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Liquefied Petroleum Gas Industry Profile

Vol. I: An Overview of the Industry

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16. Abstract

This report provides a broad, factual description of the U.S. liquefied petroleum gas (LP-gas) industry. The basic purpose of the report is to provide analysts and policymakers in government and industry with a comprehensive overview of the LP-gas industry that can be used as a tool in the decision-making process.

The report is contained in two volumes: Volume I provides the basic discussion of the LP-gas industry. Volume II supplements the presentation of Volume I with appendices containing additional detail on selected topics. The presentation in Volume II is primarily in the form of tables, maps, and figures. Volume II may be obtained from the U.S. Department of Transportation, Transportation Systems Center, Economic Analysis Division, 55 Broadway, Cambridge, MA 02142.

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PREFACE

This report, prepared by the Economic Analysis Division, the Transportation Systems Center, U. S. Department of Transportation, provides a broad, factual description of the U. S. LP-gas industry. The basic purpose of the report is to provide analysts and policy-makers in government and industry with a comprehensive overview of the LP-gas industry that can be used as a tool in the decision-making process.

The authors would like to thank Ms. Carol McAdam of the National LP-Gas Association for her assistance in the preparation of this document.

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EXECUTIVE SUMMARY

This report is contained in two volumes. Volume I provides the basic discussion of the LP-gas industry. Volume II supplements the presentation of Volume I with appendices containing additional detail on selected topics. The presentation in Volume II is primarily in the form of tables, maps, and figures. Volume II may be obtained from the Economic Analysis Division, Department of Transportation's Transportation Systems Center, 55 Broadway, Cambridge, MA 02142.

The topics considered in Volume I include: What is LP-Gas?, LP-gas consumption, supply, storage, transport, marketing, and regulation. The volume ends with a bibliography and a listing of the information contained in Volume II, by topic.

LP-gas (or LPG) generally refers to propane, iso- and normal butane, and mixtures of these light carbons. It may also include propylene and the butylenes.

LP-gas is consumed around the world. The U. S. leads the world in the consumption of LP-gas. LPG is the fourth most important energy source in the U. S. It is an especially important energy source in rural areas, where approximately half of the farms use it.

LP-gas is used in a wide variety of applications. The most important use of LPG is for space heating. LPG is used in the residential and commercial sectors, the manufacture of chemicals, synthetic rubber and gasoline, the secondary recovery of petroleum, and the product delivered by many gas utilities, as well as in agriculture and internal combustion engines. The residential and commercial sectors, combined, are the heaviest consumers of LPG, followed by the manufacture of gasoline and the manufacture of chemicals and synthetic rubber.

LP-gas is produced at gas processing plants from the output of natural gas wells and at refineries as a by-product of the refining process. Roughly two-thirds of U. S. production comes from gas processing plants and one-third from refineries. Only about ten percent of refinery production actually finds its way into the market. The production technology used at gas processing plants has evolved rapidly. At first, simple compression techniques were used; later, various absorption techniques were developed. Currently, the most commonly used process is refrigerated absorption.

INTRODUCTION

Overview

This report is an examination of liquefied petroleum gas (LP-gas) use in the United States. Its aim is to provide analysts and decision-makers in the U. S. Department of Transportation (DOT) and industry with a concise, yet comprehensive, overview of the industry. Given the mission of DOT to assure the safe and efficient transport of hazardous materials, including LP-gas, in the U. S., the primary focus of the report is on understanding the interactions between the demand for LP-gas and the complex logistical network that the industry has evolved to supply that demand. Since LP-gas is not only a hazardous material, but also an important energy source and raw material that plays an important role in the economic well-being of the nation, the economic aspects of the industry are included along with transport and safety.

The report consists of two volumes, this volume and a volume of appendices. This first volume contains the basic discussion of LP-gas in the U. S. The second volume of the report complements and supplements the sections in the first, with additional detail on selected topics, often in tables and figures. In the following sections of this volume, the topics considered are, in order, What is LP-Gas?, LP-gas consumption, supply, storage, transport, marketing, and regulation. The volume ends with a bibliography and an appendix listing of the information contained in Volume II.

Sources of Information

Much of the information contained in this document was developed from industry sources and government publications. The safety data used in the report were obtained mainly from the Materials Transportation Bureau's Hazardous Materials Information System database. A very important source of data on LP-gas consumption and production was the National LP-Gas Association's annual publication, "LP-Gas Market Facts." Four trade periodicals proved to be valuable aids in understanding the LP-gas industry and were consulted extensively in developing this report. These were the OIL AND GAS JOURNAL, LP/GAS, the BUTANE-PROPANE NEWS, and the BPN WEEKLY PROPANE NEWSLETTER. A selected bibliography of the sources consulted can be found toward the end of this report.

TABLE 1.

SELECTED PHYSICAL CHARACTERISTICS OF LP-GASES

Characteristic	Propane	Iso-Butane	Normal Butane
Molecular Weight	44.094	58.120	58.120
Boiling Point at 14.696 psi, °F	-43.7	10.9	31.1
Lb/Gallon at 60°F	4.224	4.685	4.863
Ratio, gas vol/liquid vol - actual	267.6	221.1	230.1
Flammable Limits			
Lower percentage in air	2.37	1.80	1.86
Upper percentage in air	9.50	8.44	8.41
Octane number	over 100	99	92

Source of data: "Liquefied Petroleum Gas," PETROLEUM PRODUCTS HANDBOOK, Guthrie, ed., McGraw-Hill, New York, 1960, page 3-3.

- The use of LP-gas to produce synthetic natural gas (SNG) and in the secondary recovery of petroleum, combined with LP-gas use for agriculture, and other miscellaneous uses, accounted for 9.0 percent of total U. S. LP-gas consumption in 1978 (SNG is methane produced from LP-gas or a similar hydrocarbon feedstock).

- LP-gas is also used in the production of gasoline. In 1978, approximately 3.7 billion gallons, or 19.7 percent of total LP-gas consumption, were used in the production of gasoline, making gasoline blending the second most important use of LP-gas after consumption by the residential and commercial sectors.

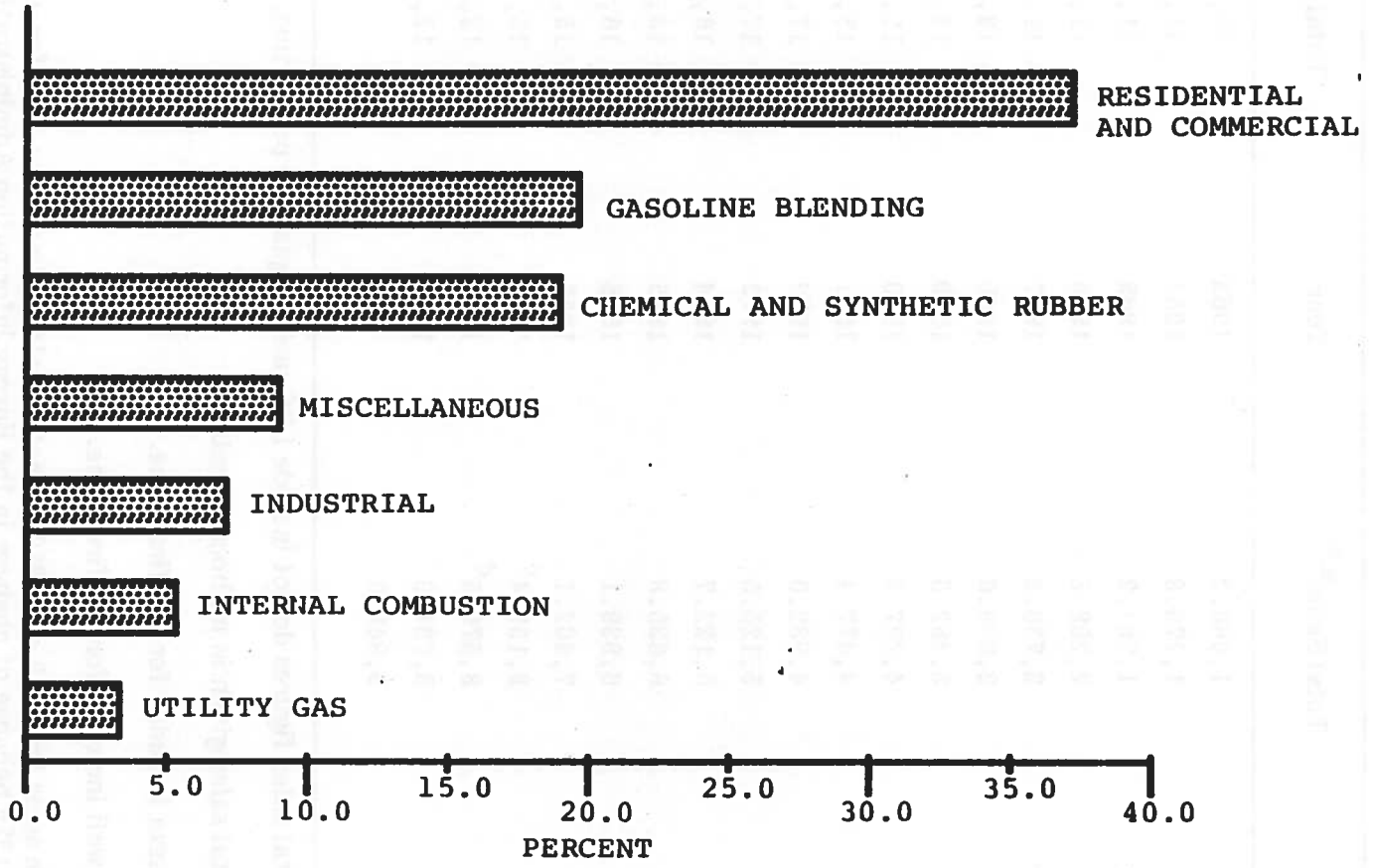
Growth in Consumption

Between 1944 and 1969, LPG sales experienced a rather dramatic growth in the U. S. (see Table 2). Exclusive of gasoline production, sales during the period increased by more than 1,300 percent. The reasons for this growth of LP-gas sales rest on four characteristics of LP-gas--its ease and economy of transportation, efficiency and cleanliness of combustion, ease of use, and similarity to natural gas. Ease and economy of transportation are, of course, great advantages for a fuel. This is particularly true when the market for fuel is, to a large extent, national, as is the case with LP-gas. Efficiency and cleanliness of combustion, and ease of use, make LP-gas an attractive energy source, especially where emissions must be controlled. Finally, and perhaps most significantly, LP-gas is said to be a "perfect supplement" to natural gas when "properly aerated and controlled." This allows LP-gas to be used to meet the peak-shaving requirements of gas utilities and gives it its potential as a backup fuel when regular supplies of natural gas are interrupted.

Annual sales in the decade following 1970 were generally lower than sales in 1969, with only three exceptions. There appear to be two primary reasons for this (beyond the relatively mild winters experienced during this period). First, the natural gas distribution system in the U. S. continued to expand during this period despite periodic natural gas curtailments, putting pressure on LP-gas sales. Historically, natural gas has maintained a distinct cost advantage over LP-gas for most uses.

FIGURE 1.

LPG CONSUMPTION IN 1978



Source of data: NLPGA, "1978 LP-Gas Markets Facts."

TABLE 3.

SALES[a] OF LPG BY STATE, 1980[b]

STATE	SALES	STATE	SALES
Alabama	171.2	Montana	62.5
Alaska	6.6	Nebraska	155.6
Arizona	55.0	Nevada	30.4
Arkansas	167.7	New Hampshire	44.3
California	664.0	New Jersey	255.4
Colorado	133.9	New Mexico	162.9
Connecticut	51.9	New York	194.8
Delaware	110.6	North Carolina	276.0
Florida	370.7	North Dakota	45.0
Georgia	257.5	Ohio	1,531.1
Hawaii	54.4	Oklahoma	310.9
Idaho	34.4	Oregon	46.8
Illinois	1,342.5	Pennsylvania	251.0
Indiana	275.4	Rhode Island	10.1
Iowa	386.3	South Carolina	*
Kansas	290.7	South Dakota	87.5
Kentucky	353.6	Tennessee	96.4
Louisiana	1,828.9	Texas	6,565.4
Maine	30.2	Utah	45.0
Maryland & D.C.	71.4	Vermont	*
Massachusetts	73.5	Virginia	*
Michigan	233.0	Washington	51.4
Minnesota	266.2	West Virginia	118.8
Mississippi	196.9	Wisconsin	208.8
Missouri	315.5	Wyoming	70.2
		Total	18,603.9

a Sales are given in millions of gallons. Figures include sales of ethane.

b Sales for 1980 cannot be related to data prior to 1979 because of changes in the Energy Information Administration's reporting procedures.

* data withheld

Source: NLPGA, "1980 LP-Gas Market Facts." Original source of data is U.S. Department of Energy, Energy Information Administration.

LP-GAS SUPPLY

Domestic Production

LP-gas is recovered at gas wells or at refineries as a byproduct of the refining process. Map 1 illustrates the geographic distribution in the U. S. of both types of production. Generally, it is assumed that roughly one-third of total U. S. production has come from refineries and two-thirds from gas processing plants. Recent production levels bear out this rule of thumb, with 35 percent of production coming from refinery production and 65 percent from processing gas plants, which recover LP-gas from oil-well and gas-well gas. The various extraction processes used by gas plants are compression, adsorption, oil absorption, refrigerated absorption, and cryogenic. The annual production of LPG between 1954 and 1980 is presented in Table 5.

Refinery creation of LP-gas, largely propane, is a substantial portion of domestic production. However, only about one-tenth of the propane produced as a consequence of refinery operations ever reaches the market place. Most is used at the refinery as fuel. Refiners view propane as a byproduct of the refining process. Gasoline demand exerts great leverage on the choice of which products a refinery will use, since fully half of the crude oil entering the refinery will leave in this form. Only about 2 percent of the crude is turned into propane, however.

Changes in the demand for natural gas directly affect the capacity of the gas processing industry to produce LP-gas. They do not, however, directly affect the production of LP-gas. In 1980, when LP-gas production was at a 12-year low, the number of gas processing plants, 809, represented a nine-year high. In addition, exploration around that time was booming. The explanation, of course, is that the gas processing industry is dominated by the production of "dry" natural gas; the production of any other product from the natural gas stream is ancillary.

Production of LP-gas by state is detailed in Table 6. Texas and Louisiana lead the other states in total gas processing capacity, followed by Kansas, Oklahoma, and New Mexico. Generally, as might be expected, the West South Central census region leads the country in the production of LP-gas. The capacity and throughput of the top 20 producer firms in 1979 was 56.8 and 32.1 billion cubic feet/day (bcf/d),

Ownership of Production Facilities

The number of firms engaged in the leasing and ownership of petroleum and natural gas reserves, and in production and gas processing facilities, indicates that no firm has clear leadership in terms of production; and consequently, production and supply of LP-gas generally approximates a competitive market industry. Table 11 contains the LPG production by the top twenty firms in the business in 1979.

Fully integrated firms control (as defined in the USA OIL INDUSTRY DIRECTORY) 70 percent of gas processing capacity, while pipeline firms are next with 12.5 percent. Smaller independent firms operate 10 percent of capacity and the remainder goes to large independent producers. Average capacity for each category is as follows:

Fully integrated firms	——	1,600 MMcf/d
Large independent firms	——	150 MMcf/d
Small independent firms	——	120 MMcf/d
Pipeline firms	——	650 MMcf/d

Capital Expansion

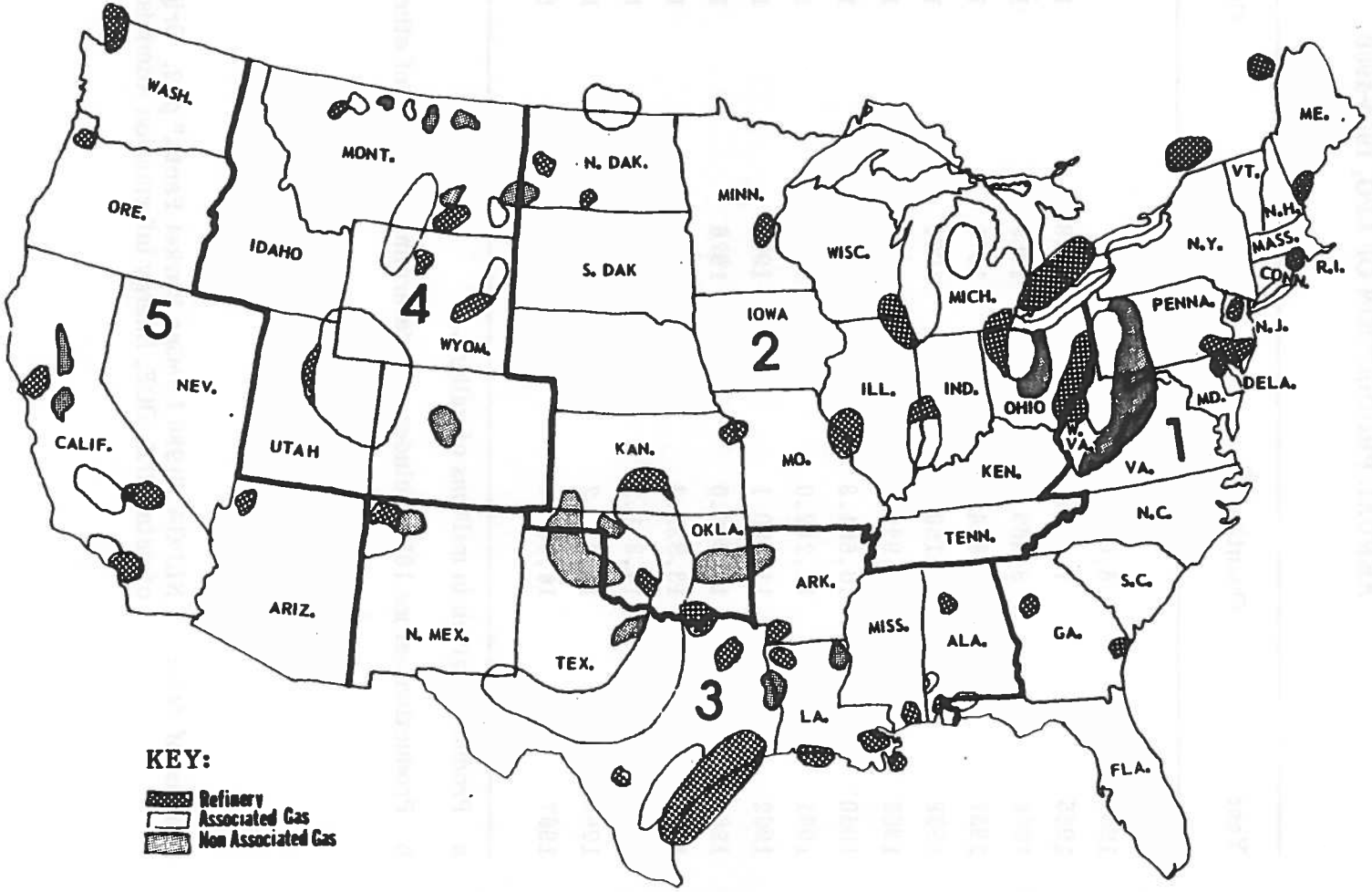
In 1980, about 13 percent of new capacity was accounted for by the top 10 firms in terms of combined capacity. The other 87 percent is being carried out by firms controlling less than six percent of combined capacity. The size of new plants being constructed in 1980 varied from three MMcf/d to 150 MMcf/d. This considerable disparity in plant size has existed for some time, which seems to indicate a lack of significant scale economies.

The West South Central region had the largest increase in plants, while the Pacific region showed the largest decline, losing, however, only three plants. The overall change, 1979 to 1980, was an increase in 10 plants nationwide, to a total of 809.

In terms of actual processing capacity, Texas was a net loser of capacity (although it showed an increase of four firms over the same time span), and Louisiana showed the largest gain in capacity (with an increase of only two plants).

MAP 1

LPG PRODUCTION AREAS



Source: U.S. GAO, LIQUEFIED ENERGY GASES SAFETY, p. 14-3.

TABLE 6.

LP-GAS PRODUCTION STATISTICS BY STATE, 1980

State	No. of Plants	Gas Capacity	Gas Throughput	Propane	Iso-Butane	Normal Butane	LP-Gas Mix
Alabama	5	182.0	134.1	177.9	-	141.7	-
Alaska	2	49.4	40.3	7.2	-	-	-
Arkansas	4	152.0	78.3	16.9	4.1	11.7	-
California	38	1,260.5	403.0	245.6	15.5	49.7	9.3
Colorado	27	797.6	527.0	144.9	0.4	71.3	6.3
Florida	3	907.7	781.0	384.3	-	234.7	-
Illinois	2	551.5	411.0	395.7	35.0	76.7	-
Indiana	1	5.6	0.8	3.3	-	-	-
Kansas	23	4,988.5	3,480.6	942.7	103.6	395.6	-
Kentucky	2	951.0	660.2	-	-	-	-
Louisiana	102	23,688.3	14,410.6	1,905.5	544.8	688.0	418.8
Michigan	8	715.0	457.7	128.1	0.5	3.5	-
Mississippi	7	1,002.0	515.7	9.3	-	8.9	3.1
Montana	8	60.9	36.3	32.3	-	10.6	-
Nebraska	2	22.5	4.0	5.4	-	2.0	-
New Mexico	36	3,587.9	2,742.0	356.9	21.0	112.7	13.5
North Dakota	8	452.2	239.0	131.1	-	53.2	9.7
Oklahoma	93	4,462.4	2,984.8	677.7	97.4	231.2	372.0
Texas	384	24,856.8	14,462.9	4,111.2	493.3	2,116.0	1,050.6
Utah	11	598.5	308.5	141.7	13.0	89.8	10.9
West Virginia	4	368.0	244.2	133.0	22.0	40.0	-
Wyoming	39	1,378.4	758.1	360.1	32.5	165.8	81.2
Total	809	71,038.7	43,680.1	10,310.8	1,383.1	4,503.1	1,975.4

*Capacity and throughput are measured in millions of cubic feet per day (MMcfd). Production figures are given in thousands of gallons per day, and were calculated by dividing yearly production by 365. Where throughput figures were unavailable, they were estimated at 80 percent of capacity.

Source: "Gas Processing," OIL AND GAS JOURNAL, July 13, 1981, p. 94.

TABLE 8.

U.S. LPG IMPORTS* AS A PERCENTAGE OF TOTAL SUPPLY, 1972-1980
(thousands of bbls)

	1972	1973	1974	1975	1976	1977	1978	1979	1980
Total Dom.Prod.[1]	425,040	430,220	410,540	395,380	389,830	387,720	379,178	361,414	354,182
Propane	308,180	311,750	293,990	285,830	280,310	283,005	276,807	263,325	257,495
Butane	106,890	108,470	107,200	102,450	101,410	97,368	94,088	93,563	91,719
B-P Mix	9,970	10,000	9,350	7,100	8,110	7,347	8,283	4,526	4,968
Total Imports	32,400	48,000	44,970	40,730	47,440	58,927	40,889	62,576	56,711
Propane	15,850	25,790	21,460	22,060	24,770	31,427	20,639	32,268	25,344
Butane	16,550	22,210	23,510	18,670	22,670	20,893	12,459	21,548	20,709
B-P Mix	-	-	-	-	-	6,607	7,791	8,760	10,658
Total Supply	457,440	478,220	455,510	436,110	437,270	446,647	420,067	423,990	410,893
Propane	324,030	337,540	315,450	307,890	305,080	314,432	297,446	295,593	282,839
Butane	123,440	130,680	130,710	121,120	124,080	118,261	106,547	115,111	112,428
B-P Mix	9,970	10,000	9,350	7,100	8,110	13,954	16,074	13,286	15,626
Imports as a % of Supply, Total	7.08%	10.04%	9.87%	9.34%	10.85%	13.19%	9.73%	14.76%	13.80%
Propane	4.89%	7.64%	6.80%	7.16%	8.12%	10.0%	6.94%	10.92%	8.96%
Butane	13.41%	17.0%	17.99%	15.41%	18.27%	17.67%	11.69%	18.72%	18.42%
B-P Mix	-	-	-	-	-	47.35%	48.47%	65.93%	68.21%

*Propane + Butane + B-P Mix (excludes ethane, ethane-propane mix, isobutane)

[1]Production at refineries and gas processing plants for all uses.

Source: U.S. Dept. of Energy, Energy Information Administration, Energy Data Reports,"Annual Petroleum Statements."

TABLE 9. (Cont.)

U. S. LP-GAS IMPORTS BY COUNTRY OF ORIGIN, 1974-1979

(Thousands of barrels and percent of yearly total)

Country	Year					
	1974	1975	1976	1977	1978	1979
Neth. Ant.	595	81	-	138	33	-
	(1%)	(s)	-	(s)	(s)	-
Ecuador	-	-	12	-	5	-
	-	-	(s)	-	(s)	-
Other	400	198	621	1,726	50	143
	(1%)	(s)	(1%)	(3%)	(s)	(s)
Total	44,810	41,167	47,531	59,181	41,143	63,526
	(100%)	(100%)	(100%)	(100%)	(100%)	(100%)

s: Greater than zero but less than 1200 bbls or greater than zero but less than 0.5%.

Source of data: U.S. Bureau of the Census, Foreign Trade Division.

TABLE 10.

OCEANBORNE LP-GAS IMPORTS, 1977-1980, BY CUSTOMS DISTRICT/IMPORT TERMINAL

(Thousands of cubic meters)

Customs District	Import Terminal	Year			
		1977	1978	1979	1980
01	Newington, NH	207.0	169.4	117.5	35.8
04	Boston, MA	337.9	170.4	176.8	126.8
05	Providence, RI	163.6	84.4	-	62.2
11	Philadelphia, PA (includes Marcus Hook)	31.2	79.1	246.6	274.1
14	Norfolk, VA	224.7	66.8	22.4	-
20	New Orleans, LA	-	-	-	-
21	Hackberry, LA	-	-	-	14.8
22	Corpus Christi, TX	358.9	138.8	316.9	-
27	Los Angeles, CA	-	44.5	58.9	-
30	Ferndale, WA	22.1	-	0.1	-
52	Miami, FL (Port Everglades)	4.9	-	0.4	0.4
53	Houston, TX	1106.6	433.3	970.7	256.9
	Total	2456.9	1142.7	1910.2	796.1

Source: U.S. Bureau of the Census, Foreign Trade Division.

LP-GAS STORAGE

Overview

Since LP-gas is over 200 times as "compact" when stored as a liquid rather than as a gas, this form of storage is preferred. The gas can be either cooled or pressurized to reach this state, and both techniques are used for commercial and residential storage in this country. The most common pressure storage is undoubtedly the small cylinders used to fuel a camp stove and the familiar cylindrical tanks found outside many homes. LP-gas is also held under pressure at commercial facilities, generally in salt domes or cavities mined from granite or some other rock. Refrigerated storage is used when suitable underground storage is unavailable. The need for great amounts of storage stems in part from the seasonal nature of demand. As indicated above, LP-gas may be stored above or below ground. The locations of the major underground storage facilities are indicated on Map 3. The bulk underground storage capacities for each of the states in the U. S. can be found in Table 12. The underground methods, salt-washed and mined storage, are cheaper than aboveground methods, though the former require suitable geological formations, while pressurized or refrigerated tanks, the aboveground methods in use, do not.

While the bulk of LP-gas storage in the U. S. is underground, a number of import terminals located in urban areas have significant aboveground storage. In most cases, this storage is located in industrial areas where few or no persons reside within 1/2-mile of the storage site. Populations, and population densities, often increase rapidly beyond a 1/2-mile radius, however.

There is a substantial excess handling capacity at import terminals. Excess handling capacity estimates suggest a nearly 10-fold increase in oceanborne LP-gas imports is possible with existing facilities.

Ownership of Storage Facilities

The need for large amounts of storage for LP-gas relative to production is largely due to the strong seasonal component of demand, coupled with the fact that production is relatively constant over a year's time. This non-conformity of production to consumption gives rise to the need for seasonal storage requirements.

MAP 3

MAJOR UNDERGROUND LPG STORAGE FACILITIES

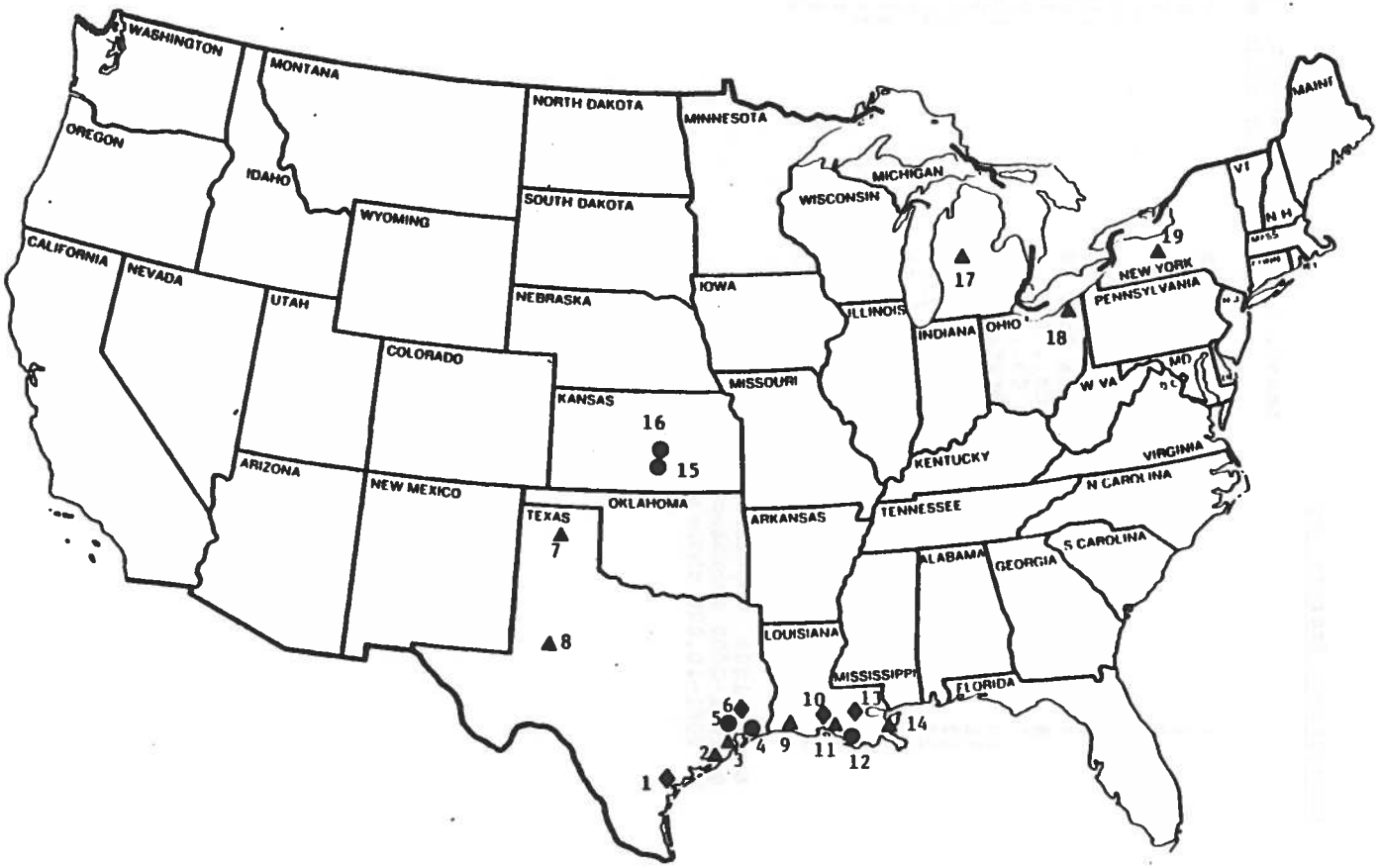


TABLE 12.

U.S. LPG UNDERGROUND BULK STORAGE CAPACITIES*

BY STATE, 1980

State	Propane	Butanes	Others	Total
Alabama	7.5	-	-	7.5
Arizona	104.0	93.0	-	197.0
Georgia	10.9	-	-	10.9
Illinois	80.4	45.8	1.8	128.0
Indiana	41.0	26.4	-	67.6
Iowa	22.5	2.1	-	24.6
Kansas	2,091.3	515.3	37.5	2,644.2
Kentucky	25.1	3.4	1.1	29.5
Louisiana	895.9	732.1	1,150.1	2,778.1
Maryland and D.C.	6.3	-	-	6.3
Michigan	194.0	49.4	12.0	255.4
Minnesota	13.9	-	-	13.9
Mississippi	915.1	-	-	915.1
Missouri	44.4	-	-	44.4
Nebraska	31.7	-	-	31.7
New Jersey	9.7	10.5	-	20.2
New Mexico	30.3	2.0	-	32.3
New York	210.2	-	-	210.2
Ohio	281.0	44.2	6.4	331.7
Oklahoma	42.8	16.0	14.9	73.6
Pennsylvania	48.7	32.1	20.0	100.8
South Carolina	80.0	-	-	80.0
Texas	2,135.3	1,616.9	1,935.9	5,688.1
Utah	5.3	-	-	5.3
Virginia	-	-	12.7	12.7
West Virginia	21.0	-	-	21.0
Total Capacity	7,348.4	3,189.2	3,192.3	13,729.9

*Capacities given in millions of gallons.

Source of data: NLPGA, "1980 LP-Gas Market Facts." Original source was Gas Processors Association.

TABLE 14.

COMPARISON OF TOP TWENTY FIRMS ENGAGED IN LPG STORAGE AND PRODUCTION

Rank	Storage Company	Percent of Total Storage Capacity	Rank	Production Company	Percent of Total LPG Production
1	Wanda Petroleum Co.	8.5	1	Exxon Corp.	10.9
2	Warren Petroleum (Gulf)	8.4	2	Texaco, Inc.	8.9
3	Texas Eastern Products Pipeline Company	7.8	3	Standard Oil (Indiana)	6.3
4	Cities Service Co.	4.2	4	InterNorth	5.6
5	Texas Brine Corp.	3.4	5	Cities Service Co.	5.0
6	Phillips Petroleum Co.	3.4	6	Mobil Corp.	4.8
7	Coastal States Marketing, Inc.	3.3	7	Conoco, Inc.	4.3
8	Texaco, Inc.	3.1	8	Sun Company, Inc.	4.2
9	Diamond Shamrock Oil and Gas Company	3.0	9	Shell Oil Co.	4.1
10	Union Texas Petroleum	2.9	10	Atlantic Richfield Co.	4.0
11	Home Petroleum Corp.	2.7	11	Getty Oil Co.	2.8
12	Mobil Oil Corp.	2.5	12	Delta Drilling Co.	2.7
13	UPG, Inc.	2.0	13	Standard Oil (California)	2.3
14	Tenneco Oil Co.	1.8	14	Sid Richardson	2.3
15	Consolidated Storage, Inc.	1.7	15	Gulf Oil Corp.	2.3
16	Mid American Pipeline	1.6	16	Union Pacific Corp.	2.2
17	Amoco Oil Company	1.3	17	Pioneer Gas Products	2.2

THE TRANSPORT OF LP-GAS

Overview

Liquefied petroleum gas for the U. S. market is transported by a variety of modes. Long-distance domestic transport occurs primarily by truck, rail, pipeline, and water (see Tables 15 and 16). Local movement of LPG is mainly by truck. Imports from Canada generally come to the U. S. by pipeline, truck, and rail, and from Mexico by truck and rail, while imports from overseas are brought by LP-gas tanker. Map 4 presents a general overview of the flow of LPG in the U. S.

For LP-gas transport in the U. S., there are an estimated 17,600 miles of dedicated pipeline trunk lines; 16,000 railway tank cars; 25,000 transport and delivery trucks, and 60 LP-gas tankers and barges. The world LP-gas tankship fleet consists of about 560 ships.

Pipelines are the most important method of moving LP-gas long distances when considering the quantities transported, followed in order by truck, rail, and water movement. In terms of barrel-miles, pipelines have been the most important mode for transporting LP-gas for a number of years.

What follows is a mode-by-mode description of the transportation of LP-gas, and its historical safety record. The safety of LPG transport is quite important. LPG transport accidents can have serious consequences. Figure 2 diagrams the events that could occur if a transport accident were to cause a leak or spill of LPG. The safety performance for the transportation of LP-gas by the various modes can be compared with the risk of other well-known phenomena using Table 17.

Pipeline Transportation

The transport of LP-gas by pipeline is a relatively new phenomenon. Up to the mid-1950's, LP-gas was almost exclusively shipped by truck or rail; very little was shipped by pipeline. Today, well over 90 percent of all LP-gas is shipped at least part of the way to its destination by pipeline, and pipeline transport accounts for over 70 percent of the total LP-gas barrel-miles moved. This increase in LP-gas throughput occurred concurrently with a tremendous increase in available LP-gas pipeline

cargo tank. In total, 540 firms registered cargo tanks with the U. S. Department of Transportation.

According to the 1972 Census of Transportation, private carriage is the predominant form of LP-gas truck transport, accounting for 80 percent of the ton-miles and 71 percent of the total tons of LP-gas transported in the U. S.

From 1971 through 1980, there were 292 LP-gas incidents on interstate movements involving trucks (see Table 20). These accidents resulted in 27 deaths, 167 injuries, and damage amounting to $2.8 million. Of these incidents, 46 had fires and/or explosions, with 22 deaths, 82 injuries, and $1 million damage resulting. The remaining 246 incidents accounted for five deaths, 85 injuries, and $1.7 million in damages. It should be noted that the deaths, injuries, and damages reported here are all directly attributable to the LP-gas cargo.

Rail Transportation

Rail transport of LP-gas diminished over the decade ending with 1980. Rail-only carriage declined from about 10 percent of the total quantity transported in 1969 to less than 1.5 percent in 1978, while the percentage of total barrel-miles moved by rail declined from 14 percent in 1969 to 4 percent in 1978.

On interstate movements of LP-gas by rail over the 10-year period from 1971 to 1980, there were 48 reported fires and/or explosions in which 484 people were injured, 26 were killed, and property damage totalled $13 million (see Table 21). Additionally, there were 785 spills resulting in no fires or explosions (except those that happened before 1974) but that had associated with them 20 injuries, 2 deaths, and $2.7 million in damages. Of the total 486 recorded injuries due to rail incidents, 453 were the result of just three accidents. Five rail accidents account for $12.4 million of the total $15.8 million in property damage attributable to rail accidents. These accidents appear to be the exception, not the rule. Most rail incidents, it must be noted, have no injuries, no deaths, and no reported damage. As with the pipeline and truck accidents, what is reported here for rail is directly attributable to the LP-gas cargo being transported.

TABLE 15.

LONG-DISTANCE DOMESTIC BULK TRANSPORT OF LPG BY MODE MEASURED IN MILLIONS OF BARRELS, 1969-1978

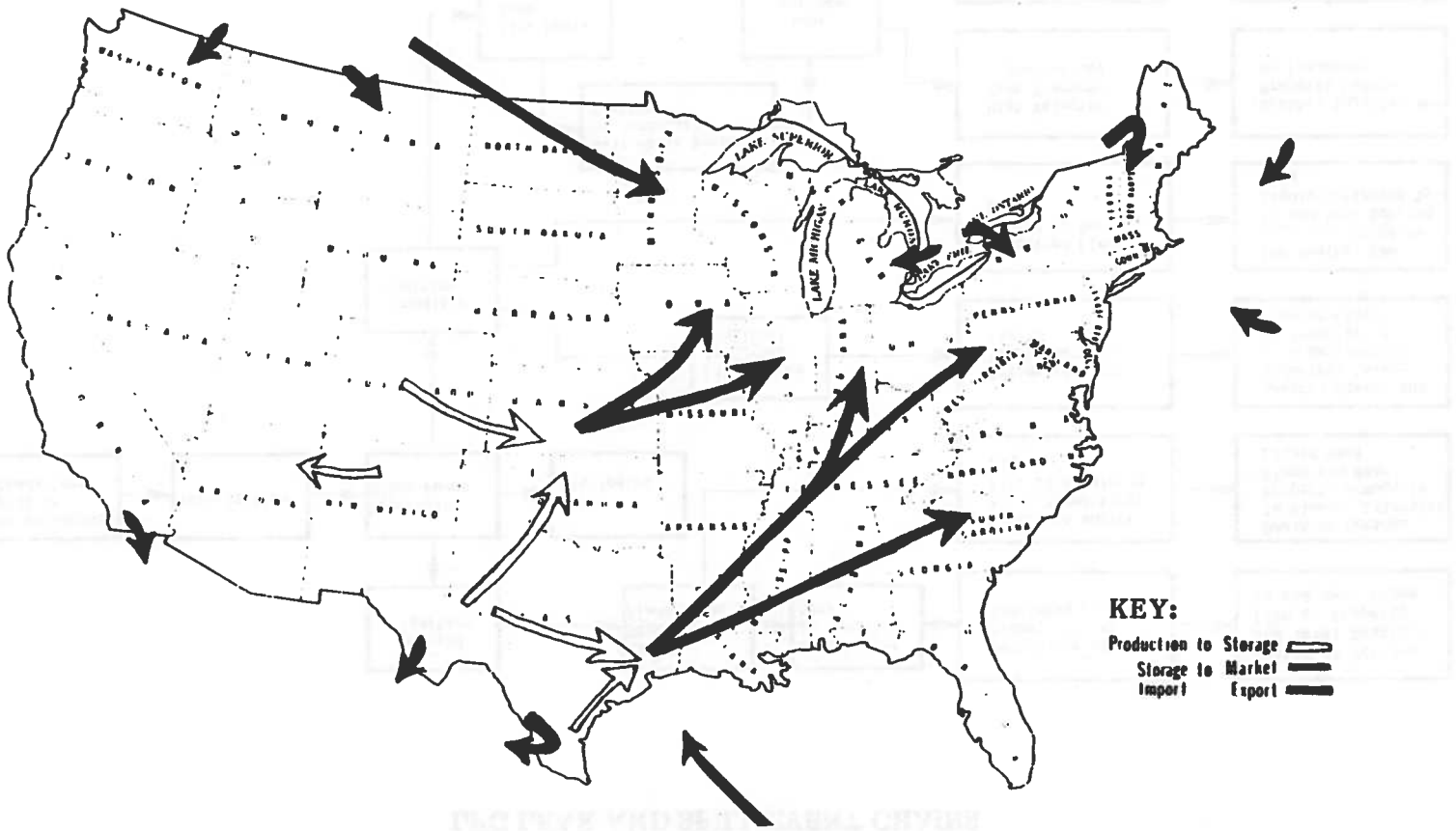
Mode	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978
Truck	108.2	81.5	88.4	94.4	63.4	32.3	17.8	16.1	19.0	15.9
(%)	(24.3)	(18.2)	(19.4)	(18.2)	(12.0)	(6.3)	(3.8)	(3.4)	(3.4)	(3.5)
Rail	44.2	38.4	29.3	27.9	33.7	11.8	6.9	4.3	6.3	6.9
(%)	(9.9)	(8.6)	(6.4)	(5.4)	(6.4)	(2.3)	(1.5)	(0.9)	(0.9)	(1.5)
Pipeline-Truck	271.7	310.7	328.1	384.8	417.9	457.5	433.5	425.6	429.0	406.2
(%)	(61.0)	(69.5)	(71.8)	(74.0)	(79.0)	(89.2)	(91.9)	(90.6)	(90.6)	(90.3)
Pipeline-Rail	17.3	13.0	8.8	10.3	11.6	9.6	12.4	21.4	22.6	19.6
(%)	(3.9)	(2.9)	(1.9)	(2.0)	(2.2)	(1.9)	(2.6)	(4.6)	(4.6)	(4.4)
Tanker or Barge	4.1	3.9	2.2	2.5	2.0	1.6	1.1	2.6	2.1	1.3
(%)	(0.9)	(0.9)	(0.5)	(0.5)	(0.4)	(0.3)	(0.2)	(0.5)	(0.5)	(0.3)
Total	445.6	447.3	456.8	519.9	528.5	512.8	471.6	470.0	497.1	449.9

*Approximately 90% of the volume in this category is transported by pipelines prior to tanker or barge movement.

Source of data: National LP-Gas Association, "LP-Gas Market Facts," various years.

MAP 4

LPG PRODUCTION FLOWS



Source: U.S. GAO, LIQUEFIED ENERGY GASES SAFETY, p. 14-12.

TABLE 17.

SELECTED COMPARATIVE RISKS

Event	Estimated Risk (Fatalities per year)
All Accidents	103,030
Motor Vehicle Accidents	46,700
Air Crashes	1,552
Drowning	720
Dam Failures	35
Lightning	10
Gasoline	28
Air Crashes (Persons on Ground)	6
Meteorites	.001
Interstate Movement of LPG by	
Rail	2.8
Truck	2.7
Pipeline	2.5
Total of Rail, Truck, and Pipeline	8.0

Sources of information: Geffen, et al., AN ASSESSMENT OF THE RISK OF TRANSPORTING PROPANE BY TRUCK AND TRAIN, Battelle Pacific Northwest Laboratory, March 1980, 1-4; U.S. DOT, "Liquid Pipeline" Data Base; Wilson and Crouch, RISK/BENEFIT ANALYSIS, Ballinger Publishing Company, Cambridge, MA, p. 176.

MAP 5 (CONT.)

Pipeline Key:

[1]	Mid-America	[10]	Arbuckle
[2]	Phillips	[11]	Great Northern
[3]	Okan	[12]	Cochin
[4]	TET	[13]	Kaneb
[5]	Dixie	[14]	Shell
[6]	Marathon	[15]	Texaco-Cities Service
[7]	Buckeye	[16]	Badger
[8]	Cherokee	[17]	Chapperal
[9]	Northern (HTI)		

Sources for Map: International Petroleum Encyclopedia, 1980, pp. 40-41, 46-47, 60-61, 70, 78-79, 80, 81, API, "Products Pipline Map," 1973; Petroleum Publishing Company, "Products Pipelines in the United States and Canada," 1979; NPC, Petroleum Storage and Transportation Capacities, Vol. III, p. E-2; and Clark, p. 15.

TABLE 19.

LP-GAS TRANSPORT RECORD—PIPELINES, 1971-1980

Year	Incidents	Deaths	Injuries	Damages
1971	44	0	0	$ 147,869
1972	16	5	6	53,645
1973	22	1	1	52,962
1974	26	0	2	1,144,052
1975	25	6	14	620,620
1976	13	5	1	960,945
1977	20	2	4	176,422
1978	25	3	3	3,126,293
1979	34	3	9	1,332,142
1980*	4	0	1	80,080
Total	229	25	41	$7,695,030

*1980 data incomplete.

Note: Incidents included in data limited to those occurring in interstate movements of LPG. Deaths, injuries, and damages reported are those attributable to LPG.

Source of data: U.S. DOT, "Liquid Pipeline" Data Base.

TABLE 21.

LP-GAS TRANSPORT RECORD—RAIL,

1971-1980

Year	Fires and/or Explosions				Spills, No Fires or Explosions			
	Incidents	Deaths	Injuries	Damages	Incidents	Deaths	Injuries	Damages
1971	NA*	NA	NA	NA	19*	0	0	$ 5,460
1972	NA	NA	NA	NA	36	0	5	740,811
1973	NA	NA	NA	NA	45	2	1	498,767
1974	7	7	404	$ 8,416,500	64	0	0	22,725
1975	14	0	3	1,312,500	59	0	9	405,792
1976	2	2	12	1,003,000	95	0	0	5,338
1977	4	2	13	2,086,171	106	0	4	871,994
1978	7	15	52	206,942	96	0	0	162,294
1979	5	0	0	0	119	0	0	5,538
1980	9	0	0	10,050	146	0	1	8,499
Total	48	26	484	$13,035,163	785	2	20	$2,727,218

*Note: Prior to 1974, records do not indicate the occurrence of fires or explosions.
Incidents included in data limited to those occurring in interstate movements of LPG.
Deaths, injuries, and damages reported are those attributable to LPG.

Source of data: U.S. DOT, "Hazardous Materials" Data Base

TABLE 23.

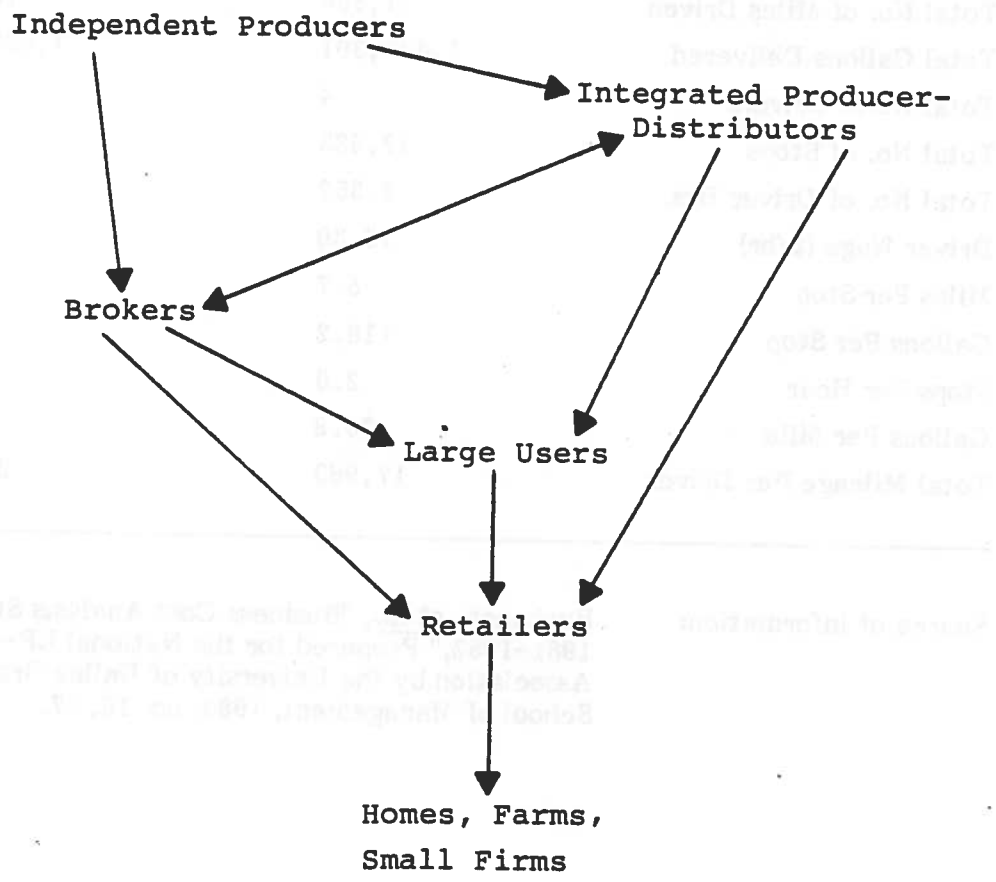
LP-GAS TRANSPORT ACCIDENT RECORD—TANKSHIPS, WORLDWIDE, 1964-1980

Type of Incident	Number of Serious Incidents			Cargo Leakage	Cargo Fire
	1979	1980	1964-1980		
Collision while underway	1	0	10	0	0
Struck while moored	0	1	6	0	0
Contact with stationary object	2	0	4	0	0
Grounding	2	4	12	0	0
Explosion/fire on board	0	1	10	0	0
Spillage of cargo	0	0	1	1	0
Total	5	6	43	1	0

Sources of data: Poten & Partners, Inc., LIQUEFIED GAS SHIP SAFETY. ANALYSIS OF THE RECORD: 1964-1979, Poten & Partners, New York, May 1980, p. 5; Poten & Partners, Inc., "Liquefied Gas Ship Safety. Analysis of the Record: 1980 Supplement," Poten & Partners, New York, May 1981.

FIGURE 3.

SIMPLIFIED LPG MARKETING DISTRIBUTION PATTERN



Source: O. Doering, III, "Shortages, Market Dislocations and the Retail Price Freeze", Purdue University, Department of Agricultural Economics, no date, p. 5.

TABLE 25.

SELECTED ADDITIONAL LPG MARKETER SALES AND SERVICE ACTIVITIES

Sell space heaters
Sell water heaters
Install ranges
Install clothes dryers
Sell gas ranges
Sell clothes dryers
Sell central furnaces
Install central heating
Install carburetion for internal combustion engines
Sell natural gas appliances
Sell comm/industrial heaters
Sell boilers
Install duct work
Sell agricultural burners
Install boilers
Sell diversified items
Sell electrical appliances
Do servicing for others and install water heaters
Sell industrial furnaces
Sell water softening equipment
Sell anhydrous ammonia

Source: After Clark, AN INTRODUCTION TO LP-GASES, Vol. 1, 1973, p. 46.

TABLE 27.

SAMPLE RATES-MINNESOTA, DECEMBER 1978

Type of Rate	Amount		Cents/Gallon
Tank Rate	123	gallons	41.5
	250	gallons	38.5
	500	gallons	37.5
Step Rate			
	1-600	gallons	47.7
	601-1500	gallons	37.5
	1501-2500	gallons	35.6
	2501-5000	gallons	34.6
	5000+	gallons	33.6
Tank - Step Rate			
Tank size			
123-gallon:	1-100	gallons	57.9
	101-200	gallons	50.9
	200+	gallons	47.9
250-gallons:	1-300	gallons	52.9
	301-600	gallons	46.9
	601-1000	gallons	44.9
	1000+	gallons	41.9
500-gallon:	1-500	gallons	50.9
	501-1000	gallons	44.9
	1001-4000	gallons	41.9
	4000+	gallons	38.9

Flat rate category is not shown since the charge does not vary

Source: "What Minnesota's Energy Agency Learned About LPG Rate Structures," BUTANE-PROPANE NEWS, July 1979, p. 20. Original source: Submission by the Minnesota Energy Agency to the U. S. DOE based on a survey of propane dealers in Minnesota conducted in December, 1978.

State and Local Safety Regulation

Most states have adopted, in whole or in part, the Federal Motor Carrier safety regulations and hazardous materials regulations to cover all intrastate movements of LP-gas and generally follow the National Fire Protection Association's standards, particularly NFPA No. 58, modified where considered appropriate.

A few cities, such as New York and Boston, and other localities also regulate LP-gas safety. The regulation basically consists of the enforcement of local fire codes. Other safety related controls imposed at the local level include facility standards and access restrictions on certain roads and tunnels.

APPENDIX: INDEX TO RELATED INFORMATION IN VOLUME II

Section

LP-GAS:

Appendix A of Volume II contains several tables related to this section. The tables are:

- o Table A.1 Gross Heat Values of Combustion
- o Table A.2 Boiling Point of Liquid at Atmospheric Pressure
- o Table A.3 Flammability Limits
- o Table A.4 Propane Content in Natural Gas Streams

THE CONSUMPTION OF LP-GAS:

Additional information on the topic of LP-gas consumption can be found in Appendix B of Volume II. The contents of Appendix B are:

- o Table B.1 Selected Uses of LP-Gas
- o Map B.1 Areas Using Propane To Cure Tobacco
- o Table B.2 LP-Gas/NGL-Based Synthetic Natural Gas Plants In The U. S.

LP-GAS SUPPLY:

Additional information on supply is contained in Volume II of this report. The following is a list of the tables, figures, maps, and appendices in Volume II relating to the supply of LP-gas.

General

- o Figure C.1.1 Absorption-Oil Recovery Process
- o Figure C.1.2 Cryogenic Recovery Process
- o Table C.1.1 Type And Number of Extraction Processes

Imports

- Table C.2.1 Major New LPG Production Facilities (Overseas)
- Table C.2.2 Year-To-Year Percentage Changes In LPG Supply, 1975-1979
- Table C.2.3 Oceanborne Imports of LPG, 1974-1979
- Table C.2.4 Annual Handling Capacities, Major LPG Import Terminals
- Table C.2.5 LPG Import Terminal Unloading And Storage Capacities
- Appendix C.3 Marine Import Terminal Sites
- Table C.4.7 Concentration In Annual Handling Capacity of Major LPG Import Firms
- Table C.4.8 Concentration In LPG Import Terminal Storage Capacities
- Table D.2 Aboveground Storage At Import Terminals
- Table D.4 Total Aboveground Storage of LP-Gas: Import Terminals
- Table D.5 LP-Gas Facilities--Aboveground Storage At Major Import Terminals

Ownership Of Facilities

- Notes On Measuring Concentration of Ownership
- Table C.4.1 Critical Concentration Ratios
- Table C.4.2 Market Concentration In OCS Oil And Gas Leases, 1954-1976
- Table C.4.3 Ownership of Proven U. S. Natural Gas Reserves, 1978
- Table C.4.4 Proven U. S. Natural Gas Reserves--Concentration Ratios, 1975-1978
- Table C.4.5 LP-Gas Production Concentration, Top 20 Firms, 1979
- Table C.4.6 Top 20 Gas Processors in 1979, Ranked By Capacity
- Table C.4.7 Concentration In Annual Handling Capacity of Major LPG Import Firms
- Table C.4.8 Concentration In LPG Import Terminal Storage Capacity
- Table C.4.9 Entry In The OCS Oil And Gas Lease Market, 1954-1976
- Table C.4.10 Capacity Ownership Summary

- o Table E.1.4 LP-Gas Barge Ownership And Use By Selected Companies
- o Figure E.1.2 Schematic of LP-Gas Tanker
- o Table E.1.5 LP-Gas Ship Operating Characteristics
- o Table E.1.6 Major LP-Gas Tankships, 1980
- o Table E.1.7 Liquefied Natural Gas Tankships Capable of Transporting LP-Gas, 1980
- o Table E.1.8 Tanker And Barge Movements of LP-Gas From The Gulf Coast To Other Regions
- o Figure E.1.3 Transport Costs, 1977
- o Table E.1.9 Estimated Contract Prices of LP-Gas Carriers In Foreign Shipyards
- o Table E.1.10 Estimated Annual Cost Structure For Low-Cost Foreign-Flag LP-Gas Carrier, RAS TANURA to Japan
- o Table E.1.11 Cargo Tanks In Service, January 1, 1980
- o Table E.1.12 Financial And Operating Data For Selected Common Carrier LP-Gas Transporters
- o Table E.2.1 Complete Listing of LP-Gas Rail And Truck Accidents, 1971-1980
- o Table E.3.1 Complete Listing of LP-Gas Pipeline Accidents, 1971-1980
- o Table E.4.1 LP-Gas Tank Barge Casualties, FY 1971-1980
- o Table E.5.1 Complete Listing of LP-Gas Tankship Accidents, Worldwide, 1964-1979
- o Table E.5.2 Complete Listing of LP-Gas Tankship Accidents, Worldwide, 1980

In addition, the following table from Appendix C.5 also contains information relating to the transport of LP-gas.

- o Table C.5.3 Financial Statistics--Natural Gas Pipeline/Transmission Firms

MARKETING LP-GAS:

Volume II contains several tables related to this section. The tables are:

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