Assessing the Risk of an LNG Terminal

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Natural gas is used to meet 25 per cent of the energy needs of the United States, and there are strong arguments that favor its continued use: it burns cleanly; an efficient distribution system exists; and consumers prefer it as the fuel for heating homes and other buildings. Natural gas is also essential in the production of fertilizers and other chemicals.

Though demand has been increasing, U.S. production of natural gas has been declining since 1971—a circumstance which leads us to plan to exploit the significant supplies of natural gas in many developing areas of the world where there is little or no demand for the gas (see "Energy for the Third World" by William F. Martin and Frank Pinto, June/July, pp. 48–56). A growing international trade in natural gas is likely in the years ahead. Indeed, by 1990 the world trade in natural gas could rise to between 5.3 and 8.12 trillion cubic feet, with the U.S. as the principal user. The American Gas Association is of the opinion that U.S. imports of natural gas, which are currently 10 to 15 billion cubic feet per year, could reach 1.6 trillion by 1985 (about 10 per cent of the total gas supply), 2.4 trillion by 1990, and 3 trillion by 1995.

Natural gas is easily and cheaply transported by pipeline. But transportation where pipelines do not exist poses significant problems because of the large volume occupied by the gas at ambient temperatures. To solve this problem, a technology has been developed to convert natural gas to liquid by cooling it to a temperature of −259°F (−162°C), in which state it occupies 1/600th of the original volume. This liquefied natural gas (LNG) can then be shipped in specially constructed oceangoing tankers. A liquefaction facility is required at the source of the gas, and regasification is required before the fuel enters whatever distribution network is to bring the gas to its ultimate users.

Liquefied natural gas is colorless and odorless, and by itself it will not burn. It weighs about 28 pounds per cubic foot and therefore will float on water. LNG will vaporize rapidly if exposed to ambient temperatures; in the vapor state it is not poisonous but could cause asphyxiation due to the absence of oxygen. When dispersed in the air and when the
concentration falls to between 5 and 15 per cent, the mixture is flammable.

The Public Risks in LNG Commerce

The risks to the public in the handling of LNG arise because spilled LNG vaporizes rapidly. The vapor may either catch on fire at the location of the spill, resulting in a "pool fire"; or it may form a vapor cloud which can be carried downwind with the possibility of ignition and burnback toward the source.

In the unlikely event that there is a spillage of LNG on land from storage tank or piping failure, the LNG will vaporize quickly for a short period of time—two to three minutes—until the ground beneath it freezes. Thereafter, vaporization will continue to take place slowly. Vapor cloud formation is possible during the first few minutes and far less likely thereafter. LNG facilities are required to have fire suppressant equipment, and storage tanks must be provided with dikes which can, as a minimum, contain all the liquid stored (typically 90,000 cubic meters per tank); and a buffer zone is required between the dike and the boundary of the facility. Consequently, the public risk (that is, the risk to persons outside the facility) of LNG spills within the facility is considered minor.

The major concern for public safety is connected with an LNG spill on water or at a terminal as a result of a tanker-related accident. One postulated hazard is the possibility of a flameless vapor explosion when LNG comes in contact with water. This represents a very rapid vaporization of the LNG but does not involve combustion; it is a physical rather than chemical phenomenon. Tests indicate that the pressures generated by such an explosion—if in fact it could occur—are relatively small (100 pounds per square inch) even very close to the surface of the liquid and attenuate rapidly with distance.

A more serious hazard is presented by a scenario in which a vapor cloud from LNG spilled on water ignites either at the spill location—with a potential hazard to people and property in the vicinity of the spill—or after the vapor cloud is carried downwind. Lives and property within the cloud or close to its boundary would be affected.

An LNG detonation has never been observed in an unconfined space, and tests using a high explosive charge for ignition have failed to produce a detonation.

A potential risk to the public has been alleged from a phenomenon called "rollover," which results from the mixing of two or more LNG shipments with different composition and density in a storage system. This mixing may cause the pressure to build up in storage tanks and result in venting of natural gas. Modern facilities have procedures for preventing "rollover" by controlling the loading procedure, and this is no longer considered a significant problem.

Weighing the Risks and Their Odds

Before any LNG import or export project can operate, more than 130 federal, state, and local permits must be obtained. The Federal Energy Regulatory Commission (formerly the Federal Power Commission), the Office of Pipeline Safety Operations, and Coast Guard are the major federal agencies involved. Among other matters, these agencies are concerned with evaluation of public risks, and that turns out to be a challenging problem in technology and policy.

Every system for producing and converting energy for human use presents hazards, and evaluating these in quantitative terms is critically important. It is a curious fact that we tend to take for granted the hazards in conventional energy systems, such as those based in coal and oil, and to focus our concern on the public risk involved in proposed new energy developments. To complicate matters, there is no clear definition of acceptable public risk for particular populations, particular activities, or society as a whole; clearly, one accepts a higher-than-average level of risk in certain occupations (coal mining, for example) and activities (competitive athletics and automobile transportation).

What is in fact the public risk associated with handling liquefied natural gas? The answer for any particular facility clearly depends on its design, size, location, and management. Perhaps the best way to put these issues in perspective is with an example—an analysis of the proposed La Salle Terminal, a marine terminal and LNG vaporization facility planned by the El Paso LNG Co. and its subsidiaries in Matagorda Bay, Texas.

Matagorda Bay, approximately 120 miles southwest of Houston on the Texas Gulf coast, is a sparsely populated area. The proposal is to receive,
process, and distribute LNG from Algeria, delivered to the terminal by a fleet of LNG carriers. There would be approximately 143 carrier arrivals per year, each carrier delivering some 125,000 cubic meters of LNG; total production would be about one billion cubic feet of natural gas per day.

**Safety at the La Salle Terminal**

In simplest outline, operations at the La Salle Terminal would be conducted in the following way: after an LNG carrier berths, its LNG cargo would be transferred through refrigerated (cryogenic) piping to one of three LNG storage tanks, each of 100,000 cubic meters capacity. The LNG would be withdrawn as required from these tanks, revaporized, and then piped to consumers through a high-pressure intrastate pipeline. No surface transportation of LNG is anticipated.

Special safety procedures and techniques are proposed in all phases of the design, construction, and operation of the La Salle Terminal and the LNG fleet serving it.

Storage tanks will be diked and will be designed to minimize spillage, and there will be additional spill impounding areas at the facility. This assures that any accidental release of LNG and its subsequent spreading will be contained at all times within the plant boundaries. The facility will be provided with automatic vapor dispersion and fire control systems adequate to minimize any hazards from thermal radiation or vapor dispersion at any plant boundary line under any credible weather conditions.

The LNG carriers will be of special double-hull and double-bottom construction and will use sophisticated anti-collision and navigational systems. Special U.S. Coast Guard operating procedures will be in effect in Matagorda Bay.

But despite all of these safety considerations designed to reduce to an extremely low level the likelihood of an LNG accident with consequences to the public, such an event is possible. It could be initiated by a spill of LNG resulting from a ship collision or a terminal-equipment malfunction. The circumstances required to cause such a spill suggest that the vapor being formed would be immediately ignited, resulting in a pool fire. If the released LNG were not immediately ignited the very cold liquid (−260°F) would rapidly evaporate, forming a cloud of gas, heavier than air, moving across the surface of the earth. If this cloud should come into contact with an ignition source, such as a gas pilot light, the flame of a cigarette lighter, or an electric spark, before the ratio of vaporized LNG to air becomes too low to allow ignition, the vapor cloud could ignite and burn, leading to property damage, injuries, and perhaps fatalities.

**The Risk Analysis Model**

To analyze the risk of such accidents, we used a risk analysis process which included the development of accident scenarios and their associated probabilities, quantification of public risks, and evaluation of public risks. The components of the risk analysis model are indicated in [figure 1]. The complexities required that we make some simplifying assumptions, but the spirit of the analysis required that all assumptions be stated explicitly and conservatively so that our analysis would tend to overestimate the public risks.

Any risk analysis begins with an accident scenario, a sequence of events that must occur for public risk to exist. It must incorporate assumptions about the nature and location of the hypothetical LNG spill, the wind and weather conditions, the sources of ignition, and the effectiveness of spill and fire control systems. These are all built into an event tree, such as that shown in [figure 2]. A representative accident scenario could then be described as follows: an LNG carrier collision occurs in the harbor, releasing an LNG spill of a specified size. There is no immediate ignition, so a vapor cloud forms. The wind is from the east at 10 miles per hour; the eighth ignition source ignites the vapor cloud. The event tree shows that this chain of unlikely events must take place in a specific sequence.

In the risk analysis model, we calculate the annual probability of a particular scenario involving vapor cloud travel as the product of the following factors:

- The annual probability of the initiating accident,
- The probability of no immediate ignition for that accident,
- The probability of the wind direction,
The probability of the wind speed and the air stability, given that wind direction, and
- The probability that the nth ignition source ignites the vapor cloud.

Similarly, the probability of a particular accident scenario which results in a pool fire is equal to the annual probability of the initiating accident multiplied by the probability of immediate ignition.

**Analyzing the Risk at Matagorda**

In the course of our analysis, we constructed accident scenarios and calculated probabilities for all combinations of these individual events, and finally we computed the public risks due to LNG terminal operations.

There are no generally accepted criteria for evaluating public risk. The approach used here was to compare risks generated from this project with existing risks to the public, with risks from alternate energy sources, and with levels of acceptable public risks suggested in the literature. We examined these risks using four criteria:

- **Societal risk**—the total expected fatalities per year.
- **Individual risk**—the probability of an exposed individual becoming a fatality per year.
- **Group risk**—the probability of an exposed individual in a specific group becoming a fatality per year.
- **Risk of multiple fatalities**—the probability of exceeding specific numbers of fatalities per year.

We categorized the events that might cause LNG spills as follows:

- Natural hazards (for example, hurricanes and earthquakes) which affect the facilities.
- External man-made hazards (for example, aircraft crashes) which affect the facilities.
- Accidents involving the LNG carrier fleet.
- Accidents within the La Salle Terminal.

**Analyzing the Dangers of Natural Events**

Our analysis of the various natural hazards, including earthquakes, severe winds, storm waves and tsunamis, and meteorites suggested that none of these represent significant public risk in comparison to the risks associated with other types of accidents. The likelihood that an earthquake would produce a ground acceleration at the La Salle Terminal site large enough to exceed the design specification of the storage tanks is approximately $10^{-11}$ per year. Even if the tank did rupture with such an earthquake, the analysis for the onshore facilities indicates that public risk is essentially nil. There is a higher probability of pipe breaks than of storage tank failure due to ground motions, but the analysis indicates that the results are inconsequential to public risk.
The main source of severe winds in the vicinity of Matagorda Bay is hurricanes. The primary concern with wind is its effect on the storage tanks, since all LNG carriers will leave and remain outside of Matagorda Bay if any winds greater than 60 m.p.h. are forecast or observed. The tanks are designed to withstand an instantaneous gust of 217 m.p.h. and a one-minute wind of 166 m.p.h. Meteorological data indicate that the latter occurs once every 100 years and the former once every 200 years. Because of the safety factors in design standards, it is unlikely that a storage tank would begin to fail even when the design wind is exceeded. But even if the tank failed completely, under these conditions wind turbulence would disperse the vapor plume before it passed terminal boundaries if a pool fire had not been ignited on the site at the point of rupture.

There are no known faults capable of generating significant tsunamis in Matagorda Bay. Furthermore, operating policy will require that in storm conditions all LNG ships leave Matagorda Bay; and since warning of impending large waves would be available, the possibility that these could cause ship accidents and contribute to public risk is believed to be negligible.

The probabilities of a meteorite penetrating a ship’s tanks in the entranceway to the harbor, in the harbor, or at the pier were calculated to be $3.23 \times 10^{-10}$, $5.49 \times 10^{-10}$, and $9.32 \times 10^{-9}$ per year, respectively—over two orders of magnitude smaller than the probability of ship collisions. We considered this probability essentially negligible and made no further analysis of this possibility. The likelihoods of meteorites penetrating terminal storage tanks and rupturing terminal pipelines were also essentially negligible, and since accidents in these cases would be contained within the terminal boundary, they were not investigated further.

**Man-Made Hazards: Aircraft, Sabotage, and Collisions**

There are no major airports in the vicinity of Matagorda Bay, though small planes operate at the local Port O’Connor airstrip and there is a helicopter landing site in Port O’Connor from which approximately 25 flights leave daily for oil platforms in the Gulf of Mexico. It is assumed that there is no risk to the public from airplane crashes into the storage tanks or LNG pipelines, because the consequences of such events would be confined to the terminal area. For crashes of airplanes into ships, we assumed that...
up to 10,000 cubic meters of LNG might be released in 12 minutes, and this scenario is included in the risk analysis. Accident possibilities from helicopter flights are not included in the analysis, because it is assumed that flight patterns can be arranged to avoid operations where LNG carriers are operating.

Qualitative examination of the potential risks due to sabotage indicates that the possibility of sabotage by determined terrorists cannot be completely eliminated by reasonable engineering or security systems. However, we believe that immediate ignition would very likely occur because of the violence required of a saboteur seeking to release the LNG, and this means that the consequences would be confined to the spill area. Furthermore, the decision to operate LNG terminals anywhere in the U.S. implies acceptance of some risk of terrorism.

The most serious accidents involve the collision of LNG carriers with other vessels, ramming of stationary or floating objects, and grounding of LNG carriers. Their probabilities were calculated for three areas of operations in the Matagorda Bay:

- The entranceway, the immediate approach route to and through the cut in Matagorda Peninsula;
- The harbor, the ship channel within Matagorda Bay; and
- The piers, the waters between the ship channel and the berth.

Either one or two cargo tanks may be involved in such a collision. The most credible spill event due to collision turns out to be the rupture of one cargo tank involving 19,400 cubic meters of LNG. The maximum credible spill event due to collision is considered to be the simultaneous rupture of two adjacent cargo tanks, involving up to 38,800 cubic meters of LNG. The most credible spill due to ramming is 10,000 cubic meters. The analysis of grounding accidents indicated a probability for cargo tank rupture so small as to be statistically insignificant. All these findings are summarized in Table 1. Since land spills have been ruled out as insignificant to public risk, the attention in the rest of our study of public risks associated with the operation of the La Salle Terminal was devoted entirely to analyzing water spills.

Vaporization of the LNG would commence imme-
diately following a cargo tank penetration. Any heat source of sufficient temperature and duration could cause ignition of this vapor. The primary ignition sources would be the friction and sparking generated by the immense forces involved in the penetration; these would probably generate temperatures from 1,600° to 2,700° F., far in excess of the ignition temperature of methane in air (1,000° F.). Secondary ignition sources on the carrier, such as boilers, galley fires, electrical cables, and light fixtures, will also be present and exposed to the spilled LNG as a result of whatever accident is taking place. We assume that immediate ignition will almost surely occur under such circumstances; the probability assumed is 0.99.

If immediate ignition does not occur, and in cases of accidental spills caused by negligence on board carriers (where immediate ignition may not occur) the characteristics of wind, on-shore ignition sources, and public activities become important in computing public risk. The movement and behavior of an LNG plume would depend on wind direction, wind speed, and air stability. For the most credible spill of one tank (19,400 cubic meters spilled instantaneously), with a 10 m.p.h. wind and typical air stability, the vapor cloud could travel up to 3.31 miles, if not ignited, in roughly 25 minutes. Thereafter the LNG would be dispersed so much that its average concentration would be below the lower flammable limit of 5 per cent. It is within this 25-minute period that the probability of ignition—and thus of injury and death due to ignition—must be critically analyzed.

A vapor plume can be ignited from a variety of sources such as spark plugs, open flames, pilot lights, and electrical sparks due to short circuits. Because of the difficulty of tabulating all possible ignition sources, we conservatively assumed that each house or building and each recreational boat or commercial fishing vessel has one ignition source. To assume fewer sources is conservative because it implies a larger likelihood that a vapor cloud would cover a larger area before ignition. It was assumed that the probability that any source ignited the vapor plume was 0.1.

In analyzing injuries and fatalities due to burns, we assumed for this study that a thermal radiation of 5,300 B.t.u. per square foot per hour would be the lower limit resulting in fatalities. (This standard is conservative; one would actually expect only blistering of skin exposed for five seconds to such thermal radiation.) Such a radiation level would be found 1,100 feet from the center of an LNG pool fire resulting from 10,000 cubic meters of LNG spilled in 12 minutes, 2,500 feet from a pool fire resulting from either the 19,400 or 38,800 cubic meter spills of LNG, and 525 feet from a vapor plume fire.

Having agreed on these assumptions, we needed information on the distribution of population in the vicinity of the La Salle Terminal to determine the expected annual number of public fatalities and the annual risk levels to individuals (that is, the probability that any individual might become a fatality per year) due to the LNG terminal operation. This turned out to present some unexpected complications because of large seasonal and weekly fluctuations in the population. After preliminary analysis, we decided that three combinations—nontourist season (November through March), tourist weekends, and tourist weekdays—would be necessary to adequately describe population distributions. The risk quantification considered each of these cases separately. In the end, our population study indicated that we could reasonably assume 3.62 people per permanent household, 4.02 people per occupied transient household, 4.5 people per recreational boat, and 2.5 people per commercial fishing boat.

An Illustrative Calculation

To show how all this information was used, we illustrate the calculation of the average number of fatalities under one accident scenario: a collision between an LNG carrier and another ship in the harbor at the intersection of the ship channel and intercoastal waterway (see figure 3) on a weekday during the tourist season. This collision produces an instantaneous one-tank spill of 19,400 cubic meters of LNG. Furthermore, the spill does not immediately ignite, so that a vapor cloud forms. The wind is from the east at 10 m.p.h. with typical air stability. The eighth ignition source ignites the vapor cloud.

The probability of this accident scenario is the product of the following factors:

- The annual probability of a collision releasing one tank of LNG (most credible spill) in the harbor during a weekday in tourist season (the annual probability is $6.49 \times 10^{-7}$ [table 1]);
- The probability that this will occur on a tourist season weekday is $2.33 \times 10^{-7}$;
[Figure 3] Mapping a hypothetical LNG accident. The La Salle Terminal for receiving and vaporizing liquefied natural gas from Algeria would be built by the El Paso LNG Co. and its subsidiaries northwest of Port O'Connor on Matagorda Bay, between Galveston and Corpus Christi, Texas. To reach it, LNG carriers would enter the Matagorda ship channel from the Gulf of Mexico. As part of the authors’ risk analysis, they studied the probability of a collision scenario in which one tank of an LNG carrier was ruptured so as to instantaneously release 19,400 cubic meters of LNG. A 10 m.p.h. east wind would move the resulting vapor cloud toward the town of Port O'Connor, where fatalities from possible ignition of the vapor cloud might exceed 400. But the probability of this specific episode is shown to be $2.71 \times 10^{-12}$, and the expected fatalities per year among residents and visitors to Port O'Connor due to the proposed LNG facility is $1.7 \times 10^{-3}$.
<table>
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<th>Wind speed (m.p.h.)</th>
<th>Stability class</th>
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<th>Northeast</th>
<th>East</th>
<th>Southeast</th>
<th>South</th>
<th>Southwest</th>
<th>West</th>
<th>Northwest</th>
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<tr>
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<td>0.0763</td>
<td>0.0499</td>
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<td>0.3198</td>
<td>0.0411</td>
<td>0.0929</td>
<td>0.4195</td>
</tr>
</tbody>
</table>

- the probability (0.01) of no ignition in this collision;
- the probability (0.131) that the wind is from the east;
- the probability that, given an east wind, it is 10 m.p.h. with the assumed stability (0.1856—[table 2]); and
- the probability that the eighth ignition source ignites the vapor cloud (0.0478).

The calculation, using the probabilities indicated, is:

\[
2.33 \times 10^{-7} \times 0.01 \times 0.131 \times 0.1856 \times 0.0478 = 2.71 \times 10^{-12}.
\]

To calculate the expected fatalities from this accident scenario on a tourist-season weekday, we calculate the maximum extent of the flammable vapor plume (if it is not ignited) and superimpose this area on a map of the Matagorda Bay area (see figure 3). Then we assemble a count of the population in this plume area, using the tourist season weekday distribution of occupied houses, boats in the harbor, and transient population. The expected number of recreational boats in the plume's path is two; no commercial boats are assumed in this area on tourist season weekdays. On such days an average of 1,000 daytime transient visitors are in Port O'Connor, essentially all of them on the beach to the east of the town. The plume covers 34 per cent of the beach, and so we assume that 340 daytime transient visitors are within the vapor cloud. Thirty-seven permanently-occupied dwellings and 103 houses occupied by transients—a total of 140 households and as many ignition sources—are covered by the maximum possible plume. Assuming one person is away from each household, the average weekday daytime occupancy of these houses is taken as 2.62 and 3.02, respectively, with a weighted average of 2.91.

If the vapor cloud is ignited by the eighth ignition source, we know that it is ignited by the sixth house encountered; the two boats count as potential ignition sources. All people within this cloud at the time of ignition are assumed to be fatalities, so the expected number of fatalities in the cloud is

\[2(4.5) + 340 + 6(2.91) = 366.46.\]

In addition, we assumed that all individuals within 525 feet of the vapor cloud fire would be fatalities if exposed to thermal radiation. Based on the average population density of Port O'Connor, this could be 230 individuals, of whom 20 per cent might be outdoors and hence fatalities. Hence, the total expected fatalities from the illustrative scenario on a summer weekday is 412.46. If the probability of such an accident is \(2.71 \times 10^{-12}\), the contribution of this particular accident scenario during a tourist season weekday to the overall annual expected fatality rate is \(1.118 \times 10^{-9}\).

Similar calculations were made for all other accident scenarios leading to [table 3], showing annual expected fatalities among different population groups in the Matagorda Bay area. The probability
Table 3: This table summarizes the results of the risk analysis of the proposed La Salle Terminal near Port O'Connor, Texas. The authors computed these probabilities of death in any single year for individuals in population groups which might be affected. There is only one chance in $2.5 \times 10^{-11}$ that a permanent resident in the city would be a victim. Risks to visitors using Port O'Connor’s beach and to boaters in the harbor are somewhat greater—but remain absolutely very small. Sensitivity analyses indicated these results were not significantly affected by the basic assumptions in the model.

<table>
<thead>
<tr>
<th>Group</th>
<th>Expected fatalities per year</th>
<th>Number of people sharing the risk</th>
<th>Risk per person per year</th>
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</thead>
<tbody>
<tr>
<td>Permanent population in Port O’Connor</td>
<td>$2.0 \times 10^{-6}$</td>
<td>800</td>
<td>$2.5 \times 10^{-11}$</td>
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<tr>
<td>Permanent population in Indiana Lake Visitors</td>
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<td>80</td>
<td>$1.7 \times 10^{-9}$</td>
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<tr>
<td>Transient daytime visitors</td>
<td>$2.5 \times 10^{-6}$</td>
<td>2500</td>
<td>$9.9 \times 10^{-10}$</td>
</tr>
<tr>
<td>Individuals in boats</td>
<td>$1.35 \times 10^{-5}$</td>
<td>3000</td>
<td>$4.5 \times 10^{-9}$</td>
</tr>
<tr>
<td>All individuals exposed to risk</td>
<td>$1.7 \times 10^{-5}$</td>
<td>9000</td>
<td>$1.9 \times 10^{-9}$</td>
</tr>
</tbody>
</table>

of exceeding a specific number of fatalities in a given year is shown in Figure 4.

**Risk Evaluation: How LNG Compares**

To put these figures in perspective, it’s necessary to compare them with similar figures for other forms of energy production.

The La Salle Terminal is designed to receive and vaporize approximately one billion cubic feet of natural gas per day. This is equivalent to the power produced by eighteen 1,000-megawatt electric power plants operating at a 70 percent capacity factor. Based on 1970 data for the State of Wisconsin used by W.A. Buchring, the expected number of deaths to the public due to transporting fuel or direct deaths due to plant accidents for a 1,000-megawatt coal facility was 0.695 per year. The implication of 18 such plants is 12.51 expected fatalities per year; this compares with La Salle’s expected level of 0.000017. Buchring’s corresponding number for 18,000-megawatt nuclear plants is 0.36 expected fatalities per year.

Other individual risk levels due to government and private activities have been computed. The risk to an average individual in the U.S. due to fire is 16,000 times greater than the risk to an individual exposed to the operations of the proposed La Salle Terminal. The group with the highest annual risk from the proposed LNG facility is people in boats. The risk is $4.5 \times 10^{-9}$ per person—one chance in approximately 220 million. From the La Salle Terminal, the annual risk per person in Port O’Connor is $2.5 \times 10^{-11}$. The expected public risk due to gas distribution systems in the U.S. is $5.15 \times 10^{-7}$ per individual per year, which represents one chance in 1.9 million; this is 271 times as great as the possibility of death due to the operations of the proposed La Salle Terminal. Public fatalities due to electric shock in electrically wired residences are $1.11 \times 10^{-10}$ per individual per year.

To help interpret these risks, consider the following. Approximately 65 meteorites weighing more than one pound hit the United States each year; if one owns a one-floor house with 3,050 square feet, the probability that one of these meteorites will hit that house within a year is $1.9 \times 10^{-7}$. This is identical to the average individual risk to operation of the La Salle Terminal.
Quantified Public Risk
The method of formal risk analysis described in this article has several important features: it permits integration of judgments from experts in various fields into a logical framework, assumptions can be stated explicitly, sensitivity analyses can be conducted to appraise the significance of the assumptions, and the public risk can be systematically estimated. In addition, because explicit risks are assigned, strategies to reduce risks can be identified.

The analysis showed clearly that the risks to the public from the operation of the La Salle Terminal were below those to which the population in the vicinity of the terminal is exposed at the present time. The study was used in preparing the safety analysis report submitted to the Federal Power Commission. The final Environmental Impact Statement issued by the Federal Power Commission has stated that the levels of public risk associated with the La Salle Terminal facility are acceptable.