LNG: Today's Link with Tomorrow's Energy

The Energy Outlook

California is running short of natural gas, a situation that will lead to a major energy crisis unless new gas supplies arrive in time.

The state depends on natural gas for nearly half its energy needs, not counting transportation. Short supplies of this vital fuel would disrupt the economy, cause widespread unemployment and foul the air as more polluting energy sources were substituted for gas.

And yet, this situation is marching steadily toward reality. Each year since 1971 California's gas supplies have been declining.

If this trend is permitted to continue, the state's gas utilities predict that as early as 1981, California's total supplies might not be able to meet all the requirements of highest priority customers—homes and small industries and businesses which cannot use substitute fuels. The situation is even more pessimistic in Southern California (see fig. 1).

Obviously, we must conserve all the energy we can but even a concerted effort will not offset the impact of declining supplies. The only realistic solution for the state's near-term energy needs is more gas.

One solution for stemming the coming crisis is liquefied natural gas. LNG is not new but it has never before played a major role in California's energy supply planning. This brochure will examine that role as well as LNG's technology and safety considerations.

Gas Supply and LNG's Role

California receives nearly all of its gas from Texas, Oklahoma, New Mexico and Western Canada, as well as from fields within the state itself. Because these supplies are either declining or merely stable, the state's largest gas utilities are actively searching for new sources.

Subsidiaries of Pacific Lighting Corporation, Los Angeles, parent firm of Southern California Gas Co., and Pacific Gas and Electric Co. (PG&E), San Francisco, are each members of the Arctic Gas Project. The project seeks to build a pipeline to bring gas from Alaska's North Slope overland to the lower 48 states. It is anticipated that California will receive roughly 30 percent of this gas, beginning in 1982 or later. Another Pacific Lighting subsidiary is involved in a coal gasification project in northwest New Mexico that would be the nation's first commercial-scale plant to produce high quality gas from coal.

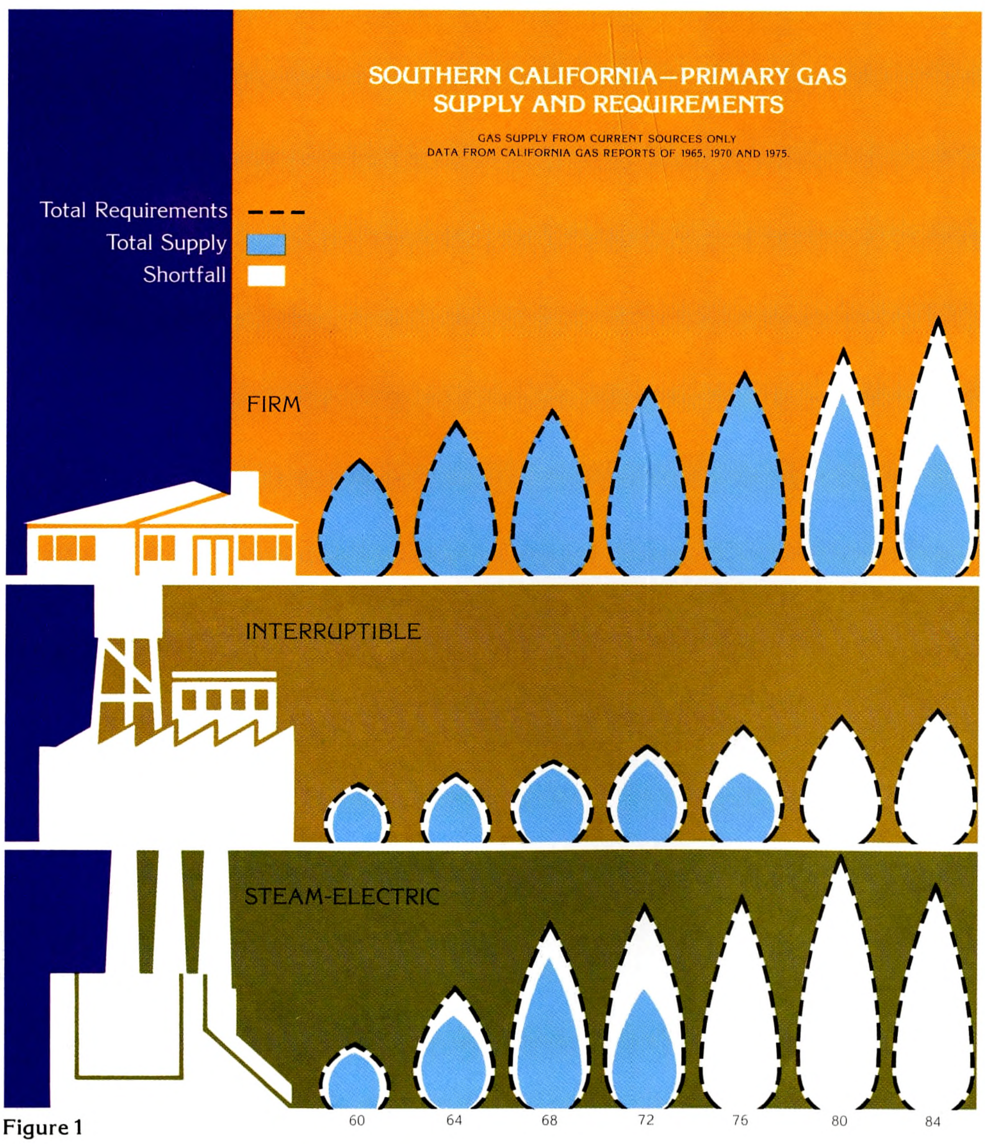


Figure 1

LNG holds an equal, if not greater promise for California's energy future. As a coastal state, it's in an ideal position to import foreign and domestic LNG from throughout the Pacific basin. The region is rich in supply potential all the way from Alaska to South America and stretching as far as Indonesia, Malaysia and Australia. Estimated reserves of gas available for export from these areas total approximately 375 trillion cubic feet. By comparison, last year the entire U.S. consumed about 20 trillion cubic feet of gas.

Projects to tap this huge gas supply for California are already in the works, jointly involving subsidiaries of Pacific Lighting and PG&E. One project will lead to deliveries of up to 400 million cubic feet per day (MMcfd) of natural gas from South Alaska to a terminal proposed for Los Angeles Harbor. A second will result in LNG imports of 500 MMcfd from Indonesia to a receiving facility planned for Oxnard. The Indonesia project alone would supply enough gas to serve the average daily requirements of more than 1.8 million residential customers.

A third facility, at Point Conception, could receive LNG as a part of a proposal by El Paso Alaska LNG Co. for moving North Slope gas. The El Paso proposal is competing with the Arctic Gas Project for federal approval.

Boston, Massachusetts

Chula Vista, California

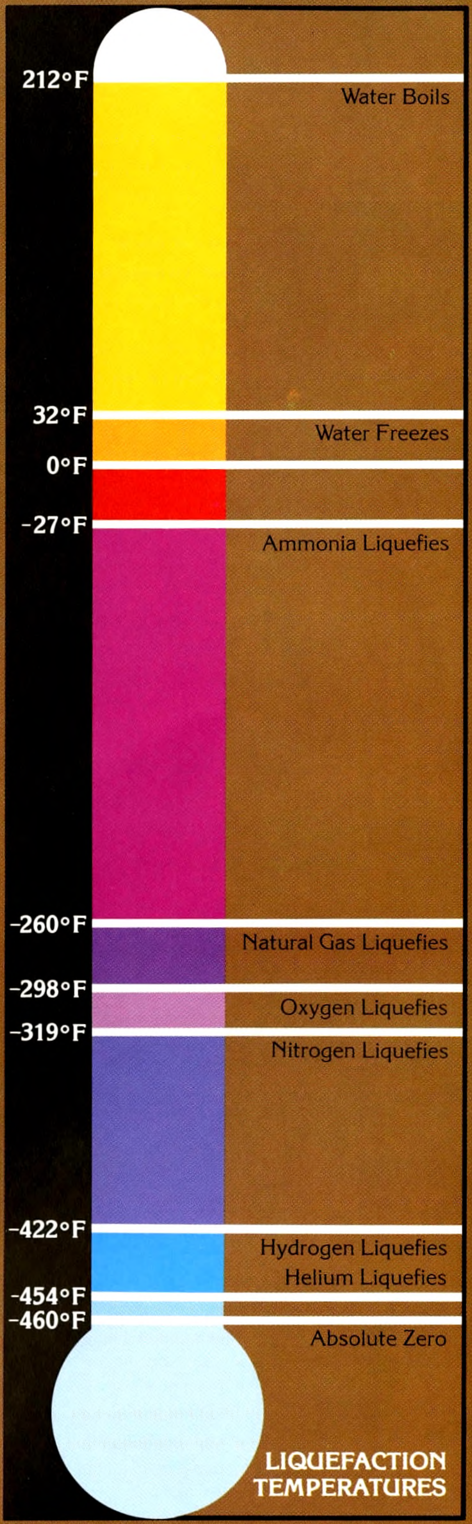


Figure 2

The Vital Statistics of LNG

Liquefied natural gas is a cryogen, that is, a substance created by very low temperatures. Cryogenics, the science which studies the production and effects of low temperatures, is nearly 100 years old. Oxygen was first liquefied (at − 298 degrees, Fahrenheit) before the turn of the century but it was World War II and the space age which followed that boosted the practical applications of this frigid science.

Today, cryogenics is widely used in the food industry as well as by the medical profession. Other promising cold applications are being studied, such as increased efficiency in the conduction of electricity.

How cold is cold? At normal atmospheric pressure, natural gas must be chilled to − 260° F before it condenses into a liquid. Even so, it ranks as a relatively warm cryogen when compared to the temperatures at which such common gases as oxygen and nitrogen become liquids (see fig. 2).

At such extreme temperatures, all gases share one important characteristic—they shrink in volume. In the case of natural gas, roughly 600 cubic feet will condense into a single cubic foot of liquid. This is why it is feasible to store gas as LNG and to transport large quantities of it in the insulated holds of specially built ships (see fig. 4).

Natural gas is liquefied and later revaporized without changing any of the chemical properties that make it such a desirable fuel (see fig. 3). Composed mainly of methane, natural gas, both before liquefaction and after revaporization, is lighter than air, colorless, odorless (a scent is added for detection purposes) and non-toxic.

Like oil and coal, natural gas is found in the ground, the product of decayed flora and fauna. It is the cleanest burning of these fossil fuels and the most versatile for industrial uses. To burn, there must be a mixture of 5-15 percent gas and 85-95 percent air brought in contact with an ignition source.

Gas in the form of LNG must be revaporized as well as mixed with air before it will ignite. During the early stages of vaporization the cold gas is heavier than air and will remain close to the surface until it warms and dissipates into the air. This characteristic requires special attention in safety designs for LNG facilities.

Another unusual characteristic was discovered during a series of spill tests on water that resulted in low energy flameless explosions. Study revealed these low energy level explosions only occurred when methane composition of the LNG was 40 percent or less. In contrast, the California LNG projects will have a methane composition of 90 percent or more.

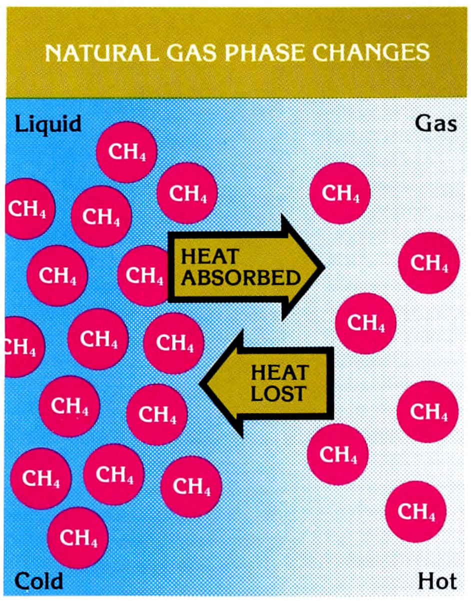


Figure 3

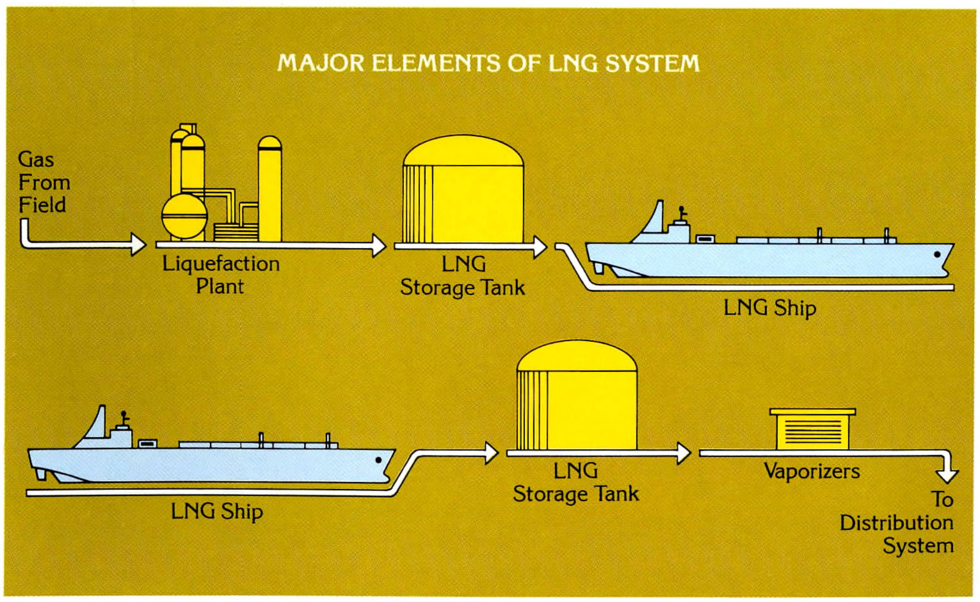


Figure 4

LNG Technology on Land

The California projects will utilize the latest refinements of a proven technology—both on land and at sea. From Boston to Chula Vista, near San Diego, a total of 46 major LNG facilities is operating in the United States (see table 1). The majority of these plants act as a sort of energy deep freeze, taking gas received during summer months when demand is low, liquefying and storing it for revaporization on winter days when customers need more gas than usual.

Aside from these "peakshaving" uses, LNG can also be employed in "baseload" operations as a principal source of supply to meet normal daily demands. There are two such facilities now operating in the U.S.: a receiving terminal in Everett, Massachusetts, and a liquefaction plant in Nikiski, Alaska.

In addition to these major plants, another 48 satellite facilities are in operation throughout the country. They do not have their own liquefaction capabilities and their LNG is delivered to them by tank truck, ship, barge or even rail car.

These plants raise the total number of LNG facilities currently serving U.S. homes and industries to nearly 100. More are planned.

Beyond our shores, LNG baseload operations involve 12 facilities in eight countries (see fig.6). Last year international trade equaled 1.83 billion cubic feet per day of natural gas, or a little more than two percent of the world's total 1975 usage. The bulk of this trade involves Japan and Western Europe.

TABLE 1 • MAJOR U.S. LNG FACILITIES

Company	Location	Storage Capacity (million cu ft)	Year of Operation
Alabama Gas Corp.	Birmingham, Ala.	1,250	1965
Alabama Gas Corp.	Coosada, Ala.	600	1972
Arkansas-Missouri Power Co.	Yarbro, Ark.	374	1973
Atlanta Gas Light Co.	Riverdale, Ga.	2,500	1972
Baltimore Gas & Electric Co.	Baltimore, Md.	1,000	1971
Bay State Gas Co.	Ludlow, Mass.	1,000	1973
Boston Gas Co.	Boston, Mass.	2,120	1968
Boston Gas Co.	Lynn, Mass.	1,000	1972
Brooklyn Union Gas Co.	Brooklyn, N.Y.	1,625	1968
Chattanooga Gas Co.	Chattanooga, Tenn.	1,200	1973
Citizens Gas & Coke Utility	Beech Grove, Ind.	1,000	1972
Commonwealth Natural Gas Corp.	Tidewater, Va.	1,200	1972
Connecticut Natural Gas Corp.	Rocky Hill, Conn.	1,200	1972
Consolidated Edison of N.Y.	Astoria, N.Y.	1,000	1974
Delmarva Power & Light Co.	Wilmington, Del.	250	1972
Distrigas Corp.	Everett, Mass.	3,250	1971
East Tennessee Natural Gas Co.	Fordtown, Tenn.	1,200	1975
Fall River Gas Co.	Fall River, Mass.	150	1970
Gas Light Co. of Columbus	Columbus, Ga.	500	1974
Intermountain Gas Co.	Boise, Idaho	600	1974
Iowa-Illinois Gas & Electric Co.	Bettendorf, Ia.	500	1972
Iowa Power & Light Co.	Des Moines, Ia.	400	1975
Kokomo Gas & Fuel, Inc.	Kokomo, Ind.	400	1973
Long Island Lighting Co.	Holbrook, N.Y.	600	1971
Lowell Gas Co.	Lowell, Mass.	1,000	1969
Memphis Light, Gas & Water Division	Memphis, Tenn.	1,000	1967
Metro Utilities District	Omaha, Neb.	1,000	1975
NEGEA-Air Products and Chemicals, Inc.	Hopkinton, Mass.	3,000	1967
Northern Indiana Public Service	La Porte, Ind.	2,000	1974
Northern Natural Gas Co.	Wrenshall, Minn.	2,165	1975
Northern States Power Co.	Eau Claire, Wisc.	270	1969
Northern States Power Co.	Wescott, Minn.	2,000	1975
Northwest Natural Gas Co.	Portland, Ore.	625	1969
Northwest Pipeline Corp.	Plymouth, Wash.	1,200	1976
Peoples Gas, Light & Coke Co.	Fisher, Ill.	2,000	1972
Philadelphia Electric Co.	W. Conshohocken, Pa.	1,200	1972
Philadelphia Gas Works	Philadelphia, Pa.	4,000	1969
Phillips Petroleum Co., Marathon Oil Co.	Kenai, Alaska	2,300	1969
Piedmont Natural Gas Co.	Charlotte, N.C.	1,000	1973
Roanoke Gas Co.	Roanoke, Va.	200	1972
San Diego Gas & Electric Co.	Chula Vista, Calif.	1,825	1965
Southern Connecticut Gas Co.	Milford, Conn.	1,200	1972
Tennessee Natural Gas Lines	Nashville, Tenn.	1,000	1973
Transcontinental Gas Pipe Line Corp.	Hackensack, N.J.	2,000	1965
UGI Corp.	Temple, Pa.	250	1972
Wisconsin Natural Gas Co.	Oak Creek, Wisc.	256	1965

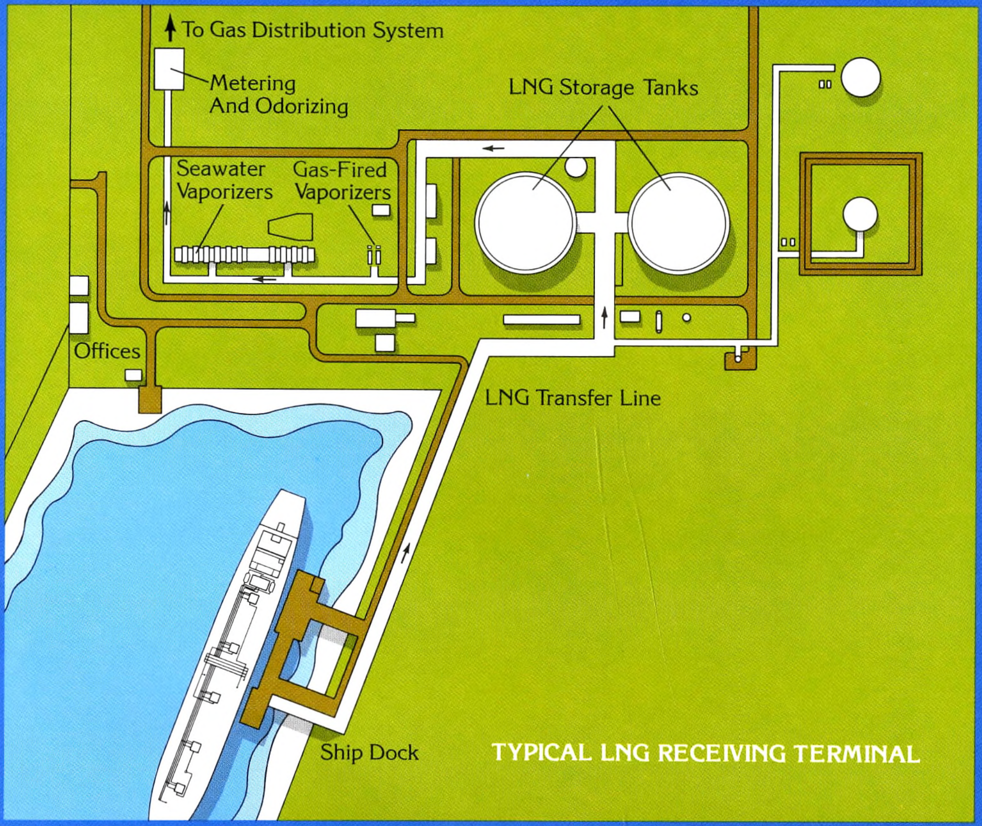


Figure 5

LNG loading arms

Everett, Massachusetts

Nikiski, Alaska

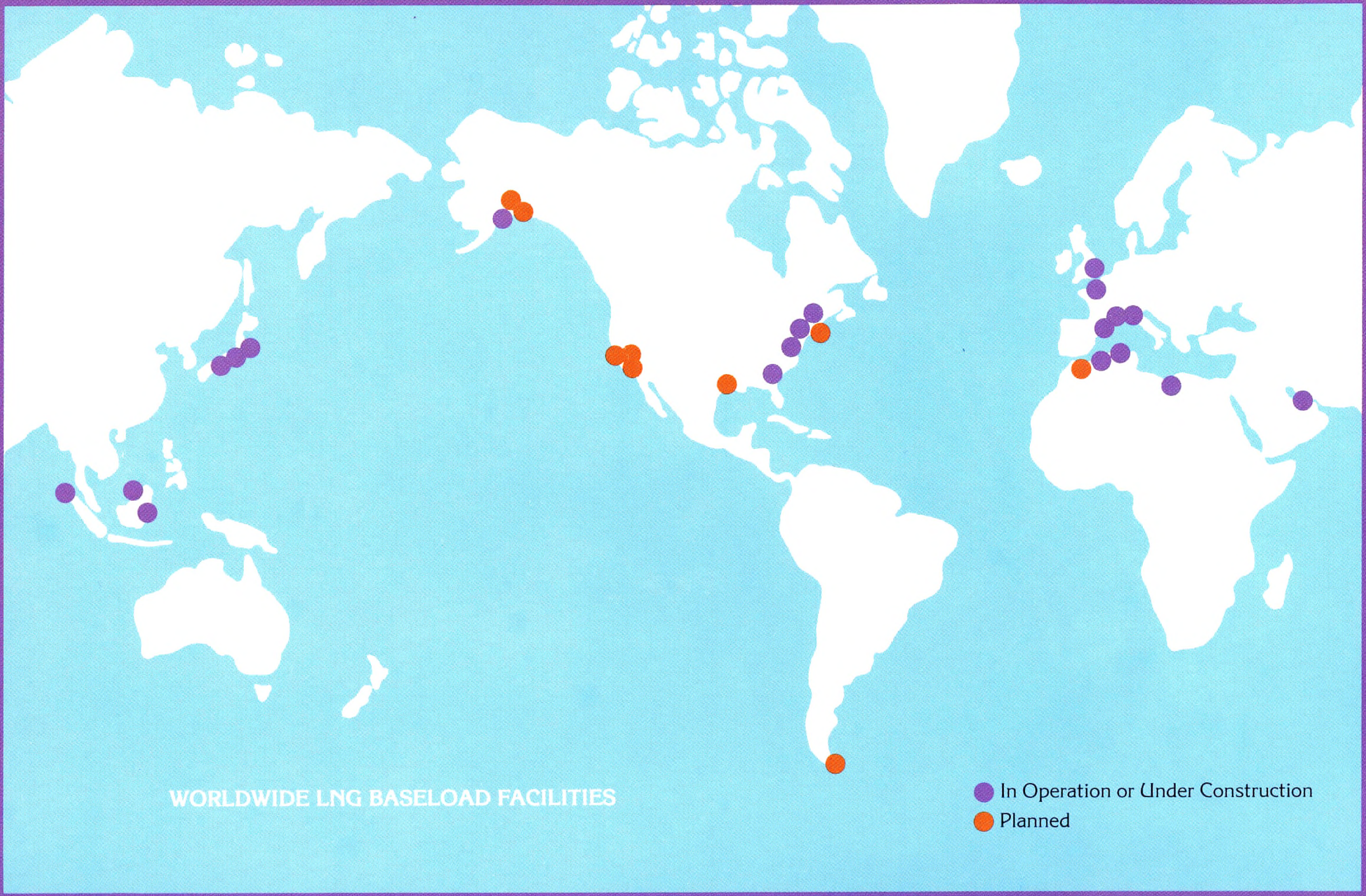


Figure 6

Maryland, USA

Georgia, USA

Projects now in the planning stages could triple world commerce to 5.9 billion cubic feet per day by the early 1980s. If these all materialize, LNG would provide 80 percent of Japan's gas needs, 9 percent of Western Europe's needs and 8 percent of U.S. needs.

The California Terminals

Worldwide experience with LNG will be put to work in the California receiving terminals now being planned here.
A closer look at their step-by-step operations reveals how the technology will be applied in unloading, storing, vaporizing and distributing natural gas from across the sea.

Once an LNG ship ties up at the terminal's berth, large crane-like unloading arms will be connected. Four arms will carry LNG and one will return vapor from the shore-based tanks to the ship so that at no time will a flammable gas-air mixture be permitted to form either in the ship's tanks or the shore-based tanks. Nor will LNG vapors be vented to the atmosphere during normal plant or ship operations. When the ship's tanks have been emptied, the arms will be disconnected and the ship will begin its return trip.

Each storage tank will be literally a tank within a tank. Their double-wall construction will consist of an inner tank of cold resistant 9 percent nickel steel to hold the LNG, then a layer of insulation and a carbon steel outer tank. There are approximately 150 LNG storage tanks in use around the world and more than 90 percent of them employ this basic kind of design.

The liquefied gas will be vaporized at the facilities on a 24-hour basis. Under normal operation, the cold liquid will be warmed by seawater which will then be returned to the ocean. The feasibility of additional commercial uses for the cold temperatures derived from the LNG is under study. During periods of increased demands, gas-fired vaporizers will augment deliveries from the terminals.

Once the LNG is revaporized, it will be odorized and metered before being sent into distribution systems for everyday use.

Algeria

New York, USA

LNG Technology at Sea

Liquefied natural gas took its first ocean voyage in 1959. The ship was a converted dry cargo vessel aptly named the "Methane Pioneer" carrying 5,000 cubic meters of LNG from Louisiana to England. She was the forerunner of an ocean-going technology that today supports growing international trade with a fleet of some 30 vessels.

Expansion of the global market will bring corresponding growth in shipping, increasing the world fleet to around 60 LNG carriers within a decade.

Ships serving the Pacific Lighting-PG&E projects will range between 120,000 and 130,000 cubic meters of capacity. When revaporized, this quantity of gas is enough to supply one day's average demand of Southern California Gas Co., the nation's largest gas utility.

The heart of an LNG carrier is its cargo containment system made up of separate tanks surrounded by insulation (see fig. 7). These tanks do not require refrigeration or pressurization to maintain the gas as a liquid. The insulation alone is sufficient. A small amount of the cargo is expected to revaporize and it will be used in the ship's engines, which will also use fuel oil.

Shipping Regulation

The design and construction of these ships, as well as their operation, are closely regulated.

The U.S. Coast Guard has authority over domestic shipbuilding. In addition, it regulates the operation and navigation of both U.S. and foreign vessels in U.S. waters. Foreign flag ships carrying LNG into or out of U.S. ports must obtain a Letter of Compliance from the Coast Guard. Inspection of the ship and its cargo containment and safety systems are Coast Guard requirements.

Classification societies play an important role, too, in the regulation of LNG ship construction. These societies are non-profit, independent organizations founded in countries around the world to evaluate for insurance underwriters the strength and seaworthiness of vessels.

In the U.S., the American Bureau of Shipping approves ship plans, oversees construction and witnesses tests and sea trials. An annual inspection is also part of maintaining society classification. Without classification it would be impossible for an LNG carrier to be insured or obtain Coast Guard approval.

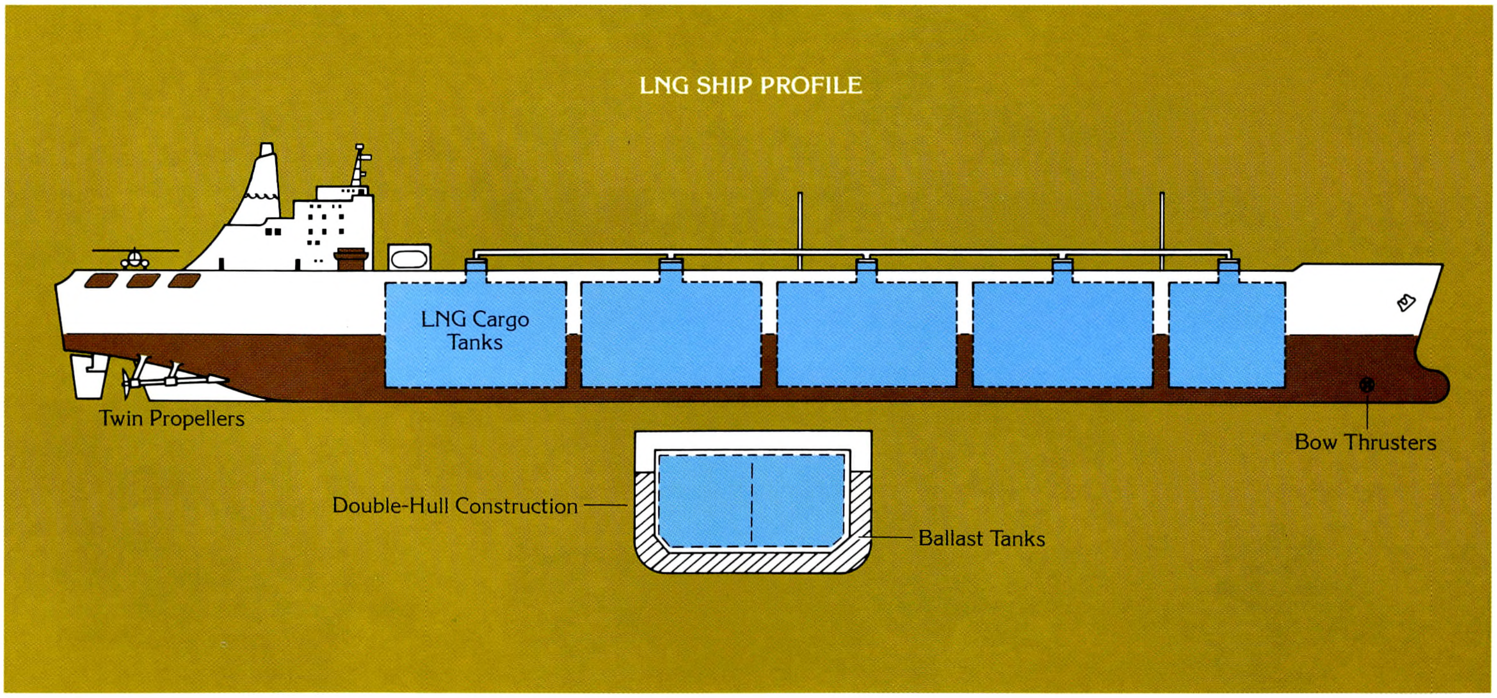
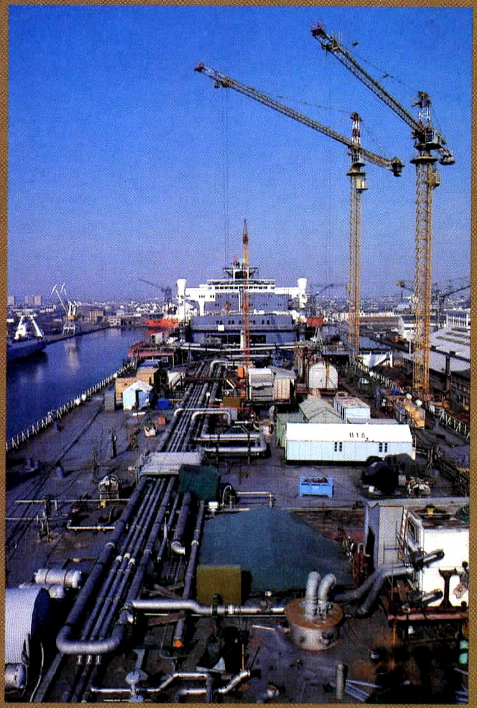


Figure 7

LNG ship "Ben Franklin" will carry gas imports from Indonesia.



LNG ship construction

Seismic test, L.A. Harbor

Gas utility training is invaluable for extensive welding at LNG facilities.

LNG fire training

Safety: a Primary Consideration

Safety of the individual, whether an employee, customer or member of the general public, is a basic element of operations for all companies involved in the California projects. It is built into the design, a result of careful analysis of a facility's operation requirements and efforts to reduce the chances of an accident.

The terminals for these projects will be built and operated by Western LNG Terminal Associates, a partnership formed by Pacific Lighting and PG&E subsidiaries. Each facility will meet or exceed the requirements of all the codes and regulations which govern its operations. These include:

- Federal safety standards for natural gas transport
- Federal port and sea safety regulations
- Regulations governing safety of workers
- National Fire Protection Association standards
- Local building, fire and electrical codes
- Air and water pollution codes

Guarding Against Spills

One major safety consideration in LNG operations is accidental release of the cold liquid. The terminals and ships have been designed to deal with a spill in a two-step process.

The first is to prevent or reduce the possibility of an LNG spill by using proven materials, meticulous quality control, safety equipment and careful training. The second step involves stopping and controlling spills that might occur. This can be done by using automated and individually activated systems to cut off LNG flow quickly, or secondary containment systems to keep spills isolated and minimize the dispersion of vaporizing gas.

This design approach is distinctively reflected in the double-wall construction of the storage tanks already discussed. At the Los Angeles Harbor and Oxnard sites, in addition, a high concrete dike will surround each tank, capable of holding 125 percent of the contents. The high dike will sharply restrict the amount of flammable vapor from a tank spill, keeping it within the boundaries of the facility.

Other safety related elements of design include the extensive use of welds instead of flanges to join the LNG piping, as an added precaution against leakage and spills. All unloading, storage and vaporization operations will be carefully monitored. Temperature and pressure sensors will warn of any hazardous conditions. Gas and flame detectors will be placed at key locations, capable of activating automatic fire control systems.

Southern California is, of course, subject to earthquakes. In recognizing this fact, Western LNG Terminal has established rigorous, conservative earthquake design standards for its planned facilities. The standards set by the company have been based on an analysis of extreme seismic events which might occur at the terminal sites.

The magnitude of such a "maximum credible earthquake" was established by Dames & Moore, consulting engineers with extensive experience in the earth sciences. The firm studied data from the U.S. Geological Survey and from tests conducted in the site areas. The engineers studied the seismology, geology and soils at each site as well as all the significant fault zones in the region capable of generating a temblor.

Lindvall, Richter and Associates, an engineering consulting firm which includes noted earthquake researcher Dr. Charles Richter, made an independent review of the company's studies and concurred in the findings.

As a result of these carefully established design standards, the California LNG storage and containment facilities will be able to withstand the most severe earthquake expected at their locations without allowing LNG to escape.

Shipping Operations

The ships will mirror the same built-in safety considerations as the land-based facilities. One example is their double-hull design. The space between hulls is used to carry ballast water and at the same time, reduces the threat of tank rupture in the event of a ship collision and essentially eliminates the threat of tank rupture from ramming or grounding near the planned California terminals.

LNG is about half the specific gravity of water. This means a fully loaded LNG carrier has a shallower draft than vessels of comparable size. Not only does this add to maneuverability, but the resulting high profile also offers better visibility.

Each ship will carry sensing elements to help detect and locate any possible cargo leak, no matter how small. As an extra precaution, empty spaces in the hull, plus the insulation surrounding the tanks, will be filled with a non-flammable gas rather than air.

Additional features include bow thrusters, which will add to ship maneuverability at low speeds, and the latest in general navigation, communication and collision avoidance systems.

Such design characteristics and precautions will help assure continuation of a record of service that has seen no collisions resulting in spills and no fires involving LNG ships in more than 2,000 voyages since the Methane Pioneer made her first trip.

In terms of their geography, the three terminal sites themselves offer their own safety characteristics. Two of the proposed terminals, Oxnard and Point Conception, lie on the open shore with little traffic in the immediate vicinity. In the case of L.A. Harbor, a short section of the entrance and main channel will be crossed by the LNG carriers in order to reach a protected channel that will lead to the site. In each case, the site's specific location will make it possible to enforce a simple but strict LNG ship operating rule: do not approach the terminal if another ship is in the way.

Accident Studies

In 1944, a tank rupture at the nation's first LNG storage facility in Cleveland released more than a million gallons of LNG. The resulting fire killed 133 persons and injured another 300. It is important to note two things: The tanks that failed used only 3½ percent nickel steel alloy (regulations now require 9 percent which is

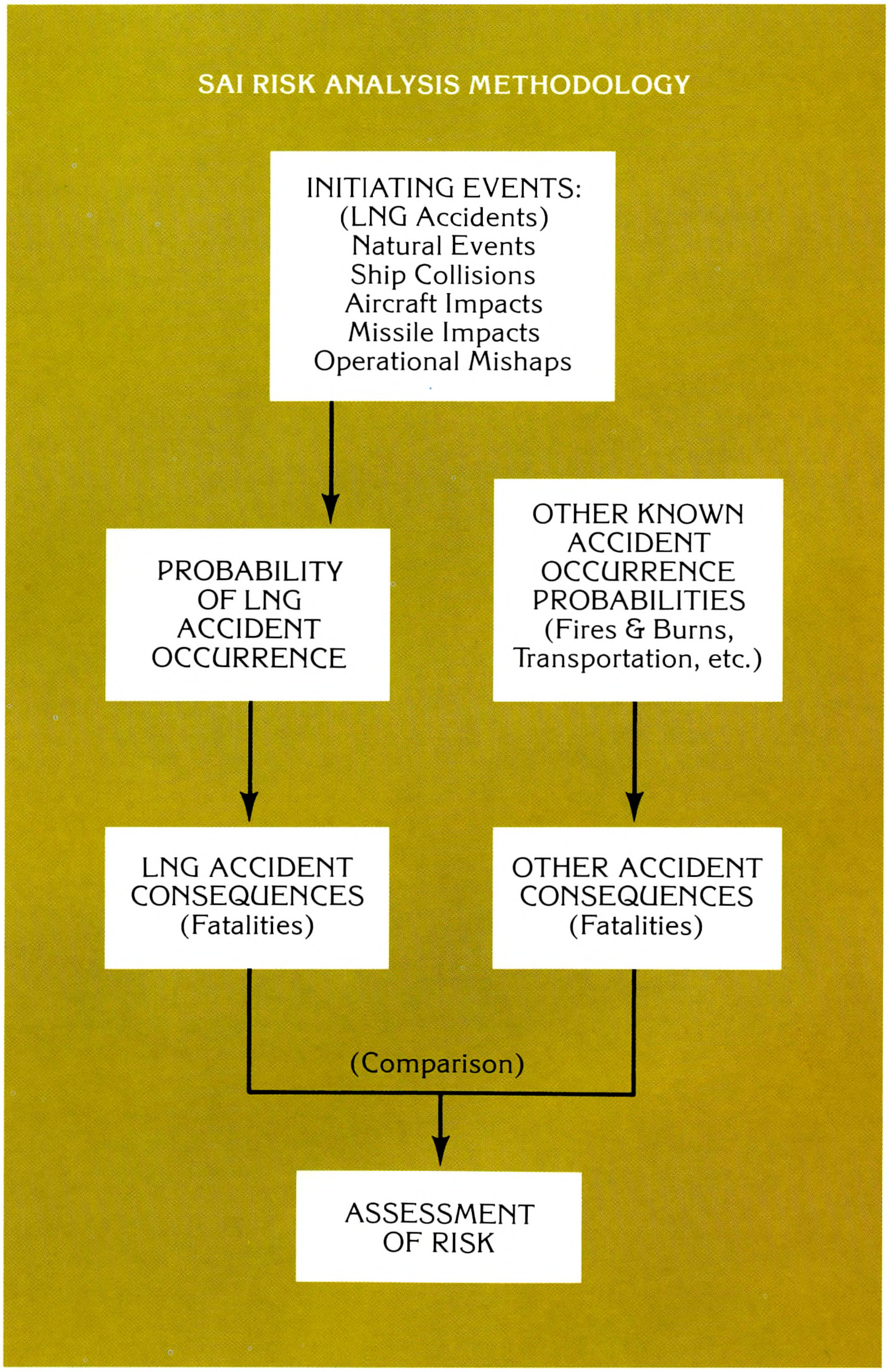
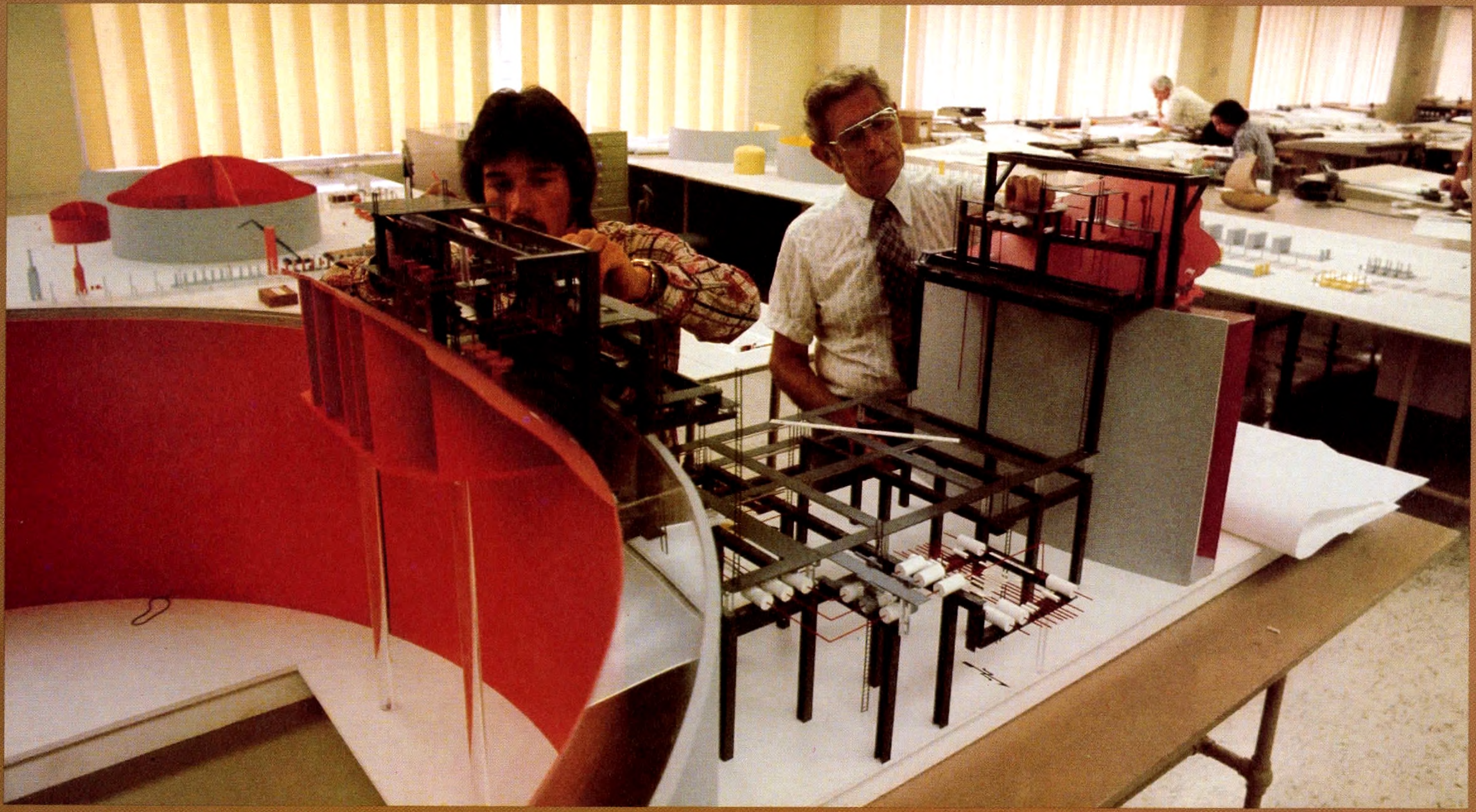


Figure 8

Proposed Los Angeles Harbor terminal site

Proposed Oxnard terminal site



Models aid design of LNG facilities.

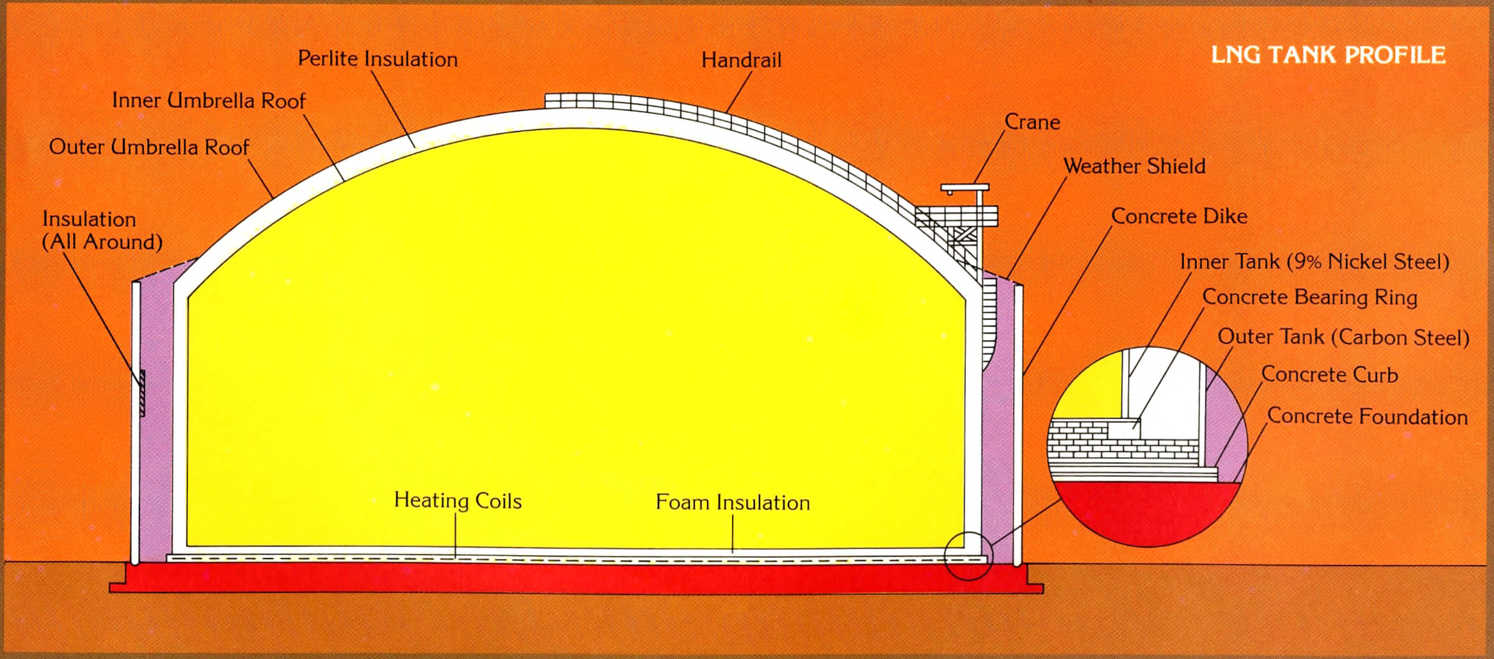


Figure 9

TABLE 2 • COMPARISON OF LNG OPERATIONS RISK ASSESSMENT WITH KNOWN RISKS

Cause of Death	Fatality Probability per Person per Year
Ill Health	1 in 120
Transportation Accidents	1 in 3,500
Home Accidents	1 in 9,000
Crime (homicide)	1 in 11,000
Fires & Burns	1 in 30,000
Electrocution in the Home	1 in 1,000,000
LNG-related, L.A. Harbor (within 5/8 of a mile)	1 in 9,000,000
LNG-related, Oxnard (within 5/8 of a mile)	1 in 15,000,000

adequate for even colder cryogens) and the Cleveland facilities had only partial secondary containment. Dikes such as those planned at the California terminals would have avoided the disaster completely.

Another major accident occurred in 1973 when fire killed 40 workmen inside a storage tank on New York's Staten Island. The tank had been empty for over a year and all the workers involved were inside the tank repairing the nonmetallic liner when the fire started. The Staten Island tank had been designed to protect the surrounding population in case of an accident and proved itself effective. No damages or injuries occurred outside the tank.

In order to thoroughly assess potential risks of the California facilities' designs and operating practices prior to their construction, an independent study was underwritten by Western LNG Terminal. The study, prepared by Science Applications Inc., assessed the level of risk to the general public posed by LNG operations at the three California facilities.

Based in La Jolla, Calif., SAI is a national scientific research and development firm with extensive background in risk analysis and other scientific studies, largely for government agencies such as the U.S. Air Force and the National Science Foundation. The firm was asked to evaluate the planned facilities, determine the chances of an accident happening and analyze the resulting risks (see fig.8). To do this, SAI brought together a wide range of data on LNG and constructed complex mathematical models for computers to simulate large LNG spills and to analyze the potential threat of a major release of flammable vapor.

Assessing the Risk

Throughout the course of their studies, SAI scientists assumed the worst possible conditions in order to avoid underestimating any risks to the public.

The final assessment of risks was then compared to known risks (see table 2). The results were necessarily stated in mathematical terms, the language of statistics, but the overall conclusion of the study was that the risks at each site were extremely low.

The studies showed, for example, that even persons living within the closest 5/8 of a mile (1 kilometer) to the L.A. Harbor terminal would be 300 times more likely to die in a fire of general origin than in an LNG-related fire. For persons living within the closest 5/8 of a mile to the Oxnard facility, chances of their dying in a fire of general origin would be 500 times greater than their dying in an LNG blaze.

The Coast Guard has reached conclusions similar to those of SAI with respect to risks of LNG transport. After sponsoring and reviewing studies of LNG spills on water, the Coast Guard has testified that enough is known about LNG and its handling for it to be safely transported in U.S. waters.

Pacific Lighting's major insurance underwriters also agree.

 They do not view the planned LNG projects with evidence of any special concern, but are treating the ventures as they would any commercial or industrial installation.

Before ground can be broken on construction of any of the California terminals, their safety as well as many other elements are reviewed by a number of agencies from federal to state and local levels. Within their areas of responsibility, these agencies (see table 3) must be satisfied with the planned LNG facilities before issuing their approval.

Conclusion

In short, then, few can deny that California's immediate energy future depends on a continuing supply of natural gas. With supplies running low, liquefied natural gas represents a logical and viable solution to our energy problems.

LNG, as the natural gas from which it comes, is a potentially hazardous substance. Like any fossil fuel, it must be handled with respect. When proper precautions are taken, LNG can be safely handled as a dependable source of energy. Western LNG Terminal's planned facilities and the ships that will serve them will incorporate all proper precautions.

LNG can truly serve as today's link with tomorrow's energy.

TABLE 3 • SOURCES OF REGULATIONS, PERMITS AND APPROVALS REQUIRED TO ESTABLISH AN LNG FACILITY

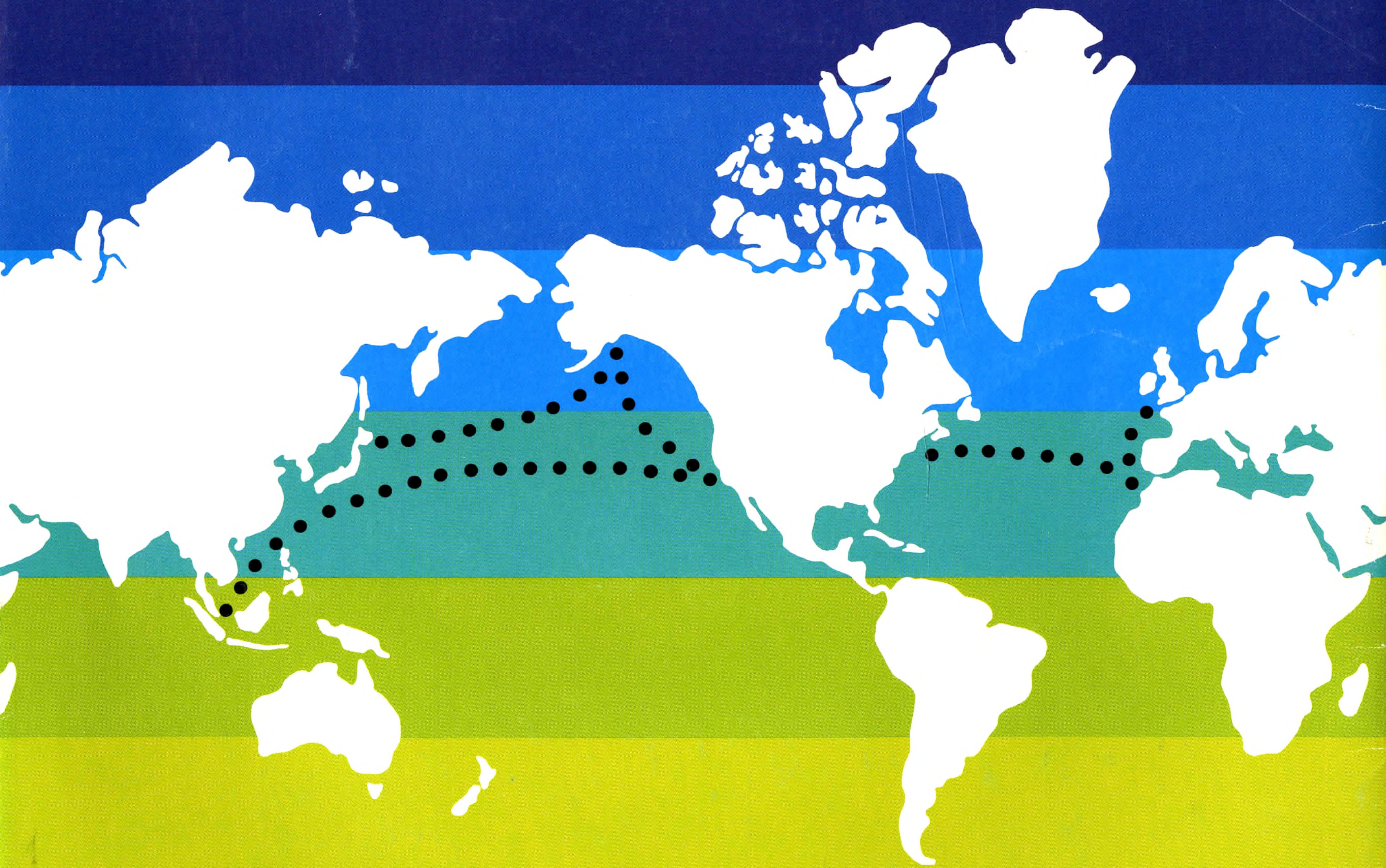
(Examples)

Federal Authorities:

Corps of Engineers, Department of the Army
Environmental Protection Agency
Federal Aviation Administration
Federal Power Commission
Materials Transportation Bureau
Occupational Safety and Health Administration
U.S. Coast Guard

State and Local Authorities: (California)

Air Pollution Control District
Building and Safety Department
City Council
Coastal Zone Conservation Commission
Division of Industrial Safety
Fire Department
Harbor Commission
Planning Department
Regional Water Quality Control Board
State Lands Commission



Western LNG Terminal Company
a subsidiary of
Pacific Lighting Corporation