

DOCUMENT RESUME

06801 - [B2367431]

[Liquefied Energy Gases Safety]. August 21, 1978. 22 pp. + enclosure (3 pp.).

Testimony before the Senate Committee on Commerce, Science, and Transportation; by Monte Canfield, Jr., Director, Energy and Minerals Div.

Contact: Energy and Minerals Div.

Organization Concerned: Department of Transportation; Department of Energy; Federal Energy Regulatory Commission; Interstate Commerce Commission.

Congressional Relevance: Senate Committee on Commerce, Science, and Transportation.

Authority: 46 U.S.C. 183.

Problems associated with liquefied energy gases (LEG), including liquefied natural gas (LNG) and liquefied petroleum gas (LPG), were considered. The increasing number of LEG storage facilities increases the probability that some will experience natural forces greater than those they are required to withstand by the Uniform Building Code. LEG storage facilities are also vulnerable to sabotage which could lead to tank failure. Dikes may not be able to contain spills in the event of tank failure in a large proportion of facilities, and this could be catastrophic in densely populated areas. With reference to LEG transportation: LNG ships are least vulnerable of all the systems involved in LNG transportation and storage; single hull LPG and naphtha ships are more vulnerable than LNG ships in the event of an accident or sabotage; no plans or equipment exist to cope with a major LEG spill; LEG trucks and railcars moving through densely populated areas pose a serious threat to public safety; and both are vulnerable to accidents and sabotage. Under present corporate structures and legal limits on liability, injured parties would not be fully compensated in the event of a major LEG accident, and no Federal agency deals with offsite liability for LEG accidents. Action should be taken by Federal agencies and the Congress to insure that LEG facilities are located away from densely populated areas and are built to stronger codes and standards, the movement of LEG in densely populated areas is restricted, and the security of LEG facilities and vehicles is upgraded. Also, regulations need to be coordinated and Federal research programs redirected and stepped up. (HTW)

7431

UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C.

FOR RELEASE ON DELIVERY
AT 9 A.M., MONDAY
AUGUST 21, 1978

TESTIMONY OF
MONTE CANFIELD, JR., DIRECTOR
ENERGY AND MINERALS DIVISION
ON LIQUEFIED ENERGY GASES
BEFORE THE
COMMITTEE ON COMMERCE, SCIENCE AND TRANSPORTATION

Mr. Chairman:

I am happy to be here to discuss the GAO report, Liquefied Energy Gases Safety, which was issued on July 31 of this year. This report was a coordinated effort involving GAO employees, companies under contract, and distinguished consultants.

My testimony will begin with a brief primer and then focus on five major areas: Storage facilities; Transportation, Liability; Research; and Regulation. A short discussion of the potential consequences of a large LEG spill is given in the addendum to my testimony.

Energy gases (natural gas, propane, and butane) are liquefied in order to reduce their volume hundreds of times. This facilitates their transportation and storage, but magnifies the potential hazard.

Liquefied energy gases (LEG) are often stored and transported in densely populated areas. Outside their containers, these liquids rapidly vaporize and become highly flammable and explosive gases. One cubic meter of liquefied natural gas (LNG)

makes 424,000 cubic feet of highly flammable natural gas-air mixture. One cubic meter of liquefied petroleum gas (propane and/or butane) makes a slightly larger volume of flammable gas-air mixture. A major spill in a densely populated area, whether by accident, natural forces, or sabotage, could be catastrophic.

Because of this potential danger and the possible increase in the use of these liquefied gases, we believe that now is an appropriate time to examine the critical safety issues and take those actions necessary to protect the public.

We believe that the Nation's LEG needs can be met without posing undue risk to the public if the recommendations developed in our report are adopted by the Congress and the Federal agencies involved. LEG facilities must be located away from densely populated areas and built to stronger codes and standards. The movement of LEG in densely populated areas must be restricted, and the security of LEG facilities and vehicles upgraded. Regulations need to be coordinated, and Federal research programs redirected and stepped up.

A BRIEF PRIMER

Although there are many differences in their physical properties and technologies, LNG and liquefied petroleum gas (LPG) are similar substances and have many safety and security problems in common. This has made it convenient to consider them together as LEG. Naphtha, a less hazardous substance, is included in the report to compare its regulations and handling with those of LEG.

LNG, LPG, and naphtha together make up about 3 percent of the energy used in this country. They are produced domestically and are imported. All three are used to supplement domestic natural gas supplies.

LNG and LPG will only burn at the surface of the liquid. When spilled, however, both substances quickly vaporize. Because LPG vapor and cold LNG vapor are heavier than air, they form a low spreading cloud, which becomes highly flammable as it mixes with air. An LNG vapor cloud is flammable when the LNG concentration is between 5 and 14 percent (the balance being air). The flammable range of an LPG cloud is between 2 and 9 percent LPG.

Overview of LNG Storage and Transportation

In the summer, when natural gas demand is low, excess gas is liquefied and stored in highly insulated tanks. A typical large LNG storage tank can hold 95,000 cubic meters--enough to make nearly 2 billion cubic feet of natural gas. When demand peaks in cold weather, the LNG is either regasified and pumped through gas pipelines to customers, or delivered by truck to other gas companies where it is similarly processed.

Such "peakshaving" plants have been operating in the United States for several years. Most large LNG storage facilities are for peakshaving. There are currently 45 of these which hold more than 23,000 cubic meters. There are about 75 LNG trucks, each with about 40 cubic meters capacity.

Recently, LNG has been imported in ships. These imports, which now supply less than one-tenth of one percent of U.S. natural gas demand, could supply up to 15 percent by 1985.* This would require more than 40 LNG tankers to operate regularly in and out of U.S. harbors. A typical new LNG tanker carries about 125,000 cubic meters.

The 14 major LNG import terminals now operating throughout the world are "base-load" facilities. The LNG is piped from the ship to storage tanks from which it is constantly regasified or re-shipped, instead of being saved for peak demand periods.

There are three LNG import terminals currently operating in this country. The Everett, Massachusetts terminal began operations in 1971. The Cove Point Maryland terminal and the Elba Island, Georgia terminal began operations this Spring. Two terminals are now under construction, and several more have been proposed.

Overview of LPG Storage and Transportation

The much greater use of LPG has drawn less public attention than the relatively new LNG industry. LPG has been used for many years for a variety of purposes, including making synthetic natural gas and providing power on farms.

About 85 percent of the LPG in bulk storage is kept under pressure in underground salt domes or mined caverns. LPG is also stored in aboveground tanks, many of which are small. There are only 20 LPG aboveground storage facilities that hold more than 23,000 cubic meters.

Domestic transportation of LPG is mostly by pipeline, with the remainder distributed in trucks or railcars. There are 70,000 miles of LPG high-pressure pipeline, 16,000 LPG rail cars, and 25,000 LPG transport and delivery vehicles. A large LPG truck trailer holds about 40 cubic meters.

Ten major LPG import terminals are now operating in the United States, and imports of LPG may rise substantially. LPG ships are smaller than LNG ships; typical new ones hold 75,000 cubic meters.

LEG STORAGE FACILITIES

VULNERABILITY TO NATURAL FORCES

LEG storage tanks are usually designed to the Uniform Building Code (UBC) standards for their particular geographic areas, the same standards used for most inhabited buildings. They essentially require that LEG tanks be able to withstand the largest earthquake, wind, flood, etc., locally experienced in the last 50, 100, or 200 years.

The probability of these natural forces exceeding UBC standards at a given site in a given year is low. However, the probability that the standards will be exceeded some time at some facility increases with the number of facilities and with the number of years each facility operates.

Because there are already many large LEG facilities, it is virtually certain that during their lifetime many of them will experience natural forces greater than those the UBC standards require them to withstand. This does not necessarily mean

that the facilities will fail. The UBC standards are minimum criteria, and most structures have built-in "safety margins"-- they are designed to be stronger than the standards require.

By "failure" of a tank, we mean a permanent distortion or rupture that causes significant leakage of the contained fluid. A failure is not necessarily a complete collapse.

We evaluated the LEG tank designs at five sites and found that, while they were adequately designed for the UBC earthquake and 100-year wind criteria, tanks at three of the sites had very small earthquake safety margins--two of these three, containing three large tanks, are located next to each other in Boston Harbor.

Nuclear power plants are built to higher standards than any other type of energy installation, much higher than those for LEG installations. Nevertheless, they are never located in densely populated areas. We believe that new large LEG facilities also should not be located in densely populated areas.

Most LNG storage tanks have double metal walls with insulation in between. Some are made of prestressed concrete. LPG and naphtha tanks have single walls.

The outer steel walls of LNG tanks are not normally made to withstand intense cold. Thus, if the inner tank alone fails for any reason, it is almost certain that the outer tank will rupture from the pressure and thermal shock.

The most likely cause of failure of large steel LEG tanks in an earthquake appears to be from breaking the steel straps which anchor the steel tank sides to the concrete foundation.

The tank's walls will then separate from its bottom, causing a massive spill.

Large LEG tanks made of prestressed concrete are usually much more resistant to natural forces than those made of steel.

THE ABILITY OF DIKES TO CONTAIN LARGE SPILLS

National Fire Protection Association standards require that each large LEG tank, or group of tanks, be surrounded by a dike which can hold at least the volume of the largest tank. However, most of these dikes are only designed to contain LEG spilled from relatively slow leaks. They cannot contain the surge of LEG from a massive rupture or collapse of a tank wall.

We selected six LEG facilities--with dikes built to National Fire Protection Association criteria--and calculated how much liquid could escape over the dikes. Our calculations were verified by experiments.

Our results indicate that a massive rupture or collapse of a tank wall could spill over 50 percent of the LEG at five of the facilities. The largest overflows we calculated were the two tanks at Distrigas with 64 and 62 percent. The adjacent Exxon facility ranked next with 58 percent.

Our calculations assumed an immediate, total spill of a full tank, with the fluid moving toward the nearest dike wall. Such an LNG spill occurred in Cleveland in 1944. A similar, much larger LPG spill occurred at a Shell facility in the country of Qatar in 1977.

VULNERABILITY TO SABOTAGE

Public utilities and petroleum companies in this country have often been the targets of sabotage. Many domestic and foreign groups have weapons, explosives, and ability to sabotage LEG facilities. Successful sabotage of an LEG facility in an urban area could cause a catastrophe.

We found that security procedures and physical barriers at LEG facilities are generally not adequate to deter even an untrained saboteur.

None of the LEG storage tanks we examined are impervious to sabotage, and most are highly vulnerable. Some designs provide greater protection than others against explosive penetration. Stronger designs complicate sabotage by requiring specially designed charges, more powerful explosives, and more on-site preparation. Concrete tanks are much more penetration resistant than single-wall LPG tanks. Double-wall metal LNG tanks fall in between.

In many facilities, just by manipulating the equipment, it is possible to spill a large amount of fluid outside the diked area through the draw-off lines.

LEG storage facilities in cities are often adjacent to sites that store very large quantities of other hazardous substances, including other volatile liquids. Thus, a single cause might simultaneously destroy many tanks, or a spill at one facility might cause further failures at adjacent facilities.

MAJOR CONCLUSIONS AND RECOMMENDATIONS

Our major conclusions and recommendations on LEG storage are as follows.

Conclusions

- It is virtually certain that the level of natural forces LEG facilities are required to withstand will be exceeded at many facilities in the next 50 years. This could lead to tank failure, particularly where safety margins are low.
- Little attention has been paid to sabotage at LEG facilities, and most of them are inadequately protected and highly vulnerable to sabotage. Sabotage could also lead to tank failure.
- If an LEG tank fails in a densely populated area, it could cause a catastrophe.
- In the event of a massive rupture or collapse of a tank wall, over 50 percent of the LEG could escape over the dikes at five of the six LEG facilities we examined.

Recommendations to Federal Agencies

We recommend that the Secretaries of Transportation and Energy and the Federal Energy Regulatory Commission take steps to ensure that:

- All new, large LEG storage facilities are built in remote areas. However, if, in spite of our recommendations, new LEG storage facilities are built and operated in other than remote areas, standards similar to those used in building and operating nuclear plants should be applied.

--No existing large LEG storage facilities in other than remote areas are expanded in size or use.

--Any new, large LEG storage facilities not built in remote areas have inground tanks, with the highest level of fluid below ground level.

We also recommend that the Secretary of Energy evaluate each existing, large LEG storage facility and recommend to the President and the Congress the actions necessary to protect the public from the hazards associated with them.

Recommendations to the Congress

We recommend that the Congress:

--Enact legislation requiring that guards at LEG facilities carry weapons and be authorized to use them if necessary to prevent sabotage.

--Enact legislation extending Federal authority to cover large LEG storage facilities which are presently not covered by Federal regulation. Many large urban LPG storage areas are not presently covered.

LEG TRANSPORTATION

LEG SHIPS

LNG ships, which hold up to 165,000 cubic meters, are probably the least vulnerable of all the systems involved in LNG transportation and storage. They are double-hulled and have insulated cargo tanks made of welded 9 percent nickel-alloy steel or aluminum alloy, both of which can withstand intense cold.

On the other hand, most LPG and naphtha ships are single-hulled. These ships, the largest of which hold 100,000 cubic meters, are much less resistant to collisions and sabotage than LNG tankers.

Ships are most susceptible to collision while entering ports through narrow, winding ship channels. They are most vulnerable to sabotage while tied up at terminals.

Since human error is a contributing factor in 85 percent of all marine casualties and operating problems, the best precaution against accidents and sabotage is to have highly-skilled, well-trained personnel operating the ships and terminals.

We have studied the Coast Guard's port operating procedures, and the training requirements for LEG ship's crews, and believe that they need to be improved.

The Coast Guard inspects all LNG ships before they enter U.S. harbors. These inspections do not include the operating condition of control equipment such as steering engines, propulsion machinery, and electronic devices.

In February 1976, the Coast Guard issued Liquefied Natural Gas - Views and Practices, Policy and Safety. The publication offers valuable guidance, but its procedures are not mandatory. Its implementation is left to the discretion of each Captain of the Port. It is the Captain of the Port who decides whether malfunctions in ships's safety systems are serious enough to bar their entry into a U.S. harbor. There are no specific Coast Guard guidelines covering LPG.

LEG TRUCKS

While LEG trucks carry only 40 cubic meters, far less than LEG ships, they move routinely through major metropolitan areas, where a relatively small spill can have very serious consequences.

LNG truck trailers have a higher center of gravity than most tank trucks, which makes them particularly susceptible to rolling over. However, they have inner and outer tanks with insulation in between and thus are quite resistant to puncture and cargo loss. LPG trucks also have a high center of gravity, although lower than LNG trucks; but they are single-walled and pressurized, and are therefore more vulnerable than LNG trucks to cracks and punctures and more likely to explode in fires.

We confirmed through discussions with LNG transport companies at least 12 LNG trailer accidents. Two of the accidents, which led to LNG spills, pointed out two vulnerable areas on LNG truck tanks--the unprotected portion of the trailer face, and the rear piping.

There have been many LPG truck accidents, some with severe consequences. For example, a 1975 LPG truck accident near Eagle Pass, Texas, caused explosions which killed 16 people and injured 45.

If an LEG truck fell off of an urban elevated highway, it would probably split open on the street below. LEG and its vapors could then flow down into sewers, subways, and basements. Because of its low boiling point, LEG would quickly vaporize, generating a pressure which would spread the invisible, odorless

less, explosive gas. The 40 cubic meters of LNG in one truck, vaporized and mixed with air in flammable proportions, are enough to fill more than 110 miles of 6-foot diameter sewer line, or 15 miles of a 16-foot diameter subway system. Other types of large trucks have fallen off urban elevated highways.

DOT has no special inspection program for LEG trucks. For all U.S. trucking, there are only 128 inspectors to monitor 160,000 licensed carriers and 3 million commercial vehicles.

The Interstate Commerce Commission (ICC) issues special certificates for LNG transport, but LNG can also be hauled under ICC certificates for the bulk transportation of petroleum products or liquid chemicals. An ICC certified company can hire 'leased operators' to operate under its certificate. This means that LNG may be trucked by companies which have not had to prove their competence to ICC. ICC certificates do not restrict truck routes.

LEG trucks could be easily hijacked or sabotaged. A truck might be hijacked for extortion or for malicious use of the cargo. Trucks that routinely operate over established routes are easy targets for saboteurs. LEG trucks are particularly dangerous, because they allow the easy capture, delivery, and release of a large amount of explosive material any place the terrorist chooses.

LPG RAILCARS

Ten percent of America's 1.7 million railroad freight cars are hazardous materials tank cars. About 16,000 of these, each

with approximately 115 cubic meters capacity, carry LPG. LNG is not transported by rail.

LPG cars are involved in many of the 10,000 railroad accidents that occur in this country each year. There are often more than 10 consecutive LPG cars on a train. If vapors from one LPG car ignite, the fire may cause a second, unpunctured car to rupture in a "Boiling Liquid Expanding Vapor Explosion," or BLEVE. Each fire and explosion contributes to the heating and weakening of neighboring cars and makes additional explosions more likely.

The latest LPG railroad catastrophe occurred February 1978, in Waverly, Tennessee. An LPG car exploded two days after a derailment, apparently as a result of internal damage during the accident and a rise in the atmospheric temperature. Fifteen were killed and over 40 injured.

LPG railcars travel through densely populated areas of cities, even cities which prohibit LPG storage. An LEG railcar or truck accident in a densely populated area, could cause far greater damage.

The Department of Transportation believes that their proposed new regulations for tank car construction are sufficient for their safe operation. We believe that restriction of routes is also necessary.

LPG tank cars are as vulnerable to sabotage as LPG trucks. The tanks can be breached with readily available weapons and explosives, and the cars can be derailed at predetermined times and places. The fact that they must stay on the tracks,

however, greatly limits the possibility of hijacking and the places they can be taken.

MAJOR CONCLUSIONS AND RECOMMENDATIONS

Our major conclusions and recommendations on LEG transportation are as follows.

LNG ships are probably the least vulnerable of all the systems involved in LNG storage and transportation. Single hull LPG and naphtha ships are more vulnerable than LNG ships in the event of an accident or sabotage. No plans or equipment exist to cope with a major LEG spill. If the Coast Guard is to effectively supervise the increasing number of LEG cargo transfer operations, it will need more money and manpower, revised regulations, and new plans and policies.

LEG trucks and railcars moving through densely populated areas pose a serious threat to public safety. The dangers present in trucking LEG are far greater than those involved in trucking less volatile petroleum products such as fuel oil, naphtha, and gasoline. Both LEG trucks and LPG railcars are vulnerable to accidents and sabotage. An LEG spill in a densely populated area could lead to a catastrophe.

We recommend that the Secretary of Transportation and the ICC:

--Prohibit trucking of LEG through densely populated areas and any areas that have features that increase

the vulnerability to a major LEG spill (e.g., sewer systems, tunnel openings, subways) unless delivery is other impossible. The Department of Transportation should also give particular attention to avoiding routes with highway configurations which make tank rupture accidents likely (e.g., elevated roadways, overpasses, high-speed traffic, roadside abutments).

--Prohibit the travel of LPG railcars through densely populated areas unless it is impossible to deliver the LPG otherwise.

LIABILITY AND COMPENSATION

A major LEG accident could cause damage of such severity that injured parties could not be fully compensated under existing arrangements. Present corporate structures and legal limits on liability offer great protection to the parent corporations. This may diminish their incentives for safety. At present, no Federal agency addresses the question of offsite liability for LEG accidents.

Each LNG ship is usually owned or leased by a separately incorporated subsidiary of a parent firm, and the LNG is stored in terminals owned by other subsidiaries. In many cases, the parent firms are wholly-owned subsidiaries of still larger firms.

Most of the assets in the system are protected by these corporate chains, and the top corporations, which derive all of the profits, would generally not be liable for the consequences of an accident. The front-line companies, which are most vulnerable to liability claims, are usually the most thinly capitalized in the chain. Most of their assets may be the ship or terminal itself, which is unlikely to survive an accident that does extensive offsite damage.

The liability of shipowners and bareboat ship charterers is limited by U.S. statute to the post-accident value of the vessel, plus any amounts owing for freight, if they can prove that they did not know about the causes of the accident.

Claimants after a major LNG accident would face long, complex, and expensive litigation involving potential complications at every step in the legal process. If the defendant

corporation is foreign-owned, it and its assets may be out of reach--in fact, it may be impossible to serve legal papers on the corporation unless it maintains an agent in the United States.

It is not always possible to prove the primary cause of a major accident, since critical evidence may be destroyed by the accident itself. If the accident results from sabotage or natural forces, the company may not be liable at all.

Present and planned liability coverage for LNG import terminals ranges from \$50 million to \$190 million per incident. Ten states require proof of liability insurance for LFG facilities, but the maximum required is only \$100,000 per incident.

The present liability and compensation system is not equitable and does not provide sufficient incentives for safety. We believe that the corporate owners who profit from LEG operations should bear liability for a major accident.

The banks and insurance companies which finance LEG ships and terminals insist that all companies in the corporate chain co-sign notes. This insures that, in the event of a catastrophic accident, the lending institutions will be protected by the assets of the whole corporate chain. Public safety deserves no less protection.

Recommendations to the Congress

We recommend that the Congress enact legislation which would:

- Require corporations transporting, storing, or using significant amounts of flammable materials to (1) carry the maximum liability insurance available from the private sector, and (2) contribute money to a Federal Hazardous Materials Compensation Fund.
- Provide that the United States be subrogated to the rights of injured persons compensated by the fund so that the Attorney General of the United States can sue companies or persons responsible for an LEG incident to recover whatever monies the fund has paid out.
- Allow injured parties to sue all companies in the corporate chain for all damages beyond those covered by insurance and the fund.

We also recommend that the Congress:

- Enact legislation which requires that strict liability be applied in all accidents involving LNG and LPG, and consider requiring that strict liability be applied to other highly hazardous materials.
- Amend the 1851 Act (46 U.S.C. 183) which limits the liability of owners and bareboat charterers of ships and barges by substantially raising the statutory limit for vessels carrying hazardous materials.

Recommendations to the Secretary of Energy
and the Federal Energy Regulatory Commission

We recommend that the Secretary of Energy and the Federal Energy Regulatory Commission:

- Ensure that adequate compensation for offsite damage will be available to injured parties before permitting LNG projects to proceed.
- Use their authority to require that importers and LNG tanker companies maintain agents for the receipt of legal documents in all states in which they operate.

LEG SAFETY RESEARCH

The limited research that has been carried out on LEG spills and LEG vapor cloud behavior does not provide a sound basis for assessing LEG hazards.

LEG risk assessment studies have not reached a stage where their conclusions can be relied on. Until they do, regulators will have to attempt to make timely, prudent, siting and other critical judgments with the realization that many important safety questions cannot yet be answered with confidence.

DOE's currently planned LNG safety research program will not provide answers soon enough. We believe that an effective safety research program, focusing on those issues most important to decision makers, can be carried out within two years for less than one-fifth of the \$50 million DOE is planning to spend on long-term LNG research. We have made detailed suggestions for such a program in our report.

FEDERAL REGULATION OF LEG

Present Federal efforts to regulate LEG and naphtha do not adequately protect public health and safety. We believe that most Federal regulatory responsibilities for energy health and safety should be consolidated into a single, independent agency. This was one of the options for Congressional consideration provided in GAO's 1977 report, "Energy Policy Decisionmaking, Organization, and National Energy Goals".

With a mandate to adequately protect the public health and safety, such an agency could assemble a technical staff capable of developing appropriate regulations and inspecting and enforcing the implementation of those regulations.

We recommend that the Congress:

- Consider creating an Energy Health and Safety Regulatory Agency. The new agency could include the Nuclear Regulatory Commission; the pipeline safety aspects of fuel transportation on land, now handled by DOT; and safety aspects of importing energy, now handled by DOE, plus all safety responsibilities formerly carried out by the Federal Power Commission.
- Consider including within the Energy Health and Safety Regulatory Agency the safety regulation of LEG carried by truck and train. DOT would continue to be responsible for all safety regulation of motor carriers and railroads, except those transporting nuclear materials and LEG. The Environmental Protection Agency should

retain the responsibility for setting air and water quality standards impacting on energy development use, and waste disposal.

--Consider making the Energy Health and Safety Regulatory Agency completely independent of DOE, or including it within DOE with strong statutory provisions to insure its independence.

That concludes my testimony, Mr. Chairman. I would be happy to answer any questions on it, or on the report.

ADDENDUM

THE POTENTIAL CONSEQUENCES

THE EFFECTS OF A LARGE LEG SPILL

While LEG storage and transportation in densely populated areas are very hazardous, it is difficult to estimate the effect of a large LEG spill.

The only significant U.S. LNG spill, in Cleveland in 1944, involved a relatively small amount compared to the quantities stored in urban areas today, about one-fifteenth of one large modern tank.

Some insight can be gained from the spill of naphtha into the sewers of Akron, Ohio, in June 1977. Although naphtha is much less volatile than LEG and less than 15 cubic meters were spilled, the incident caused violent explosions more than 8 miles from the point of the spill.

LEG vapors are highly explosive in confinement, and can explode in the open air--although the conditions which allow this are not completely understood. In Port Hudson, Missouri, in 1970, a relatively small propane leak from a pipeline break led to a large detonation propagating through the open air.

If LEG spreads across a city through sewers, subways, or other underground conduits, or if a massive burning cloud is blown along by a strong wind, a city may be faced with a very large number of ignitions and explosions across a wide area.

No present or foreseeable equipment can put out a very large LEG fire.

THE CLEVELAND ACCIDENT

The only major LNG spill in the United States occurred in Cleveland, on October 20, 1944. It resulted in fires and explosions that killed 130 people, injured 225 more, and resulted in property damage estimated at \$7 million.

Casualties could have been much higher if the spill had taken place at a different time of day. At the time of the fire, most children were at school and most men were at work. Furthermore, the National Fire Protection Association Newsletter of November 1944 said:

"The fact that the wind was blowing away from the congested part of the area is believed to have been a major factor in prevention of an even more devastating conflagration which could have destroyed a very large part of the East Side."

The Cleveland accident virtually halted LNG use in this Nation for 20 years.

The following facts are significant.

- Both the tank manufacturer and the gas company assumed that a small leak would precede any more serious spill, and that it would be detected and repaired.
- The gas company took precautions to control small and moderate rates of LNG spillage. They assumed that a sudden, massive spill was extremely unlikely and not

worth worrying about. The same assumption is made today in designing dikes around LEG facilities.

--The plant site was selected because it was already company property and was appropriately located on the gas distribution system. The company felt it was building a safe plant that could be located anywhere. Similar assumptions about the safety of LEG plants in urban areas are made today.

--The proximity of other industrial facilities, residences, storm sewers, or other conduits was not considered.

--The Cleveland accident was caused by an amount of LNG which is very small by modern standards. Less than 6,300 cubic meters of LNG spilled and a large portion of that remained on the company property. Typical large LNG storage tanks hold up to 95,000 cubic meters, and one site may have several tanks.

The Bureau of Mines study of the Cleveland accident contained the following recommendations, which have yet to be generally adopted.

1. Plants dealing with large quantities of liquefied flammable gases should be isolated at considerable distance from inhabited areas.
2. Extreme caution should be taken to prevent spilled gas from entering storm sewers or other underground conduits.