect the public safety. As I have stated earlier, I do believe that some extensions and modifications of the reports, particularly the Sandia report, are necessary if the goal is to ensure rational consideration of the potential consequences to the public of very large releases of LNG which I believe that we are even more compelled to consider after 9/11.

Q. Please explain what thermal radiation flux criterion was used by Sandia and the ABS Group and what thermal radiation flux criterion should be used.

A. The Sandia Laboratory and ABS Group reports suggest a thermal radiation flux criterion of 5 KW/m^2 for use in determining the thermal radiation hazard zone. There is a scientific consensus that a 5 KW/m^2 thermal flux, impinging on unprotected skin, can cause second-degree burns to persons exposed for approximately 30 seconds. It is important to understand that even more serious injuries could result from a 5 KW/m^2 exposure for longer times (> 30 seconds), and that serious injuries could result from even lower thermal flux exposures (<5 KW/m^2) at larger distances if the exposure time were longer. In order to provide distances of separation which would ensure that unprotected persons would not be affected, I believe the criteria for safe separation should be based on a lower thermal flux value of approximately 1.5 KW/m^2.

Q. Would the NGLs pose any additional hazards at the Port of Long Beach?

A. Yes, the introduction of NGLs at the facility, either by receipt in the imported LNG (“hot gas”) or as a result of separation, handling and storage of NGL, will introduce additional hazards that are not normally considered in the handling of LNG that is essentially pure methane. First, it is known from experimental programs performed by the Coast Guard that although pure methane is very unlikely to undergo damaging explosive reaction when unconfined, mixtures of methane with heavy components such as ethane and propane, when contained in concentrations greater than about 12-18%, are subject to high order explosions. Second, the storage of NGLs portends an additional hazard, the potential for boiling liquid expanding vapor explosions (BLEVE) of vessels containing NGL. Devastating failures of NGL containments have occurred repeatedly during the last 4 or 5 decades, and the potential for such explosions in the NGL portion of the LNG terminal to compromise the much larger LNG containments cannot be ignored.

Q. Your report refers to an LNG road tanker, which had exploded on June 22, 2002 near Tivissa, Catalonia, Spain. Are there any risks posed by the LNG trailer trucks which would be loaded at the Port of Long Beach under SES's proposal?

A.. Yes, as a result of the recent explosion of the LNG road tanker carrying LNG in Spain, as well as further study of the BLEVE mechanism which suggests that other LNG containers might also be vulnerable to such failures, the potential for boiling liquid expanding vapor explosions of vessels containing LNG can no longer be ignored. This is important to the POLB terminal consideration because current plans are that up to 45 LNG trucks carrying approximately 10,000 gallons of LNG will depart the terminal daily, and because certain types of containment vessels used in the terminal, or more likely, on the ships that serve the terminal, could be subject to failure via the BLEVE mechanism. The risk of accident or terrorist attack that could result in such explosions should not be ignored.

Q. Is your 3-mile recommendation based upon a worst case scenario for the Port of Long Beach?

A. No, I am very concerned that such events as provide the basis for the 3 mile distance I am recommending would be of such severity as to make it highly likely, if not almost certain, that further failures of LNG containment vessels would occur. I repeat here my concern that the exposure to the ship from such a pool fire would have the potential to cause cascading, or even simultaneous failures of the remaining tanks on the vessel, resulting in total loss of the vessel and burning of its contents. Furthermore, I believe that insufficient attention has been given to the vulnerability of land storage tanks to terrorist attack, or even to the vulnerability of land storage tanks to natural events such as earthquakes and tsunamis, consideration of which is in order, as recent events remind us.

Q. Did you visit the proposed LNG terminal site in the course of preparing your report to the CPSD?

A. Yes, the purpose of my visit to the site was to get a better understanding of the characteristics of the site that related to the protection of the public and adjacent infrastructure. In my opinion, the approximately 25 acre site provides very minimal separation between the LNG spill impoundments (designated on the facility plans) and the facility's property line; indeed, it is difficult for me to see how the applicant can meet the exclusion zone requirements of 49 CFR 193, much less provide a reasonable safety zone for the public or surrounding infrastructure.

Q. Is it your position that there should not be any new LNG import terminals constructed in or around the United States?

A. No, that is not my intention, nor do I believe it is a necessary result. I do have serious concerns about the adequacy of current regulations, particularly with the failure to consider the consequences of marine releases of LNG. I have serious concerns as well about the suitability of selected sites and of the associated marine transport, and I believe that the process underway to approve LNG import terminal sites is moving far too hastily and without sufficiently careful deliberation. However, I am also convinced of the necessity to consider most carefully some expansion of LNG importation because of the value it can bring. And I am no less convinced that we have in our grasp sufficient scientific tools to enable us to provide the public with reasonable assurance of its safety in today's environment. I believe that proper use of those tools and methods can and will permit the location, even onshore, of LNG regasification facilities that present acceptable risks to the public when all of the relevant trade-offs of risk and benefit are considered.

However, I do not believe that to be the case for the proposed LNG terminal in the Port of Long Beach, because of the very large populations in the affected zone, and the near certainty that it would be practically impossible to evacuate those people in sufficient time following an incident to get them out of harm's way. And while the public safety should be considered of paramount importance, I also believe that, assuming the availability of alternative sites that will meet the nations' needs, it just does not make good sense to place an LNG terminal in the POLB because of the potential (and the associated attraction) for a terrorist attack to cause extreme damage and disruption that could well have major national consequences.

Q. Dr. Havens, on the FERC's website and the California Energy Commission's (CEC) website, there are two proposed LNG import terminals listed in federal waters offshore Southern California: BHP Billiton at Cabrillo Port and Crystal Energy on the Platform Grace. According to the CEC's LNG project descriptions, BHP Billiton's proposed LNG terminal would be approximately 14 miles offshore and Crystal Energy's proposed LNG terminal would be approximately 10.5 miles offshore. (See http://www.energy.ca.gov/lng/documents/2004-02-24_DFG_LARSON.PDF). Do these proposed LNG import terminals pose the safety risks to the people onshore, which you have testified that SES's proposed LNG import terminal would pose at the Port of Long Beach?

A. No. The distances from shore of either of these projects would obviously protect the public from events which I have testified could put them in harm's way approximately three miles from a rapid initial spill of 3,000,000 gallons of LNG onto water, an event that is widely considered by the scientific community to be credible. Although I have stated that a 3,000,000 gallon rapid spill should not be assumed to be the worst case that could be realized, because of the possibility that the ensuing fire could result in further failures of the LNG containment systems, it is my opinion that the separation distances from shore provided by either the Cabrillo Port or Platform Grace locations would keep the public onshore out of harm's way.

Q. Does this conclude your testimony?

A. Yes. It does.

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Exhibit PUC-1

UNITED STATES OF AMERICA
BEFORE THE
FEDERAL ENERGY REGULATORY COMMISSION

Sound Energy Solutions	Docket No. CP04-58-000

DECLARATION OF JERRY HAVENS

I, Jerry Havens, declare under penalty of perjury that the answers appearing in the foregoing prepared direct testimony are true and correct to the best of my knowledge and belief, and that if asked the questions appearing therein, my answers would, under oath, be the same.

Executed at Fayetteville, Arkansas, this first day of October, 2005.

/s/ JERRY HAVENS
Jerry Havens

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EXHIBIT PUC-3

Exhibit PUC-3

CALIFORNIA PUBLIC UTILITIES COMMISSION

CPSD

Consumer Protection and Safety Division

An Assessment of the Potential Hazards to the Public Associated with Siting an LNG Import Terminal in the Port of Long Beach

Prepared By

Dr. Jerry Havens, President
Havens Associates, Inc.
809 Lighton Trail
Fayetteville, AR 72701

September 14, 2005

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report was prepared at the request of the Consumer Protection and Safety Division of the CPUC for an assessment of public safety issues that should be considered regarding the proposed siting of an LNG import terminal in the Port of Long Beach.

The history of LNG importation in the United States is reviewed, describing the siting and continuing operation of the present six LNG import terminals, and the proposal for a very large expansion in the country's LNG infrastructure - more than fifty proposals for LNG import terminals to be located in the continental United States, Southern Canada, Mexico, and the Caribbean Islands – is described. As there appear to be many more proposals than for which there is a demonstrated need, it is all the more important to ensure that the siting process involves, to the maximum extent possible, careful consideration of potential hazards to the public and adjacent infrastructure so as to give full consideration to the best alternatives available.

The potential hazards to the public of the proposed POLB terminal are defined as fire and explosion hazards, and an assessment is provided of the adequacy of the present regulation, 49 CFR 193, to protect the public.

Since the regulations were promulgated in the early Eighties, after the terminals now operating had been built and commenced operation, and since there was no rush to build additional LNG import terminals until about the year 2000, the regulations were largely unused for import terminal siting. As a result, the regulations did not, and still do not, give serious consideration to the terrorist threat that began in this country September 11, 2001. The current regulations do not effectively address the many serious questions posed by the present requirement to consider events that could be caused by malicious intent, nor is sufficient attention being paid to the reality that malicious intent changes the whole safety picture – hence the process has outrun the development of the regulations to deal with it, and the present regulations fail to address this most important new paradigm.

Most importantly in consideration of the post 9/11 threat, there is presently no requirement, much less enforcement, of exclusion zones to protect the public from LNG spills which could occur from the ships that serve the import terminal. The failure to provide for the protection of the public and surrounding infrastructure from major releases of LNG that could occur from the ships serving the facility must be considered all the more important now as a result of recent government sponsored reports, for which there is now scientific consensus, that indicate that the danger zones extending from large, but credible, spills on water are likely to pose greater threats than would either accidental or terrorist caused releases from the land part of the terminal.

The regulation does not provide for consideration of boiling liquid expanding vapor explosions (BLEVEs) or unconfined vapor cloud explosion (UVCE) hazards, although the proposed terminal is designed to import LNG containing natural gas liquids (NGL) in amounts sufficient to raise serious questions about the potential for UVCEs following large LNG spills. The possibility of BLEVEs of LNG ship tanks, particularly the ship tanks which rely on non-fire-resistive insulation to keep the LNG from vaporizing, is not considered, although it is clear that there is a significant potential for occurrence of cascading failures that could jeopardize the ship and all of its content of LNG.

The report then presents an assessment of the consequences to the public that could result from credible accidental or terrorist caused releases of flammable liquefied fuels, either from the land part of the facility or the ships that would serve it.

Accidents and Terrorist Actions

The current regulations, particularly regarding provisions for public safety, focus on the land based part of the terminal. There are specific requirements for liquid containment and impoundment systems that are designed to limit the spreading of LNG that might be released either from the LNG tanks themselves or from transfer lines in the facility. But such control and mitigation measures could not be effectively applied to releases that could occur from an LNG ship, either at the jetty or in transit thereto, because spills onto water could not be effectively contained.

For spills on water, there have been government sponsored studies that provide information sufficient to define the (credible) spills that could occur as well as the consequences that could result.

The ABS Group and Sandia reports agree that the release of LNG in the amount of approximately 3,000,000 gallons (half of one typical LNG ship tank) is credible,

- in that such a release could result from accidental collisions between ships with sufficient momentum (mass and speed) to cause such a breach of containment, or

- that such a release could be caused by terrorists with means that are readily available to them.

Furthermore, the ABS Group and Sandia reports agree that a release of 3,000,000 gallons of LNG onto water could result in:

- Pool fires which would expose persons with unprotected skin to thermal fluxes (5 KW/m^2) that could cause second degree burn injury in approximately 30 seconds at a distance of approximately 1 mile, and

- Flammable vapor clouds, if the spilled material were not ignited upon release, that could extend downwind to distances between 2 and 3 miles. It is reasonable to assume that persons caught in the fire if the cloud were ignited would be killed or seriously injured.

The author is in essential agreement with these consequence estimates but believes the following modifications are required if they are to be used to ensure public safety:

- Since the thermal radiation flux criterion (5 KW/m^2) used by Sandia and the ABS Group could cause second degree burns in thirty seconds, it is not sufficiently protective of public safety; a lower value, approximately 1.5 KW/m^2, is recommended here. This value is already being used by other segments of the regulatory system, both nationally and internationally, based on its definition as the highest thermal flux to which an unprotected person can be continuously exposed without injury. If the 1.5 KW/m^2 criterion is used, it is anticipated that the distance of 1 mile (associated with the higher flux level) would be increased to between 1 ½ and 2 miles.

- As the Sandia Report states unequivocably that cascading failures of ship tanks cannot be ruled out and further states that in their opinion failures of as many as 3 tanks could occur, this scenario must be considered credible. As Sandia estimates that the hazard distance from this scenario could be extended by approximately one-third, the distance to the 1.5 KW/m^2 flux level would then be increased to approximately 2 ½ to 3 miles.

- The ABS Group's high-end estimates for the vapor cloud distance to the 2.5 % gas concentration level (based on releases from a 5 meter diameter hole in the containment) are approximately 3 miles. The Sandia estimates for the credible scenario analyzed are closer to 2 miles, but their calculations reflect the distance to the 5% gas concentration level rather than the 2.5% level which is accepted to represent the better criterion for vapor cloud travel distance that could pose a hazard to the public. Use of the lower flammable gas concentration criteria would be expected to extend the hazard distance to about 3 miles.

Based on this information, which the author believes to be the best available, and which is in general agreement with widely held views in the scientific community, a minimum distance is specified here for the extent to which the public could be put in harm's way from the initial release of approximately 3,000,000 gallons of LNG onto water at the POLB. It is approximately 3 miles.

Consideration of Worst Possible Cases

A minimum 3 mile radius circle around the proposed terminal is proposed to demarcate the area in which events deemed credible could cause serious injury to the public. The minimum distance to demarcate expected damage to infrastructure would be of lesser extent, depending on the criterion selected for damage. Any consideration of the consequences to POLB infrastructure must consider the wide variety of flammable and other hazardous materials routinely handled, as the area in which significant damage to infrastructure could occur (beyond the terminal and the ship) encompasses sections of one of the largest and busiest ports in the country. The POLB receives very large crude oil carriers (VLCC) at a jetty located within several hundred feet of the eastern boundary of the proposed LNG facility, and a major container terminal which almost certainly receives hazardous cargo lies adjacent to the western side of the proposed site, along which the LNG ship will be berthed.

It must be emphasized that the 3 mile distance recommended here is based primarily on the assumption that approximately 3,000,000 gallons of LNG is spilled onto water, as it appears there is little doubt that either pool fire radiation thermal fluxes or flammable vapor clouds from such a spill could put the public in harm's way out to that distance. However, it is a minimum specification, because it does not address the possibility of more serious events which could occur.

There is very real concern that such events as provide the basis for the 3 mile consequence distance would be of such severity as to make it highly likely, if not almost certain, that further failures of containments would occur. In particular, there is serious concern that the exposure to the ship from such a pool fire would have the potential to cause cascading failures of the remaining tanks on the vessel, resulting in total loss of the vessel and burning of its contents. There can be no doubt that the consequences of such a worst-possible-case event could be more severe.

Finally, the report states that the vulnerability of the land based part of the facility needs to be considered more carefully, as the author believes that insufficient attention has been given to the vulnerability of the land based facility to such natural phenomena as earthquakes and tsunamis, as well as to the facility's vulnerability to terrorist attack.

CHAPTER 1

INTRODUCTION

This report was prepared for the Consumer Protection and Safety Division (CPSD) of the California Public Utilities Commission. The CPSD requested that I prepare a science-based assessment of public safety issues that should be considered regarding the proposed siting of an LNG import terminal in the Port of Long Beach, California.

My resume is attached as Exhibit A. I have been researching methods for assessing the potential consequences of major spills of liquefied natural gas (LNG) and natural gas liquids (NGL) for more than thirty years. As the history of LNG import terminal siting in the United States, indeed the world, is largely confined to a similar period, I believe that I have a unique perspective on the issue of the hazards which LNG terminal activities can pose to public safety. I also believe that it is important to consider LNG safety issues in the broader context of increasing usage by society of other liquefied fuel and chemical gases that pose similar hazards. I particularly appreciate this opportunity to put the issues of public safety surrounding the proposed siting of an LNG import terminal in the Port of Long Beach into a scientifically reasoned context - based on my observation and study during the last three decades to understand the consequences that could occur to the public as a result of major spills of liquefied gaseous fuels onto land or water.

In my view, the importance of careful and sober consideration of the potential threat to public safety and to critical infrastructure of the decision to site a large LNG import terminal in the Port of Long Beach cannot be overstated. No liquefied fuel import terminals have been sited in urban areas of the United States since the Distrigas plant began operation in Everett, MA, in Boston Harbor, in 1971. In the interim three decades the world has experienced several catastrophic industrial accidents which were so severe as to importantly influence worldwide regulatory controls intended to lessen the likelihood as well as the potential consequences of accidental releases. Most importantly, no LNG facilities at all have been sited in this country since 9/11, and I believe that 9/11 completely changed, or should and will change, our methods as well as our thinking about the new paradigm in which major hazards complexes must be considered.

It is important for the reader to understand that this assessment is intentionally and solely directed to the realistic definition of the consequences to the public and surrounding infrastructure that could occur from a major release of flammable liquids at the proposed terminal or from the ships that will serve it, with no consideration given to the likelihood of occurrence of the events which are considered I believe that the first step in determining a rationale for a decision whether or not to site the proposed LNG terminal in the Port of Long Beach is to define the possible (credible) consequences of major releases of hazardous materials, and I believe that such determination should be made independently of any arguments advanced regarding the probability (likelihood) of such events' occurrence.

This approach is all the more appropriate since the tragic events of 9/11, as historical experience regarding LNG accidents (or accidental occurrences of any kind) cannot be used to quantify the probability of a terrorist attack.

1.1 LNG Importation in the United States

Proposals for large scale importation into the United States are not new, importation of LNG into the States having begun in the early Seventies. Although the technology of LNG storage and shipping has advanced in several areas, there are many similarities between the storage and shipping methods utilized in the Seventies and those proposed today. Indeed, all of the import terminals built in the Seventies are still in operation, and are proposed for operation for at least two decades into the future.

By the early Seventies the marine carriage of LNG had been proven technologically, and several ventures were proposed to import LNG into the United States, at the time principally from Algeria to the east and gulf coasts and from far-east gas sources such as Indonesia to the west coast. By the end of the Seventies, four import terminals were operating on the east and gulf coasts of the United States – at Everett, Massachusetts, beginning in 1971; near Savanna (Elba Island), Georgia, beginning in 1978; at Cove Point, Maryland, beginning in 1978; and at Lake Charles, Louisiana, beginning in 1982. A fifth terminal, at Kenai, Alaska, intended for export, principally to Japan, began operation in 1969. The terminal in Everett has been in operation continuously; the terminals at Elba Island, Cove Point, and Lake Charles are currently operating after a period in mothballs (different for each) which resulted from decreased need for LNG importation. The fifth import terminal was constructed and began operating in Penuelas, Puerto Rico, in 2000, and the Gulf Gateway Energy Bridge deepwater port commenced operation this year in the Gulf of Mexico.

To serve the needs of these United States import terminals as well as the needs of even faster growing LNG importation by Japan and Europe, a fleet of LNG carriers was constructed. Currently, there are approximately 165 LNG carriers in service worldwide, several of which were built for the trade that began in the Seventies. Eighteen carriers have been retired from service, and approximately 85 new ones are on order. Typical LNG carriers built in the Seventies, some of which are in use today, carry approximately 125,000 cubic meters of LNG, but the proposed terminals today are planned to receive carriers with capacity up to 250,000 cubic meters (approximately 66 million gallons).

During the period in which the first four terminals (described above) were constructed, there were additional proposals to build and operate LNG import terminals in California, with three specific sites receiving principal consideration – Los Angeles Harbor (Terminal Island), Point Conception, and Oxnard. For all three of these proposed locations, detailed risk assessment studies were prepared to define the hazards to the public that might occur as a result of accidental spills of LNG. None of the proposed California terminals were built, presumably as a result of indications that they would not be profitable in view of a reassessment of the demand for natural gas. It is important to note that because the terminal project applications were withdrawn for reasons other than consideration of their safety hazards, it is fair to say that the issues of public safety were never effectively resolved, and consideration of the risks to the public of such ventures languished - until about the year 2000.

1.2 Proposed Expansion in LNG Importation

The United States is presently considering a very large expansion of its LNG import infrastructure. As addition to the five land and one offshore import terminals currently operating in this country, as many as fifty new LNG import terminals to be sited in the continental United States, Southern Canada, Mexico, and the Caribbean Islands have been proposed. Additional proposals have been announced during the preparation of this report. All of these plans are said to be based on projections for greatly increased LNG use, both in quantity and as a percentage of total energy use.

Although this report is not intended to address the need for new LNG import terminals, I think that it should be noted that there have been no projections of demand for LNG that suggest our need (before 2025) for more than perhaps as many as a third of this number, and quite likely fewer. Viewed thus, the large number of proposals appears to be in some important part the result of significant competition to “win” in the selection process.

Although the majority of these terminals have been proposed at onshore locations, including some proposed for urban areas, as in Long Beach, a significant number are now planned for installation offshore.

With more proposed terminals than for which there is a justified need, I believe it all the more important to ensure that the siting process involves, to the maximum extent possible, careful consideration of potential hazards to the public and adjacent infrastructure.

1.3 Public Safety Concerns about LNG Terminal Siting

To begin, let me define the terms liquefied natural gas (LNG) and natural gas liquids (NGL).

LNG is natural gas that has been cooled, at normal atmospheric pressure, to approximately -260 ^{o}F, its liquefaction temperature varying depending on the composition of the gas. Methane, the principal component of LNG, cannot be liquefied by pressure alone. Although liquefaction by cooling to higher temperatures (> -260 ^{o}F) at elevated pressure is possible (combinations of cooling and pressurization are utilized in some LNG applications, such as vehicle fuels), the LNG that would be received at the Long Beach Terminal would be contained in ship tanks designed for nominal atmospheric pressure operation, i.e., with design pressures not exceeding approximately one atmosphere, and stored in land tanks under similar, nominally atmospheric pressure, conditions. Based largely on historical precedent, most LNG safety and risk assessments have assumed LNG to be principally methane, and present regulatory requirements for determining danger zones around LNG spills allow, at least implicitly, description of its composition as pure methane.

However, the composition of the LNG that would arrive at the proposed Long Beach terminal will depend upon several variable factors, including the location of gas production (the composition of natural gas from different producing fields can vary significantly) and the degree of processing of the natural gas, either during liquefaction at the export terminal or following the receipt of the LNG at the import terminal, to remove heavier molecular weight hydrocarbons such as ethane, propane, and butane. Such heavier molecular weight compounds, mixed in varying concentrations, are commonly referred to as natural gas liquids (NGL). Since the proposed terminal in Long Beach could import LNG containing substantial amounts of natural gas liquids, and since the terminal is designed to process the LNG after receipt to separate the NGL for (separate) distribution, a thorough assessment of the hazards which could be posed to the public should consider both the LNG and NGL components of the facility. Furthermore, since the degrees of hazard to the public depend, beyond the most immediate and compelling factor of the very large quantities of LNG, on important differences that are known to exist in the fire and explosion hazard potentials of LNG and NGL, any assessment of the potential hazards to the public from the proposed terminal should consider the hazards specific to LNG and NGL, as well as any potential for more serious events which could result from the storage and handling of the materials in combination.

The concerns for public safety associated with the current proposals to site new LNG terminals are essentially the same as those identified in the Seventies when LNG terminals were introduced to the United States. I have observed that the degree to which the public raised concerns about public safety varied considerably in the gulf, east, and west coast regions. There appeared to be the least opposition in the gulf coast region, with somewhat greater resistance on the east coast, particularly in New York and New England, and perhaps greatest regarding the siting of the three terminals proposed in California. It is significant, I believe, to the present discussion to note (again) that the Distrigas terminal in Everett, Massachusetts, is the only terminal constructed to date in a major urban area in the United States. There have been voiced far more concerns about the Everett facility than for the other terminals, which by comparison are located more remotely (from the public).

It is also my observation that similar variations exist in these same regions today in their response to LNG terminal siting proposals – least in the gulf region (with the notable exception of Mobile, Alabama, where Exxon Mobil has withdrawn its proposal for a terminal in Mobile Bay), followed by similar responses (both for and against the projects) from the public to proposals on the east and west coasts. So far, the proposals for terminals to be sited in unarguably urban areas, notably Fall River, Massachusetts, on the east coast, and Long Beach on the west coast, appear to be among the most contentious (regarding the public safety issue) of the proposals under active evaluation.

But there are present today (at least) three new and significant factors that require careful consideration before reaching a decision to site a liquefied gas import terminal, particularly if the site is in an urban area.

The first is the aforementioned offshore placement of LNG import terminals. Although at the beginning of the current expansion phase, there were many objections advanced to the offshore alternative, including most prominently issues of economy (it was suggested that offshore installations would be too expensive) and increased vulnerability to scheduling interruptions caused by weather, the offshore option appears to be gaining acceptance, with several terminals proposed for offshore locations off of the west, gulf, and east coasts. At least one offshore LNG facility (The Gulf Gateway Energy Bridge deepwater port, owned by Excelerate Energy Limited Partnership) has commenced operation this year in the Gulf of Mexico. It appears that the viability, of at least this type of offshore importation project (Energy Bridge), is no longer in question.

Second, during the ensuing three decades since the LNG terminals on the east and west coasts commenced operation, the world has experienced several catastrophic industrial accidents, the major consequences of which should be seriously considered before reaching a decision to site a potential major hazard industrial facility, such as the proposed LNG terminal, in a congested area such as the Port of Long Beach. Most importantly to the present in that regard, there have been a substantial number of liquefied gaseous fuel accidents involving containment failures due to boiling liquid expanding vapor explosions (BLEVEs) as well as unconfined vapor cloud explosions (UCVEs), the most severe in this hemisphere (in terms of human casualties) having occurred in an outlying area of Mexico City in 1984. That event resulted in more than 600 deaths, thousands of serious injuries, and the complete devastation of an entire NGL storage and distribution facility.

Third, and perhaps of greatest importance to the present consideration of siting an LNG terminal in the Port of Long Beach, is the terrorist threat, which the public perceives with growing concern. Although sabotage appears to have been given some consideration in the siting of terminals in the Seventies, to my knowledge no organized efforts were undertaken at that time to quantify the consequences that might result from sabotage or to attempt to quantify the likelihood of such occurrences. But, since 9/11, concerns about terrorist attacks that could pose significant threats to public safety are very real, and they are fast growing. The energy infrastructure of our country is of particular concern, because of the potential for terrorist attacks to cause events that could directly endanger the public as well as deprive us of energy that we require.

The Department of Homeland Security has identified LNG infrastructure, one component of the much larger chemical/energy infrastructure, as a potential terrorist target of concern. The Department's concern results, primarily I believe, from the recognition that liquefied gas fuel storage tanks, either on land or on ships, must necessarily concentrate very large amounts of energy (as LNG and NGL) in individual containment systems in order to be economical. The terminal proposed for the POLB will have storage capacity for approximately 86,000,000 gallons of LNG, and the ships that are initially planned to serve the terminal will carry approximately 38,500,000 gallons of LNG. However, the facility is being constructed so as to enable it to receive ships carrying up to about 53,000,000 gallons of LNG, and possibly more. The potential for terrorist attack to release large quantities of highly flammable fuels from such large storage vessels thus is seen to carry with it the potential for such attacks to endanger the public offsite as well as to effect horrendous damage to infrastructure. In my opinion, these factors demand that LNG infrastructure such as the proposed Long Beach terminal be identified as potential terrorist targets of opportunity.

I believe, and have so testified before Congress, that since 9/11 we no longer have the luxury of considering only means for reducing the probability of accidents (through more effective management strategies) to a level that is considered to justify the attendant risk – we now are forced to consider malicious acts as well. And, I believe that it is imperative that the dangers to the public from possible spills that could occur as a result of terrorist attack, particularly those spills which might occur from a tankship and thus onto water (for which there are few if any control measures), be most carefully considered in the current rush to site additional LNG import terminals in our country. Finally, in this regard, I have notified the Secretary of Homeland Security (Exhibit B) of my concerns about specific features of LNG carriers which I believe may make those ships vulnerable to terrorist attack. The specific issues, which I will address later in order to put them into a proper context, are the use of non-fire-resistive insulation on the containment vessels (LNG tanks) and the potential for major failures of the ship's structure due to direct contact with spilled LNG, which, having temperatures as low as (minus) 260 ^{o}F, has been demonstrated repeatedly to cause brittle fracture of carbon steels. Since my appeal to the Department of Homeland Security, there have appeared important reports of studies designed to clarify several outstanding issues, particularly those issues regarding the consequences that can be anticipated from large releases of LNG onto water; I will attempt to summarize the current state of our knowledge regarding these critically important matters in this report.

Finally, I have tried to prepare this report in a form which will be useful to policy makers, whom I believe are not always sufficiently informed on such matters, and to the public, whom I believe are becoming increasingly concerned, as I am, that issues of public safety surrounding the nation's chemical/energy infrastructure are not receiving the attention that is demanded, particularly post 9/11. Quoting from the foreword which I wrote for the chapter on Major Hazard Control, in <u>Lee's Loss Prevention in the Process Industries</u>, "It is my belief that the major hazards problems society faces are less a problem of insufficient information about those hazards and more a problem of insufficient application of the tools that we have in hand." In this regard, I believe it is important to note that the reports on LNG hazards which have been recently prepared and mentioned above, especially the reports by the ABS Group and the Sandia Group, do provide information which provides effective answers to several technical questions concerning large spills of LNG onto water which have been particularly contentious. It is in that vein that I have prepared this report with a view to cutting through the technical details to provide the public with my summary of the information which is now available, along with my candid view of what that information should mean to the public and its policy makers whom are considering the siting of an LNG import terminal in the POLB. I believe it is absolutely imperative that we get this one right, as it will have the potential for setting extremely important precedents in our attempts to balance the risks and benefits of increased LNG importation, that task having been made immensely more difficult by the threat of terrorist attack.

CHAPTER 2

POTENTIAL HAZARDS TO THE PUBLIC OF THE PROPOSED LNG TERMINAL IN THE PORT OF LONG BEACH

2.1 Location and Description of the Proposed Terminal

Location

The satellite photo below shows the harbors of Los Angeles and Long Beach, with adjacent cities of Los Angeles to the west and north and Long Beach to the north and east. The proposed location of the LNG terminal in the Port of Long Beach is on an approximately twenty-five acre site on the east side of Pier T. For purposes of scaling, a circle with one mile radius is centered on the location of the tanker offloading site, which will be on the west side of the land parcel designated "TERMINAL".[1]

[1] This satellite view, which extends to distances of three to four miles from the proposed terminal, will be used later in this report to delineate the minimum extent of zones in which the public and infrastructure could be endangered by major releases from containment of flammable liquefied gases - for which there is now good scientific agreement that are deemed to be credible.

Descripton

For purposes of this report, which is primarily directed to consideration of public safety issues, the principal components of the LNG terminal are summarized below.

- An LNG ship berth with 4 LNG unloading arms;
  - 2 liquid arms designed for a capacity of 24,150 gallons per minute (gpm) each, allowing ship offloading at 48,300 gpm,
  - 1 liquid/vapor hybrid arm, and
  - 1 vapor arm.

- 2 LNG receiving tanks, each with a gross volume of 42.3 million gallons of LNG at a temperature of -260 F and a normal pressure of 1 to 3 psig. (LNG-1, LNG-2 on plot plan);

- 6 in-tank LNG pumps, each sized for 2,500 gpm;

- Seven LNG primary booster pumps, each sized for 1,830 gpm;

- Seven LNG secondary booster pumps; each sized for 1980 gpm;

- Four shell and tube vaporizers, each sized for 350 million standard cubic feet of gas per day using a primary closed loop water system heated with three direct-fired heaters and circulation pumps;

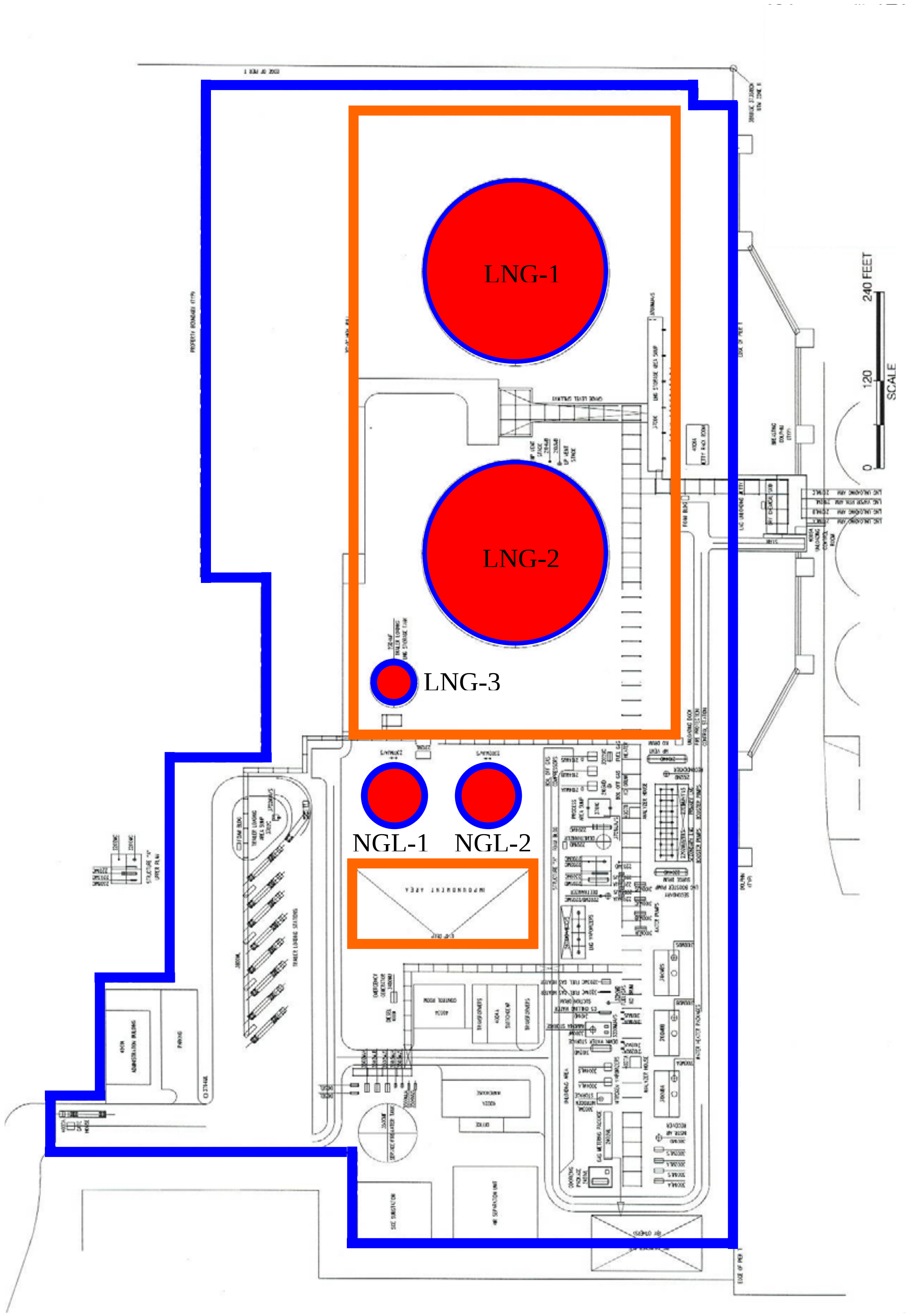
- Three boiloff gas compressors and associated condensing systems;

- An LNG trailer truck loading facility, including an LNG receiving/storage tank with a capacity of 1,000,000 gallons of vehicle quality LNG for distribution via eight trailer loading bays (LNG-3 on plot plan). An average of 45 trucks will be loaded per day.

- An NGL recovery system, for which the final design appears to remain under consideration, will provide for the recovery and distribution off site of natural gas liquids, principally ethane and propane, via pipeline and/or trailer truck loading;

The terminal plot plan follows, with designation of the location of the primary storage tanks (in red), spill impoundments (in orange), and site boundary in blue. The total area of the site is approximately 25 acres. (Information from Sound Energy Solutions Long Beach LNG Import Project Resource Report 1, General Project Description, Jan. 2004)

Exhibit PUC-3



***The author is aware that consideration is being given to altering the requirements for NGL storage, perhaps even eliminating it. As the author is not privy to any final decision in this regard, this description is based on the site description from SES' January 2004 report.

2.2 LNG (Liquefied Natural Gas) and NGL (Natural Gas Liquids) Hazards

The primary hazards (to the public) that can result from the errant release of liquefied gas fuels such as LNG and NGL from the proposed terminal activities in the POLB are:

- Fire hazard
  - Liquid pool fires
  - Vapor cloud fires

- Explosion hazards
  - Confined vapor cloud explosions
  - Unconfined vapor cloud explosions (UVCE)
  - Boiling liquid expanding vapor explosions (BLEVE)

There are other hazards that require identification and consideration. However it is noted here that they can be of different degrees of concern for LNG and NGL and, in any case, are of less concern than the fire and explosion hazards because, with caveats noted in the specific descriptions that follow, these hazards would not be expected to extend offsite and therefore would not directly affect the public:

- Toxicity hazard
- Cryogenic ("cold" burn) hazard
- Rapid phase transition (flameless explosion) hazard

These last three hazards will be described briefly, for completeness, and then relegated to secondary importance in order to prioritize the main concerns for public safety.

2.2.1 Toxicity Hazards

LNG is natural gas that has been cooled to its condensation temperature; its composition can vary significantly depending upon the source of the gas. However, LNG normally contains as its principal component methane, with heavier hydrocarbons such as ethane, propane, butane, etc., comprising the much smaller remainder.

For purposes of assessing the hazards of LNG, it is appropriate to consider the toxicity of LNG vapor to be that of methane, the principal component, with modification as deemed necessary to allow for consideration of the toxicity of the heavier components which may be present.

Since methane is not a toxic material, it normally poses a hazard only if breathed in sufficient quantity to displace necessary quantities of oxygen (asphyxiation). Consequently methane is not expected to pose a toxicity hazard to the public at the proposed terminal since the public would not be expected to be exposed to high enough concentrations to result in severe displacement of oxygen. Furthermore, the toxicity of the heavier components contained in the LNG, which for our purposes here also can be considered to be simple asphyxiants, is not expected to pose a hazard to the public because of the low concentrations to which the public would be exposed.

Similarly to LNG, which usually contains small amounts of NGL, the components of NGL (ethane and propane are suggested to be the primary natural gas liquids to be stored at the Long Beach Terminal) are not expected to pose a primary hazard to the public, since concentrations of these gases sufficient to asphyxiate people would not be expected to extend off site except in the most extreme conditions, and in such cases the fire and explosion hazards pose much greater hazards.

2.2.2 Cryogenic ("Cold Burn") Hazards

LNG, as pure methane, has a temperature of approximately -260 F. It is a cryogenic liquid, and exposure of human tissue to such temperatures can cause immediate severe injury. The author investigated an accidental release of LNG that occurred in 1977 in Arzew, Algeria, where a man was killed as a result of being deluged with LNG from a ruptured cryogenic valve. However, injury to the public is not expected to occur by exposure to such extreme temperatures because the region near a release of LNG where contact with either the liquid or cold vapor could cause such "cold" burns would not be expected to extend to distances where the public could be exposed.

Natural gas liquids such as ethane and propane, unlike methane, can be liquefied by pressure alone. Consequently, NGL can be stored either under pressure, refrigerated, or in combination. However, since refrigerated NGL is at a much higher temperature than LNG, and since low gas temperatures that could result due to depressurization of (pressurized) NGL would not be expected to extend to distances where the public could be exposed, NGL is not expected to pose "cold burn" hazards to the public at the POLB.

2.2.3 Rapid Phase Transition (Flameless Explosion) Hazards

If a small volume of LNG is rapidly poured into water, the LNG can be heated by the water to temperatures greater than its normal boiling point while remaining in the liquid state. The (liquid) LNG is then said to be *superheated*. If several degrees of superheat are achieved, the evaporation (boiling) process which follows can be essentially instantaneous, with the result that significant pressure increases (overpressures) can result. Such overpressures can cause damage similar to the overpressures caused by more *conventional explosions* which are normally associated with rapid combustion of a chemical or fuel.

The rapid phase transition (RPT) of LNG added to water was first observed, unexpectedly, in a laboratory experiment performed in the Sixties at the U. S. Bureau of Mines. Subsequent research into the phenomenon has been performed by several organizations, most prominently by inhouse industry research programs. All of the work of which I am aware is relatively small scale, but there have been calls for additional research to better determine the scaling characteristics of rapid phase transitions.

As in the case of cryogenic (cold burn) hazards, the damaging overpressures that could occur from rapid phase transitions would be local, and the resulting overpressures are not expected to extend to distances which could endanger the public.

However, there is continuing interest in, and a need for, further research to study the scaling characteristics of RPT's. Although dangers to the public are not expected to result directly from RPT overpressures, their importance in the public safety context lies in the potential for RPT's to cause secondary damage which could lead to cascading failures and further releases of LNG.

The author is not aware of damaging rapid phase transitions having occurred for spills of NGL onto water, although the NGL content of LNG, which is much colder, appears to have some relation to RPT occurrence (as it does as well to UVCE occurrence, as we will see). In any case, as large spills onto water at the POLB terminal are expected primarily from the LNG carrier, and since impoundment areas are expected to be provided for any NGL storage tanks, large spills onto water of NGL at the terminal are not expected.

2.2.4 Fire Hazards

There are two ways that very large fires (that could endanger the public) can result from a major LNG spill – pool fires and vapor cloud fires.

Pool Fires on Land

Spilled LNG will evaporate rapidly due to high rates of heat transfer from the warm surroundings (primarily the earth's surface) to the cold liquid. The vapor evolving from the liquid pool will mix with air to form a gas-air mixture which will burn in the concentration range of approximately 5% to 15% LNG vapor (the concentration range that is flammable for methane-air mixtures). Such mixtures of LNG vapor and air will inevitably form when LNG is spilled, and if an ignition source such as an open flame or spark is present at a location where the gas mixture is within the flammable range a large pool fire will result. In this instance the fire will immediately burn through the gas mixture from the point of ignition to the liquid pool. The resulting "pool fire" is similar in many ways to any other pool fire where liquid hydrocarbons, such as gasoline, are burning – but it should be noted that because the LNG is so cold, heat transferred from the surroundings will cause the LNG to evaporate much faster, thus effectively "feeding" the fire at much higher rates than would occur from a gasoline spill, and even faster than would occur for a refrigerated NGL spill (because the NGL is not nearly as cold). In any case, the fire results from the combustion of the fuel vapors which have evaporated from the liquid pool and have been mixed with air to result in flammable concentrations. An LNG pool fire, which has the potential to burn significantly "faster" than higher boiling point hydrocarbons, can seriously endanger the public, either through direct contact with the fire, or through heat radiated by the fire.

It should be noted here that it is in this context that the statement that “LNG does not burn”, or variations thereon, is frequently found in the literature purporting to educate the public regarding LNG safety. While the statement is literally true, it is not helpful, and it can be seriously misleading, as the statement is also (literally) true if applied to any other liquid hydrocarbon fuel such as gasoline or NGL. It can be misleading because the statement that LNG does not burn could imply that there is something different in the combustion mechanism of LNG from other hydrocarbon fuels – in this sense, there is not.

Because very large releases of LNG, attended as they would likely be by violent circumstances which could result in ignition (thus preventing the formation of a flammable vapor cloud that could leave the site), I believe that the potential danger to the public from LNG spills is probably greatest from the very large pool fires that would more likely occur. I emphasize that I am talking about fires resulting from the spillage of several millions of gallons of LNG (each of the two primary storage tanks at the POLB terminal will contain more than 40,000,000 gallons of LNG). We have no experience with such fires, but we do know that they could not be extinguished and would just have to burn themselves out, and the radiant heat extending outward from the fires edge could ignite combustible materials as well as cause serious burns to people at considerable distances from the fire’s edge. The distances from such fires to which harm to the public could extend will be a primary focus of this report.

NGL pool fires on land may be considered similarly with LNG pool fires, with at least two potentially important differences, the implications of which are not completely understood, especially for very large fires:

- NGL, whether it be pressurized or refrigerated, will not evaporate as fast as LNG will due to heat transfer from the ground surface, hence the burning rate (and associated heat flux from the fire) may be somewhat smaller.

- NGL fires have been observed to produce more smoke than LNG fires, with the result that the heat flux radiated out from the fires edge can be significantly changed.

<u>Vapor Cloud Fires</u>

If LNG is spilled and evaporates to form a gas/air mixture in which there are located no sources of ignition (an ignition source is a high temperature “point” source of energy such as a spark or flame), the gas-air mixture (“gas cloud”) which forms, although possibly containing a large amount of gas that is in the flammable concentration range, will not ignite, and the cloud will drift until it either contacts an ignition source or all of the cloud becomes diluted below its *lower flammable limit* (approximately 5% methane in air) - it will then disperse harmlessly. If ignition occurs during the drifting of the cloud the result is a vapor cloud fire.

If the gas cloud formed is not ignited immediately it will be carried downwind, or will spread more or less radially (due to gravity forces on the heavier-than-air gas mixture) in the absence of wind. Both spreading by the wind and gravity spreading are accompanied by gas-air mixing and thus dilution of the cloud.[2]

If, however, an ignition source is encountered at a location where the gas concentration is within the flammable concentration range, ignition will occur (at that location) and the fire will spread throughout the part of the cloud which is in the flammable concentration range. This is the so-called "flash fire" or vapor cloud fire. An LNG vapor cloud fire can endanger the public, either through direct contact with the fire, or through radiated heat from the burning cloud.

I think it important to state here again that my opinion that pool fires pose a greater risk than vapor cloud fires (see above) is based on the potential for high consequences *accompanied by the high probability that ignition will occur* as a result of the violent circumstances that would be expected to effect such a release. However, as I have said above, the consequences of credible events that might occur that could impact public safety require determination *independently* of consideration of the likelihood of the occurrence. Finally, I note here that the current federal regulations for siting LNG facilities require the determination of vapor cloud dispersion exclusion zones to protect the public safety, and no consideration is given to ignition probability in the determination of those exclusion zones. Therefore, it remains critically important to

[2] Photograph of an LNG spill onto water at Maplin Sands, UK, in the Eighties. The LNG spill volume was of order 10,000 gallons, with a moderate wind from top right to bottom left. White objects are floating instrument platforms. For scaling, radius of circle (dike) is approximately 450 feet. This spill volume is representative of the largest LNG spills that have been conducted on water to study vapor dispersion.

determine the potential consequences of delayed ignition of large flammable vapor clouds.[3]

[3] Sequence of photographs (top to bottom) showing an LNG vapor cloud fire over water – tests conducted at Maplin Sands, UK, in the Eighties. Wind is from right to left with maximum visible cloud extent at the left of the top picture. Ignition occurred near the left side of the gap in the cloud in the top photograph, and the cloud has burned nearly back to the liquid pool in the bottom photograph. Spill volumes are similar to the photograph in footnote 1, and the diameter of the circular dike is approximately 900 feet.

Vapor cloud fires that would result if an NGL vapor cloud were ignited may be also considered similarly to LNG fires, with at least three potentially important differences:

- The flammability range for NGL is significantly different than for methane, the principal component of LNG. Most importantly here, the lower flammable limit for NGL is lower than that for LNG; for ethane it is about 3%, and for propane it is just over 2%. This is significant because it means that NGL vapor clouds will remain flammable at lower concentrations, and therefore will have the potential to remain flammable for greater distances (than for an equivalent volume of methane vapor). As a result, the extent of potential danger to the public is increased.

- NGL vapors may be heavier than air because of their higher molecular weights. For example, propane's molecular weight is 44, causing its density to be about 50% greater than air at the same temperature and pressure. This is important because the density stratification in such a vapor cloud decreases the dispersion rate (by decreased mixing with air) and can result in increased downwind travel before the gas cloud concentration falls below the lower flammable limit, thus increasing the extent of potential danger to the public.

- As will be discussed in more detail below, NGL vapor clouds are known to be susceptible to high-order explosion if ignited, even in the absence of confinement. Therefore, the improbability of explosion due to absence of confinement, a factor which is considered highly important in the assessment of LNG safety, does not apply to NGL vapor clouds. As there have been several catastrophic explosions of NGL vapor clouds, this hazard will be considered prominently in this report.

2.2.5 Confined Vapor Cloud Explosion Hazards

There is no need here to further define the potential for explosions of confined LNG or NGL vapor/air mixtures, of which we are all aware. However, the potential for explosions of confined LNG or NGL vapors are important to this hazard assessment because they have the potential for release of energy and ejection of projectiles that could jeopardize other NGL or LNG containments.

2.2.6 Unconfined Vapor Cloud Explosion (UVCE) Hazards

The term explosion is used here to describe combustion reactions (that we normally call "burning", i.e., reaction of the gas in question with the oxygen in the air) which achieve such rapid rates that significant overpressures (local pressures higher than the atmospheric pressure) develop. Such overpressures can cause severe damage – they constitute the "blast" effect in conventional explosions.

The forces released in conventional explosive materials (such as dynamite) typically result from very rapid *reactions of materials that are totally contained in the explosive* *material*. In such materials both the "fuel" and the "oxidizer" are already present. In contrast, explosions of fuel gases such as methane or propane cannot occur unless the gas (fuel) is mixed with air (containing oxygen) such that the mixture has a concentration within the flammable range (for methane this is approximately 5% to 15% in air). Such *physical* processes (as mixing with air), which are necessary for the gas to burn (or explode), place gas/air fires and explosions in a lower hazard class than materials like dynamite, which are "ready to go" if ignited, i.e., without the necessity that the material first be mixed with anything else. Furthermore, if the methane concentration is less than 5% (the *lower flammable limit*) concentration, the mixture will not burn, much less explode – it is said to be too *lean*. Similarly, if the methane concentration is higher than 15% (*the upper flammable limit*) concentration, the mixture will not burn (or explode) – it is said to be too *rich*.

If a methane/air mixture within the flammable concentration range is ignited, the rate of reaction (the burning rate, i.e., how fast the flame moves through the gas mixture) varies depending on a number of factors, one of the most important of which is *confinement.* We all know that natural gas (normally principally composed of methane) explodes all of the time – *when it is confined*. We all have read about, and many have experienced, the blast effect that occurs when leaking (flammable) gas is released into a confined volume (say the kitchen) and its ignition (say by a light switch) blows the building apart.

Conventional wisdom, even scientific opinion, held until fairly recently (the Seventies) that unconfined gas/air clouds such as are formed by gases such as methane, propane, and the higher molecular weight hydrocarbon, will not explode if unconfined. This is important to the present discussion because it goes straight to the question of whether the cloud formed by LNG vapors mixing with air following a major LNG spill could explode (develop damaging overpressures) when the cloud is not confined.

Today, damaging explosions of hydrocarbon gas/air mixtures are of very great concern because of accidents which have demonstrated the propensity of some hydrocarbon gases, when mixed to the correct proportions with air, to explode with devastating damage, *even when unconfined*. There is not time or space here to provide the details, but it can be stated that at least three such unconfined vapor cloud explosions (UVCEs) that occurred at Flixborough, England, in 1974; Mexico City in 1984; and in Pasadena, Texas, in 1989, were so devastating that they resulted in extensive changes in the national and international regulatory requirements for dealing with chemical hazards.

What does this have to do with LNG? There is a scientific consensus (supported by experimental data) that methane/air mixtures which are unconfined are very unlikely to explode. The LNG industry and the Government are sufficiently confident of this fact that the explosion of an unconfined LNG vapor/air cloud is not considered credible. As a result, the most severe hazard is considered to be fire. I have studied this question, and I agree with the contention that unconfined methane/air mixtures are very unlikely (but not impossible) to explode.

But the story doesn't end there. It has already been stated that the composition of LNG imported into the United States varies significantly depending on several factors, most prominently the gas source location. LNG is imported from some locations that provide nearly pure methane. LNG is also imported from some other locations with concentrations of heavier hydrocarbons as high as 15-20%. Such gas is termed "hot gas" in the industry because its calorific value (energy content) is higher than an equivalent volume of methane. Typical heavy hydrocarbon gases present in LNG are ethane and propane, but others are present as well.

We know now that even unconfined vapor cloud explosions (UVCEs) cannot be dismissed for LNG spills if the gas contains significant amounts (say greater than about 12 to 18%, based on Coast Guard sponsored tests at China Lake in the Eighties) of gas components heavier than methane. Furthermore, enrichment in higher boiling point components of the liquid remaining as the LNG vaporizes can lead to vapor cloud concentrations that could pose a UVCE hazard, even if the concentration of the heavies in the liquid initially spilled do not. Since the LNG terminal proposed to be located in the POLB is planned to receive "hot gas"[4], and to engage in the storage and distribution of natural gas liquids (NGL) that are separated from the imported LNG, *questions of whether major releases of LNG at the terminal might pose an unconfined vapor cloud explosion hazard, with the attendant potential to initiate further cascading effects, remain highly relevant.*

There is now no question that GNL vapor clouds can explode with devastating force. Consequently, as the POLB terminal will have some, perhaps yet to be determined, quantities of GNL on the site (primarily ethane and propane), the potential for releases at the terminal to result in high order vapor cloud explosions must be given primary consideration in the assessment of potential hazards to the public and surrounding infrastructure.

Although there are numerous examples of unconfined vapor cloud explosions that have occurred in the chemical manufacturing, storage, and transportation sectors, it is not necessary, nor is there time here, to give a complete list of occurrences. Two events which appear to be highly relevant to this POLB hazard assessment will be highlighted here:

- A fire and explosion occurred in 2004 at the LNG export terminal in Skikda, Algeria. Preliminary reports indicate that damaging unconfined vapor cloud explosions appear to have occurred. If so, this would be the first UVCE which has been reported in an LNG terminal (to the author's knowledge). Final reports have not been released, so there is admittedly some speculation involved here. That said, it appears to the author that damaging explosions did occur both in confined spaces and in unconfined spaces in the export terminal at Skikda. It is important to point out that since the releases are believed to have occurred in parts

[4] The author is aware of consideration being given to changing the specifications of the LNG that would be accepted by the proposed terminal. As stated earlier, this report has been prepared based on the descriptions made available from the SES Resource Report dated January 2004.

of the facility which would not have been handling LNG, but rather natural gas liquids, that the unconfined vapor cloud explosions experienced probably involved NGL. Nevertheless, particularly since the POLB will handle similar natural gas liquids, the recent experience in Algeria is highly relevant.

- The disaster which occurred on November 19, 1984, in San Juan Ixhuatepec (Mexico City), Mexico, is directly relevant to the consideration of the POLB LNG terminal, because the Mexico City facility provided for storage of quantities of NGL which are very similar to the quantities that could be stored at the NGL component of the POLB terminal. The Mexico City terminal, built for the distribution of LPG which came by pipeline from distant refineries, had an overall storage capacity of approximately 4,200,000 gallons of LPG in 6 large spherical tanks and 48 horizontal cylindrical tanks. The catastrophe started with the rupture, due to pumping overpressure, of an eight inch transfer line. The LPG thus released caught fire, causing fire impingement on one of the spherical tanks. The resulting cascading failure involved multiple unconfined vapor cloud explosions (UCVEs) accompanying the large fires which occurred. 574 people are reported to have been killed and more than 7,000 injured, of whom 144 later died in the hospital. Some 39,000 people were rendered homeless or were evacuated, and the terminal was destroyed.

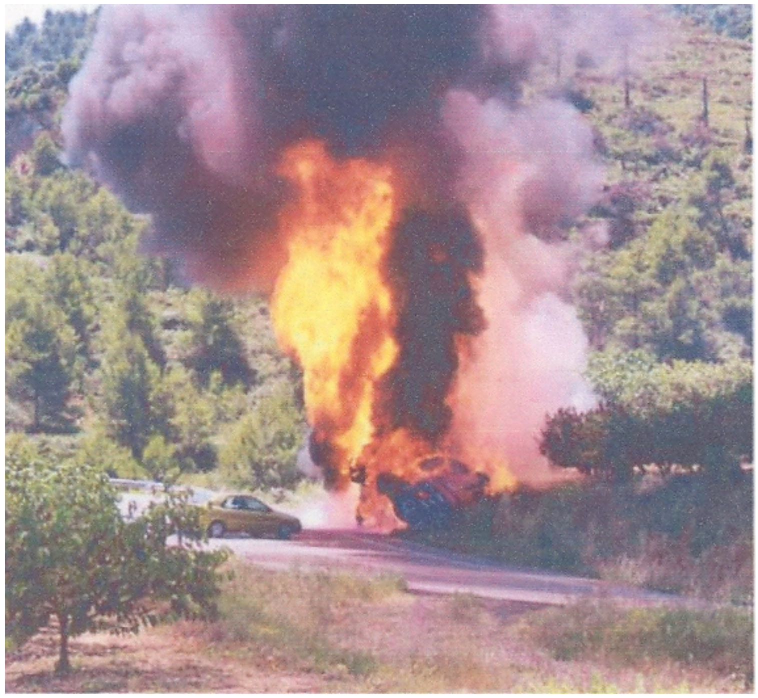
2.2.7 Boiling Liquid Expanding Vapor Explosion (BLEVE) Hazards

The acronym BLEVE is short for "Boiling Liquid Expanding Vapor Explosion". There have been a large number of devastating BLEVEs in the chemical process industry and in the transportation sector, including railroad and highway truck incidents. BLEVEs occur when a pressure vessel containing a flammable liquid is exposed to fire so that the metal comprising the containment loses strength and ruptures. When a vessel containing liquid under pressure is exposed to fire, the liquid heats up and the vapor pressure rises, increasing the pressure in the vessel. When this pressure reaches the set pressure of the pressure relief valve (PRV), the valve opens to relieve the pressure. The liquid level in the vessel falls as the vapor is released to the atmosphere. While the liquid is effective in cooling that part of the vessel wall which is in contact with it, those parts of the wall (above the liquid) that are exposed to vapor are not as effectively cooled. After a time, as metal which is not cooled by liquid is exposed to fire, the metal becomes hot and weakens and is subject to rupture. It is important to note that rupture can occur even though the pressure relief valve is operating correctly as designed. This is because a pressure vessel is designed to withstand the relief valve set pressure, but only at the design temperature conditions. If the metal is heated to higher temperature, it may lose strength sufficiently to rupture. Further, and most importantly to the consideration of the failure of LNG tanks to fire exposure, the pressure relief valves must be sized to allow relief of the vapor produced with fire exposure to the tank. I will return to this question when the vulnerability of LNG containments is considered.

Just as the conventional wisdom before about 1970 minimized the potential for explosion of unconfined LNG vapor clouds, that wisdom has also held that boiling liquid expanding vapor explosions of LNG containments are not possible. It appears that the conventional wisdom may have to be updated for BLEVEs of LNG as well.

An LNG road tanker exploded on 22 June 2002 near Tivissa, Catalonia (Spain), after the driver lost control on a downhill section of the C-44 road.[5] The tanker turned over, tipping onto its left side. Witnesses said that flames[6] appeared immediately between the cabin and the trailer, and after approximately 20 minutes, the tank exploded. There was a small explosion, then a strong hiss and then a much larger explosion. Immediately after the small explosion, the fire disappeared and a white cloud appeared. This cloud ignited immediately, giving rise to the larger explosion, a fireball. Assuming that all of the mass initially contained in the tank was involved in the fireball, approximately 12,700 gallons of LNG would have burned. Accepted mathematical modeling techniques suggest that the fireball diameter would have been about 500 feet, the height about 370 feet, and the duration approximately 12 seconds. These model predictions appear to be consistent with the facts that the fireball resulted in serious burns to two persons at a distance of 650 feet from the tanker. Major parts of the truck were projected to significant distances. The rear part of the tank, including the rear undercarriage of the truck, was ejected to a distance of 260 feet. A section of the front of the truck with maximum dimension of approximately 12 feet was projected more than 400 feet, and the motor and cabin covered a distance of more than 840 feet from the explosion.

[5] Planas-Cuchi, E., et.al, "Explosion of a road tanker containing liquefied natural gas", Journal of Loss Prevention in the Process Industries, 17 (2004), pp 315-321.
[6] The photograph shows the jet fire from the tanker 2 minutes after the accident and approximately 18 min before the BLEVE. The author is not aware of any photographs of the fireball (but see footnote 7).



This LNG truck accident has been described in some detail because its occurrence suggests, if not demands, that renewed consideration be given to the potential for BLEVEs of LNG containers to occur. Perhaps most importantly, the road tanker was insulated with polyurethane insulation, and the early failure of the insulation would be expected to allow the container to more quickly reach temperatures giving rise to failure as well as allow heat transfer to the cargo which would significantly elevate the pressure in the tank beyond the ability of the PRV to relieve the greatly increased LNG vaporization. It is this mechanism, failure of the insulation followed by overpressure of the tank leading to rupture, which may have been exemplified in the Spanish road tanker explosion, that I have appealed to the Department of Homeland Security to consider as being applicable to LNG ships whose containers are insulated with foamed plastic insulation materials such as polystyrene and polyurethane[7].

There have been repeated incidents of BLEVEs of truck and rail containers of NGL, many having occurred in the Seventies and Eighties before the mechanism of the occurrence was understood. And, as was stated earlier, there have been devastating occurrences of BLEVEs in industrial storage and distribution facilities, perhaps most appropriately exemplified here by the disaster of November 19, 1984, in San Juan Ixhuatepec (Mexico City), Mexico. The Mexico City disaster is particularly relevant to the present considerations because the quantity of NGL stored in the Mexico City facility was similar to the quantity that could be stored in the POLB LNG terminal. Although the catastrophe started with the rupture of an eight inch transfer line, the first subsequent

[7] On July 5, 1973, in Kingman, AZ, a rail car containing approximately 10,000 gallons of propane began leaking during unloading, and the gas ignited. About a half hour later the tank BLEVE'd. The diameter of the fireball was approximately 400 feet, similar, if somewhat smaller, than the size predicted for the LNG BLEVE described in footnote 6. Note telephone poles for scaling and the railcar end being projected.

major failure is thought to have been a BLEVE of one of the NGL storage spheres, and the subsequent cascading failures involved multiple large BLEVEs.

2.2.8 Special Hazards of LNG and NGL Spills on Water

There are special hazards of spills of LNG or NGL that could result from spills of either material on water, because, in addition to the (lesser) hazards of rapid phase transitions that could result from LNG spills considered earlier, it would be impracticable, if not impossible, to contain the spread of either of these liquid fuels on water. Consequently, there would be nothing to limit the size of the liquid pool that would result except the limiting amount of material spilled and the physical constraints which would limit its spread on the water. Since the size of the liquid fuel pool would determine the size (areal extent) of the fire, large spills on water could easily result in fires much larger than those which would be contained in the purpose-designed spill impoundment areas on land.[8]

[8] The photograph illustrates an LNG pool fire on water. Somewhat less than 10,000 gallons of LNG was spilled; the resulting fire is about 50 feet in diameter and 250 feet high. This test, conducted by the U.S. Coast Guard at China Lake, CA, in the Eighties, is also representative of the largest LNG pool fires that have been studied.

Exhibit PUC-3

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As will be described and justified in more detail subsequently in this report, there is now scientific consensus that rapid spillage of at least one half of a typical single LNG ship container, approximately 3,000,000 gallons, is a “credible event”, as it has been determined that it could be caused by an intentional (terrorist) act with means that are readily available to such groups. The fire from such a spill, particularly if it occurred onto water and was therefore uncontained, would be very large, perhaps up to a half-mile in diameter, or larger if more of the containment system failed. We have no experience with such fires, but we do know that they could not be extinguished and would just have to burn themselves out, and the radiant heat extending outward from the fires edge could ignite combustible materials as well as cause serious burns to people at substantial distances from the fire’s edge. The distances from such fires to which harm to the public, as well as damage to infrastructure, could extend will be a primary focus of this report.

Furthermore, although it is considered highly likely (but we do not know enough to say impossible) that early, if not immediate, ignition of the gas air mixtures above such a spill would occur as a result of the violent circumstances (as in an allision or collision of a ship or a terrorist attack) that would be expected to accompany such a major release, it is imperative that the extents of flammable vapor cloud travel that might result from major spills of LNG onto water (which are most likely to occur from the ship) be considered in the assessment of hazards that could result at the POLB LNG terminal.

CHAPTER 3

ADEQUACY OF CURRENT REGULATIONS TO PROVIDE FOR PUBLIC SAFETY

This part of my report gives my answer to the question: *To what extent do present U.S. regulations that govern LNG terminal siting adequately protect the public from the consequences of LNG releases that could occur?*

Although U.S. Regulations currently require enforcement of <u>some</u> safety exclusion zones intended for the protection of the public (by prohibiting their presence therein), I believe they fall seriously short of achieving the intended objective:

- The regulations were promulgated in the early Eighties largely as a result of concerns for public safety that arose in the Seventies. Since there was no rush to build additional LNG import terminals until about the year 2000, the regulations were largely unused for import terminal siting. As a result, the regulations did not, and still do not, give serious consideration to the terrorist threat that began in this country September 11, 2001. Instead, the regulation method and approach relied on, and still relies on, consideration only of accidental occurrences that could affect the public. Hence, the current regulations do not effectively address the many serious questions posed by the present requirement to consider events that could be caused by malicious intent. Nor is sufficient attention being paid to the reality that malicious intent changes the whole safety picture. We no longer have the option to just “better” manage the risks involved so as to reduce the probability of occurrence of accidents to an acceptable level. The siting in an urban area of an LNG terminal, with its requirements to concentrate immense quantities of hazardous materials, takes on a new dimension. Unfortunately, the process has outrun the development of the regulations to deal with it, and the present regulations fail to address this most important new paradigm.

- Perhaps most importantly, in consideration of the post 9/11 threat, there is presently no requirement, much less enforcement, of exclusion zones to protect the public from LNG spills which could occur from the ships that serve the import terminal. The failure to provide for the protection of the public and surrounding infrastructure from major releases of LNG that could occur from the ships serving the facility must be considered all the more important now as a result of recent government sponsored reports, for which there is now scientific consensus, that indicate that the danger zones extending from large, but credible, spills on water are likely to pose greater threats than would either accidental or terrorist caused releases from the land part of the terminal.

3.1 49 CFR 193 LNG Terminal Siting Provisions for Public Safety

The regulation that specifies requirements for siting LNG import terminals in the United States is 49 CFR 193, entitled *Liquefied natural gas facilities: Federal standards*.

Part 193 -- *Liquefied natural gas facilities: Federal standards* contains numerous sections describing requirements designed to provide for safe operation of an LNG import terminal. However, most of these sections are directed to the attainment of safe operation of the plant, and therefore they do not directly address the public safety issue. There are two sections of the regulation that directly address requirements to provide for safety of the public (offsite):

193.2057 *Thermal Radiation Protection,*

and

193.2059 *Flammable vapor dispersion protection*.

It is noted that the three other LNG hazards described earlier; toxicity, cryogenic ("cold burn"), and rapid phase transition, are not addressed, as these three potential hazards are not expected to affect the public offsite. Explosion hazards (not covered by the regulation) will be considered herein.

Before proceeding to the description of Sections 193.2057 and 193.2059, and to the question of their adequacy to provide protection to the public, I believe it will be helpful to briefly summarize the development of these two sections of the regulation.

During the Seventies, when the four presently operating LNG facilities were constructed in the United States, 49 CFR 193 had not yet been promulgated. The applications for certification of the terminals that were built in Everett, Massachusetts; Cove Point, Maryland; Elba Island, Georgia; and Lake Charles, Louisiana, were decided largely based on guidance contained in industry consensus standards, notably NFPA (National Fire Protection Agency) 59A – *Standard for the Production, Storage, and Handling of Liquefied Natural Gas (LNG)*.

However, as a result of public concerns that arose during the Seventies about LNG terminal siting safety issues, notably those that arose in California regarding the proposals to site terminals at Los Angeles, Oxnard, and Point Conception, Congress mandated a research program on LNG safety, and authorized an expenditure of approximately $40,000,000 (in 1977 dollars) on LNG safety studies. That research program carried out basic LNG safety research directed to development of methods to define more accurately and realistically the consequences that could result from major spills of LNG. The research effort was directed to three hazards which were considered highest priority;

- liquid pool fires,
- vapor cloud fires, and
- vapor cloud explosions.

Following completion of these research programs, which still constitute much if not most of the research results and data relating to LNG spill consequences that are available in the public domain, 49 CFR 193 was promulgated - in the early Eighties.

I was called upon from time to time for advice by persons in the U.S. Department of Transportation who were preparing the draft regulations that evolved into 49 CFR 193, primarily in the area of my principal expertise, LNG vapor dispersion. My association (with DOT, at that time) was with Mr. Walter Dennis. Walter Dennis was actively involved in the drafting of the sections of 49 CFR 193 identified above (Sections 2057 and 2059), and I had several conversations with him regarding these sections of the regulation, particularly regarding the selection and application of methods for determining vapor dispersion distances. I believe that Walter Dennis was the person primarily responsible for developing Sections 193.2057 and 2059. This is important to the present discussion because Mr. Dennis subsequently advised industry (at their request) regarding the methods to be followed in the determination of exclusion zones required by the regulation. Walter Dennis died (in the late Eighties, I believe) when interest in LNG importation was languishing. I believe that his advice regarding the determination of vapor cloud exclusion zones has been used improperly so as to downplay the severity of the hazards which the regulation is designed to protect against.

(At least partly) as a result, there remains confusion even today about the correct determination of vapor cloud dispersion exclusion zones for spills of LNG which could occur into impoundments on the land terminal. I have prepared reports for the City of Fall River, MA, and I have filed testimony with FERC as well, which describe errors that I believe were made in the preparation of the Draft Environmental Impact Statement for the Weaver's Cove Project proposed to be sited in the Taunton River at Fall River.

With that background, I return to consideration of 49 CFR 193. When 49 CFR 193 was promulgated in the Eighties, it provided for the determination of *exclusions zones* for *vapor dispersion* and *thermal radiation*. The term *exclusion zone* is defined in the current regulation:

"Exclusion zone means an area surrounding an LNG facility in which an operator or government agency legally controls all activities in accordance with Sec. 193.2057 and Sec. 193.2059 for as long as the facility is in operation."

This definition is critically important because it follows that the intent of the regulation is that the *consequences* of vapor cloud dispersion and fire radiation scenarios must be specified by determination of the distances to which each of these hazards would extend from the spill, and once those distances are determined, the resulting exclusion zones must be controlled by the owner of the facility or the government. Thus the regulation provides for the prevention of members of the public from occupying the areas included by the exclusion zones, and therefore prevents them from being exposed to the associated hazards. Importantly, no consideration is given to the probability of such hazards being realized (the regulation is *consequence* driven, i.e. it gives no consideration to the probability of the occurrence), it simply defines the extents of the *exclusion zones* which are enforced to ensure that the public is not exposed to danger. *As I have stated earlier, I believe that such a consequence driven requirement for the establishment of exclusion zones to protect the public is all the more appropriate today in view of the potential* *severity of the terrorist threat, for which historical accident experience, however good, provides little assurance to the public.*

It is noted here that there is no mention in 49 CFR 193 of explosions, either vapor cloud explosions (confined or unconfined) or boiling liquid expanding vapor explosions. I will return to this important omission later.

3.1.1 Exclusion Zones for LNG Pool Fires

Section 193.2057 of the Federal Standard is excerpted below.

Sec. 193.2057 Thermal radiation protection.

Each LNG container and LNG transfer system must have a thermal exclusion zone in accordance with section 2-2.3.1 of ANSI/NFPA 59A with the following exceptions:

(a) The thermal radiation distances shall be calculated using Gas Research Institute's (GRI) report GRI-89/0176, which is also available as the "LNGFIRE III" computer model produced by GRI. The use of other alternate models which take into account the same physical factors and have been validated by experimental test data shall be permitted subject to the Administrator's approval.

(b) In calculating exclusion distances, the wind speed producing the maximum exclusion distances shall be used except for wind speeds that occur less than 5 percent of the time based on recorded data for the area.

(c) In calculating exclusion distances, the ambient temperature and relative humidity that produce the maximum exclusion distances shall be used except for values that occur less than five percent of the time based on recorded data for the area.

Amdt. 193-17, 65 FR 10958, Mar. 1, 2000]

It is critically important to note here that the determination of exclusion zones for LNG pool fires requires specification of the criterion to be used to define the extent of the thermal flux hazard, i.e., a criteria for determining how far away from the fire must the public be to be protected. 49 CFR 193 presently requires that thermal exclusion zones be defined by the (mathematical model) prediction of the distance to which a person, at ground level, would be exposed to thermal radiation flux of 5 KW/m^2 (~1600 $Btu/hr/ft^2$). This thermal flux has been determined to have the potential to cause second degree burns to unprotected skin in approximately 30 seconds.

But, as I have previously testified to FERC, I believe that the criterion of a 5 KW/m^2 flux level merits further consideration, because exposure at this intensity to persons could result in serious burns within time periods which would not be sufficient for evacuation or escape. Further, although fire fighting personnel equipped with protective gear could work in such an environment for considerable time, they would not be able to provide evacuation or removal of unprotected persons in time to prevent injury. It is known that the flux level would have to be reduced to about 1.5 KW/m^2 before unprotected persons could be exposed continuously without thermal radiation injury. Consequently, I believe that serious consideration should be given to defining exclusion zones to protect the public from thermal radiation hazards using such a lower (~1.5 KW/m^2) thermal radiation flux criterion. However, whether or not DOT defines the exclusion zone using such a lower thermal radiation flux criterion, I believe that FERC should use the lower thermal flux criteria in order to protect the public from such very large fires. It is very important to recognize that a policy which prevents public presence only where there would be exposure to 5 KW/m^2 or greater is not consistent with the public interest, because the public could receive serious injuries at lower flux levels if exposed for longer time periods (including time periods that would still be insufficient to provide for sheltering or evacuation). That is why I have suggested that serious consideration of the lower value of 1.5 KW/m^2 as the "safety" criterion – as this value is widely recognized as being the highest value of thermal radiation exposure from which the public would not receive serious injury even if exposed for longer time periods."

For the determination of thermal radiation exclusion zones for the land side of the facility, the credible spill scenario must be defined for input to the LNGFIRE III model. The scenario then is defined by specifying the dimensions of the impoundment area that will contain the spill, and then specifying the rate and total amount of LNG that is spilled. Two types of spill scenarios are possible:

- Spillage from the LNG storage tank

and

- Spillage from a part of the piping system external to the storage tank.

Spillage from the LNG Storage tank

It is my understanding that the storage tank design proposed for the Long Beach Long Beach facility is a Total Containment design, which means essentially that the inner tank in contact with the LNG is surrounded by a prestressed concrete outer tank wall and covered with a similarly constructed roof. To my knowledge, no tanks of the this type have so far been constructed in the continental United States (the Penuelas, Puerto Rico, tank has a prestressed concrete outer tank, but I do not believe it has a concrete roof), but such tanks are currently being proposed for several other locations. It is my understanding that there remain some questions about the procedures to be followed for such installations, even questions relating to the lack of "definitions" for the various tank systems that are being considered. Nevertheless, 49 CFR 193 appears to have been interpreted by DOT, at least in the case of the DEIS and EIS's prepared for the Weaver's Cove terminal in Fall River, MA, in such a manner that the regulation does not require consideration of LNG spills that would penetrate the outer containment wall. It is my understanding, based on DEIS's that have been produced for terminals with similar tank design proposals, that the thermal radiation zones for fires associated with spills from the inner tank are (therefore) to be determined by assuming that the spilled LNG would be *contained* by the concrete outer wall. As a result, the fire scenario envisioned is an elevated, or "tank-top", fire with the diameter (size) of the fire determined by the diameter of the outer concrete tank. For such determinations, I believe that application of the prescribed method (LNGFIRE III) is adequate.

However, there remains a question about the validity of the assumption that failure of the outer concrete wall is incredible. Although I agree that such a failure due to accident would seem to be extremely remote, I cannot agree that such an event is impossible for a terrorist to achieve – witness our tragic experience on 9/11 when two large airliners were highjacked and flown into the World Trade Towers with devastating results. To my knowledge no analyses have been made available to the public which address the possibility of complete failure of a "total containment" LNG storage tank. I will return to the consideration of "worst case" events after consideration of the current requirements for determination of exclusion zones.

Spillage from the Piping System

Here, also, the regulations prescribe detail that cannot be adequately described here. However, it is my understanding that the intent of the regulation is to prescribe the credible spill events (for determination of exclusion zones) by identifying the portions of the pipeline systems that carry LNG at the largest rates in the facility, and then to assume a guillotine break in said line with flow at the maximum rate maintained for a period of ten minutes. It appears that negotiations with DOT in the past have in some cases resulted in approval of procedures which will ensure limiting the duration of flow (by automatic shut-off systems) to shorter periods, but I assume here the requirement for a ten-minute spill duration.

In either case, LNGFIRE III application is straightforward, since the fire size is prescribed by the outer boundary of the area (impoundment) into which the spill occurs. In summary, I believe the application of LNGFIRE III, to LNG pool fires contained in liquid impoundment areas, adequately describes the thermal radiation hazard for the purpose of determining exclusion zones to protect the public.

3.1.2 Exclusion Zones for Vapor Cloud Dispersion

Section 193.2059 of the Federal Standard is excerpted below.

Sec. 193.2059 Flammable vapor-gas dispersion protection.

Each LNG container and LNG transfer system must have a dispersion exclusion zone in accordance with section 2-2.3.2 of ANSI/NFPA 59A with the following exceptions:

(a) Flammable vapor-gas dispersion distances must be determined in accordance with the model described in the Gas Research Institute report GRI-89/0242, ``LNG Vapor Dispersion Prediction with the DEGADIS Dense Gas Dispersion Model." Alternatively, in order to account for additional cloud dilution which may be caused by the complex flow patterns induced by tank and dike structure, dispersion distances may be calculated in accordance with the model described in the Gas Research Institute report GRI 96/0396.5, ``Evaluation of Mitigation Methods for Accidental LNG Releases. Volume 5: Using FEM3A for LNG Accident Consequence Analyses". The use of alternate models which take into account the same physical factors and have been validated by experimental test data shall be permitted, subject to the Administrator's approval.

(b) The following dispersion parameters must be used in computing dispersion distances:

(1) Average gas concentration in air = 2.5 percent.[9]

(2) Dispersion conditions are a combination of those which result in longer predicted downwind dispersion distances than other weather conditions at the site at least 90 percent of the time, based on figures maintained by National Weather Service of the U.S. Department of Commerce, or as an alternative where the model used gives longer distances at lower wind speeds, Atmospheric Stability (Pasquill Class) F, wind speed = 4.5 miles per hour (2.01 meters/sec) at reference height of 10 meters, relative humidity = 50.0 percent, and atmospheric temperature = average in the region.

(3) The elevation for contour (receptor) output H = 0.5 meters.

(4) A surface roughness factor of 0.03 meters shall be used. Higher values for the roughness factor may be used if it can be shown that the terrain both upwind and downwind of the vapor cloud has dense vegetation and that the vapor cloud height is more than ten times the height of the obstacles encountered by the vapor cloud.

(c) The design spill shall be determined in accordance with section 2-2.3.3 of ANSI/NFPA 59A.

[Amdt. 193-17, 65 FR 10959, Mar. 1, 2000]

Again, it is important to note that the DEGADIS and FEM3A model(s) for calculating the exclusion zones for vapor cloud dispersion are *prescribed*. The DEGADIS model was promulgated in the regulation in an amendment dated in the early Nineties, and the

[9]The 2.5 percent concentration represents one half the lower flammable limit concentration of methane (5%). This concentration level is intended to define the cloud average concentration at a point which would prevent the presence of flammable (greater than or equal to 5 %) "pockets" of gas which could be ignited. Hence this concentration level is used as the criterion for delineating the hazard distance.

(alternate) FEM3A model was promulgated in the regulation in the amendment dated Mar. 1, 2000. I am the co-author, with Dr. Tom Spicer, of the DEGADIS model, and Dr. Spicer and I directed the research program sponsored by GRI (since about 1985) to validate a computational fluid dynamics model (FEM3A was ultimately selected, based on consideration of several candidate models) for LNG vapor dispersion application. I support the use of the DEGADIS and FEM3A models. Based on my knowledge of the models and my review of the development of both, I believe that, together, they incorporate reasonably the latest information obtained in the federally sponsored large scale LNG field test programs conducted by the Coast Guard at China Lake, CA, and at the Liquefied Gaseous Fuels Spill Test Facility (LGFSTF) located near Mercury, Nevada, in the Seventies and Eighties, as well as the results of other research programs that have been conducted, principally in the Chemical Hazards Research Center Wind Tunnel at the University of Arkansas.

The DEGADIS model is limited to application to dispersion of vapor clouds (including LNG vapor clouds) resulting from spills onto a flat surface (ground or water) with dispersion over flat, obstacle-free terrain. FEM3A was developed in a followup effort (to DEGADIS) to provide a mathematical model applicable to the determination of the effects on dispersion of manmade obstacles (such as tanks, dikes, or process equipment and structures) and/or significant terrain features. I believe that these two models, correctly applied for the situations for which they are designed, are adequate tools for determining vapor cloud exclusion zones which will ensure public safety. And, similarly to the previous discussion on thermal radiation exclusion zones, I believe that the application of these models, *respecting the limitations of each*, is relatively straightforward for the determination of vapor cloud exclusion zones extending from spills bounded by containment structures (dikes and impoundments) on land.

It is clearly the intent of 49 CFR 193 that enforcement of a vapor cloud dispersion protection exclusion zone implies that the area included be controlled by the facility operator or an agency of the government. It is also clear that the intent of the regulation is to provide for the enforcement of vapor cloud dispersion protection zones as the method for ensuring the safety of the public, since such exclusion zones clearly prohibit the presence of the public therein.

For the determination of vapor cloud dispersion exclusion zones for the land side of the facility, the credible spill scenario must be defined for input to either the DEGADIS model or the FEM3A model. The scenario is defined by specifying the dimensions of the impoundment area that will contain the spill, and then specifying the rate and total amount of LNG that is spilled. Again, two types of spill scenarios are possible:

- Spillage from the LNG storage tank

and

- Spillage from a part of the piping system external to the storage tank.

Spillage from the LNG Storage tank

As stated before, it is my understanding that the storage tank design proposed for the Long Beach Long Beach facility is a Total Containment design, which means essentially that the inner tank in contact with the LNG is surrounded by a prestressed concrete outer tank wall.

Further, it is my understanding, based on DEIS's that have been produced for terminals with similar tank design proposals, that the vapor cloud dispersion exclusion zones associated with spills from the inner tank are to be determined by assuming that the spilled LNG would be *contained* by the concrete outer wall. As a result the vapor cloud dispersion scenario envisioned is an elevated, "tank-top" vapor release, with the diameter (size) of the release determined by the diameter of the outer concrete tank. For such determinations, I believe that application of the FEM3A method, although untested for such use, is appropriate. However, the DEGADIS model was designed for applications to *ground level* releases, and I cannot recommend it to describe the tank-top release scenario.

I do note that vapor releases from the top of the tank would be expected to pose significantly less hazard to the public than would equivalent releases at ground level, particularly if accompanied by high wind conditions.

However, as in the case of the determination of fire radiation exclusion zones, there remains a question about the validity of the assumption that failure of the outer concrete wall is incredible, as (to my knowledge) no analyses have been made available to the public which address the possibility of complete failure of a "total containment" LNG storage tank. I will return to the consideration of "worst case" events after consideration of the current requirements for determination of exclusion zones.

Spillage from the Piping System

Here, also, the regulations prescribe detail that cannot be adequately described here. However I believe that the intent of the regulation was, and remains, to prescribe the credible spill events (for determination of exclusion zones) by identifying the portions of the LNG transfer systems (pipes) that carry LNG at the largest rates in the facility, and then to assume a guillotine break in said (pipe)line with flow at the maximum rate maintained for a period of ten minutes. I do note here that DOT has considered, and approved, procedures which would ensure limiting the duration of flow (by automatic shut-off systems) to shorter periods, but here I assume the requirement for a ten-minute spill duration.

For such spillage into an impounded (or diked) area, the containment afforded limits the liquid (LNG) spreading that can occur, and therefore effectively determines the area extent of the source of vapor (evolving from the spilled LNG).

But, there remain questions even about the requirements for specification of the leak rates that have not been resolved. I have filed testimony with FERC which describes my complaints that the present specification of "accidental leakage rate" design spills by NFPA 59A (which has been incorporated in 49 CFR 193 since the year 2000, effectively replacing the previous requirement for 10 minute full flow spills from the largest transfer line in the facility), have the effect of reducing the requirement for consideration of these (larger spills) that were the intent of the regulation - with the final result that the downwind vapor hazard is downplayed. FERC has not even been consistent in this regard, since they have given approval for submissions from facility applicants that contained transfer line spills with volumes ranging from 28,900 gallons (3-inch line break) all the way to 812,000 gallons (guillotine rupture of ship unloading line).

But, however the spill rate and volume is determined, the vapor cloud dispersion protection exclusion zone determination is not as straightforward as that for the determination of the thermal radiation protection exclusion zone, because:

- DEGADIS was designed to predict dispersion from spills on a flat surface, with dispersion proceeding on a flat surface, *in the absence of significant terrain features or manmade structures that would obstruct the wind or gas cloud flow*. A dike (or the vertical walls of an impoundment) designed to contain the spilled LNG (liquid) causes "holdup" of the gas until the gas overflows the impounded volume. The DEGADIS model does not allow direct accounting for the effect of the vapor "holdup" that occurs within the impounded/diked area. Although provisional methods have been suggested in the past for using DEGADIS under such conditions, such methods have been demonstrated to be in error, as will be discussed subsequently. It is now clear that utilization of certain methods provisionally suggested in the Eighties (for determining gas "holdup") can lead to serious errors in the determination of vapor cloud dispersion protection exclusion zones.

- Research conducted during the last two decades has resulted in the Department of Transportation's acceptance and approval of the use of the FEM3A vapor dispersion model. The FEM3A model *provides for prediction of the holdup that occurs in an impoundment area* as well as for other effects of obstacles or terrain features on dispersion of an LNG vapor cloud.

3.2 The Potentials for Unconfined Vapor Cloud Explosions and Boiling Liquid Expanding Vapor Explosions are not Addressed

Unconfined Vapor Cloud Explosion Hazard

The concern for the potential of unconfined vapor cloud explosion hazards at the proposed LNG terminal in Long Beach is directly related to the composition of the LNG that will be imported to the facility. It is anticipated that significant quantities of "hot gas", i.e., LNG containing significant quantities of hydrocarbons heavier than methane will be received at the terminal., and the plant is being designed to remove such heavy components (ethane, propane, etc.) for marketing and distribution from the facility.

Since it does not appear practicable to remove the heavier components of the gas *as it is being unloaded from the tanker into the storage tanks*, it is presumed that the “hot gas” NGL components will have to be stored, at least temporarily, prior to their distribution off site. Consequently, it is presumed that there could be significant quantities of LNG containing heavier hydrocarbons such as ethane, propane, etc., that will be stored and handled in the facility.

The problem of explosion potential of LNG vapor clouds has been studied. I quote directly from U.S. Coast Guard Report CG-M-03-80 entitled *U.S. Coast Guard Liquefied Natural Gas Research at China Lake*, dated January 1, 1980 (pages 12-13):

“Since unconfined vapor clouds composed of LPG have detonated after tank car and pipeline accidents, the next group of high explosive direct initiator tests involved the system methane-propane stoichiometric in air, always using a 1.35 kg Composition B initiator in a 5 m hemisphere.

….

The test series was run in the sequence 90% methane-10% propane, 57.6%-42.4%, 76.8%-23.2%, 81.6%-18.4%, and 86.4%-13.6%. Only methane concentrations above 81.6% failed to produce a vapor cloud detonation. The velocity of the fuel-air detonation wave was 1800 m/s and the maximum pressure was 15.5 bars in the 81.6%-18.4% test. Clearly, for the 1.35 kg initiator, the critical percentage of propane for the methane-propane-air detonation is between 13.6% and 18.4% propane; financial restrictions prevented the determination of critical concentrations for other initiator sizes. Theory suggests that the use of propane as a sensitizer is representative of all hydrocarbons heavier than methane. The 13.6% sensitizer concentration has special consideration as the commercial LNG being imported into the U.S. east coast has about 14% higher hydrocarbons.”

Based on this report, which to my knowledge has not been called into question, it is clear that there is a potential unconfined vapor cloud explosion (UVCE) hazard associated with the errant release of LNG containing heavier (than methane) hydrocarbons in amounts in the range 13 -18% (and higher).

Furthermore, it is important to note that the explosions described in the Coast Guard Report were gas phase *detonations*, which means that the flame (reaction front) speeds were greater than the speed of sound in the unburned gas mixture. It is now well understood that damaging overpressures can occur in unconfined vapor cloud explosions even when flame speeds are well below those which result in detonations. The bottom line here is that LNG with concentrations above the range 13-18% has been shown to have the potential to *detonate when unconfined*, and there is consequently a very real potential for UVCE’s to occur with damaging overpressures when such (unconfined) gas-air mixtures are ignited.

Consequently, although the present regulations do not require consideration of the UVCE hazard associated with vapor clouds that might result from spills of LNG, consideration of the UVCE hazard is relevant for the proposed Sound Energy Solutions terminal *if it is to import "hot gas" that may have concentrations of heavier components in the range above approximately 13-18%*.

Finally, it is noted that enrichment in higher boiling point components of the liquid remaining on the water as the LNG vaporizes can lead to vapor cloud concentrations that pose a UVCE hazard, even if the concentration of the heavies in the liquid initially spilled do not.

Boiling Liquid Expanding Vapor Explosions

If the decision is made to install NGL storage at the facility, consideration must be given to the potential for BLEVEs to occur in the event that the storage tanks are exposed to fire. The potential for NGL BLEVEs to threaten either public safety or infrastructure to distances greater than are already anticipated to be credible for large LNG pool fire or vapor cloud dispersion hazards appears to be low; however there is very real potential for severe mechanical damage (by explosive force or due to ejected missile impact) to the primary LNG storage facilities (or a ship at the jetty) that could cause cascading events that would worsen the situation.

In view of the recent apparent occurrence of a BLEVE of an LNG tank truck in Spain, the potential for BLEVEs of the trucks serving the facility, as well as LNG storage tanks, cannot be ruled out. However, the potential for BLEVE-like explosions appear to be much more likely from the ship containers than from the more heavily constructed and more fire-resistively insulated LNG storage tanks on land.

3.3 There is a Critical Need for Exclusion Zones for LNG Spills on Water

The potential for catastrophic releases from LNG carriers that service an LNG import terminal are acknowledged by FERC in several Draft and Final Environmental Impact Statements, including both for the Weaver's Cove Project in Fall River, MA. FERC has consistently stated that such catastrophic releases would be most likely caused by terrorist attack, and FERC's own analyses have shown that the consequences of such ship-side releases that have been identified tentatively as "credible" are far greater than the hazards posed by the land-side LNG spill scenarios. Nevertheless, the Commission continues to dismiss these hazards on the grounds that the threat of such events (large pool fires on water, or large vapor cloud formation following a spill on water) can be "managed".

I cannot support FERC's statement (from the Weaver's Cove and other Impact Statements) that "While the risks associated with the transportation of any hazardous cargo can never be entirely eliminated, they can be managed". In my opinion, this statement, with no justification provided, does nothing to provide the public confidence in FERC's ability to "manage" these risks. Indeed, I believe that it downplays the importance of the principal threat to public safety that is associated with the operation of any LNG import terminal – a terrorist attack that could result in catastrophic spills of LNG onto water.

I believe my recent testimony before the Subcommittee on Energy Policy, Natural Resources and Regulatory Affairs, provides adequate explanation of my view on this matter. Although the inclusion here of that testimony is repetitive of my earlier comments, I believe such repetition is warranted:

Testimony of Dr. Jerry Havens
Before the Congressional Subcommittee on Energy Policy,
Natural Resources and Regulatory Affairs
Tuesday, June 22, 2004

Mr. Chairman and Members of the Committee: My name is Jerry Havens. I am a Distinguished Professor of Chemical Engineering at the University of Arkansas. I appreciate this opportunity to address this hearing on Federal and State Roles in LNG Import Terminal and Deepwater Port Siting. I am speaking here today as a citizen-scientist, and not as an agent of my University.

I have for some thirty years been studying methods for assessing the potential consequences of major accidental releases of LNG. My remarks here today are about the estimation of the extents of danger to the public around such spills.

I believe that the potential danger to the public from LNG spills is mainly from the very large fires that could occur. I want to emphasize that I am talking about fires resulting from the spillage of several millions of gallons of LNG – a single tank on a typical LNG carrier contains six or more million gallons of liquefied natural gas. The fire from such a spill, if it occurred onto water and was therefore uncontained, would be very large, perhaps up to a half-mile in diameter, or larger if more of the containment system failed. We have no experience with fires this large, but we do know that they could not be extinguished, they would just have to burn themselves out, and the radiant heat extending outward from the fires edge could cause serious burns to people even at larger distances.

There are two ways that very large fires can follow a major LNG spill. If LNG is spilled it will rapidly evaporate and the vapors will mix with air to form a mixture which will burn in the concentration range of approximately 5% to 15% LNG vapor. Such mixtures of LNG vapor and air will inevitably form when LNG is spilled, and if an ignition source such as an open flame or spark are present, as would be highly likely to accompany the violent circumstances that would cause a major release, a large pool fire will result. However, if no ignition sources are present in the flammable gas mixture a vapor cloud will result, and the cloud will spread downwind from the spill until it either contacts an ignition source or becomes diluted below its flammable concentration - it will then disperse harmlessly.

The maximum distances of the danger zones extending from a pool fire or a flammable vapor cloud determine the zones which would endanger the public. It is the estimation of these distances, which are identified in 49 CFR 193 as <u>*pool fire radiation*</u> *and* <u>*vapor cloud dispersion exclusion zones*</u>*, that I want to inform you about, because such exclusion zones are required in order to ensure that people are not exposed to danger if such a fire should occur, and such requirements determine the effectiveness of the LNG siting regulations to provide for public safety.*

I first began studying the prediction with mathematical models of vapor cloud travel distances in the 1970's, when as this Committee knows, the first wave of interest in LNG importation arrived in the United States. I am privileged to have had an important role in the development of the current regulatory requirements for determining vapor cloud exclusion zones to support requests to FERC for LNG terminal siting. Both of the computer models currently required by 49 CFR 193 for calculating vapor cloud exclusion distances were the result of developments by my Associates and I at the University of Arkansas. I have also followed closely and have been involved in, if less directly, the development of the methods required by 49 CFR 193 for determining pool fire radiation exclusion zones.

In my opinion the current requirements in 49 CFR 193 for determining both pool fire radiation and vapor cloud dispersion exclusion zones around LNG terminals are based on good science, and they are adequate for their purpose. Indeed, the present regulations are the result of considerably more research on LNG safety than has been performed for many other hazardous materials that are routinely transported and stored in very large quantity. Furthermore, I believe it is important to emphasize that the hazards associated with LNG, aside from the localized dangers involved with handling any cryogenic fluid, are neither unique nor extreme when compared with other hazardous materials handled in bulk. The potential dangers we are discussing today are brought into the present focus because of the enormous amount of energy that must necessarily be concentrated to enable economical transport of liquefied natural gas across the world's oceans.

However, the suitability of the methods required by the regulations for determining exclusion zone distances is not in serious dispute. The problem lies in the specification of the LNG spill scenarios that must be considered.

Current U.S. regulations require that exclusion zones be calculated for spills in the land-based portion of an LNG import terminal only – the regulations do not currently apply to spills that might occur from the LNG vessel onto water.

Because spills on land are subject to a variety of control measures to limit the area extent of the spill, such as dikes or impoundment systems, exclusion zones in support of requests for siting land-based LNG terminals are typically, in my experience, less than one thousand feet. However, if exclusion zones were required to protect the public from LNG spills onto water from an LNG vessel at the jetty or in route to or from the terminal, there is good scientific consensus that the fire radiation exclusion zones could extend to a mile *or more if the entire contents of a single tank were rapidly spilled, and the vapor cloud dispersion zone could extend for a similar spill to several miles. Obviously, if the regulations were applied to the determination of exclusion zones to protect the public from LNG tanker spills onto water, it would have a very important effect on siting decisions. It seems clear to me that such consideration would raise very serious concerns about the siting of LNG terminals where people within the exclusion zone distances would be endangered. It is very sobering to me to realize that the ongoing LNG siting debate regarding public safety comes down to this, and I sincerely hope that those responsible for protecting the public recognize and seriously consider this very important question.*

Since 911 we no longer have the luxury of considering only means for reducing the probability of accidents to a level that justifies the attendant risk. I believe that it is imperative that the dangers to the public from possible releases from a LNG carrier onto water be considered in the siting of LNG terminals in our country.

I must also tell you that I am very concerned that spills from LNG vessels caused by terrorist attack might not be limited to the partial contents of a single tank on the vessel, as is widely assumed. Because of those concerns, I wrote to the Secretary of Homeland Security in late February to urge the Department to consider the vulnerability of LNG carriers to terrorist attacks as part of their deliberations on LNG terminal siting. Because some of the matters that I believed worthy of consideration are sensitive, I do not think it is appropriate to discuss them in detail here, but I will try as best I can to address any questions you may have about this subject. I am very disappointed that I have not received any response from the Department of Homeland Security regarding my concerns.

Thank you, that concludes my comments.

I stand by this statement, and I believe it is particularly relevant to the consideration of siting the Sound Energy Solutions LNG Project in Long Beach Harbor.

Today, although the science community has acknowledged the need for additional experimental data that can be used to address some uncertainties which remain in the extrapolation of consequence distances from the approximately 10,000 gallon spill range that has been studied to the approximately 10,000,000 gallon range that has been determined to be credible to result from a terrorist attack on an LNG ship, it is clear that there is scientific (and government) consensus that methods which have recently been evaluated by the ABS Group for FERC and by the Sandia National Laboratory for the Department of Energy are suitable for the estimation of the extent of the thermal radiation or vapor cloud dispersion hazard distances that would extend from major releases of LNG onto water in the Port of Long Beach.

It is not necessary to repeat in detail the findings of either the ABS Group or Sandia Lab reports, both of which are attached as exhibits to this report. I will just summarize my reading of the conclusions of both reports which I believe are germane to the consideration of the proposed LNG terminal in the POLB.

The ABS Group and Sandia Lab reports, which appear to be now largely accepted by all of the regulatory agencies involved, including the Coast Guard, as being the best current guidance on these matters, emphasize for their extensive analyses of the consequences of marine spills just one (size) spill scenario. That is the spillage onto water of 12,500 cubic meters LNG – this figure being representative of approximately one half of a single tank on a typical LNG ship. The choice of spillage of half a tank (rather than a full tank) appears to be the result of the reports' authors' consideration of the extreme implausibility if not impossibility of the rapid spillage of the entire tank as an initial result of a terrorist attack.

Thermal Radiation from LNG Pool Fires on Water

Setting aside unnecessary precision, I believe that the ABS Group and Sandia Lab reports are in essential agreement that persons exposed to the thermal radiation from a pool fire burning on a 12,500 cubic meter (approximately 3,000,000 gallons) spill on water could receive second degree burns on unprotected skin in about 30 seconds at a distance of approximately one mile from the center of the spill.

I endorse these findings on thermal radiation consequences of LNG pool fires on waters from the ABSG and Sandia Reports, as far as they go.

But, as I have stated before, I do not think these predictions address sufficiently the real requirements to provide for public safety. I am convinced that the use of a thermal flux criterion that would result in second degree burns in 30 seconds is not appropriate for delineating distances necessary to ensure public safety. This (second degree burn criteria) is not sufficient because such exposure essentially ensures that serious burns will occur at that distance to persons who cannot gain shelter within 30 seconds. In addition to the obvious difficulties that would confront any able-bodied individual's attempt to flee from such a threat, there remain very serious questions about the almost certain inability of those less able to do so. As considerably lower thermal flux criteria (~1.5 KW/m^2) are prescribed in other national and international regulations designed to provide safe separation distances for the public from fires, I believe that FERC should consider such a lower thermal flux criteria, which could increase the distances prescribed in the ABSG and Sandia reports by as much as one and a half to two times, to ensure the public safety from such large LNG fires.

Finally, regarding calls for more research in this area, I have already stated that there are some important needs. It is my understanding that Sandia and others are considering the need for more large scale LNG fire testing. If such tests were conducted with appropriate scientific planning, and if such tests were conducted for the purpose of obtaining experimental data which could be used to verify mathematical modeling methods (as opposed to one-time "demonstration" tests), I would endorse them, as I feel that additional testing would be worthwhile to provide better means of predicting the consequences of very large fires that could follow massive LNG spillage onto water.

<u>LNG Vapor Cloud Dispersion from Spills on Water</u>

I here also endorse the estimates of LNG vapor cloud dispersion presented in the Sandia and ABS Group reports, which range, considering all of the uncertainties identified in the reports, between approximately two and three miles. I note that while I have reviewed and am in agreement with the methodology used by the ABS Group for making these estimates (they in part used DEGADIS, of which I am a co-author), the Sandia report estimates were reportedly obtained using a CFD model called VULCAN, which I have not had the opportunity to evaluate, and which to my knowledge has not been independently evaluated for such use. I believe that the estimate of two to three miles of flammable vapor cloud travel that could result from an unignited spill of one half of the LNG contained in a single containment is at once reasonable and sufficient for consideration of the consequences of such spills of LNG in the POLB.

<u>There is a Real Concern for Cascading Failures to Occur</u>

But, I believe that limiting our consideration of the potential consequences of a very large LNG release and fire on water to the <u>initial result</u> of a terrorist attack is not sufficient. That would be like ignoring the collapse of the Twin Towers, because their collapse was not the initial result of the attack. Lest I neglect the consideration due of the worst case consequences of large scale tanker spills, it is important to note that the Sandia report states unequivocably that cascading events that could result either from brittle fracture of structural steel on the ship (due to LNG contact with the steel) or failure of the vaporization of the cargo at rates exceeding the capability of the pressure relief valves, cannot be ruled out.

We know that foamed plastic insulation, widely used on LNG carriers, including ships with both of these tank types, would be highly susceptible to failure by melting or decomposition. It is a cardinal safety rule that the pressure limits on tanks carrying flammable or reactive materials not be exceeded, as such exceedance portends catastrophic rupture of the containment. Such a rupture could lead to the release of a full tank of roughly 6,000,000 gallons of LNG, as well as the release from multiple tanks. While, as has been stated, the Sandia report concludes that such cascading events would be very unlikely to involve more than three of the five tanks on a typical LNG carrier – for a total release of 18,000,000 gallons (or more from the larger carriers now proposed) compared to the 3,000,000 gallon release on which all the modeling has been based – the basis for the Sandia report's “optimism” in this regard is unexplained. Once cascading failures begin, I do not know what would stop the process from resulting in the total loss and burning of all of the LNG aboard the carrier.

CHAPTER 4

CONCLUSIONS

CONSEQUENCES OF CREDIBLE ACCIDENTS AND TERRORIST ACTIONS, AND CONSIDERATION OF WORST POSSIBLE CASES

The objective here is to specify, based on observations of historical and experimental data, and supported by science-based guidance regarding the possibility of occurrence of postulated scenarios, the distances from such credible events to which the public as well as important infrastructure could be in harm's way.

Such a *consequence assessment* is a two step process:

1. The credibility (meaning here, the consistency of the event's occurrence with natural laws which we know to control such processes) of the postulated event must be established. For example, we can respond quickly and certainly to statements that an LNG ship contains the equivalent of fifty or more Hiroshima-size atomic bombs (a literal truth) with a certainty, based on physical laws, that the energy contained in an LNG storage tank cannot be released in a time frame sufficiently short to allow a meaningful comparison with the effects of fifty nuclear weapons each with a nominal 20 kiloton explosive energy release. It just cannot happen. However, we cannot dismiss the hazard on that basis either; instead we must consider the physical limitations which determine the length of time during which that energy could be released (in this case, by fire) in order to objectively define the consequences which could result.

2. Starting with the defined credible event, it is then required to determine the distance to which the hazard would extend. This process typically requires specification of both the total amount (of the hazardous material, measured here as energy content) released and the time frame over which the release occurs. As is true of many of the arguments advanced in this report, this is really just application of common sense - a very small spill rate, even continued for a very long time, would not be expected to pose the fire hazard that would result from the more rapid release of the same amount of material. An objective quantitative determination of the (hazard) distance is also a two step process.

    a. First a criterion for damage must be selected. For the present case these criteria are; for fires, specification of the permissible level of thermal flux exposure; and for vapor clouds, specification of the concentration level below which the cloud does not pose a flammable hazard because it could not be ignited.

    b. Finally, as the scenario being considered often involves releases with magnitudes potentially much more damaging than have been experienced, we have to extrapolate our experience to determine an

> objective measure of the consequence that can be expected. The best, if not the only, tools we have for such extrapolations are physical (such as wind tunnel) or mathematical models.

Utilizing information summarized in Chapters 2 and 3 of this report, I will summarize what I believe to be the present state of information about the quantities (and rates of release) of liquefied energy fuels that could occur associated with the operation of the proposed LNG terminal in the POLB, as well as the consequences to the public and infrastructure that could result.

Accidents and Terrorist Actions

The current regulations, particularly regarding provisions for public safety, focus on the land based part of the terminal. There are specific requirements for liquid containment and impoundment systems that are designed to limit the spreading of LNG that might be released either from the LNG tanks themselves or from transfer lines in the facility. But such control and mitigation measures could not be effectively applied to releases that could occur from an LNG ship, either at the jetty or in transit thereto, because spills onto water could not be effectively contained, and these concerns appear to have spurred the government's completion of two recent reports that deal with the tanker safety issue.

Before moving to consideration of the potential for, and consequences of, large LNG spills on water, I think it important to state that, in contrast to the attention given to the potential for large spills on water, very little attention is presently given to the vulnerability of land storage tanks to terrorist attack, or even to the vulnerability of land storage tanks to natural events such as earthquakes and tsunamis, consideration of which would appear to be highly relevant for the proposed POLB terminal. I believe that the vulnerability of the land tanks to such accidental or terrorist caused events, as well as to natural events such as earthquakes and tsunamis, needs to be considered carefully in order to provide the public assurance that we understand the potential consequences of releases that could occur on land as well as we now know them for spills on water. Fortunately, we have much more complete information regarding LNG spills onto water.

The ABS Group and Sandia reports agree that the release of LNG in the amount of approximately 3,000,000 gallons (half of one typical LNG ship tank) is credible,

- in that such a release could result from accidental collisions between ships with sufficient momentum (mass and speed) to cause such a breach of containment, or

- that such a release could be caused by terrorists with means that are readily available to them.

Furthermore, the ABS Group and Sandia reports agree, within the precision required here, that a release of 3,000,000 gallons of LNG onto water could result in:

- Pool fires which would expose persons with unprotected skin to thermal fluxes that could cause second degree burn injury in approximately 30 seconds (5 KW/m^2) at a distance of approximately 1 mile.

- Flammable vapor clouds, if the spilled material were not ignited upon release, that could extend downwind to distances between 2 and 3 miles. It is assumed here that persons that were caught in such a fire as might occur if the flammable cloud were ignited would be seriously injured, if not killed.

The author is in essential agreement with these consequence estimates but believes the following modifications are required if they are to be used to ensure public safety:

- Since the thermal radiation flux criterion (5 KW/m^2) used by Sandia and the ABS Group could cause second degree burns in thirty seconds, it is not sufficiently protective of public safety; a lower value, approximately 1.5 KW/m^2, is recommended here. This value is already being used by other segments of the regulatory system, both nationally and internationally, based on its definition as the highest thermal flux to which an unprotected person can be continuously exposed without injury. If the 1.5 KW/m^2 criterion is used, it is anticipated that the distance of 1 mile (associated with the higher flux level) would be increased to between 1 ½ and 2 miles.

- As the Sandia Report states unequivocably that cascading failures of ship tanks cannot be ruled out and further states that in their opinion failures of as many as 3 tanks could occur, this scenario must be considered credible. As Sandia estimates that the hazard distance from this scenario could be extended by approximately one-third, the distance to the 1.5 KW/m^2 flux level would then be increased to approximately 2 ½ to 3 miles.

- The ABS Group's high-end estimates for the vapor cloud distance to the 2.5 % gas concentration level (based on releases from a 5 meter diameter hole in the containment) are approximately 3 miles. The Sandia estimates for the credible scenario analyzed are closer to 2 miles, but their calculations reflect the distance to the 5% gas concentration level rather than the 2.5% level which is accepted to represent the better criterion for vapor cloud travel distance that could pose a hazard to the public. Use of the lower flammable gas concentration criteria would be expected to extend the hazard distance to about 3 miles.

Based on this information, which is believed to be the best that is available - and is in general agreement with widely held views in the scientific community, a <u>minimum</u> distance is specified here for the extent to which the public could be exposed to injury from the initial release of approximately 3,000,000 gallons of LNG onto water at the POLB. It is approximately 3 miles.

Consideration of Worst Possible Cases

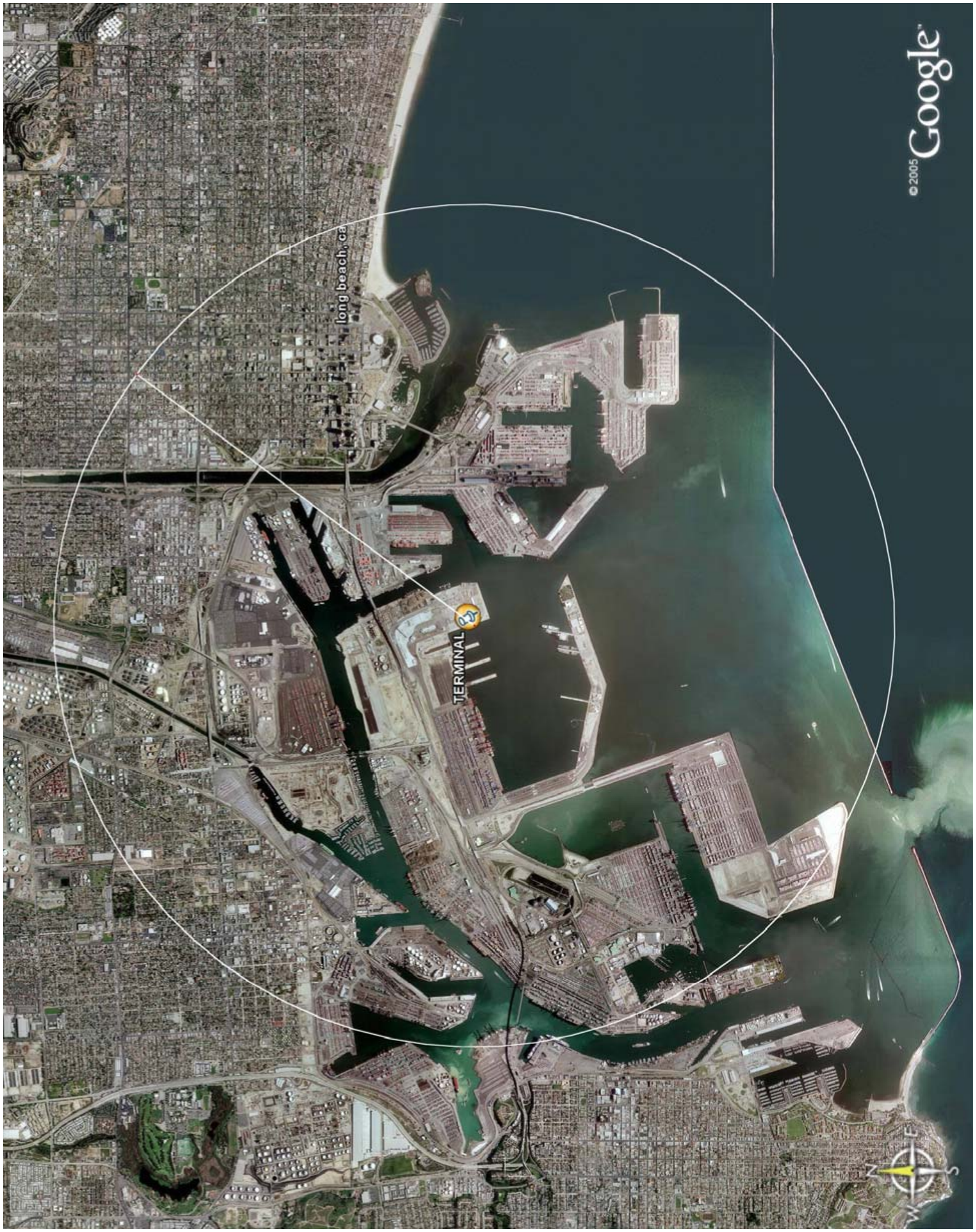
I am recommending a minimum 3 mile radius circle around the proposed terminal to demarcate the area in which events deemed credible could cause serious injury to the public. The minimum distance to demarcate expected damage to infrastructure would be of lesser extent, depending on the criterion selected for damage.

As I have stated that the danger zone around the tanker extends to the route of the tanker approach to the facility, I observe that exposure of the public from incidents of spillage onto the water from the ship appears to be greatest when the ship is at the terminal jetty, rather than during its approach, since the terminal appears to be closer to populated areas than is any segment of its route to the terminal. Exposure of port infrastructure during the approach, based on my observation of the aerial view, would seem to be similarly concentrated at the terminal site, but such a conclusion does not consider any special hazards or vulnerabilities at different locations in the port. Estimation of the consequences to the POLB of a large release of LNG in the port must consider the wide variety of flammable and other hazardous materials routinely handled, as the area in which significant damage to infrastructure could occur (beyond the terminal and the ship) encompasses large sections of one of the largest and busiest ports in the country. The POLB receives very large crude oil carriers (VLCC) at a jetty located within several hundred feet of the eastern boundary of the proposed LNG facility, and a major container terminal which almost certainly receives hazardous cargo lies adjacent to the western side of the proposed site, along which the LNG ship will be berthed. It is noted that the area designated for the terminal's construction, approximately 25 acres, appears to be significantly smaller than the other (existing) terminals in the United States (with the possible exception of the Everett terminal – I do not know at the time of writing what the Everett terminal's area is). In any case, there is very minimal separation between the LNG spill impoundments and the facility's property line in the proposed terminal in the POLB; indeed, it is difficult for me to see how the applicant can meet the exclusion zone requirements of 49 CFR 193, much less provide a reasonable safety zone for the public or surrounding infrastructure.

It must be emphasized that the 3 mile zone is based primarily on the assumption that approximately 3,000,000 gallons of LNG is spilled onto water, as it appears there is little doubt that either pool fire radiation thermal fluxes or flammable vapor clouds from such a spill could put the public in harms way at that distance. However, it is a minimum specification, because it does not address the possibility of even more serious events.

I am very concerned that such events as provide the basis for the 3 mile consequence distance would be of such severity as to make it highly likely, if not almost certain, that further failures of containments, either of LNG or NGL, would occur. In particular, I repeat here my concern that the exposure to the ship of such a pool fire would have the potential to cause cascading failures of the remaining tanks on the vessel, resulting in total loss of the vessel and burning of its contents. There can be no doubt that the consequences of such a worst-possible-case event could be more severe than the rapid release of approximately 3,000,000 gallons of LNG onto water considered in this report.

Exhibit PUC-3



The radius of the circle extending from the terminal location is three miles.

Exhibit PUC-3

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