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PROPANE, BUTANE, AND RELATED FUELS

By

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PREFACE

The distribution and utilization of propane and butane is a relatively new and rapidly growing industry. The National Bureau of Standards receives so many requests for information regarding these products that it seemed necessary to summarize, in a letter circular, the information most frequently requested. Letter Circular 292, issued in 1930, was recently revised and reissued as Letter Circular 503. The demand for this has been too great to be economically met by a mimeographed paper, and it was, therefore, decided to print it, with minor amendments, in the regular series of Bureau Circulars.

LYMAN J. BRIGGS, *Director*.

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By E. R. Weaver

ABSTRACT

The composition, manufacture, properties, and methods of distribution of commercial propane and butane are described. There is a brief discussion of methods of storage and utilization of such fuels, including the cost and uniformity of service, particularly with domestic appliances. Domestic systems using hydrocarbons of higher boiling points are included in the discussion. Trade names and the kind of fuel to which each applies are listed.

CONTENTS

I. PURPOSE AND SCOPE OF THIS CIRCULAR

This circular has been prepared to take the place of Bureau Letter Circular 503, of the same title, issued September 1, 1937. It gives information most frequently requested by correspondents of this Bureau regarding the hydrocarbon fuels, principally propane and butane, which are commonly transported as liquids but are used as gases.

Liquid propane and butane are still very commonly referred to as "bottled" gases because of their extensive distribution to domestic users in comparatively small portable cylinders popularly called bottles. Transportation in tank cars, and local delivery in tank trucks from which consumers' reservoirs are filled, have become as common in recent years as the use of "bottles", and the term "bottled gas" may no longer be generally descriptive, but, for the sake of brevity, will be used occasionally in this circular.

Although the industrial uses of propane and butane now probably exceed in importance their domestic uses, the circular is devoted mainly to the latter for the following three reasons: The number of inquiries from persons interested in domestic uses of the gases is much greater than from those concerned with their industrial uses; industrial uses are so varied that individual consideration must usually be given to inquiries regarding them; and, industrial users usually have enough at stake to justify the purchase of a comprehensive handbook [1] on the subject of the fuels or a study of the original literature to be found in technical journals and other publications.

Butane, and rarely propane, is sometimes mixed with air or other gas before delivery to the burner. The fuel supplied in this way is not essentially different from that supplied by "gas machines" using gasoline or other relatively high-boiling hydrocarbons, and gas machines still compete with the liquefied gases for domestic use. Brief attention is, accordingly, given to equipment of this type.

II. CONSTITUENTS OF PETROLEUM GASES AND SOME OF THEIR PROPERTIES

Natural gas and petroleum as they occur in nature consist of mixtures of many substances. These are chiefly compounds of hydrogen and carbon, called "hydrocarbons" by the chemist. The predominant "family" of hydrocarbons is called the "saturated series," and their compositions vary in a regular manner, beginning with methane, which has one atom of carbon and four of hydrogen in each molecule and is represented by the symbol CH_4. The first six members of the series and the symbols representing their compositions are as follows: Methane, CH_4; ethane, C_2H_6; propane, C_3H_8; butane, C_4H_{10}; pentane, C_5H_{12}; hexane, C_6H_{14}. In the case of butane and higher members of the series, different arrangements of the atoms in the molecule are possible and cause slightly different properties. There are two butanes and three pentanes. Ordinarily these different "isomers" are not separated, the only common exception being that "isobutane" is frequently separated from "normal butane."

The properties which mainly determine the different methods of transporting and using these fuels are the temperatures and pressures at which their vapors condense to liquids. Methane is the principal constituent of the vast quantities of natural gas distributed from the wells through pipes and is a so-called "permanent" gas, which means that at ordinary temperatures it cannot be liquefied by applying pressure, no matter how great. It is nearly as hard to liquefy, by a combination of great pressure and low temperature, as is air. Hexane, at the other end of the list given, is a liquid which boils at 69° C (156° F), and is one of the important constituents of ordinary gasoline. Gasoline itself is a mixture containing, in the main, still higher members of the methane series of hydrocarbons, but also much hexane and appreciable amounts of pentane. It is with the substances which are intermediate in composition between methane and hexane and especially with propane and butane that this circular is primarily concerned.

Ethane can be liquefied by pressure alone at temperatures as high as 32° C (90° F), but if metal containers are to be filled with the liquid, they must be of excessively heavy construction to be safe at temperatures to which they would be frequently exposed if made an article of commerce. Ethane is, therefore, seldom distributed alone,

[1] The Handbook of Butane-Propane Gases, of which there are two editions and a supplement, published by Western Business Papers, Inc., 124 W. Fourth St., Los Angeles, Calif., is very comprehensive. Much of the information in this Circular was taken, with permission, from that source.

and is of importance in this discussion only as its presence in solution in propane and butane affects their properties.

Propane is a gas at atmospheric pressure at all temperatures likely to be encountered in the United States, but can be liquefied by moderate pressure and is safe in a container of reasonable strength. Under practically all probable conditions of domestic use, a cylinder of liquid propane will, therefore, deliver a continuous supply of gas at a pressure ample for its effective utilization. Normal butane boils at about the freezing point of water and, since its evaporation cools it somewhat, its liquid cannot be made to supply gas at a satisfactory pressure unless the surroundings of the container are at a temperature considerably above that point. Isobutane is somewhat more volatile than normal butane. Pentane boils at about 36° C (97° F) and is, therefore, a liquid at atmospheric pressure within the usual range of indoor temperatures.

Although the hydrocarbons previously mentioned are the only gases and very low-boiling liquids among the hydrocarbons that usually occur in important quantity in nature, the process of making gasoline and other commercial products from crude oil produces another series of hydrocarbons the individuals of which differ from those of the methane series in having two less atoms of hydrogen per molecule. The first member of this series is ethylene, C_2H_4. It is a familiar anesthetic and has many uses as a raw material in the chemical industry. The next two members of the series, propylene, C_3H_6, and butylene, C_4H_8, are also produced in oil refineries, together with propane and butane, from which they are not easily separated by distillation. They have strong odors and a moderate amount of them is frequently added to propane and butane to make the detection of leaks easier. The properties of propylene and butylene which affect their use as fuels are nearly the same as the corresponding properties of propane and butane; hence, they are not always separated, and the liquefied gases from refineries contain both series of hydrocarbons.

The properties of the hydrocarbons mentioned which are of most importance in connection with their use as fuels are given in table 1. In this table, heating values in Btu per pound are computed from the heats of combustion per mole observed by F. D. Rossini, of this Bureau, and 12.01 as the atomic weight of carbon. The heating values (in Btu per cu ft) and specific gravities of the vapors, except those of pentane and butylene, have been corrected for deviations from the ideal gas laws at 60° F and 1 atmosphere. Pentane is a liquid at 60° F, but its concentration in gas mixtures, even those in which it is the only fuel, is usually low, and it has been assigned the heating value and specific gravity corresponding to an ideal gas. The vapor pressures given were obtained graphically by plotting various vapor-pressure data, drawing curves to average the best of them, and adjusting the curves to pass through the boiling points and critical points reported in International Critical Tables. Other data are from various sources.

TABLE 1.—*Characteristic properties of hydrocarbons which may be present in liquefied petroleum fuels*

Substance	Ethane	Propane	Isobutane	Normal butane	Pentane	Propylene	Butylene
Formula	C_2H_6	C_3H_8	C_4H_{10}	C_4H_{10}	C_5H_{12}	C_3H_6	C_4H_8
Boiling point, °F	−127	−44	14	33	97	−53	20–34
Pounds per gallon of liquid at 60° F	3.11	4.24	4.72	4.85	5.25	4.37	5.0 to 5.1
Heating value of the gas:							
Btu per pound	22,340	21,680	21,280	21,330	21,110	21,050	20,840
Btu per gallon	69,500	91,900	100,400	103,400	110,800	92,000	105,200
Btu per cu ft at 60°, 30 in. Hg	1,790	2,572	3,364	3,393	4,023	2,379	3,190
Specific gravity of gas	1.05	1.55	2.08	2.14	2.49	1.46	1.98
Vapor pressure, pounds, gage at:							
−44° F	88	0	−9	−12	−14	3	−12
0	206	24	−4	7	−13	32	−6
33	343	54	7	0	−11	69	4
70	553	112	27	16	−6	135	21
100	----------	196	55	37	4	218	43
130	----------	271	93	64	11	323	74
150	----------	346	128	87	21	420	116
Volume of air required to burn 1 volume of gas	16.7	23.9	31.0	31.0	38.2	21.5	28.6

The fuel "gases" in liquid form in the cylinders are not explosive except as any other confined gas, carbon dioxide or ammonia, for example, is explosive. If a cylinder is heated, the pressure increases. A safety device must be provided which will certainly relieve the pressure before there is danger of rupturing the tank itself; otherwise, a cylinder exposed to fire would explode with the combined effect of a boiler explosion and the sudden release of a great quantity of combustible gas. Actually, no case of the explosion of a liquefied petroleum container has come to the attention of the National Bureau of Standards, although many of them, ranging in size from tank cars downward, have been in fires. The safety devices have always released the pressure, and the liquid fuel, cooled by its own evaporation, has boiled evenly and produced flames of moderate size at the relief openings.

Mixtures of the gas with air will burn with explosive force just as will mixtures of air with any other combustible gas, vapor, or dust. The material is not explosive by itself, however, in the sense that acetylene is.

The petroleum gases are not poisonous, but their leakage should be guarded against even more carefully than that of manufactured gas because of fire hazard. They are heavier than air and tend to accumulate at floor level, in contrast to ordinary manufactured or natural gases, which are lighter than air and rise. Ordinarily, convection through a building tends to bring in air at the bottom and force it out at the top of each room. There is, therefore, little chance for a heavy gas to escape from a room until it has become thoroughly mixed with the air by the slow process of diffusion. A flame in the lower part of a room is more hazardous to the occupants than one of equal intensity in the upper part, among other reasons, because of the danger of igniting clothing. These facts combine with its high heating value per unit volume to make the escape of even a little petroleum gas a serious hazard.

III. MANUFACTURE OF LIQUEFIED PETROLEUM GASES

The natural gases which constitute the principal source of liquefied petroleum gas were used as a source of gasoline for many years before the portion which could be kept liquid only under pressure was introduced extensively into commerce. Because the natural gases richest in gasoline were drawn from the top of the casings of oil wells, they were called "casing-head gases" and the gasoline separated both from them and from "dry" natural gas (unaccompanied by oil) was called "casing-head gasoline." Casing-head gasoline, more recently named and now generally called "natural" gasoline, as distinguished from the gasoline made in refineries, was separated from the gas (1) by compression and cooling or by compression alone; (2) by dissolving under pressure in an oil somewhat less volatile than kerosene, from which it could subsequently be distilled; or (3) by "adsorbing" in a porous material, such as "activated" charcoal, from which it was later driven by steam. In every case the higher hydrocarbons, pentane, hexane, etc., which were wanted as gasoline, were accompanied by more or less of the lower hydrocarbons, propane and butane, which were not wanted, because they made the gasoline too volatile. Originally the natural gasolines were allowed to "weather", that is, the dissolved propane and the other gases were allowed to escape at ordinary temperature and pressure, accompanied by a large amount of the gasoline vapor, until the gasoline was stable enough for sale. Eventually the process of submitting these escaping gases to "fractional distillation" was introduced, primarily for the purpose of recovering the gasoline they carried with them. Fractional distillation (or rectification) is the general process for separating liquids of somewhat different boiling points which occur together in solution by repeatedly evaporating and condensing portions of the mixtures. It is a process widely applied in the chemical industries; its most familiar examples are the separation of alcohol and water to make "distilled liquors", and the preparation of oxygen by the fractional distillation of liquid air.

At first, fractional distillation of natural gasolines appears to have been used only to prevent the loss of gasoline during the removal of propane and butane, which were returned to the natural-gas line. Later the mixture of propane and butane with some ethane and pentane, liquefied together, began to find a market; but it was not long before the advantages of a complete separation of the gases, and their marketing as separate products, became apparent. This complete separation, like the partial separation first used, is accomplished by fractional distillation. At the present time both the mixed gases and the substantially pure substances, propane, butane, and pentane, are being marketed in large quantities.

IV. SOURCES OF AND MARKETS FOR LIQUEFIED FUEL GASES

Tables 2 and 3, taken from Mineral Market Reports of the U. S. Bureau of Mines, show the rapid development, in recent years, of the sale of the liquefied fuel gases, and the uses for which they are employed.

Much the greater part of the liquefied fuel gases still comes from natural gas, although oil refineries constitute another great potential source. The total quantity which could be obtained from these sources is said to be very great. It is much in excess of any possible demand for domestic uses other than househeating. The sale of the fuel for industrial heating and the production of power must meet competition with other fuels at a minor fraction of the usual retail price to domestic users. Oil refineries are able to convert the gases into gasoline and are doing so extensively. It is evident that the liquefied fuel gases must be available in practically unlimited quantities and at a cost, at the point of origin, slightly less than that of gasoline. It is also evident that this condition will continue at least until depletion of the natural sources of gas and petroleum causes radical changes in the present methods of supplying motor fuel.

V. SUPPLYING LIQUEFIED FUEL GAS FOR DOMESTIC USE

The use of liquefied petroleum gases of greatest importance, considering their relatively small margin of advantage over other fuels used for industrial heating and power, is that of bringing the advantages of gas service for cooking, water heating, and refrigeration to homes beyond the reach of city gas mains. For these domestic uses a supply of propane is as satisfactory in every respect, except the inconvenience of replacing empty cylinders, as the best manufactured or natural-gas service. Actually, because of the uniform composition of propane and because of the uniform pressure assured by regulators and an always adequate pressure at the source of supply, it is possible to design and adjust appliances much more accurately to burn propane than is the case with appliances connected to the usually variable city gas supply; and this results not only in more uniform service, but if full advantage is taken of the possibilities by the designer of the appliance, in an improvement in the efficiency with which the gas is used.

Propane is usually delivered or stored for domestic use in relatively small cylinders or "bottles" which are placed out-of-doors and above ground, usually in metal cabinets. Three somewhat different systems of supply are in common use. In the first, two cylinders of the fuel gas are installed outside the purchaser's home. Gas is used from one cylinder until it is empty. The other cylinder is then turned on, and the empty cylinder is returned to the dealer and a full one put in its place. In the second system, a single cylinder is installed; this is replaced at regular intervals before it is empty, weighed and returned to the service station for refilling. In the third system, a single container, usually of larger capacity than used in the other systems, is filled periodically from a tank truck and weighed in position without interrupting the flow of gas.

TABLE 2.—*Sales of liquefied petroleum gases in the United States*

[Thousands of gallons]

Year	Propane	Butane	Propane-butane mixtures	Pentane	Total
1926					466
1928					4, 522
1930	11, 500		[a] 6, 517		18, 017
1932	15, 182	14, 662	3, 417	854	34, 115
1934	18, 681	25, 553	10, 271	1, 922	56, 427
1935	26, 814	34, 084	13, 492	2, 465	76, 855
1936	36, 502	40, 200	27, 375	2, 833	106, 652
1937	46, 474	45, 504	46, 694	2, 833	141, 505

[a] Butane, propane-butane mixtures, and pentane.

TABLE 3.—*Marketed production of liquefied petroleum gases by uses for the year 1937*

[Thousands of gallons]

Uses	Propane	Butane	Propane-butane mixtures	Pentane	Total	Percent
Domestic	30, 436	6, 047	3, 504	836	40, 823	28. 9
Gas manufacturing	1, 077	7, 430	2, 765	8	11, 280	8. 0
Industrial fuel and chemical manufacturing	14, 567	28, 278	25, 300	1, 957	70, 102	49. 5
Internal-combustion-engine fuel	278	1, 715	14, 994		16, 987	12. 0
All other uses	116	2, 034	131	32	2, 313	1. 6
TOTAL	46, 474	45, 504	46, 694	2, 833	141, 505	100. 0
Percent	32. 8	32. 2	33. 0	2. 0	100. 0	

The second and third systems are obviously impracticable unless enough customers are grouped near together to justify the maintenance of a regular delivery service. Where customers are closely grouped, the single-cylinder systems should have advantages of convenience and economy. The two-cylinder system is available anywhere.

Unmixed butane is little used for domestic service except in the warmest parts of the United States, because temperatures too low to give adequate pressure are frequently encountered elsewhere. Even in the South, butane is usually stored underground, in part to get the containers out of sight, but chiefly in order that the heat for vaporization may be obtained from the ground in the coldest weather. It is extensively used there in sparsely settled areas because its low vapor pressure makes its delivery much less expensive than that of propane. When the liquid is stored underground, tanks large enough to hold several months' supply are sometimes employed. Because as the result of its experience with corrosion, the storage of butane underground was considered hazardous, one of the large producers and distributors of this fuel has adopted a system of storage above ground in containers which are automatically heated when weather requires it.

Pentane is used to a considerable extent for supplying individual dwellings by passing air through the pentane container (sometimes bubbling it through the liquid and sometimes passing it over surfaces of the liquid which may be increased by wicks or their equivalent), and using the resultant mixture of air and pentane vapor as the mixtures of butane and air are used from the small city plant. This system, of course, requires a means for mechanically supplying air under pressure. Aside from this requirement, the principal disadvantage of the system is the variability of the mixture with variations of the temperature of the pentane. Usually the pentane tank is buried deeply in the ground to reduce temperature changes, and several systems have devices for adding controlled amounts of air to produce mixtures of greater uniformity than that obtained by vaporization alone.

The pentane systems are essentially the same as the systems for supplying air saturated with gasoline which have been in use in many places for 40 years or more. Old plants of this type can be used with pentane with an improvement in constancy of the gas supplied. If the substitution of pentane is made, appliances will generally have to be readjusted to take more air into the burner because of the greater proportion of fuel in the mixture supplied to the burner.

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Fuel gases which have not been separated into their constituents, but remain mixtures, are as useful for enrichment of manufactured gas supplies as are the pure hydrocarbons, and their uses for industrial purposes generally present little difficulty. Complications are involved in their domestic utilization. If such mixtures are allowed to evaporate in the liquid containers, the gas first delivered is mainly the lowest-boiling substance present in appreciable quantity; that delivered when the cylinder is nearly discharged is mainly the highest-boiling substance. Such a variation in composition is too great to permit the satisfactory adjustment of appliances, hence liquid mixtures of this character are taken from the bottom of the container and vaporized in the line to the burner, usually in a specially arranged vaporizer which is sometimes heated by the burner itself, sometimes only by indoor air. No appreciable change of composition then results during the discharge of the cylinder. A mixture of this kind may contain enough ethane and propane to give a satisfactory working pressure. Otherwise, the necessary pressure may be supplied by pumping air into the supply tank. Systems for the use of these mixtures were employed several years before pure propane became commerically available, and several clever inventions were made to cope with the manifest difficulties involved in the control of pressure, the danger of leakage of the liquid from the house piping, etc.

Satisfactory uniformity of composition and pressure may result if vaporization takes place during one stage of reduction of pressure and a further reduction is made through another regulator after vaporization is complete; but vaporization in a single stage within a regulator, or vaporization at the burner is not likely to give the best results. There are "American Standards" for propane-burning appliances in accordance with which a considerable variety of appliances has been tested and approved by the American Gas Association. These appliances are probably the best available for burning liquefied petroleum gases of heating value higher than propane; but they have been tested only for use with propane containing not more than 5 percent of another hydrocarbon, and their good performance with mixtures is not assured.

In some cases different mixtures are supplied for use in summer and winter to more nearly equalize the pressure of the supply at different seasons. When this is done, a considerable change in the conditions of combustion is unavoidable, and readjustments of the appliances may be required for satisfactory service.

Town gas supplies.—The Mineral Market Reports of the U. S. Bureau of Mines quote the following information supplied by the American Gas Association:

> At the end of 1937, liquefied petroleum gas was being delivered through mains to consumers in 179 communities in 29 States by 76 companies supplying 33,300 customers.
>
> Butane-air gas with heating value ranging from 520 to 900 Btu per cu ft was supplied to 125 communities in 29 States by 65 companies. A mixture of undiluted butane and propane gas with a heating value of 2,800 to 3,000 Btu per cu ft was supplied to 14 communities in California and Nevada by 6 companies. Undiluted propane gas with a heating value of 2,550 Btu per cu ft was supplied to 40 communities in Maryland, Minnesota, New Jersey, North Dakota, Virginia, and Wisconsin by 6 companies.

If the appliances in use are properly designed for burning propane, and if the cost of the raw material is disregarded, it is an ideal gas for a public supply, particularly in a small town. The equipment required at the distributing station is extremely simple and, with the exception of the tank in which the liquid propane is stored, very inexpensive. Practically no labor or attendance is required in connection with production, since the vaporization of the liquid takes place automatically to meet any demand. Distribution is also exceedingly simple and economical. No holder is needed; there is no condensation and no corrosion in the mains; and the high heating value permits the distribution of the same amount of fuel through the same system with only about 11 percent of the variation of pressure that would be involved in the distribution of average manufactured gas. The product is always of uniform composition and for the reason just given can be maintained at nearly uniform pressure, which eliminates much of the trouble from the adjustment of appliances.

A plant for sending out a mixture of butane and air is also nearly automatic but requires some power-driven machinery, demands more attention, and possesses more possibilities for trouble than a propane system.

If we consider systems of increasing size, from the domestic unit to that which supplies a large city, it is evident that the advantages of propane are of decreasing importance and the high initial cost of propane is of increasing importance. Small systems can, therefore, use propane the more advantageously. For somewhat larger systems, butane may merit consideration when there is a substantial difference in cost in its favor, in spite of the advantages of propane in other respects. For still larger systems, the cost of butane becomes prohibitive in comparison with the cost of a manufacturing plant for the production of ordinary fuel gases, and one of the older manufacturing processes becomes the most practicable.

Propane is usually distributed without dilution. It is necessary to add another gas, usually air, to butane in order to prevent condensation in the distributing system, and to permit the entrainment of enough primary air in appliances. Unfortunately, there has been a tendency to carry this dilution to a heating value of 520 to 550 Btu, which is much too far.

If a mixture of butane and air of 525 Btu per cu ft is supplied to an appliance adjusted for a coal gas of the same heating value, at such a pressure as to result in the delivery of the same number of cubic feet (and the same number of heat units) per hour, the total amount of air in the primary mixture will be about twice as much as is desirable. If the 525-Btu mixture is supplied to a burner adjusted for a typical natural gas, the amount of air injected will be about 3.5 times what is wanted. On the other hand, a mixture of butane and air of 1,000 Btu will inject only slightly more air than is needed for best results when supplied to a burner adjusted for 525-Btu coal gas, and 60 percent more than is needed when supplied to a burner adjusted for typical natural gas.

The properties of butane, other than its ability to inject air, are such as to require, for best results, a burner substantially identical with the best burner for natural gas. Most gas appliances are made at the present time to meet the requirements of the American Gas Association when tested with typical natural and typical manufactured gases.

Actually, to use the same appliance without adjustment for average natural gas and a butane-air mixture, the heating value of the latter should be somewhat above 2,000 Btu per cu ft. However, with the usual adjustments of orifices and air-shutters, our ordinary appliances will serve excellently for the use of butane-air mixtures of 1,000 to 1,500 Btu, but a 525-Btu mixture is far outside the range of usefulness for which they were designed, and appliances to burn such a mixture are built, tested, and sold as a special class under a special set of specifications prepared by the American Gas Association. It has been popularly supposed that the distribution of the 525-Btu mixture paved the way for the subsequent use of manufactured gas of about the same heating value (or made it easier to replace such a manufactured gas with hydrocarbon), but this is not the case. The necessary alteration of appliances is much greater than if a mixture having the heating value of natural gas were delivered.

The large quantity of air delivered with the butane not only results in a troublesome problem in the utilization of the gas with existing appliances, and in the construction and marketing of a special class of new ones, but involves expense for its own transmission. In other words, the prevailing practice incurs expense to transmit air from the plant to the burner and additional expense to prevent air already surrounding the burner from entering it.

The use of liquefied hydrocarbons to supplement manufactured or natural gas during peak demands is of much interest. If either propane or butane is in storage, it can be introduced into the supply of the other gas without delay, at a rate equal to the capacity of an enormous plant for manufacturing the usual gases, and with only a negligible amount of additional labor. The cost of storage may be relatively high, however, because peak loads occur infrequently and this portion of the plant is "idle" most of the time. The enrichment of gas is one of the few important applications for which it makes little difference whether a single hydrocarbon or a mixture is employed.

VI. INDUSTRIAL USES OF LIQUEFIED FUEL GASES

The industrial uses of the liquefied fuel gases are too varied and specialized to be discussed in any detail here. As a matter of interest, several uses will be mentioned. Butane is extensively employed for heating processes in manufacturing plants, usually because it is obtainable, in the large quantity used, at a lower cost per heat unit than must be paid for gas from the local gas company. Butane is used in preference to propane because the lower cost of transportation and storage is added to only inappreciably in an industrial plant by the necessity of pumping and vaporizing with steam in cold weather. Considerations other than cost, which sometimes favor butane over the local gas supply, are greater uniformity, which is particularly important when a heating operation is included in the cycle of an automatic machine, a slightly higher rate of flame propagation than that of natural gas, and the possibility of producing a more radiant and more strongly carbonizing (smoky) flame than with either natural or manufactured gas. In some plants, large quantities of blast furnace gas are available but cannot be effectively used alone because their extreme dilutions with inert gases result in unstable flames or inability to produce sufficiently high temperatures. These gases may be made useful by enriching with butane.

Mixtures in which butane is the principal constituent are being used increasingly as a motor fuel, particularly for lines of trucks which pass near a source of origin or wholesale supply and act as their own "distributors." An interesting combination of uses is sometimes made in the case of trucks carrying perishable food products which utilize the cooling effect of vaporization of the motor fuel to refrigerate the food compartment. Butane is also used to produce refrigeration in a wholly different way, as the fuel for a machine of the absorption type—the now familiar "gas refrigerator." This application has been made particularly to railroad cars.

VII. INSTALLATION OF EQUIPMENT FOR STORING AND USING LIQUEFIED FUEL GAS

The National Board of Fire Underwriters and the National Fire Protection Association have jointly endorsed regulations and good practice requirements dealing with the storage of liquefied petroleum gas and the installation of liquefied petroleum gas systems. These include: [2] Regulations for the Design, Installation, and Construction of Containers and Pertinent Equipment for the Storage and Handling of Liquefied Petroleum Gases No. 58; Regulations Covering the Installation of Compressed Gas Systems Other Than Acetylene for Lighting and Heating No. 52; Requirements for the Construction and Protection of Tank Trucks and Tank Trailers for the Transportation of Liquefied Petroleum Gases; Liquefied Petroleum Gas as a Motor Fuel; and a code covering the Construction and Installation of Liquefied Petroleum Gas Systems intended for enforcement by fire marshals or other public safety agencies.

Everyone undertaking the handling or use of these fuels for the first time should secure the pertinent set of rules and assure themselves that they are followed. Those engaged in the transportation of the gases must, of course, comply with the rules of the Interstate Commerce Commission. Local officials should be consulted to learn whether there are any applicable State or municipal regulations. A brief discussion of potential hazards, with a few suggestions which go beyond the formal rules, follows.

Propane is usually delivered to appliances under a pressure equivalent to 11 inches of water column, and the same pressure is employed, in some cases, at least, for mixtures of higher heating value. However, as heating value is increased it is increasingly difficult to construct appliances which will inject enough air for good combustion unless the pressure of the gas is increased also. The rules of the National Fire Protection Association forbid the introduction of gas or liquid into a house at more than 20 lb per sq in., but where a liquid of vapor pressure higher than this is permitted to reach the regulator, compliance with the limit at all times is uncertain. The range of composition of explosive mixtures of these gases with air is narrow, but the minimum amount of fuel required to form one is very small, approximately 2 percent for propane and 1.5 percent for butane. The fact that a gas heavier than air does not readily escape from a room has already been noted. Some, at least, of the materials commonly relied on to make the joints tight in ordinary gas piping are softened by the petroleum gases to the extent of becoming useless. If any material must be employed for this purpose, it should be one especially prepared for

[2] These rules can be obtained from The National Fire Protection Association, 60 Batterymarch St., Boston, Mass.

use with these gases. Taking all these facts into consideration, it is evident that an ordinary job of "gas fitting" will not do for these fuels. This does not mean that it is difficult to convey them safely within the building. It does mean that the installation of "house piping" should be as simple as possible and that extraordinary attention should be given to every evidence of leakage. It is preferable to use seamless metal tubing in a single piece from the supply outside the building to the appliance, if practicable. Copper is generally used. Commercial copper tubing has an abundance of strength if adequately supported, is not corroded under ordinary household conditions, and is easy to install securely.

Regulators, and pressure reliefs if used, should be vented to a point from which gas that flows downward will be least likely to enter a building. The storage containers and all connections must be protected from tampering and from danger of breakage by ice sliding from the roof, from settling of the building or the fuel container, etc. Connections through which liquid could be discharged if they were broken should be avoided if possible. Where this is not possible, excess flow or reverse-flow check valves should be installed inside the storage container, or so attached to it that breakage cannot occur between them.

The discharge of gas and liquid from a container presents hazards of widely different degree which should be recognized by everyone having to handle or install equipment for these fuels. Taking the definite case of commercial butane at 70° F as an example, fuel will be discharged through an opening below the liquid surface at approximately 15 times the initial rate of discharge that would take place through an equal opening above the liquid level. A fact that may be of equal importance is that, if the discharge of gas is rapid, the container and its contents are quickly cooled by evaporation, but that when liquid is discharged vaporization takes place outside the container, usually under conditions that will not much affect the temperature of the surface of the liquid within the container. Accordingly, the vapor pressure of the fuel, the force by which it is expelled, diminishes rapidly during the escape of gas, but very little during the escape of liquid. Assuming, in the case of a container full of butane initially at 70° that the rate of transfer of heat to the container from the surroundings is negligibly slow in comparison with cooling by evaporation, only about 5 percent of the fuel would be discharged from an opening in the top of the tank in the time required to empty the tank through an opening of the same size in the bottom. After that the rate of escape of fuel from the top would steadily diminish until the normal boiling point was reached, when about 87 percent of its original contents would still be in the container.

When a fuel gas heavier than air escapes in large quantity in the open, it spreads over the ground and at the same time mixes with air by diffusion, forming a blanket of explosive mixture which may drift with the wind to a considerable distance before becoming too dilute to burn. If the explosive mixture is ignited it may be very destructive. This is why it is so important that connections to the bottom of a storage tank be avoided as far as practicable, and that they always be protected from accidental rapid discharge by excess-flow or reverse-flow check valves.

Storage of butane or propane underground must be considered more hazardous than storage above ground for several reasons. Underground leaks are hard to detect or repair. The density of the gas makes it tend to remain in underground channels, if any exist, where a lighter gas would find its way to the surface, and basement and foundation walls offer no positive protection against the entry of gas. Of much greater importance, however, is the fact that no reliable method has been found to prevent the corrosion of iron underground, and the relatively thin walls of the fuel containers will eventually be perforated in all except the least corrosive of soils. When this occurs it is probable that in most cases minute leaks will develop which will be detected before serious harm results from them. It can never be certain, however, that large breaks will not occur without warning, as has happened many times in the case of water mains. The danger of this is the more serious because corrosion is usually most rapid on the under side of a buried vessel where the support given by the surrounding soil will tend to prevent leakage until a considerable area has been weakened, and where liquid rather than gas will escape through the opening when perforation occurs.

For the reasons given it is recommended that no fuel more volatile than pentane be stored below ground, but if it is, the owner should remain aware of the hazard of corrosion and on the lookout to detect the first indication that gas is escaping into the soil. When that occurs, inspection by digging about the reservoir *must not be made until all liquid has been removed from the tank.* When perforation first occurs, it is possible that the tank is so weakened over considerable areas that it would not withstand the internal pressure except for the support of the surrounding earth. To remove this while liquid is still present is to invite almost certain disaster.

Since the individual cannot possess facilities for pumping out the tank and storing the liquid, any company maintaining delivery service to underground storage should have equipment for the emergency removal of liquid and should keep its customers informed of that fact.

In the absence of facilities for quickly removing the liquid, the only safe thing to do in case leakage from an underground tank is suspected is to connect the above-ground piping to an outlet at which a very large flame will not endanger neighboring property, to ignite the gas at that point, and allow the fuel to burn rapidly until exhausted. The liquid will be cooled enough by its own evaporation to promptly relieve the pressure within the tank.

Purchase of gases.—Liquefied petroleum gases are usually sold by weight, either directly by weighing containers on the customers' premises before and after the fuel is used, or less directly by supplying cylinders of standard content from which the fuel is used until exhausted. The exchangeable cylinders employed range in capacity from 20 to 420 pounds. The ones most commonly delivered hold 100 pounds; the 20-pound cylinders are sold in stores and returned when empty like ginger ale bottles. When containers too large or inaccessible to be weighed are filled from a tank-car or truck, the liquid may be measured either by gaging the levels of the liquid in the container before and after filling or by a liquid flowmeter at the time the fuel is transferred. When gas is distributed from a central point through a system of piping it is, of course, necessary to determine its distribution among the purchasers with gas meters. To a small but apparently increasing extent, fuel is being sold through gas meters also in systems delivering gas to only one customer each. This method has the merit that the volume of gas used is permanently registered on the meter dials and can be checked at any time by the purchaser. Even if a mistake is made in reading the meter, it is rectified the next time the meter is read. To check the weight or the volume of liquid fuel, the purchaser must be present at the time of delivery or make measurements for himself before any fuel is used. Many things contribute to more than offset this advantage of measuring the volume of gas. A gas meter is less reliable than the instruments used to measure weights or liquid volumes; the amount of fuel contained in a given volume of gas is greatly affected by the composition and temperature of the fuel; the gas meter is notoriously the weakest point in a system of gas piping even as usually installed for city gas and the introduction of the gas meter adds materially to the complication and first cost of the system. Liquid measurement is also affected by temperature and composition, but to a much smaller extent than gas measurement, and it is entirely practicable to measure the temperature (or preferably the vapor pressure) of the fuel at the time it is delivered and to make a correction for it.

Accordingly, the purchase and sale of liquefied petroleum gas by weight appears preferable, with measurement of the liquid the second choice. In case the gas is measured the purchaser must be able to rely on a constant known heating value and should consider cost only on the basis of the number of Btu delivered. In any case, purchasers should insist that the vendors state prices per pound, per gallon, or per million Btu (or other definite convenient heat unit), and not as the equivalent of a certain volume of natural or manufactured gas. The latter basis is permissible only if the heating value of the city gas is stated and the amounts of energy said to be equivalent are actually the same. In the past, some of the claims made for equivalence have apparently been based on an assumed difference in efficiency which might rarely be obtained in "top-burner" cooking but not in other uses of the fuel.

The purchaser should also insist on knowing whether he is to receive propane, butane, or a mixture and, if the latter, what its composition is. He should not credit claims of superiority for a particular brand of the same material, nor for any difference in "efficiency," reduced to the basis of heat units, for one of these fuels over another.

The prices of the fuels depend largely on transportation and distribution cost and vary with the locality. Usually, propane for domestic supply retails between 6 and 10 cents per pound. Pentane and the mixed hydrocarbons are usually cheaper. For purposes of comparison, it may be noted that pure propane at 10 cents per pound costs $4.61 per million Btu. The other fuels differ only a little from this figure. The 600 Btu gas supplied in Washington, D. C., at 90 cents per thousand cubic feet costs $1.50 per million Btu. Kerosene at 10 cents per gallon costs 78 cents per million Btu. Electricity at 3 cents per kilowatt-hour costs $8.79 per million Btu.

Relative efficiencies of application of the heat in use are, of course, to be taken into account in judging the cost of service. If appliances designed for propane are used, there will be some improvement in efficiency when using propane for cooking as compared with city gas;

perhaps as much as 10 percent. Relative efficiencies of bottled gas and electricity are harder to estimate, largely because of differences in the way in which they are used. As a rough estimate, based on what is believed to be average practice, the cost of bottled gas and electricity will be equal for cooking if the price of fuel per pound is 3½ times the cost of electricity per kilowatt-hour. Water-heating will cost about the same if the price of a pound of propane is about 4½ times that of a kilowatt-hour; but for equal costs for refrigeration the two prices must be approximately equal. It is assumed that appliances of comparable quality will be used in each case. Kerosene will equal propane in cost for cooking if the price per gallon is about 4 times the cost of propane per pound; for water-heating if it is about 5½ times as great.

VIII. SELECTION AND ADJUSTMENT OF APPLIANCES FOR THE USE OF LIQUEFIED PETROLEUM GASES

The cost of liquefied petroleum gases is such as to justify considerable care in the selection of the appliances with which they are used. In general, the recommendations of the company supplying the fuel should be followed, but the purchaser should have in mind the fact that an appliance built to burn propane differs from one for manufactured or natural gas only in the change of a few simple dimensions, mainly burner openings, and that these differences do not justify any large increase in cost over an appliance of similar quality designed for use with the usual city supplies. The appliance and its accessories including pressure controls should be carefully adjusted by an expert after installation, and should not be changed by the user without consulting the company which supplies the gas.

IX. EFFECT OF IMPURITIES IN PROPANE

If the gas is evaporated in the supply tank and drawn from the top, it is essential that the liquid be propane of fairly high purity. Otherwise, a decided change in composition will result during the discharge of the fuel. The presence of a little ethane may cause a great deal of trouble from backfiring (flashing back) or blowing from the ports (burner openings) when a fresh cylinder is first connected. The presence of butane, on the other hand, will result in improperly aerated flames and incomplete combustion, with possible production of carbon monoxide in harmful amounts, particularly when the fuel is nearly exhausted. Using the American Gas Association's selected values for the permissible limits of the "index of change of performance of appliances" as a criterion, approximately 40 percent of one hydrocarbon in the next hydrocarbon of the series should not make necessary a change of adjustment of the appliance. However, this relationship was derived for the permissible limits with the usually variable city supplies. The close adjustment of propane-burning appliances to the optimum condition is the only thing that makes possible the superior efficiency of propane, hence, no such variation as wide as this is compatible with the claims for superiority of this fuel. Table 4 shows the variation in the composition of the gas drawn at constant temperature from a cylinder filled originally with propane containing

10 percent of ethane. Table 5 gives similar data for variation in composition of gas drawn from a supply of propane contaminated with 10 percent of butane.

Table 6 is given to show the different extents to which impurities affect the constancy of composition of the gas in the case of a single-cylinder system. If half the fuel is used after each filling with propane containing 10 percent of butane, the variation in composition during use is only about 10 percent of that which results if the double-cylinder system is employed. Obviously, the smaller the fraction of the supply used between replenishments, the more uniform is the supply.

TABLE 4.—*Composition of liquid and vapor during the vaporization of a liquid containing at the start 90 percent of propane and 10 percent of ethane*

[Vaporization at 70° F]

Percentage of original liquid remaining	Ethane in vapor	Ethane in remaining liquid
Percent	*Percent*	*Percent*
100	32.4	10.0
90	26.7	7.2
80	20.0	5.3
70	15.2	3.9
50	6.4	1.6
30	1.2	0.29
20	0.35	.08
10	.04	.004

TABLE 5.—*Composition of liquid and vapor during the vaporization of a liquid containing at the start 90 percent of propane and 10 percent of butane*

[Vaporization at 70° F]

Percentage of original liquid remaining	Propane in vapor	Propane in remaining liquid
Percent	*Percent*	*Percent*
100	97.4	90
75	96.6	88
50	95.3	83
35	94.0	79
25	91.2	73
15	87	62
10	80	46
5	65	20
2	17	5
1	3	0.8

TABLE 6.—*Composition of liquid and gas in a container repeatedly filled with a mixture of 90 percent of propane and 10 percent of butane if one-half of the material is used from the container after each filling*

Number of fillings	Composition after filling		Composition when container is half empty	
	Propane in liquid	Propane in vapor	Propane in liquid	Propane in vapor
	Percent	*Percent*	*Percent*	*Percent*
1	90.0	97.4	83.0	95.3
2	86.5	96.4	76.9	93.1
3	83.5	95.5	72.9	91.5
4	81.5	94.8	69.2	90.0
5	79.6	94.2	67.3	89.1
8	77.2	93.2	63.3	87.5
10	76.4	92.9	62.4	87.2
20	76.1	92.8	62.2	87.0

Table 7 is given to show the effect on the operation of a burner of varying the composition of the mixture from propane to butane. For a burner to remain in perfect adjustment without changes by the operator, the "Btu per hour" (column 4) and the "percentage of air required for combustion" (column 5) which is injected as primary air (air which enters the burner with the gas) should remain unchanged.

Similar data are given in table 8 for the gases prepared by saturating air with pentane at different temperatures. The importance of placing the pentane container where the temperature will be as uniform as possible or adopting other means for maintaining a uniform mixture is clearly shown. (At a depth of 6 feet the average ground temperature varies about 20° F between winter and summer, the maximum varying, of course, with latitude.) The extreme variation shown in the table is too great for satisfactory service. Probably the "index of change of performance of appliances" supplied with mixtures of pentane and air should be kept within the same limits as for city gas. This would limit a burner which had been adjusted with air saturated with pentane at 70° F to service (without readjustment) with air saturated between about 65° and 75° F.

TABLE 7.—*Properties of mixtures of gaseous propane and n-butane*

Under "operation of burner" it is assumed that a burner is adjusted with pure propane to give 10,000 Btu per hour and 60 percent of the air required for combustion is primary air]

Propane in mixture	Heating value	Specific gravity (Air=1)	Operation of a burner	
			Btu/hr	Primary air required for combustion
Percent	*Btu/cu ft*			*Percent*
100	2, 572	1. 55	10, 000	60
90	2, 654	1. 61	10, 130	59
75	2, 777	1. 70	10, 340	58
50	2, 982	1. 84	10, 680	56
25	3, 188	1. 99	10, 990	55
0	3, 393	2. 14	11, 300	53

TABLE 8.—*Composition and other properties of air saturated at different temperatures with pentane vapor*

[Under "operation of burner" it is assumed that a burner is adjusted for a mixture saturated at 70° F to give 10,000 Btu per hour and to take 60 percent of the air required for combustion as primary air (including the air in the gas supply)].

Temperature	Pentane in mixture	Specific gravity (Air=1)	Heating value	Operation of a burner	
				Btu/hr	Primary air required for combustion
°F	*Percent*		*Btu/cu ft*		*Percent*
32	24	1. 38	985	4, 600	134
50	38	1. 60	1, 560	6, 700	90
70	62	1. 97	2, 540	10, 000	60
97	100	2. 57	4, 100	14, 100	41

X. TRADE NAMES FOR LIQUEFIED PETROLEUM GASES

Unfortunately, a considerable amount of confusion exists in the trade names for liquefied petroleum gases. Each of several trade names applies to a whole series of different substances from one producer. The same material from the same producer may be given several trade names by different distributors, and finally the same name has been used at different times, and perhaps at the same time by different producers, for different products.

TABLE 9

[Prepared from the information available May 15, 1938, mainly supplied through the courtesy of the Liquefied Petroleum Gas Manufacturers Association or taken with permission from the Supplement to the Handbook of Butane-Propane Gases.]

Fuel types: Pr, propane; Bu, butane; IB, isobutane; and Pen, pentane. (Proportions stated for mixtures are only approximate.) *Systems:* AG, above ground (replaceable cylinders); AGT, above-ground storage containers serviced by tank truck; and BG, below-ground storage containers. *Activity:* P, producer; and R, reseller.

* = Marketed through system of resellers also.

Trade name	Company	System	Fuel	Activity
Algas	American Liquid Gas Co., Los Angeles, Calif.	AG BG	Pr Bu	R
All-Gas	Harms Oil Co., Allison, Iowa	AG	Pr	R
American Gas	Fairway Gas Service, Dayton, Ohio	BG	Bu	R
American Gas	American Gas Service Co., Benton Harbor, Mich.	BG	Bu	R
Atlantic States	Atlantic States Gas Co., New York, N. Y. Mohawk Gas Co., Courtland, N. Y. East Penn Gas Co., Lancaster, Pa.	BG	Pr 60%- Bu 40%	R
Automatic Gas	Automatic Gas Co., Inc., Tyler, Tex.	BG	Pr 10 to 15%, Bu 90 to 85%	R
Automatic system	Winton Automatic Gas Co., Kirbyville, Tex.	BG	Pr 10%- Bu 90%	
Beregas	Beregas Sytem Co., Oklahoma City, Okla.	BG	Bu	R
Be Square	*Barnsdall Oil Co., Tulsa, Okla.		Pr, Bu	P
Blaugas	Northwestern Blaugas Co., St. Paul, Minn.	AG	Pr	R
Blaugas	Omaha Blaugas Co., Omaha, Nebr.	AG	Pr	R
Blaugas	Pittsburgh Thermoline, Pittsburgh, Pa.	AG	Pr	R
Blendall	Ruesser Sales & Oil Co., Moundridge, Kans.	BG	Pr 30%- Bu 70%	R
Bluflame	*Bluflame Gas Corporation, Toledo, Ohio	AG	Pr	R
Blu-Fyr	Bamman's Gas Service, Bayshore, N. Y.	AG	Pr	R
Blu-Spot	*Universal Bottled Gas Corporation, Rochester, N. Y.	AG	IB	
Bot-L-Gas	Suburban Gas Co., Livingston, N. J.	AG	Pr	R
Bradford 7-70	Bradford Gasoline Co., Bradford, Pa.	AG	Pr 50%-Bu 50%	P
Bupane	Bupane Gas Co., Cedar Rapids, Iowa			R
Super Bupane	do	AG	Pr	
Regular Bupane	do		Bu	
Demand Bupane	do	BG	Bu 10%-Pen 90%	
Butane[1]				
Butane Gas Service	Home Gas and Fuel Co., Lake Charles, La.	BG	Bu	R
Calgas	Antelope Valley Gas Co., Southgate, Calif. Pacific Coast Liquid Gas Co., same address	AG; AGT	Pr	R
Calol Industrial Gas No. 2.	Standard Oil Co. of Calif., San Francisco, Calif. (industrial).		Pr	P
City Gas	Wisconsin Rapids Gas Co., Wisconsin Rapids, Wis.	AG	Pr	R
Coleman Bottled Gas	Coleman Lamp and Stove Co., Wichita, Kan.	AG	Pr	R
Delcogas	*United Motors Service, Inc., Detroit, Mich.	BG	Pen	R
Dixie Butane	Dixie Masek Oil Products, Eagle Lake, Tex.	BG	Bu	R
Dockson Gas	Dockson Gas, Inc., Clarksdale, Miss.	BG	Pr 10%-Bu 90%	R
Dri-Gas	Illinois Bottled Gas Co., Chicago, Ill.	AG	Pr	R
Drigas	Miami Bottled Gas, Inc., Miami, Fla.	AG BG 	Pr Bu Mixed Pr, Bu	
Drigas	Bottled Gas Products Corporation, Monticello, N. Y.	AG	Pr	R
Engco	Eastern Natural Gas Corporation, Breton Woods, N. J.	AG	Pr	R
Essotane	*Standard Oil Co. of New Jersey, New York, N. Y.	AG	Pr	P
	Standard Oil Co. of Louisiana	AG	Pr	P
	*Standard Oil Co. of Kentucky, Louisville, Ky.	AG	Pr	P
	Protane Corporation, Erie, Pa.	AG	Pr	R
	Gerow & Francisco, Liberty, N. Y.	AG	Pr	R
	Jack Rose, Inc., Pittsfield, Mass.	AG	Pr	R
Essotane B	*Standard Oil Co. of Kentucky, Louisville, Ky.		Bu	P
Fer-Gas	Fergas Co., Clovis, N. Mex.	AG BG	Pr Bu	R
Flamo	Standard Oil Co. of Calif., San Francisco, Calif.	AG	Pr	P
Fuelite	Fuelite Natural Gas Corporation, Lexington, Mass.	AG	Pr	R
Fuilgas	Fuilgas, Inc., Gainesville, Fla.	BG	Bu	R

[1] See list of marketers at end of list of trade names.

TABLE 9—Continued

Trade name	Company	System	Fuel	Activity
Gas-o-lite	Bluflame Gas Corporation, Toledo, Ohio		Pen	
Generalgas	General Gas Corporation, Baton Rouge, La	AG; BG	Bu	R
Goss Gas	Goss Gas Products Co., Pittsburgh, Pa	AG	Pr	R
Green's Fuel	*J. B. Green Plumbing & Heating Co., Sarasota, Fla.	BG	IB	R
Grimms Gas	Grimms Rural Gas Inc., Beachwood, N. J	AG	Pr	R
Goldene	Wasatch Oil Refining Co., Woods Cross, Utah	AGT	Pr 70%-Bu 30%	P
Goldene Bottled Gas	Rocky Mountain Gas Co., Salt Lake City, Utah.	AG	Pr 80%-Bu 20%	
Heatwave	Imperial Gas Co., Los Angeles, Calif	AG	Pr 30%-Bu 70%	
Hi-Heat	Hi-Heat Gas Co., New York, N. Y; Conservative Gas Co., Brooklyn, N. Y	AG	Pr 30%-Bu 70%	R
Homegas	Home Gas Corporation, Housatonic, Mass	AG	Pr	R
Homegas	Petrolane Gas Corporation, New Orelans, La	BG	Bu	R
Homegas	Home Gas Co., Minneapolis, Minn	AG	Pr	R
Home-Gas	C. I. Tenney Eng. Corporation, Minneapolis, Minn.	AG	Pr	R
Hopane (for steel cutting).	Hope Construction and Refining Co., Pittsburgh, Pa.		Pr-Bu	P
Hot Point	Gas Products Inc., Gainsville, Ga	BG	Pr 5%-Bu 95%	R
Hydro-Gas	*National Hydro-Gas Co., San Antonio, Tex	BG	Bu	P
Hydro-Gas	Corpus Christi Hydro-Gas and Equipment Corporation, Corpus Christi, Tex.			
Hydro-Gas	R. L. Edwards, San Antonio, Tex	BG	Bu	R
Hydro-gas	*Hydro-gas Co. of Calif., Santa Monica, Calif	BG	Bu	P
Insto-gas	Insto Gas Corporation, Detroit, Mich	AG	Pr	R
Jewel Gas	John W. Leahy, Danbury, Conn	AG	Pr	R
Kane-Gas-K	Sloan & Zook Co., Kane, Pa	AG	Pr,-Bu	P
Kwick-Gas	Kwick-Gas Corporation, Hudsonville, Mich	AG	Pr	R
Liquefied	Liquefied Gas Co., Arkansas Pass, Tex	BG	Bu	R
McNay Gas	McNay Gas Co., Ephrata, Pa	AG	Pr 50%-Bu 50%	R
Marlogas	J. C. Marlow Co., Mankato, Minn	AG	Pr	R
Master Gas	Automatic Gas and Stoker Co., Dayton, Ohio	AG	Pr	R
Metergas	*Blu-flame Gas Corporation, Toledo, Ohio	BG	Bu	
Minngas	Minngas Co., Tracy, Minn	AG	Pr	R
Mobilane	*General Petroleum Corporation of California, Los Angeles, Calif. (Also sells mixtures).	AGT	Pr	P
Modern Gas	Modern Gas and Sales Co., Lakewood, N. J	AG	Pr	R
Nabuco Gas	National Butane Gas Co., Memphis, Tenn	BG	Bu	R
Do	Butane Gas Co. of Mississippi, Marks, Miss	BG	Bu	R
Nat Gas	Natural Gas Co. of New Jersey, Hammonton, N. J.	AG; AGT	Pr	R
Natrogas	*Natrogas, Inc., Minneapolis, Minn	AG	Pr	R
Natural Gas	Gas-Oil Products, Inc., Oxford, Pa. (Also distributes butane and mixtures).	AG	Pr	R
New Stargas	Lone Star Gas Co., Dallas, Tex	AG	Bu	P
Naturol	Gas Oil Products Inc., Coral Gables, Fla	AG	Pr	R
Nugas	*Bradford Gasoline Co., Bradford, Pa	AG	Pr	P
Onigas	Oneida Gas Co., Rheinlander, Wis	AG	Pr	R
Ovox Fuel Gas	Verkamp Corporation, Cincinnati, Ohio. (Industrial.)	AG	Pr	R
Oxalene	Oxalene Gas and Equipment Corporation, Lynn, Mass. (Industrial only.)	AG	Pr	R
Petro Gas	Petro Gas System, Dilley, Tex	BG	Bu	R
Peoples Gas	Automatic Gas and Stoker Co., Dayton, Ohio	BG	Bu	R
Petrolane	*Petrolane, Ltd., Long Beach, Calif	AG	Pr 10 to 60%-Bu 90 to 40%	P
Petrolane Gas Fuel	Eureka Southern Gas Co., San Bernadino, Calif.	AG	Pr 33%-Bu 66%	R
Philgas	*Phillips Petroleum Co., Detroit, Mich	AG; AGT	Pr	P
Do	Southeastern Natural Gas Corporation, Miami, Fla.	AG; AGT	Pr	R
Do	Utilities Distributors, Portland, Maine	AG	Pr	R
Do	Verkamp Corporation, Cincinnati, Ohio	AG	Pr	R
Do	Pulvers Gas Service, Bridgehampton, N. Y	AG	Pr	R
Port-Gas	Port Jervis Fuel and Supply Co., Port Jervis, N. Y.	AG	Pr	R
Potter Gas	Potter Gas Service Co., Syracuse, N. Y	AG	Pr 40%-Bu 60%	R
Propane	(1)			
Protane	*Protane Corporation, Erie, Pa	BG	Bu	P
Do	Illinois Bottled Gas Co., Chicago, Ill	AG	Bu	R
Do	Protane Gas Service Co., Hawthorne, N. J			R
Protane A	*Protane Corporation, Erie, Pa	AG	Pr	P
Pyrofax	*Carbide and Carbon Chemicals Corporation, New York, N. Y.	AG	Pr	P
Do	Chas. F. Smith Co., Greensboro, N. C	AG	Pr	R
Pyrogas	The Pyrogas Co., Kansas City, Mo	AG	Pr	R

TABLE 9—Continued

Trade name	Company	System	Fuel	Activity
Pyrolane	Western Gas Distributors, Los Angeles, Calif. (Industrial.)	----	Mixed	------
Pyroline	Burdette Oxygen Co., Cleveland, Ohio	AG	Pr	R
Ranchogas	Ranchogas Co., Sonora, Tex	BG	Bu	R
Rapid Gas	Rapid Gas Corporation, Cedar Rapids, Iowa	AG	Pr	R
Readyflame	Readyflame Gas Service, Ludington, Mich	AG	Pr	R
Realgas	*Bradford Gasoline Co., Bradford, Pa	AG	Pr 40%-Bu 60%	R
Realgas	Concentrated Natural Gas Co., Plano, Ill	AG	Pr	R
Redigas	H. P. Aikman, Cazenovia, N. Y	AG	Pr	R
Do	New Gas Co., Verona, N. J	AG	Pr	R
Do	C. Wade-Dalton, Manassas, Va	AG	Pr	R
Redi-Gas	Lima Suburban Gas and Stove Co., Lima, Ohio.	AG	Pr	R
Regasco	Ruesser Sales and Oil Co., Moundridge, Kans.	AG	Pr	R
Rockgas	Imperial Gas Co., Los Angeles, Calif	AG	Pr; IB	P
Rockgas Propane	do	AG	Pr	P
Rulane	Rulane Gas Co., Cherryville, N. C	AG	Pr	R
Rural Gas	Rural Gas Co., Williamsport, Pa	AG	Pr	R
Safety Gas	Safety Gas Inc., Alexandria, La	BG	Bu	R
Shellane	Shell Petroleum Corporation, St. Louis, Mo	AG	Pr	P
Do	Shell Oil Co., San Francisco, Calif	AG	Pr	P
Shell Industrial Gas	do	--------	Industrial mixture.	P
Shengas	Consumers Utilities Co., Harrisonburg, Va	AG	Pr	R
Shipmate Gas	Stamford Foundry Co., Stamford, Conn. (Boats only.)	AG	Pr 50%-Bu 50%	R
Shorgas	Eastern Shore Gas Co., Pocomoke City, Md	AG	Pr	R
Skelgas	*Skelgas Co., Kansas City, Mo	AG	Pr	P
Solgas	Solgas, Inc., Philadelphia, Pa	AGT; BG	Pr	R
Star gas	Lone Star Gas Co., Dallas, Tex	AG	Pr	P
Suburban Bottled Gas	Suburban Gas and Appliance Co., Canton, Ohio.	AG -------	Pr; Pr 40%-Bu 60%	R
Suburban gas	Suburban Gas Co., Belvidere, N. J	AG	Pr	R
Sungas	General Natural Gas Co., Woodridge, N. Y	AG	Pr	R
Sungas	Mankes Gas Service, Monticello, N. Y	AG	Pr	R
Sungas	Sungas Co., Miami, Fla	AG	Pr	R
Thermogas	Thermogas Co., Des Moines, Iowa	AG	Pr	R
Thermoline	Pittsburgh Thermoline Co., Pittsburgh, Pa	AG	Pr	R
Trugas	*Viking Distributing Co., Charleston, W. Va.	AG	Pr 50%-Bu 50%	P
Vapo-gas	Vapo-Gas Corporation, San Antonio, Tex	BG	Bu	R
Vapyre	Vapyre Corporation, Brewster, N. Y	AGT	Pr 40%-Bu 60%	R
Wasatch Pupane	Wasatch Oil Ref. Co., Salt Lake City, Utah	AG	Pr 77%-Bu 22%	P
Webers Bottled Gas	Edward Weber, Newburgh, N. Y	AG	Pr	R
Wilco Blue Flame	E. J. Willis Co., New York, N. Y	Marine service	Pr	R
Yurown Gas	Butane Gas System Co., Grenada, Miss	BG	Bu	R

The following list of marketers of butane, who are not known to use any trade name, probably all employ underground systems.:

American Gas Service Co., Lima, Ohio.
Butane Gas Corp., Little Rock, Ark.
Butane Gas System Co., Dallas, Tex.
Coon Reel Oven Mfg. Co., Oklahoma City, Okla.
Delmel Gas Corp., Alexandria, La.
Farm and Home Equipment Co., Abbeville, La.
Farm and Ranch Gas Co., Lamesa, Tex.
N. A. James, Inc., San Angelo, Tex.
Mid-Continent Butane Equipment Co., Wichita, Kans.
Monroe Gas and Plumbing Co., Houston, Tex.
Municipalities Gas Corp., Detroit Lakes, Minn.
Peoples Gas Service Co., Lima, Ohio.
Sands Heater Co. of Houston, Houston, Tex.
Western Gas and Appliance Co., Wichita Falls, Tex.

The following is a list of resellers of propane for which no trade name has been reported to the Bureau:

Cataract Natural Gas Co., Syracuse, N. Y.
Central Jersey Gas Service, Milltown, N. J.
Country Homes Gas Service, Suffern, N. Y.

G. B. Darling & Son, Pratt, Kans.
Elmer T. Hurst, Ithaca, N. Y.
Modern Gas Co., Greenville, Ohio.
Monticello Gas and Electric Co., Monticello, N. Y.
New Jersey Northern Gas Co., Lambertville, N. J.
Propane Gas Service Co. of New Jersey, Hammonton, N. J.
Rose and Douglas, Ellenville, N. Y.
Seaboard Gas Service, Farmingdale, N. J.
Southern Liquid Gas Co., Dothan, Ala.
Suburban Gas Co., Cedar Rapids, Iowa.
Sullivan County Plumbing and Heating Co., Liberty, N. Y.
Sullivan County Gas Co., Monticello, N. Y.
Terwillinger Bros., Kerkonson, N. Y.
Wisconsin Bottled Gas Co., Medford, Wis.

The following is a list of producers for which no trade name has been reported to the Bureau:

Cannon Gasoline Co., Inc., Amarillo, Tex. (propane; butane).
Carter Oil Co., Tulsa, Okla. (propane; butane).
Cities Service Oil Co., Tulsa, Okla. (propane; butane).
Cumberland Gasoline Co., Cleveland, Ohio (butane; propane 40%—butane 60%).
Humble Oil and Refining Co., Houston, Tex. (propane; butane; isobutane).
Standard Oil Co. (Indiana), Chicago, Ill. (propane).
Standard Oil Co. of Ohio, Cleveland, Ohio (propane; butane; propane 70%—butane 30%).
Union Oil Co. of California, Los Angeles, Calif. (propane; butane).
Westoak Gasoline Co., Sayre, Okla. (propane; butane).

It is probable that nearly all the producers given in the preceding lists are in position to furnish propane, butane, and pentane or their mixtures at wholesale. Several will furnish any mixture desired by purchaser.

The following is a partial list of manufacturers of systems for pentane air mixtures or similar fuels:

American Heating and Lighting Co., Morenci, Mich. "Clark Gas Producer."
Delco Appliance Div., General Motors Co., 391 Lyell Ave., Rochester, N. Y. No longer makes the Delcogas generators but does supply "Delcogas fuel" for machines of this type.
Freeport Gas Machine Co., Freeport, Ill.
Gasair Utility Development Co., San Francisco, Calif. Systems for producing mixtures of butane and air for pipe-line distribution.
C. M. Kemp Mfg. Co., 405 E. Oliver St., Baltimore, Md.
National Lighting Co., Arkansas City, Kans.
Presto Gas Manufacturing Co., 2439–2451 Northwestern Ave., Chicago, Ill. "Gloria Gas Producing Equipment."
Tirrill Gas Machine Corporation, 19 Rector St., New York, N. Y.

WASHINGTON, June 8, 1938.